A Proposal on the Classification of Systems Tracts: Application to the Allostratigraphy and Sequence Stratigraphy of the Cretaceous Colombian Basin. Part 2: Barremian to Maastrichtian.

JAVIER GUERRERO

Grupo de Investigaciones en Estratigrafía, Sedimentología y Paleontología. Departamento de Geociencias, Universidad Nacional de Colombia. Apartado Aéreo 14490, Bogotá, Colombia. E-mail: jaguer@ciencias.unal.edu.co

GUERRERO J (2002): A Proposal on the Classification of Systems Tracts: Application to the Allostratigraphy and Sequence Stratigraphy of the Cretaceous Colombian Basin. Part 2: Barremian to Maastrichtian.
GEOLOGIA COLOMBIANA 27, Pgs. 27 - 49, 2 Figs, 1 Table, Bogotá.

ABSTRACT

The Barremian to Maastrichtian interval of the sedimentary succession from the Cretaceous Colombian Basin is divided in stratigraphic sequences and in several allostratigraphic units, which include the Fómeque, Une, and Chipaque Alloformations, the Guadalupe Allogroup, and the lower part of the Guaduas Alloformation.

The division is based on the recognition of regional surfaces of sedimentological discontinuity, corresponding mainly to Transgressive Surfaces (TS) located at the base of Transgressive Systems Tracts (TST), and Regressive Surfaces (RS) coincident with Sequence Boundaries (SB) and located at the base of Regressive Systems Tracts (RST).

The proposed allostratigraphic units are composed of facies belts, which extend across the whole basin and include laterally adjacent and essentially synchronous lithostratigraphic units. The base of the Fómeque Alloformation is located on the Transgressive Surface (TS) at the Hauterivian / Barremian boundary. The base of the Une Alloformation is located on the Regressive Surface (RS) at the Aptian / Albian boundary. The base of the Chipaque Alloformation on the Transgressive Surface (TS) at the Cenomanian / Turonian boundary, and the base of the Guadalupe Allogroup on the Regressive Surface (RS) at the Santonian / Campanian boundary.

The Une Alloformation is subdivided in allomembers, using the Transgressive Surface (TS) at the Lower Albian / Middle Albian boundary and the Regressive Surface (RS) at the Albian / Cenomanian boundary. In the same way, the Guadalupe Allogroup is subdivided in the Lower, Middle, and Upper Guadalupe Alloformations, using the Transgressive Surface (TS) at the Lower Campanian / Upper Campanian boundary and the Regressive Surface (RS) at the Campanian / Maastrichtian boundary. The succession is capped by the lower part of the Guaduas Alloformation, which is located over the Transgressive Surface (TS) at the Lower Maastrichtian / Upper Maastrichtian boundary.

Key Words: *Allostratigraphy, Back-Arc Basin, Colombia, Cretaceous, Hydrocarbon Exploration, Lithostratigraphy, Paleogeography, Sedimentology and Sequence Stratigraphy.*

RESUMEN

El intervalo Barremiano a Maastrichtiano de la sucesión sedimentaria de la Cuenca Cretácica Colombiana es dividido en secuencias estratigráficas y en varias unidades aloestratigráficas, que incluyen las Aloformaciones Fómeque, Une y Chipaque, el Alogrupo Guadalupe y la parte inferior de la Aloformación Guaduas.

La división se basa en el reconocimiento de superficies regionales de discontinuidad sedimentológica, correspondientes principalmente a Superficies Transgresivas (TS) situadas en la base de Sistemas Transgresivos (TST), y a Superficies Regresivas (RS) coincidentes con Límites de Secuencia (SB) y situadas en la base de Sistemas Regresivos (RST).

Las unidades aloestratigráficas propuestas se componen de cintas de facies que se extienden por toda la cuenca e incluyen unidades litoestratigráficas lateralmente adyacentes y esencialmente sincrónicas. La base de la Aloformación Fómeque se sitúa en la Superficie Transgresiva (TS) del límite Hauteriviano / Barremiano. La base de la Aloformación Une se sitúa en la Superficie Regresiva (RS) del límite Aptiano / Albiano. La base de la Aloformación Chipaque en la Superficie Transgresiva (TS) del límite Cenomaniano / Turoniano y la base del Alogrupo Guadalupe en la Superficie Regresiva (RS) del límite Santoniano / Campaniano.

La Aloformación Une se subdivide en alomiembros, utilizando la Superficie Transgresiva (TS) del límite Albiano Inferior / Albiano Medio y la Superficie Regresiva (RS) del límite Albiano / Cenomaniano. De igual manera, el Alogrupo Guadalupe se subdivide en las Aloformaciones Guadalupe Inferior, Medio y Superior utilizando la Superficie Transgresiva (TS) del límite Campaniano Inferior / Campaniano Superior y la Superficie Regresiva (RS) del límite Campaniano / Maastrichtiano. La sucesión es cubierta por la parte inferior de la Aloformación Guaduas, que se sitúa sobre la Superficie Transgresiva (TS) del límite Maastrichtiano Inferior / Maastrichtiano Superior.

Palabras Clave: Aloestratigrafía, Estratigrafía Secuencial, Colombia, Cretácico, Cuenca de Retroarco, Exploración de Hidrocarburos, Litoestratigrafía, Paleogeografía y Sedimentología.

INTRODUCTION

The sedimentary fill of the Cretaceous Colombian (Back–Arc) Basin has been divided in allostratigraphic units and stratigraphic sequences composed of 4 systems tracts, including the new Regressive Systems Tract (Guerrero 2002).

The subdivision of sequences in Regressive (RST), Lowstand (LST), Transgressive (TST), and Highstand (HST) Systems Tracts can be applied to sedimentary successions regardless of the geomorphology of the margin (shelves /slopes or ramps), its terrigenous or calcareous nature, or the presence of deltas, reefs, or floor fans. The Systems Tracts are recognized in terms of strata with sedimentary patterns indicating progradation (RST), low level aggradation (LST), retrogradation (TST), and high level aggradation (HST).

Progradation, aggradation, and retrogradation are understood in terms of relative sea level resulting from the interaction of eustasy, subsidence, and sediment supply. The relationship is that eustatic rise and basin subsidence create accommodation space, which is filled by the available sediment supply, so that relative sea level could change or remain stable for a period of time. Accommodation space could also be created during eustatic fall if it is less (produced at a minor velocity) than basin subsidence.

Long-term progradation results when accommodation is less than sediment supply so that there is relative shallowing upward (sea level fall) of the sedimentary environments of the succession, as indicated by a general coarsening-upward and thickening-upward trend of strata. Retrogradation is produced when sediment supply is less than accommodation so that there is relative deepening upward (sea level rise) of the sedimentary environments of the succession, as indicated by a general fining-upward and thinning-upward trend of strata. Aggradation results when sediment supply balances accommodation space, so that there is neither a relative sea level change nor a relative shallowing or deepening of sedimentary environments.

The available information from the sedimentary fill of the Cretaceous Colombian Basin is examined, so that a framework of sedimentary environments, systems tracts, allostratigraphic units, stratigraphic sequences, and lithostratigraphic units is presented here. Part 1 (Guerrero 2002) includes a proposal on the classification of systems tracts and the stratigraphy of the Tithonian/Berriasian to Hauterivian interval, meanwhile that this part deals with Barremian to Maastrichtian strata.

Villeta Allogroup (new unit). Barremian to Santonian.

The Villeta Allogroup includes strata deposited during a rather long time interval of approximately 45 Ma, from the Barremian to the Santonian, during two and a half cycles of relative sea level rise and fall. It is divided in three well-defined units, including the Fómeque (Barremian and Aptian), Une (Albian and Cenomanian), and Chipaque (Turonian to Santonian) Alloformations, already proposed by Guerrero *et al.* (2000). The type locality of the allogroup is the same one of the Villeta Group (Hettner 1892; Hubach 1931b, 1951, 1957), SE of Bogotá in the vicinities of the towns of Fómeque, Une, and Chipaque. The Villeta Group is composed mainly of black mudstone/shale (Fómeque and Chipaque Formations) separated by a sandstone/

mudstone/sandstone interval (Une Formation).

The Villeta Group is a unit essentially recognized in the Eastern Cordillera on the Bogotá and Villeta areas (HETTNER 1892; HUBACH 1931b, 1951, 1957; JULIVERT *et al.* 1968; CÁCERES & ETAYO 1969; GUERRERO & SARMIENTO 1996; MARTÍNEZ & VERGARA 1999; GUERRERO *et al.* 2000). Toward the axis of the basin on the W, and farther away from the source area in the Guyana Shield, the sandstones of the Une Formation become thinner and finer grained, so that they almost disappear, making the stratigraphic subdivision more complicated. Stratigraphy of the Villeta Group W of Bogotá was attempted as subdivision in horizons and formations separated by unnamed units (HUBACH 1931B; CÁCERES & ETAYO 1969; ETAYO, 1979), which still remain relatively unknown. More recently, MARTÍNEZ & VERGARA (1999) presented generalized sections of parts of the succession from 3 localities W of Bogotá. To date, stratigraphy is still confusing because of tectonic complications and definition of formations in different localities, which involve parts of a unit in other units of nearby localities. However, and despite the early stage of knowledge of the succession, a correspondence of relative sea level allows a comparison of the formations of the Villeta Group in the E and W flanks of the Eastern Cordillera. This comparison of the horizons of the Villeta unit within the Eastern Cordillera is an idea that dates back from HUBACH (1931b). The successions from the Bogotá and Villeta areas illustrate the lateral facies changes of different formational units in an E-W direction. Approximately 80 km to the W and NW of the type locality near Bogotá, the Villeta Group is subdivided in the Trincheras, Socotá, Hiló, Pacho, La Frontera, and Conejo Formations. Source area should be from the E because quartz arenites are reported within the minor sandstone intervals of the unit; however, since location is near the center of the basin, detailed petrography would have to be performed to discard other possible connections.

Fómeque Alloformation (GUERRERO *et al.* 2000). Retrogradational to aggradational strata of Barremian and Aptian age.

The Fómeque Alloformation includes strata deposited during relatively fast sea level rise and high sea levels. These Barremian and Aptian strata are retrogradational (TST) to high aggradational (HST), including the Fómeque, Trincheras, and Paja Formations on the central and E sides of the Basin, and the Yuruma Formation on the N extreme of the country. The base of the Fómeque Alloformation is placed in a major transgressive surface (TS) at or very near the Hauterivian/Barremian boundary.

Basal transgressive successions initiated during that interval of time include the Yaví Formation and the lower and middle members of the Caballos Formation on the W side of the basin in the Upper Magdalena Valley, as well as the Río Negro and Apón Formations in the Perijá area.

The Fómeque Formation (HUBACH 1931b, 1945, 1951, 1957) is composed of 500 to 600 m of black mudstone and shale with abundant pyrite. Minor interbeddings of sandstone in medium beds, present in the lowermost part of the unit, are replaced in a short interval by medium beds of biosparite and biomicrite. The Fómeque Formation is exposed SE of Bogotá, near the town of Fómeque and in the Une River; it overlies sandstone of the Alto de Cáqueza Formation and underlies sandstone of the Une Formation. Several species of the ammonite genera *Nicklesia* and *Pulchellia* are present in the lower part of the formation indicating an Early Barremian age. Sedimentary environment is interpreted here as evolving from shallow marine offshore to medium ramp, in depths of about 15 to 100 m.

The name Trincheras Formation (CÁCERES & ETAYO 1969; ETAYO 1979) is used here with a modification, to include all the relatively fine-grained strata that overlie sandstone of the La Naveta Formation and underlie sandstone of the Socotá Formation. The term originally left out an unnamed upper level of black shale, which is included here within the formation. According to this, the Trincheras Formation is a 600 to 700 m thick, black mudstone and shale unit, which toward its lower part includes minor interbeds of sandstone and limestone in medium to thick beds. The limestones of the lowermost part include biomicrites and minor biosparites with large size (5-8 cm) bivalves. The black mudstone and shale that compose most of the unit contain abundant pyrite and also include calcareous concretions with diameters around 10-20 cm. The unit is known to contain Barremian and Aptian ammonites. Sedimentary environment is interpreted here as evolving from offshore to medium ramp, but always deeper than the laterally equivalent Fómeque Formation from the E side of the Eastern Cordillera.

The Paja Formation (MORALES *et al.* 1958) has its type locality in the Paja Creek, near the Sogamoso River, in the Bucaramanga area. The Paja Formation overlies the coarse grained limestones of the Rosablanca Formation, and underlies the coarse grained limestones of the ridge forming Tablazo Formation. The unit has a thickness of 625 m, and is composed of black shales with abundant calcareous concretions up to 30 cm in diameter. Fossils of ammonites include a succession of Barremian and Aptian genera with *Nicklesia, Pulchellia, Heteroceras,*

TABLE 1. SEQUENCE STRATIGRAPHY ALONG WITH THE ALLOSTRATIGRAPHIC AND LITHOSTRATIGRAPHIC CLASSIFICATION (N AND W SIDES) OF THE SUCCESSION FROM THE CRETACEOUS COLOMBIAN BASIN.

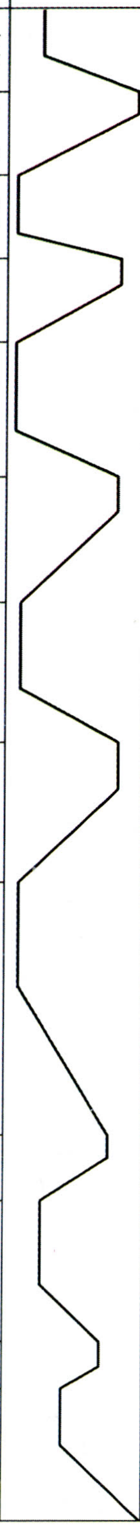
W BORDER OF THE CRETACEOUS COLOMBIAN BASIN. LITHOSTRATIGRAPHIC UNITS. UPPER MAGDALENA VALLEY	SEQUENCES	N SIDE OF THE CRETACEOUS COLOMBIAN BASIN. LITHOSTRATIGRAPHIC UNITS. CATATUMBO, W VENEZUELA, AND LA GUAJIRA	SEQUENCES	ALLOSTRATIGRAPHIC UNITS	AGES	SEQUENCES AND SYSTEMS TRACTS		RELATIVE SEA LEVELS HIGH — LOW
LOWER PART SECA FORMATION	SK 7	CATATUMBO FORMATION	SK 7	LOWER PART GUADUAS ALLOFORMATION	LATE MAASTRICHTIAN	SK 7 (9 Ma)	HST TST	
LA TABLA FORMATION; BUSCAVIDA FORMATION		MITO JUAN FORMATION		UPPER GUADALUPE ALLOFORMATION	EARLY MAASTRICHTIAN		LST RST	
OLINI GROUP: LIDITA SUPERIOR FORMATION	SK 6	COLÓN FORMATION	SK 6	MIDDLE GUADALUPE ALLOFORMATION	LATE CAMPANIAN	SK 6 (9 Ma)	HST TST	
OLINI GROUP: EL COBRE FORMATION				LOWER GUADALUPE ALLOFORMATION	EARLY CAMPANIAN		LST RST	
OLINI GROUP: LIDITA INFERIOR FORMATION	SK5	LA LUNA FORMATION	SK5	CHIPAQUE ALLOFORMATION	SANTONIAN	SK 5 (14 Ma)	HST	
LOMAGORDA FORMATION					CONIACIAN			
					TURONIAN		TST	
HONDITA FORMATION		LISURE FORMATION		UNE ALLOFORMATION: UPPER UNE ALLOMEMBER	CENOMANIAN		LST RST	
TETUÁN FORMATION	SK 4		SK 4	UNE ALLOFORMATION: MIDDLE UNE ALLOMEMBER	LATE ALBIAN	SK 4 (15 Ma)	HST	
					MIDDLE ALBIAN		TST	
CABALLOS FORMATION: UPPER SANDSTONE MEMBER				UNE ALLOFORMATION: LOWER UNE ALLOMEMBER	EARLY ALBIAN		LST RST	
CABALLOS FORMATION: MIDDLE MUDST/BIOMICR MEMBER	SK 3	YURUMA FORMATION	SK 3	FÓMEQUE ALLOFORMATION	LATE APTIAN	SK 3 (17 Ma)	HST	
CABALLOS FORMATION: LOWER SANDSTONE MEMBER; YAVÍ FORMATION					EARLY APTIAN		TST	
					BARREMIAN			
		MOINA FORMATION		ALTO DE CÁQUEZA ALLOFORMATION	LATE HAUTERIVIAN		LST RST	
			SK 2	MACANAL ALLOFORMATION	EARLY HAUTERIVIAN LATE VALANGINIAN	SK 2 (10 Ma)	HST TST	
		PALANZ FORMATION			EARLY VALANGINIAN		LST RST	
			SK 1		LATE BERRIASIAN	SK 1 (7 Ma)	HST	
				BUENAVISTA ALLOFORMATION	E BERRIASIAN L TITHONIAN		TST	

TABLE 1. SEQUENCE STRATIGRAPHY ALONG WITH THE ALLOSTRATIGRAPHIC AND LITHOSTRATIGRAPHIC CLASSIFICATION (CENT. AND E SIDES) OF THE SUCCESSION FROM THE CRETACEOUS COLOMBIAN BASIN.

AGES	SYSTEMS TRACTS	CENTRAL EASTERN AND E SIDE OF THE CRETACEOUS COLOMBIAN BASIN. LITHOSTRATIGRAPHIC UNITS. W SIDE OF THE EASTERN CORDILLERA		SEQUENCES	E SIDE OF THE CRETACEOUS COLOMBIAN BASIN. LITHOSTRATIGRAPHIC UNITS. E SIDE OF THE EASTERN CORDILLERA			SEQUENCES	E BORDER OF THE CRETACEOUS COLOMBIAN BASIN. LITHOSTRATIGRAPHIC UNITS. EASTERN LLANOS AND PUTUMAYO.
LATE MAASTRICHTIAN	HST TST		LOWER PART GUADUAS FORMATION	SK 7			LOWER PART GUADUAS FORMATION	SK 7	RUMIYACO FORMATION
EARLY MAASTRICHTIAN	LST RST	GUADALUPE GROUP	LABOR-TIERNA FORMATION	SK 7	GUADALUPE GROUP		LABOR-TIERNA AND SAN LUIS FORMATIONS	SK 7	RUMIYACO FORMATION
LATE CAMPANIAN	HST TST	GUADALUPE GROUP	PLAENERS FORMATION	SK 6	GUADALUPE GROUP		PLAENERS AND AGUACALIENTE FORMATIONS	SK 6	RUMIYACO FORMATION
EARLY CAMPANIAN	LST RST	GUADALUPE GROUP	DURA SANDSTONE FORMATION	SK 6	GUADALUPE GROUP		DURA AND SAN ANTONIO FORMATIONS	SK 6	RUMIYACO FORMATION
SANTONIAN	HST	VILLETA GROUP	CONEJO FORMATION	SK 5	VILLETA GROUP		CHIPAQUE FORMATION	SK 5	LAS IGLESIAS FORMATION
CONIACIAN	HST	VILLETA GROUP	CONEJO FORMATION	SK 5	VILLETA GROUP		CHIPAQUE FORMATION	SK 5	LAS IGLESIAS FORMATION
TURONIAN	TST	VILLETA GROUP	LA FRONTERA FORMATION	SK 5	VILLETA GROUP		CHIPAQUE FORMATION	SK 5	MASAYA FORMATION
CENOMANIAN	LST RST	VILLETA GROUP	CHURUVITA, CHIQUINQUIRA, AND PACHO FORMATIONS	SK 5	VILLETA GROUP	UNE FORMATION	UPPER SANDSTONE MEMBER		
LATE ALBIAN	HST	VILLETA GROUP	HILÓ AND SAN GIL SUPERIOR FORMATIONS	SK 4	VILLETA GROUP	UNE FORMATION	MIDDLE MUDSTONE MEMBER		
MIDDLE ALBIAN	TST	VILLETA GROUP	HILÓ AND SAN GIL SUPERIOR FORMATIONS	SK 4	VILLETA GROUP	UNE FORMATION	MIDDLE MUDSTONE MEMBER		
EARLY ALBIAN	LST RST	VILLETA GROUP	SOCOTÁ AND SAN GIL INFERIOR FORMATIONS	SK 4	VILLETA GROUP	UNE FORMATION	LOWER SANDSTONE MEMBER		
LATE APTIAN	HST	VILLETA GROUP	TRINCHERAS AND PAJA FORMATIONS	SK 3	VILLETA GROUP		FÓMEQUE FORMATION		
EARLY APTIAN	TST	VILLETA GROUP	TRINCHERAS AND PAJA FORMATIONS	SK 3	VILLETA GROUP		FÓMEQUE FORMATION		
BARREMIAN	TST	VILLETA GROUP	TRINCHERAS AND PAJA FORMATIONS	SK 3	VILLETA GROUP		FÓMEQUE FORMATION		
LATE HAUTERIVIAN	LST RST		LA NAVETA FM, VILLA DE LEIVA FM, UPPER ROSABLANCA FM, UPPER MURCA FM	SK 3	CAQUEZA GROUP		ALTO DE CÁQUEZA FORMATION		
EARLY HAUTERIVIAN LATE VALANGINIAN	HST TST		RITOQUE FORMATION AND LOWER PART OF THE ROSABLANCA FORMATION	SK 2	CAQUEZA GROUP		MACANAL FORMATION		
EARLY VALANGINIAN	LST RST		ARCABUCO FORMATION	SK 2	CAQUEZA GROUP		MACANAL FORMATION		
LATE BERRIASIAN	HST		ARCABUCO FORMATION	SK 1	CAQUEZA GROUP		MACANAL FORMATION		
E BERRIASIAN L TITHONIAN	TST		ARCABUCO FORMATION	SK 1	CAQUEZA GROUP		BUENAVISTA FORMATION		

- CHERT
- SHALE, BIOMICRITE, MARLSTONE.
- SANDST, BIOSPARITE, CONGLOMERATE.
- NON-MARINE MUDSTONE
- NON-MARINE SANDST, CONGLOMERATE.

Santandericeras, Cheloniceras, and *Colombiceras.* The unit was also dated in an area S of Bucaramanga by PATARROYO (1997), who indicated the presence of Early Barremian ammonites in the lower 20 m of the formation, including *Valdedorsella sp., Karsteniceras sp., Pseudohaploceras incertum,* and several species of *Nicklesia,* with *N. nolani, N. didayana,* and *N. dumasiana.* PATARROYO also indicated the presence of the Late Aptian in the middle to upper parts of the formation, with *Cheloniceras sp., Deshayesites sp.*, and *Dufrenoya sp.* The sedimentary environments are interpreted here as very similar to the ones of the Fómeque and Trincheras Formations, evolving from shallow offshore to medium ramp. As in all the other fine-grained units of the alloformation, organic matter is notorious in thin sections and hand samples.

In the Villa de Leiva area, the Paja Formation is restricted to the Barremian and Aptian strata included in the middle "arcillolitas abigarradas" (variegated claystone) and upper "arcillolitas con nódulos huecos" (claystone with hollow nodules) units of ETAYO (1968a, b). As indicated before, the lower mudstone / sandstone member erroneously included in the Paja Formation is included here in the Villa de Leiva Formation. According to this, the Paja Formation in the Villa de Leiva area overlies sandstone of the Villa de Leiva Formation and underlies the coarse-textured limestone and sandstone of the Lower San Gil Formation. The Paja Formation is composed here of 560 m of black mudstones and shales with abundant pyrite, which weather to reddish colors. The hollow nodules correspond to calcareous concretions with abundant pyrite, which also weather to reddish colors. The strata can be observed unaltered in the Negra Creek, where they are black mudstone and shale, including abundant calcareous concretions and minor interbeded micrite and biomicrite in medium beds. Lithology and age of the Paja Formation are very similar to the ones from the type locality in the Bucaramanga area. Ammonite faunas of Barremian age, from the lower part of the Paja Formation in the Villa de Leiva area were studied and documented by BURGL (1956) and PATARROYO (2000), as well as Late Aptian ammonite faunas from the uppermost part of the unit were studied and documented by ETAYO (1979).

Toward the N of the country, in the Guajira area, the Yuruma Formation (RENZ 1960) is composed of highly fossiliferous marlstone and biomicrite with calcareous concretions. The Yuruma Formation has a thickness of 165 m in its type locality, but could reach a maximum thickness of 600 m at other localities; its lower part contains abundant ammonites of Barremian age. The unit overlies the sandy limestones of the Moina Formation, but the upper boundary is subjected to discussion. It is proposed here that the black shales, biomicrites, and marlstones included in the "lower cogollo" by RENZ (1960) and ROLLINS (1965) should be part of the Yuruma Formation, because there is not a significant lithologic change between these strata and the underlying ones. Those shales and biomicrites included here in the upper part of the Yuruma Formation contain Aptian ammonites such as *Colombiceras aff. codazzianum, Deshayesites cf. columbianus*, and *Parahoplites obliquus* (RENZ 1960), as well as *Deshayesites stutzeri* and *Colombiceras sp.* (ROLLINS 1965). The overlying, relatively coarse-grained sandy limestones of Albian age should probably be included in the Lisure Formation.

The basal transgressive succession of the Río Negro and Apón Formations from the Perijá Andes (Colombia and Venezuela) was also deposited during the Barremian and Aptian. The Río Negro Formation (HEDBERG 1931; HEDBERG & SASS 1937) overlies with angular unconformity the basement of Late Triassic to Early Jurassic age and transitionally underlies the Aptian strata of the Apón Formation. The Río Negro Formation has a variable thickness that could reach over 1.000 m in Venezuela and is composed of a transgressive succession of conglomerates, coarse-grained arkoses, and minor mudstone beds with no fossils. The Río Negro Formation is most probably of Early Aptian (and perhaps Barremian) age.

The Apón Formation (SUTTON 1946; ROD & MAYNC 1954) is composed of transgressive limestones and shales, has a thickness of approximately 650 m, and transitionally overlies the Río Negro Formation. The lower part of the Apón Formation includes interbeded sandy biosparites, fossiliferous sandstone, rudstone biosparite, sandy mudstone, biomicrite, and dolomite. The upper part, included in the Machiques Member, is composed of black, laminated biomicrites, marlstones, and shales with calcareous concretions. The ammonites of the Apón Formation have been studied and documented by RENZ (1982), who placed the Machiques Member in the late Early Aptian and Late Aptian.

Another basal transgressive succession initiated during the Barremian and Aptian is the one in the Upper Magdalena Valley, from the W side of the basin, including a continental succession of braided to meandering streams that evolved to a marine succession of coastal sandstone and offshore mudstone (GUERRERO *et al.* 2000). The Yaví Formation (MOJICA & MACÍA 1983) is composed of a maximum of 300 m of conglomeratic sandstone, including a basal interval of pebble and cobble conglomerate that rests with angular unconformity over basement of Late Triassic to Early Jurassic age. The Yaví Formation was also included in a TST by Vergara & Guerrero (1996). Toward the upper part of the unit the reddish and multicolored mudstones in thick and very thick beds become an important element. Palynomorphs of late Early Aptian age are known from a transitional interval with the overlying unit, so that the Yaví Formation is of Early Aptian (and possibly Late Barremian) age. The overlying Caballos Formation (Corrigan, 1967) has a maximum thickness of 450 m, and includes two sandstone members separated by a mudstone/biomicrite member. The Lower Sandstone Member, which corresponds to strata deposited in coastal and shoreface environments, is also considered of Early Aptian age. The Middle Mudstone / Biomicrite Member that corresponds to shallow offshore environments contains foraminifers and ammonites of Late Aptian age (Vergara *et al.* 1995). Regarding the source area of terrigenous detritus, petrography of the entire Cretaceous succession from the Upper Magdalena Valley indicates the Ancestral Central Cordillera on the W (Guerrero *et al.* 2000).

Une Alloformation (Guerrero *et al.* 2000). Albian and Cenomanian.

The Une Alloformation includes Albian and Cenomanian strata deposited during two episodes of sea level fall (Early Albian and Cenomanian), separated by an episode of sea level rise (Middle and Late Albian). The alloformation is divided in the Lower, Middle, and Upper Une Allomembers. The type locality of the alloformation is the same one of the Une Formation (Hubach 1931a, 1931b, 1951, 1957; Renzoni 1963) in the area SE of Bogotá, near the town of Une.

The Une Formation was originally understood as a sandstone unit, but it also includes an important mudstone intercalation that serves to separate the unit in two sandstones. Campbell & Burgl (1965) referred the lower part of the formation as the "ubaque sandstone" and placed the Aptian/Albian boundary at its base. They also indicated that the Albian/Cenomanian boundary was contained within the upper Une sandstone. Campbell (1962) stated that the Albian stage forms the large scarp features that extend from the region of the town of Une to Choachí, consisting of about 1.000 m of sandstone and shale. The sandstones that predominate at the base and top of the sequence are hard, cross-bedded quartz arenites, meanwhile that the ammonite - bearing shales that predominate in the middle part of the section are black, pyritic, and contain calcareous concretions. The poorly fossiliferous Cenomanian stage outcrops near the town of Chipaque and consists of about 500 m of sandstones interbedded with siltstone, shale, and limestone. The sandstones are hard, massive, and carbonaceous; the limestones are sandy and full of oysters. Ammonite faunas that indicate an Albian age, from the area near the town of Une were cited by Campbell (1962), including *Lyelliceras pseudolyelli, Hypacanthoplites columbianus, Knemiceras attenuatum, Diploceras aff. evansi, Venezoliceras karsteni, Oxytropidoceras roissyanum, Mojsisoviczia aff. ventanillensis, Neophlycticeras aff. sexangulatum*, and *Mortoniceras sp.* Also in the type locality, from what is known today as the upper part of the Une Formation, a Cenomanian age was indicated with *Mantelliceras cf. brazoense* and the oyster *Exogyra squamata*.

In the San Luis area, approximately 110 km toward the ENE of Bogotá, in the E foothills of the Eastern Cordillera, the Une Formation has a thickness of 1.390 m according to Guerrero & Sarmiento (1996). Over there, the Lower Sandstone Member consists of 470 m, composed predominantly of sandstones which are fine grained in the lower part of the segment and coarse to very coarse and granule conglomerate in the upper part. The Middle Mudstone Member is 230 m thick, including mainly black mudstones with plant remains and laminae of coal and siderite. The Upper Sandstone Member includes 690 m, composed predominantly by sandstones of fine and medium grain, that toward the top of the unit are of coarse to very coarse grain, with granule conglomerate; glauconite is abundant in this member, which also includes a notorious assemblage of Cenomanian palynomorphs. Guerrero & Sarmiento (1996) placed the boundary between the Une and Chipaque Formations near the Cenomanian/Turonian boundary.

The stratigraphy and paleontology of the Cretaceous succession from the Cocuy area were studied by Fabre (1985) and Etayo (1985), who indicated that the Une Formation has a thickness of 1.211 m, and is composed predominantly by medium and coarse-grained quartz arenites. No age diagnostic fossils were found in the Une Formation, but it was included in the Albian and Cenomanian, because of the Late Aptian ammonites of the underlying "apón formation", and a Turonian specimen of ammonite from the lower part of the overlying Chipaque Formation. Cross bedding is present in very thick sandstone beds, separated occasionally by minor interbeddings of black, coaly mudstones. It is interesting to note that the stratigraphic section of the Une Formation in the Cocuy area does not include the middle mudstone interval observed in other localities, probably because of its proximal location to the source area in the Guyana Shield.

In the Guajira area, NE Colombia, and W Venezuela, the relatively coarse-grained Albian strata have been included in the nearly synchronous Lisure Formation (Rod & Maync 1954) and Aguardiente Formation (Notestein *et al.* 1944; Sutton 1946) that are composed of sandy biosparite and fossiliferous sandstone. They are laterally equivalent in part, with predominance toward the SE of sandstone in the Aguardiente Formation, and limestone toward the NW in the Lisure Formation, according to González *et al.* (1980: p. 237-242 and fig. IV-44). The maximum known thickness of the Aguardiente Formation is 480 m in the Mérida area, meanwhile that the maximum thickness of the Lisure Formation is 330 m in the Perijá area. The ammonite faunas illustrated by Renz (1982: plates 3 and 4) from the Perijá area place the Aptian/Albian boundary near the boundary between the Apón and Lisure Formations because the upper part of the Machiques Member (Apón Formation) includes *Parengonoceras cf. hachourii* from the Aptian/Albian transition. The Early Albian is indicated with *Prolyelliceras flandrini* from the top of the Machiques Member and *Knemiceras aff. flexiloculosum* from the basal part of the Lisure Formation. The upper part of the Lisure Formation includes *Mortoniceras aff. pricei* from the Late Albian.

On top of the Lisure Formation in the Perijá area there are 50 to 120 m of sandy biosparites with large size bivalves (including *Exogyra squamata* and *Ostrea scyphax*), which were included in the "Maraca Formation" by Rod and Maync (1954). However, such a thin interval of coarse-grained strata should be considered a member of the upper part of the Lisure and Aguardiente Formations. This coquina bed unit is assumed of Cenomanian age (Renz 1982: p. 30) because the overlying black mudstones and biomicrites of the La Luna Formation contain Early Turonian ammonites.

The middle mudstone or biomicrite member of Middle and Late Albian age, present in most sections from central and W Colombia has not been differentiated in this area of NE Colombia and W Venezuela. However, a section of the approximately 420 m thick Aguardiente Formation from Trujillo (González *et al.* 1980: fig. IV-45) indicates a 125-m thick middle portion of limestones with occasional marlstones and black mudstones, which separates the otherwise quartz sandstones of the lower and upper parts of the formation. The lower part of the Aguardiente Formation is of fine to medium grain sandstone but the upper part reaches medium to coarse grain, which is capped by 10 m of sandy biosparites with abundant oysters of the Maraca Member. The succession is conformably overlain by the mudstones/ biomicrites of the La Luna Formation.

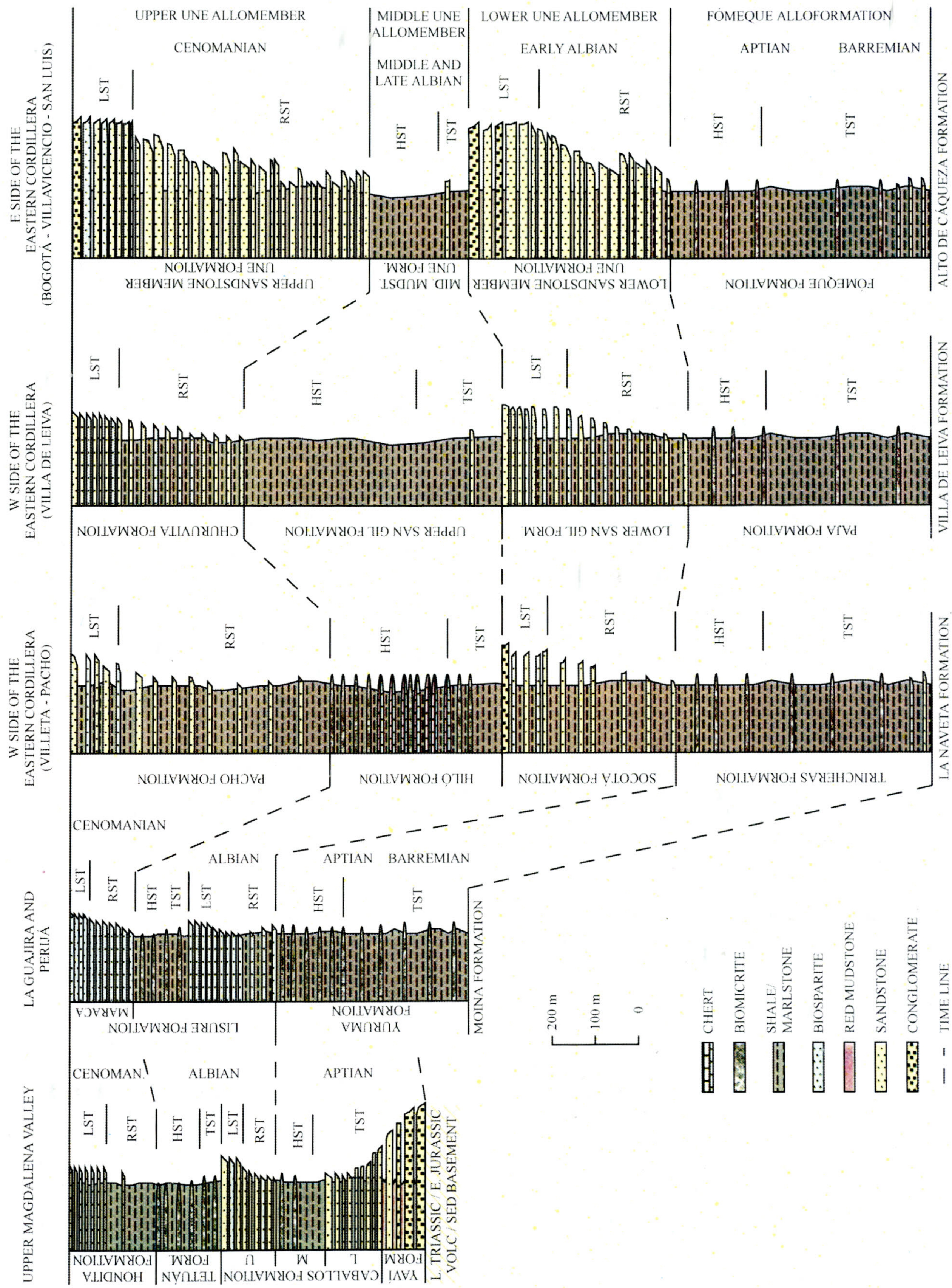
As indicated before, the Albian and Cenomanian strata of the Une Alloformation can be subdivided in central and W Colombia in three allomembers, which are characterized by notorious episodes of sea level fall and rise as discussed below.

Lower Une Allomember (Guerrero *et al.* 2000). Progradational to aggradational strata of Early Albian age.

The Lower Une Allomember includes Early Albian strata deposited during relatively fast sea level fall (RST) and low sea levels (LST). The base of the allomember coincides with a sequence boundary (SB) placed at or very near the Aptian/Albian boundary. It includes the Lower Sandstone Member of the Une Formation, as well as the Socotá and Lower San Gil Formations in the E and central sides of the basin. It also includes the Upper Sandstone Member of the Caballos Formation in the SW side of the basin. The age of the allomember is essentially Early Albian, but due to local differences in subsidence and rate of sediment supply, it also includes in some areas the uppermost part of the Late Aptian. The allomember includes important hydrocarbon reservoirs toward the borders of the basin, such as the Upper Sandstone Member of the Caballos Formation in the W, and the relatively unexplored Lower Sandstone Member of the Une Formation toward the E.

As indicated before, the Lower Sandstone Member of the Une Formation has a thickness of 470 m in the E foothills of the Eastern Cordillera. Sandstones are fine-grained, medium-bedded in the lower part of the segment and very thick bedded, coarse to very coarse toward the upper part, including granule conglomerate. Cross bedding is a common feature, which becomes very notorious and of large scale in the upper part of the member. Sand-sized coal fragments and bigger fragments of plant remains are present along with very thin beds and laminae of coal and siderite. Black mudstone is present

Fig. 1. Composing lithostratigraphic units of the Fómeque and Une Alloformations. Top datum is the transgressive surface (TS) at the Cenomanian / Turonian boundary.


E SIDE OF THE EASTERN CORDILLERA (BOGOTÁ - VILLAVICENCIO - SAN LUIS)
UPPER UNE ALLOMEMBER
CENOMANIAN
MIDDLE UNE ALLOMEMBER
MIDDLE AND LATE ALBIAN
LOWER UNE ALLOMEMBER
EARLY ALBIAN
FÓMEQUE ALLOFORMATION
APTIAN
BARREMIAN
LST
RST
HST
TST
UPPER SANDSTONE MEMBER UNE FORMATION
MID. MUDST. UNE FORM.
LOWER SANDSTONE MEMBER UNE FORMATION
FÓMEQUE FORMATION
ALTO DE CÁQUEZA FORMATION
W SIDE OF THE EASTERN CORDILLERA (VILLA DE LEIVA)
CHURUVITA FORMATION
UPPER SAN GIL FORMATION
LOWER SAN GIL FORM.
PAJA FORMATION
VILLA DE LEIVA FORMATION
W SIDE OF THE EASTERN CORDILLERA (VILLETA - PACHO)
PACHO FORMATION
HILO FORMATION
SOCOTÁ FORMATION
TRINCHERAS FORMATION
LA NAVETA FORMATION
LA GUAJIRA AND PERIJÁ
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
MARACA
LISURE FORMATION
YURUMA FORMATION
MOINA FORMATION
UPPER MAGDALENA VALLEY
CENOMAN.
ALBIAN
APTIAN
HONDITA FORMATION
TETUÁN FORM.
CABALLOS FORMATION
U
M
L
YAVÍ FORM.
L. TRIASSIC / E. JURASSIC VOLC / SED BASEMENT
200 m
100 m
0
CHERT
BIOMICRITE
SHALE/ MARLSTONE
BIOSPARITE
RED MUDSTONE
SANDSTONE
CONGLOMERATE
TIME LINE

in very thin and thin beds, which represent a very minor proportion of the member.

Toward the center of the basin in the W, sandstones become finer grained and thinner, so that they almost disappear and are replaced by other lithostratigraphic units that contain larger amounts of black mudstone. The name Socotá Formation (Cáceres & Etayo 1969; Etayo 1979) has been used in different ways because of a non-accurate definition and the lack of a published stratigraphic type section including at least part of the formations above and below. The boundaries have varied trough time and the unit has even been even divided in members and formations that are not always identifiable, so that definition is still confusing. In this paper, the Socotá Formation includes all the strata between the Trincheras and Hiló Formations. The Socotá Formation is composed of black mudstones with minor sandstone interbedings, which are very important to separate the unit from the black shales of the upper part of the Trincheras Formation and the cherts, biomicrites, and shales of the overlying Hiló Formation. These sandstone interbeddings were originally interpreted as a possible variety of turbidites (Polanía & Rodríguez, 1978), but they are most probably the result of storm beds in a shallow marine setting dominated by offshore mudstones.

Martínez & Vergara (1999: fig. 4) measured near the town of La Mesa, 50 km W of Bogotá, approximately 270 m of an interval of the Socotá Formation. It includes a succession of 120 m of fossiliferous mudstones, with minor interbeddings of siltstones and fine-grained sandstones with mono-crystalline quartz in very thin and thin beds. These are followed by 120 m of coarsening upward cycles a few meter thick, composed of calcite-cemented quartz arenites of very fine to medium grain in very thin to thick beds, underlain by siltstone/mudstone interbeddings; this portion includes ammonites, leaves, and tree trunks. A final 30-m interval includes fossiliferous mudstones with minor thin beds of fine-grained sandstones, along with granule-size quartz conglomerates. It is probable that most of the shales without sandstone interbeddings included in the "capotes formation" should be included in the lower part of the overlying Hiló Formation. Regarding the age of the Socotá Formation, the ammonites illustrated by Etayo (1979) indicate latest Aptian and Early Albian.

The relatively coarse grained strata overlying the Paja Formation in the Villa de Leiva area were included by Etayo (1968a, b, 1979) in the Lower San Gil Formation, following a designation by Hubach (1953, 1955, 1957) from an area NNE of Villa de Leiva, near the town of San Gil. The name was originally used in the area SSW of San Gil, to refer more than 300 m of sandstones, fossiliferous sandstones, and limestones 2-8 m thick, alternating with dark shales of about the same thickness. According to Etayo (1979: p. 4 and fig. 2) the Lower San Gil Formation has a thickness of 480 m. It is composed of nearly 130 m of sandy mudstones with interbeddings of sandstone, followed by 200 m of bivalve limestones with minor micaceous mudstone/siltstone beds. These are finally capped by 150 m of sandy mudstones and sandstones, which in the uppermost part include 25 m of thick-bedded fine-grained quartz sandstones and 10 m of dark-gray fine to medium grained sandstones. Etayo (1968b: tabla 1) reported a succession of forms including *Colombiceras alexandrinum, C. Riedelii, Eodouvilliceras sp., C. Obliquum*, and *Rhytidohoplites?* which would place the unit in the latest Aptian and Early Albian interval.

In the Bucaramanga area these strata are apparently more calcareous, and were included in the Tablazo Limestone by Hubach (1957) and Morales *et al.* (1958). The unit would have a thickness of 150 to 325 m, composed of extremely fossiliferous, massive-bedded limestones of coarse texture, along with clayey limestones.

In the Upper Magdalena Valley, in the SW side of the basin, the Upper Sandstone Member of the Caballos Formation (Corrigan 1967; Guerrero *et al.* 2000) includes 60-150 m of sublitharenites, quartz arenites, biosparites, and fossiliferous sandstones with abundant large size fragments and complete specimens of bivalves and other mollusks. The member has a coarsening upward pattern, reaching coarse-grained sandstone in some sections. In any case, grain size is always relatively coarser at the top than at the lower part of the member in each locality. Despite the source area located to the W in the Ancestral Central Cordillera, this part of the section includes important intervals of mature sandstones with common quartz arenites, which contrast with the lithic arenites of the rest of the Cretaceous section in the Upper Magdalena Valley. It is believed that this anomalous maturity was achieved in shoreface environments during a relatively prolonged time interval of low sea level and slow subsidence, as indicated by the reduced thickness and the progradational to low aggradational pattern of most sections. Maturity of the sandstones of the Cretaceous Colombian Basin has relation not only with the source area, but also with the sedimentary environment, so that compositional maturity, source area, and sedimentary environment must be considered together to find the explanation of anomalous compositions.

Middle Une Allomember (Guerrero et al., 2000). Retrogradational to aggradational strata of Middle and Late Albian age.

The Middle Une Allomember includes Middle and Late Albian strata deposited during relatively fast sea level rise (TST) and high sea levels (HST). The base of the allomember coincides with a major transgressive surface (TS) at or near the Early Albian / Middle Albian boundary. The unit includes the Middle Mudstone Member of the Une Formation, as well as the Hiló and Upper San Gil Formations in the E and central sides of the basin. It also includes the Tetuán Formation in the SW side of the basin, on the Upper Magdalena Valley. The allomember includes important source rocks of hydrocarbons, with significant amounts of organic matter of marine origin, being the most important one known so far in the Tetuán Formation.

The Middle Mudstone Member of the Une Formation from the San Luis area in the E foothills of the Eastern Cordillera is 230 m thick, including mainly black mudstones with plant remains and laminae of coal and siderite. The increase of siderite in laminae and very thin beds is very notorious in relation to the underlying sandstone member. In the lowermost part of this mudstone member there is a level with very abundant plant remains, including mostly leaves in a matrix of coaly mudstones and laminae of coal. Scarce medium to thick beds of coarse- to medium-grain quartz arenite are also present.

Toward the axis of the basin W of Bogotá, the time and l aterally equivalent facies include an interval of cherts, biomicrites and claystone shales known as the Hiló Formation (Hubach 1931a; Cáceres & Etayo 1969; Etayo 1979). According to Etayo (1979: p. 11 and fig. 2) the unit would have a Middle and Late Albian age and a thickness of approximately 300 m, taking the base of the unit in the first occurrence of brick like siliceous fragments. It is composed of an alternation of "lidites" or "porcellanites" with dark-gray clay-shale. According to Martínez & Vergara (1999) the Hiló Formation has a thickness of 450 m, and could include toward the top an Early Cenomanian age. It should however be noted here that differences in age and thickness are the result of placing the boundaries of the unit in different levels, because of non-accurate definitions, which lack a stratigraphic section from a well-defined type locality.

These "lidites" correspond to a field term for siliceous strata in the clay and very fine silt size range, which fracture in orthogonal prisms of 5-10 side. According to Guerrero *et al.* (2000), who studied the petrography of similar rocks of Santonian and Late Campanian age from the Upper Magdalena Valley, these cherts are diagenetic rather than primary, resulting from the replacement of micrites and fossiliferous micrites by quartz. These very finely laminated strata are believed to be the result of marine sedimentation in deep ramp environments between 150 and 250 m. The diagenetic cherts present in several levels of the Cretaceous succession do correspond to the deepest marine environments recorded in the basin, being the ones from the Middle and Late Albian Hiló Formation the oldest known to date. Associated to these beds, there are common reports of ammonites, including several species of *Oxytropidoceras*.

In the Villa de Leiva area the Middle and Late Albian succession has been included in the Upper San Gil Formation by Etayo (1968a, b, 1979), following the original designation of the unit by Hubach (1953). The unit conformably overlies the sandstones of the Lower San Gil Formation and underlies the sandstones and coquina limestones of the Churuvita Formation. According to Etayo (1979: p. 4 and fig. 2) the Upper San Gil Formation is of Middle and Late Albian age, including 620 m of dark-gray shale predominantly, with a few intercalations of sandstone or limestone toward the base of the formation. The unit contains several ammonite genera, including *Knemiceras, Engonoceras, Platiknemiceras, Tegoceras*, and *Carloscacericeras*.

In the Upper Magdalena Valley, the Middle and Late Albian strata have been included in the Tetuán Formation (Guerrero *et al.* 2000: p. 56-58 and table 6). The unit overlies the quartz sandstones and sandy biosparites of the Caballos Formation and underlies the terrigenous mudstones and lithic arenites of the Hondita Formation. The Tetuán Formation has a thickness of 150 to 200 m, composed essentially of black marlstones and biomicrites. The lower beds of the type section near the Tetuán River and the town of Ortega include *Tegoceras* and *Oxytropidoceras* along with other Middle Albian ammonites.

Upper Une Allomember (Guerrero *et al.* 2000). Progradational to aggradational strata of Cenomanian age.

The Upper Une Allomember includes Cenomanian strata deposited during relatively fast sea level fall (RST) and low sea levels (LST). The base of the allomember coincides with a sequence boundary (SB) placed at or very near the Albian/Cenomanian boundary. It includes the Upper Sandstone Member of the Une Formation, as well as the Pacho, Chiquinquirá, and Churuvita

Formations in the E and central sides of the basin. It also includes the Hondita Formation in the SW side of the basin, on the Upper Magdalena Valley. This allomember includes potential reservoirs of hydrocarbons relatively unexplored, such as the Upper Sandstone Member of the Une Formation.

The Upper Sandstone Member of the Une Formation from the E foothills of the Eastern Cordillera includes 690 m, composed predominantly by sandstones of fine and medium grain, that toward the top of the unit are of coarse to very coarse grain, with granule conglomerate. Important porosities that resulted from partial replacement of glauconite by dolomite have been detected in the unit. Black mudstones are present in a minor proportion; they are commonly bioturbated and include ichnofossils along with disseminated pyrite, coal particles and laminae, and siderite in laminae and very thin beds. Glauconite is a common component of the sandstones, being abundant in the middle and upper parts of the unit. The Upper Sandstone Member of the Une Formation includes an assemblage of Cenomanian palynomorphs (Herngreen & Dueñas, 1990; Guerrero & Sarmiento 1996), which placed the upper boundary of the Une Formation near the Cenomanian/Turonian boundary (Guerrero & Sarmiento 1996). A sequence boundary had been originally placed within the upper part of this sandstone member (Guerrero & Sarmiento 1996: p. 52), but it is now placed at the base of the unit. This sequence boundary coincides with the beginning of a relatively fast sea level fall, so that the RST is included within the lower part of the new sequence.

Toward the axis of the basin W of Bogotá, the laterally equivalent unit corresponds to the "unnamed shales" (Cáceres & Etayo 1969; Etayo 1979) that overlie the Hiló Formation and underlie the La Frontera Formation. According to Martínez & Vergara (1999) who included the unit in the "simijaca formation", it includes an approximate thickness of 800 m (apparently calculated from the average dip and mapped area), including black mudstones and shales with minor sandstone interbeddings, which reach medium to coarse grain size toward the top of the unit. However, the "simijaca formation" of Ulloa & Rodríguez (1991: fig. 5 and p. 14-15) is an invalid synonym of the lower part of the "san rafael formation" (Etayo 1968a, 1979), which in turn is an invalid synonym of the La Frontera Formation (Hubach 1931a, 1957; Cáceres & Etayo 1969; Etayo 1979) of Turonian age. Because of this, the relatively coarse grained Cenomanian strata, that overlie the shales/cherts of the Hiló Formation and underlie the shales/cherts of the La Frontera Formation, are included here in the Pacho Formation. This unit is not well defined either, but was placed in the 227 – La Mesa geologic map of Ulloa *et al.* (1993) between the Hiló Formation and La Frontera Formation to refer to mudstones and siltstones with sporadic interbeddings of sandstone. The upper part of this Cenomanian beds contain in the area W of Bogotá, the famous horizon of grainstone/rudstone biosparites and sandy biosparites with abundant specimens of the oyster Exogyra squamata.

In the Chiquinquirá area NNE of Bogotá, the Chiquinquirá Formation (Ulloa & Rodríguez 1991: p. 12-15 and figs. 5 and 6) includes 337 m of fine-grained sandstones with minor interbeddings of dark gray mudstones. According to Ulloa & Rodríguez (1991: fig. 6) the unit is considered as coeval of the Churuvita Formation; it overlies the mudstones of the Upper San Gil Formation and underlies the mudstones of the Chipaque "group". The Churuvita Formation (Etayo 1968a, 1979) from the nearby Villa de Leiva area includes 405 m of sandstones and limestones, subdivided in three intervals. These include 105 m of thick-bedded sandstones with minor thin beds of mudstone, followed by 75 m of lenticular limestone beds, rich in *Exogyra*, that alternate with mudstones and occasional sandstones. These are capped by 225 m of massive beds of fine to medium grain sandstones and massive limestones interbedded with mudstones. It is probable that a closer examination of detailed sections from the Chiquinquirá and Churuvita Formations will show that are not that different, and that the Chiquinquirá Formation is a synonym of the previously proposed Churuvita Formation.

Among other bivalves present in the Churuvita Formation it is worth to note the presence of *Exogyra squamata* and *Ostrea scyphax*, which are also present in the Cenomanian of the Maraca Member from Venezuela and in general, in the top beds of the Upper Une Allomember.

In the SW side of the basin in the Upper Magdalena Valley, the relatively coarse-grained strata of Cenomanian age have been included in the Hondita Formation (Porta 1965, 1966; Guerrero *et al.* 2000). The unit is 200-250 m thick, composed of a progradational succession of mudstones, sandy mudstones and fine-grained lithic arenites; in some localities the sandstones of the top of the unit reach coarse grain size. The formation is well dated in the Cenomanian and its upper boundary nearly coincides with the Cenomanian/Turonian boundary (Villamil 1998; Guerrero *et al.* 2000). Source area was located to the W, on the Ancestral Central Cordillera (Guerrero *et al.* 2000). Sedimentary environment of the Hondita Formation was interpreted as evolving from offshore environments at depths of no more than 100 m to lower shoreface environments at depths about 15 to 10 m.

Chipaque Alloformation (Guerrero *et al.* 2000). Retrogradational to aggradational strata of Turonian to Santonian age.

The Chipaque Alloformation includes Turonian, Coniacian, and Santonian strata deposited during relatively fast sea level rise (TST) and high sea levels (HST). The lower boundary of the Chipaque Alloformation is placed in a major transgressive surface (TS) at or near the Cenomanian/Turonian boundary. The alloformation includes the Chipaque Formation, and the succession of the La Frontera and Conejo Formations in the E and eastern-central sides of the basin. Toward the NE of the country and W Venezuela includes the La Luna Formation. It also includes the succession of the Lomagorda and Lidita Inferior Formations in the SW side of the basin, on the Upper Magdalena Valley. Basal transgressive deposits include the succession of the Masaya and Las Iglesias Formations on the previous E border of the basin, in the Putumayo and Llanos Orientales areas. The Chipaque Alloformation includes large amounts of organic matter of marine origin and constitutes an important interval of source rocks of hydrocarbons in Colombia and Venezuela. The type locality of the unit is the same one of the Chipaque Formation, near Bogotá.

The Chipaque Formation (Hubach 1951, 1957; Renzoni 1963, 1968) is composed in its type area SE of Bogotá of approximately 450 m of black mudstones, with minor interbeddings of fine-grained sandstones, although no detailed sections are available. In a reference section on the E foothills of the Eastern Cordillera, the unit measures 565 m and is composed of black mudstones, with a lesser amount of very fine and fine grained sandstones according to Guerrero & Sarmiento (1996). A detailed section of the unit indicates the presence of siderite in thin beds, coal in laminae and thin beds, leaves and other plant fragments, fining upward thin to medium beds of sandstone, Rhizocorallium and Thalassinoides ichnofossils, fish teeth, and bivalves (Guerrero and Sarmiento, 1996: p. 7-18, fig. 4). The unit is dominated by black mudstones but important sandstone intervals with glauconite and ripple bedding are also present, reaching about 1/3 of the total thickness of the unit. Sedimentary environment was interpreted as evolving from estuarine to offshore, with minor intervals of shallowing that reached the lower shoreface, above the fair weather wave base. The fining upward thin to medium beds of sandstone with mud intraclasts and phosphatic particles were interpreted as the result of gravity flows produced during storms. The amount of sandstone interbeddings diminishes toward the W, where shoreface sandstones become absent and storm beds are thinner and finer grained. The unit was dated with palynomorphs in the Turonian to Santonian time span and the relative proportion of pollen, dynoflagellates, spores and fungi was used to indicate minor relative sea level changes within the unit (Guerrero & Sarmiento, 1996: figs. 8 and 9). Similar age and environmental results were obtained from the same section, with the study of benthic foraminifers by Tchegliakova *et al.* (1997). Other partial sections reported by Vergara & Rodríguez (1997) and Vergara *et al.* (1997) indicate in general similar lithologies and ages although there is some difference in the age of the boundaries of the unit at different localities.

In the Putumayo and Llanos Orientales areas, the equivalent strata are relatively coarser grained because of their closer proximity to the source area in the Guyana Shield. The succession composed of the Masaya and Las Iglesias Formations (Mora *et al.* 1998) rests with angular unconformity on Jurassic basement and constitute a basal, fining upward, transgressive succession. The Masaya Formation includes approximately 70-80 m of sandstones that are apparently repeated by fault, so that some sections reach a thickness of approximately 160 m. The Las Iglesias Formation has a thickness of approximately 60-70 m, composed of mudstones with minor interbeddings of calcareous sandstones. The sedimentary environments of the succession are interpreted here as evolving from fluvial to shoreface and shallow offshore environments. According to the palynological ages of Geochron (in Mora *et al.* 1998), the base of the succession is close to the Cenomanian/ Turonian boundary and the upper part of it is of Santonian age. Previous unpublished studies have mentioned Albian to Cenomanian ages for basal transgressive successions in the Putumayo area, so that it is possible that strata older than the Masaya Formation could be documented for some parts of the area.

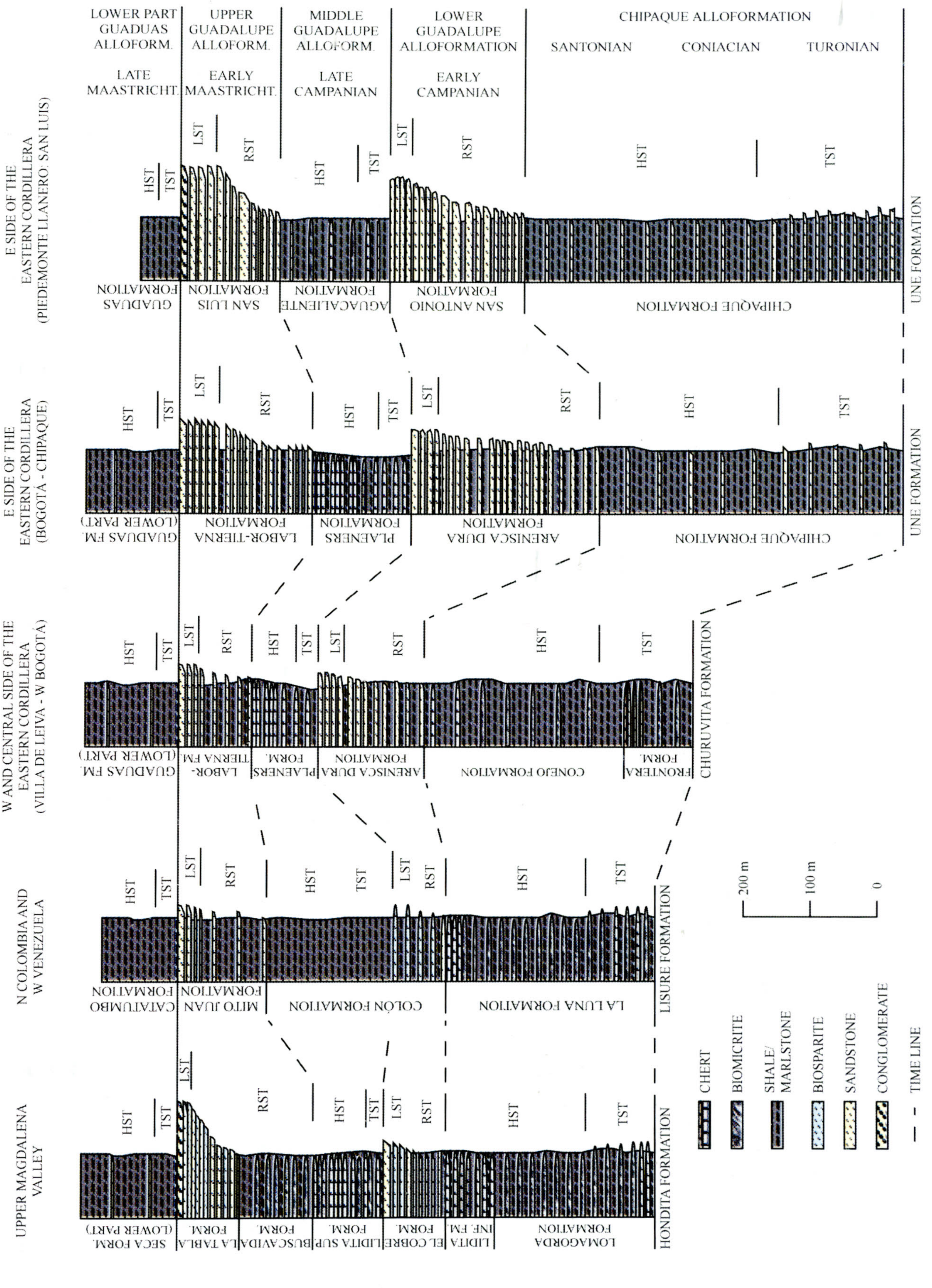
Toward the axis of the basin W of Bogotá, the sandstone interbeddings of the Chipaque Formation almost disappear so that the unit is made of black mudstones, shales, and biomicrites, with a notorious interval of "lidites" in the lower part of the unit. Over there, the Turonian to Santonian interval has been included in two units, which correspond to La Frontera (Hubach 1931a, 1957; Cáceres & Etayo 1969; Etayo 1979) and Conejo (Renzoni 1967, 1981; Etayo 1968a, b, 1979) Formations. The first unit was originally considered by Hubach (1931a, 1957) as a horizon of "lidites" from La Frontera quarry in the Villeta area (Alban County), approximately 50 km NW of Bogotá. The name was used later on with the rank of formation (Cáceres & Etayo 1969) to include approximately 52 m of Turonian strata, composed of shales with calcareous concretions and medium to thick beds of biomicrite, capped with porcellanites and cherts in thin beds (Etayo 1979). The laterally equivalent 74 m thick "san rafael formation" from the Villa de Leiva area (Etayo 1968a, 1979) is an invalid synonym of the La Frontera Formation. The overlying Conejo Formation (Renzoni 1967, 1981; Etayo, 1968a, b, 1979) includes in the Tunja and Villa de Leiva areas 250 to 300 m of Coniacian and Santonian mudstones and marlstones with large calcareous concretions, along with minor biomicrite and sandstone interbeddings. The upper unnamed interval that comprises 120 to 150 m of quartz arenites and sandy mudstones corresponds to the Arenisca Dura Formation of the overlying Guadalupe Group, so that it is excluded here from the Conejo Formation. In the other hand, the Conejo Formation has recently been extended from its type locality to the Villeta – La Mesa area by Ulloa *et al.* (1993) and Martínez & Vergara (1999). According to the last authors, the unit measures approximately 400 m, including black shales and marlstones with calcareous concretions that toward the middle part include interbeddings of medium to very thick beds of biomicrite and toward the upper part minor sandstone beds.

It should be noted that toward the W the thickness of the strata laterally equivalent to the Chipaque Formation also reach 400-450 m, but do contain more biomicrite and less sandstone interbeddings than the strata near Bogotá and in the E foothills of the Eastern Cordillera. Another interesting difference is the presence (in the lower and upper intervals of the succession) of "lidites" and cherts, which are composed of particles in the clay and very fine silt size. A curious fact is that the silicified intervals are present in proximity of thick sandstone strata, such as the ones of the Upper Une Allomember and the Lower Guadalupe Alloformation. Guerrero *et al.* (2000) indicated that the "lidite" beds are the result of a complex diagenesis that replaced calcite (biomicrite) by quartz (chert), meanwhile that other strata of the succession had the inverse replacement of siliceous particles by calcite.

Farther W, in the opposite western side of the basin, the Turonian to Santonian interval is represented by the Lomagorda and Lidita Inferior Formations (Guerrero *et al.* 2000). As noted before, part of the Turonian and Santonian strata do include intervals with diagenetic cherts. The Lomagorda Formation (Porta 1965, 1966; Guerrero *et al.* 2000) includes 170-240 m composed mainly of packstone biomicrites of foraminifers, with minor amounts of wackestone biomicrites and impure, muddy biomicrites. Close to the base of the unit there are very thin and thin bentonite beds associated, in an interval of about 5 m, with the famous thin beds fractured in cubic prisms that are referred as "lidites". Toward the upper part of the unit there are very large calcareous concretions that reach up to 2 m in diameter. The unit is well dated in the Turonian to earliest Santonian with a varied and abundant assemblage of planktic foraminifers (Vergara 1994, 1997; Guerrero *et al.* 2000). The overlying Lidita Inferior Formation (Porta 1965, 1966; Guerrero *et al.* 2000) includes 30-70 m of finely laminated fossiliferous micrites and wackestone biomicrites, in part silicified to diagenetic cherts, with interbeddings of less than 5% of laminae and thin beds of phosphatized bio- and intra- micrites of packstone texture. The Lidita Inferior Formation is of Santonian age as indicated by its foraminiferal content and the age of the units above and below (Guerrero *et al.* 2000). Sedimentary environments of the Lomagorda and Lidita Inferior Formations were regarded as evolving from shallow offshore to deep ramp.

In NE Colombia and W Venezuela the La Luna Formation (Garner 1926; Hedberg & Sass 1937) includes approximately 300 m of black, carbonaceous to bituminous, laminated micrites with marlstones and "ftanitas" (cherts). Large calcareous concretions with diameters up to 1 m are also a common feature. The age has varied within the Late Albian to Early Maastrichtian interval due to the inclusion of beds of underlying and overlying units, as different authors (*e.g.* Erlich *et al.* 2000) pick different boundaries for the unit at different localities. Because of this, it is very important to consider the lithology and age of the unit in its type locality, in the Perijá area. Over there, the name was first used to refer to the black biomicrites, marlstones, and "ftanitas" overlying the Maraca Member of the Lisure Formation (Cenomanian) and underlying the Colón Formation (Campanian). The age of the lower part of the La Luna Formation can be precisely constrained as Early Turonian based on the ammonite report by Renz (1982: p. 69 and plate 21) including *Romaniceras cf. deverianum*, from 9 m above the base of the unit in the Perijá Foothills. According to Renz (1982: p. 63-64),

Fig. 2. Composing lithostratigraphic units of the Chipaque Alloformation, Guadalupe Allogroup, and lower part of the Guaduas Alloformation. Top datum at the base of the Guaduas Alloformation is the Transgressive Surface (TS) at the Early Maastrichtian / Late Maastrichtian boundary.


LOWER PART GUADUAS ALLOFORM.
UPPER GUADALUPE ALLOFORM.
MIDDLE GUADALUPE ALLOFORM.
LOWER GUADALUPE ALLOFORMATION
CHIPAQUE ALLOFORMATION
SANTONIAN
CONIACIAN
TURONIAN
LATE MAASTRICHT.
EARLY MAASTRICHT.
LATE CAMPANIAN
EARLY CAMPANIAN
E SIDE OF THE EASTERN CORDILLERA (PIEDEMONTE LLANERO: SAN LUIS)
E SIDE OF THE EASTERN CORDILLERA (BOGOTÁ - CHIPAQUE)
W AND CENTRAL SIDE OF THE EASTERN CORDILLERA (VILLA DE LEIVA - W BOGOTÁ)
N COLOMBIA AND W VENEZUELA
UPPER MAGDALENA VALLEY
GUADUAS FORMATION
SAN LUIS FORMATION
AGUACALIENTE FORMATION
SAN ANTONIO FORMATION
CHIPAQUE FORMATION
UNE FORMATION
GUADUAS FM. (LOWER PART)
LABOR-TIERNA FORMATION
PLAENERS FORMATION
ARENISCA DURA FORMATION
LABOR-TIERNA FM.
PLAENERS FORM.
CONEJO FORMATION
FRONTERA FORM.
CHURUVITA FORMATION
CATATUMBO FORMATION
MITO JUAN FORMATION
COLÓN FORMATION
LA LUNA FORMATION
LISURE FORMATION
SECA FORM. (LOWER PART)
LA TABLA FORM.
BUSCAVIDA FORM.
LIDITA SUP FORM.
EL COBRE FORM.
LIDITA INF. FM.
LOMAGORDA FORMATION
HONDITA FORMATION
HST
TST
LST
RST
200 m
100 m
0
CHERT
BIOMICRITE
SHALE/ MARLSTONE
BIOSPARITE
SANDSTONE
CONGLOMERATE
TIME LINE

other reports of ammonites from the Perijá foothills indicate a Turonian and Coniacian age, being important the reports of Sutton (1946), that include *Hoplitoides*, *Neoptychites*, and *Eucalycoceras* from the Turonian, as well as *Barroisiceras, Peroniceras, Gauthiericeras*, and *Prionocyclus* from the Coniacian. *Texanites texanum* and *Paralenticeras sieversi*, according to Ford & Houbolt (1963) indicate a Santonian age from the upper part of the La Luna Formation. Discussions of the lithology and age of the La Luna Formation can be found in González *et al.* (1980) and Renz (1982). It is suggested here that other strata of Late Albian and Cenomanian age should be included in the Lisure Formation, or in other laterally equivalent lithostratigraphic units, but not in the La Luna Formation. The same goes for the Campanian and Maastrichtian strata, which should better be included in the Colón and Mito Juan Formations, or in other laterally equivalent units, but not in the La Luna Formation.

Guadalupe Allogroup (Guerrero & Sarmiento 1996). Campanian and Early Maastrichtian.

The Guadalupe Allogroup includes strata deposited during two episodes (Early Campanian and Early Maastrichtian) of fast sea level fall (RST) and low sea levels (LST), separated by Late Campanian strata deposited during fast sea level rise (TST) and high sea levels (HST). It includes the Guadalupe Group in the E side of the basin, and the El Cobre, Lidita Superior, Buscavida, and La Tabla Formations in the W side of it. The allogroup also includes the Colón and Mito Juan Formations toward the N of the country and W Venezuela. The Guadalupe Allogroup is divided in three units, including the Lower, Middle, and Upper Guadalupe Alloformations.

The type locality of the allogroup is the same one of the Guadalupe Group (Hettner 1892; Hubach 1931b, 1951, 1957; Renzoni 1963, 1968) in the vicinities of Bogotá. As with many other units from the Cretaceous in Colombia, original meaning has evolved trough time, as soon as the difference between chronostratigraphic and lithostratigraphic units was recognized and also as guides and codes on stratigraphic nomenclature were published. Because of these, the current understanding of the Guadalupe Group is the one proposed by Renzoni (1963, 1968), who established the base of the unit in a more acceptable and easy to recognize boundary, in the lithologic change from mudstones to sandstones. Today, the group is understood as composed predominantly of quartz arenites, with an intermediate succession of finer grained strata including mudstones and "plaeners" or "lidites" (cherts) that separate the unit in two sandstones. The sandstones of the Guadalupe Group overlie the mudstones of the Chipaque Formation and underlie the mudstones and coals of the Guaduas Formation. The Guadalupe Group is well dated in the Campanian and Early Maastrichtian with dynoflagellates, pollen, spores, foraminifers, and ammonites (Follmi *et al.* 1992; Martínez 1995; Guerrero & Sarmiento 1996; Tchegliakova *et al.* 1997; Vergara & Rodríguez 1997; Sarmiento & Guerrero 2000).

In N Colombia and W Venezuela, the Campanian and Early Maastrichtian strata are included in the Colón and Mito Juan Formations. The meaning of the Colón Formation (Liddle 1928; Kehrer 1937; Hedberg & Sass 1937) has varied since its original definition, but it is today used to refer strata above La Luna Formation and below the Mito Juan Formation. It has a thickness of 600 m in its type locality in Venezuela, but there are reports of up to 900 m in other localities, due probably to the lack of accuracy in the upper boundary with the Mito Juan Formation. Apparently, these two formations could be difficult to differentiate in the field, so that some authors refer the whole interval above La Luna Formation as Colón – Mito Juan. The Colón Formation is composed mainly of black mudstones and shales, but a thin 3-5 m interval of glauconitic sandstones and limestones is known from the base of the unit in some areas. According to Ford & Houbolt (1963), in the Perijá area there is at the base of the Colón Formation a thin 3-m interval of glauconitic limestone, followed by a 40-m interval of limestones. These are different from those of the underlying La Luna Formation because of the clear color of their "matrix" (probably cement) and their content of benthic foraminifers. Biostratigraphic data are conflicting but González *et al.* (1980) favored a Late Campanian and Early Maastrichtian age for the Colón Formation. The Mito Juan Formation (Garner 1926; Hedberg & Sass 1937; Notestein *et al.* 1944) has its type locality in the Mito Juan Creek, in the Catatumbo area from Colombia. It consists of black and greenish gray sandy mudstones that toward the top of the unit become sandstones; its thickness varies from 275 to 420 m in Colombia and from 100 to 200 m in Venezuela. Age data are scarce but indicate a Maastrichtian, according to the report of Hedberg & Sass (1937), who mentioned the presence of poorly preserved specimens of ammonites, including *Sphenodiscus* and *Coahuillites* in the Río de Oro strata. These beds from the upper part of the succession include glauconitic limestones interbedded with mudstones and sandy mudstones.

Since the lithostratigraphy and biostratigraphy of the Campanian and Maastrichtian strata from W Venezuela and N Colombia do not allow precise subdivision and dating, the episodes of sea level fall and rise included in the Guadalupe Group from Colombia can only be suspected but not documented accurately. The Colón and Mito Juan Formations are considered correlative to the Guadalupe Group at least in part, but detailed allostratigraphic, chronostratigraphic, and lithostratigraphic subdivision of the interval is considered only from the Eastern Cordillera and the Upper Magdalena Valley.

Lower Guadalupe Alloformation (Guerrero & Sarmiento 1996). Progradational and aggradational strata of Early Campanian age.

The Lower Guadalupe Alloformation includes strata deposited during relatively fast sea level fall (RST) and low sea levels (LST). The base of the unit coincides with a sequence boundary (SB) placed at or near the Santonian/Campanian boundary. The age of these strata is essentially Early Campanian, although in a few localities a latest Santonian age has been detected in its lowermost part, apparently because of differential rates of subsidence and sediment supply or because of small discrepancies in age assignments. The alloformation includes the Arenisca Dura Formation in the Bogotá area and the Arenitas de San Antonio Formation in the E foothills of the Eastern Cordillera. In the Upper Magdalena Valley it does include the El Cobre Formation.

The Arenisca Dura Formation (Hubach 1951, 1957; Renzoni 1963, 1968) has a thickness of 300 to 450 m in its type locality near Bogotá, although it could be exaggerated due to tectonic complications. According to Pérez & Salazar (1978), the unit is composed mainly by very fine-grained sandstones, which toward the base of the unit are silty and toward the top become fine and medium grained; the unit also includes minor interbeddings of mudstones.

In the E foothills of the E Cordillera, the laterally adjacent Arenitas de San Antonio Formation (Guerrero & Sarmiento 1996) measures 215 m and is composed mainly of fine and medium grained quartz arenites. These are very fine grained toward the base of the formation, meanwhile that toward the top become coarse and exceptionally very coarse, with granule conglomerate. The unit also includes minor mudstone interbeddings that represent 15 percent of its total thickness. The formation has a general coarsening upward trend including mostly progradational strata, with a 25-m thick interval of conglomeratic sandstone beds in the upper part of it, which could be considered aggradational (Guerrero & Sarmiento 1996: p. 43-45, fig. 5). The Early Campanian age of the formation has been documented with dynoflagellates, pollen, and benthic foraminifers (Guerrero & Sarmiento 1996; Tchegliakova *et al.* 1997; Sarmiento & Guerrero 2000).

In the opposite W side of the basin, in the Upper Magdalena Valley, the Early Campanian event of sea level fall deposited 60 to 120 m of fossiliferous lithic arenites and sandy biosparites of benthic foraminifers, bivalves, and fish bones, included in the El Cobre Formation (Guerrero *et al.* 2000). These strata are also coarsening upward, with very fine and fine-grained sandstones at the type locality in the Piedras area, but could reach coarser grain sizes at other localities. Although the unit is essentially of Early Campanian age, the latest Santonian appears to be present in the lowermost part of the unit in the type locality. This slightly older age is apparently due to the effect of different rates of subsidence and sediment supply acting locally, or to small differences of interpretation in age assignment. In any case, the base of the El Cobre Formation is at or very near the Santonian/Campanian boundary.

Middle Guadalupe Alloformation (Guerrero & Sarmiento 1996). Retrogradational and aggradational strata of Late Campanian age.

The Middle Guadalupe Alloformation includes strata deposited during relatively fast sea level rise (TST) and high sea levels (HST). The base of the unit is placed in a transgressive surface (TS) at or near the Early Campanian / Late Campanian boundary. The alloformation includes the Plaeners Formation in the Bogotá area and the Lodolitas de Aguacaliente Formation in the E foothills of the Eastern Cordillera. In the Upper Magdalena Valley it does include the Lidita Superior Formation. The Middle Guadalupe Alloformation is well dated in the Late Campanian interval with dynoflagellates, pollen, spores, benthic foraminifers, and planktic foraminifers (Guerrero & Sarmiento 1996; Tchegliakova *et al.* 1997; Sarmiento & Guerrero 2000; Guerrero *et al.* 2000).

The Plaeners Formation (Hubach 1951, 1957; Renzoni 1963, 1968) has in its type locality near Bogotá a thickness of approximately 70 m, which could be reduced due to tectonic complications in an inverted section. According to Pérez & Salazar (1978) it includes "siliceous" siltstones and claystones along with "lidites" and "porcellanites" fractured in cubic prisms ("plaeners"). Minor beds of very fine-grained quartz arenites constitute less than 5 percent of the unit.

The Lodolitas de Aguacaliente Formation (Guerrero & Sarmiento 1996: p. 23-26, fig. 5) in its type locality on the E foothills of the Eastern Cordillera measures 157 m and is essentially composed of black mudstones. These comprise 64% of the unit, which also has minor interbeddings of very fine and fine-grained sandstones, along with sporadic beds of "plaeners" and biomicrites. The unit includes phosphatic particles, fish spines and teeth, mud intraclasts, bioturbated strata, pebble-size calcareous concretions with abundant pyrite, and ichnofossils of *Rhizocorallium, Planolites*, and *Thalassinoides*. Some beds include calcareous cement or are very fossiliferous, with gastropods and large size 6-7 cm bivalves. The black mudstones include a varied and abundant assemblage of dynoflagellates, which allowed dating in the Late Campanian interval (GUERRERO & SARMIENTO 1996; SARMIENTO & GUERRERO 2000). Sedimentary environment was interpreted as marine, including offshore and medium ramp environments below the storm wave base. The interbeddings of fining upward sandstones with fossils and phosphatic particles correspond to storm events in offshore environments above storm wave base but below fair weather wave base. The biomicrites and silicified strata included in the field term "plaeners" represent the deepest marine environments of deposition of the unit. It is believed that the deposition of the whole formation took place most probably between 15 and 150 m depth. GUERRERO & SARMIENTO (1996: p. 60) indicated the Lodolitas de Aguacaliente Formation as the most probable source rock of hydrocarbons in the E foothills of the Eastern Cordillera, including the famous Cusiana Field.

The Lidita Superior Formation (PORTA 1965, 1966; GUERRERO *et al.* 2000) has a thickness of 60 to 160 m and is composed mainly of laminated biomicrites and cherts, with scarce thin to medium beds of phosphatized bio- and intra- micrites. In its type locality near Piedras on the Upper Magdalena Valley (GUERRERO *et al.* 2000: p.74-78, plate 8), the unit measures 60 m and exhibits an abrupt lower boundary with the underlying sandstones of the El Cobre Formation. Over there, the main lithology is composed of finely laminated, partly silicified, fossiliferous micrites and wackestone biomicrites of foraminifers. The secondary lithology is composed of phosphatized packstone beds, which are more notorious toward the base and top of the unit, reaching medium bed thickness and coarser grain size of intraclasts, and other particles, up to 2 mm in diameter. These phosphatized rocks are notoriously radioactive and composed mainly of bio- pel- and intra- micrites. The diagenetic cherts fracture in the well-known pattern of orthogonal prisms 5-10 cm referred as "lidites", which allows easy recognizance of the unit in the field. The formation was interpreted as deposited in a deep carbonate ramp with maximum depths of 200-250 m for the middle part of the unit, which includes a maximum flooding surface (MFS). The phosphatized laminae and very thin to medium beds of packstone are interpreted as distal storm beds; some of these exhibit abrupt bases and fining upward patterns. Planktic foraminifers and dynoflagellates dated the unit in the Late Campanian (GUERRERO *et al.* 2000: p. 78) and allowed correlation of it with the Lodolitas de Aguacaliente Formation in the E foothills of the Eastern Cordillera, in the opposite side of the basin.

Upper Guadalupe Alloformation (GUERRERO & SARMIENTO 1996). Progradational and aggradational strata of Early Maastrichtian age.

The Upper Guadalupe Alloformation includes strata deposited during relatively fast sea level fall (RST) and low sea levels (LST). The base of the unit is placed in a sequence boundary (SB) at or near the Campanian/ Maastrichtian boundary. The alloformation includes the Labor-Tierna Formation in the Bogotá area and the Arenitas de San Luis de Gaceno Formation in the E foothills of the Eastern Cordillera. In the Upper Magdalena Valley it does include the succession of the Buscavida and La Tabla Formations. The Upper Guadalupe Alloformation is well dated in the Early Maastrichtian interval with dynoflagellates, pollen, spores, benthic foraminifers, and planktic foraminifers (GUERRERO & SARMIENTO 1996; TCHEGLIAKOVA *et al.* 1997; SARMIENTO & GUERRERO 2000; GUERRERO *et al.* 2000).

The Labor-Tierna Formation (HUBACH 1951, 1957; RENZONI 1963, 1968; GUERRERO & SARMIENTO 1996) has in its type locality near Bogotá a thickness of approximately 225 m, composed predominantly by medium to coarse-grained quartz arenites. According to the detailed sections of PÉREZ & SALAZAR (1978), it includes in the lower part muddy sandstones of very fine to fine-grain size, interlayered with mudstones and very minor beds of "plaeners". Up section, these change to medium to coarse-grained muddy sandstones with interbeddings of mudstones and occasional "plaeners". These sandstone beds become thicker and of very coarse grain size and granule conglomerate toward the upper part of the unit, where mudstone interbeddings are very scarce and cross bedding strata in very thick beds become notorious. These quartz arenites include glauconite, muscovite, and heavy minerals trough the unit, along with fish spines and phosphate particles that are more important toward the lower part of the formation. In its type locality the Labor-Tierna Formation includes a 19-m thick interval of mudstones that separates the lower 3/4 of the formation from the uppermost part of it.

The Arenitas de San Luis de Gaceno Formation (GUERRERO & SARMIENTO 1996: p 26-28, fig. 5) in the E foothills of the Eastern Cordillera measures 149 m in its type locality and is composed mainly of medium to very coarse grained quartz arenites. The very coarse-grained sandstone comprises the single largest percentage (44%) of the total thickness of the unit, followed by 21% of coarse sandstone and 20% of medium sandstone. The lower boundary of the unit is a sharp one over the mudstones of the underlying Lodolitas de Aguacaliente Formation. The San Luis de Gaceno Formation is progradational (RST), coarsening upwards from medium to very coarse sandstone and granule conglomerate, with a minor percentage (11%) of interbeddings of mudstone and very fine to fine grained sandstone trough the unit. The uppermost 41 m of the formation include very coarse-grained sandstones with lenses of granule conglomerate, that appear to be aggradational (LST) with no apparent change in the sedimentary regime. The environment of deposition of the whole unit was considered as evolving from lower to upper shoreface, foreshore, and coastal plain. Maximum depth of sedimentation at the base of the unit was around 15 m below sea level. The content of palynomorphs of the lower part of the formation is dominated by dynoflagellates, which are replaced in the medium part of it by pollen, spores, and fungi (GUERRERO & SARMIENTO 1996: fig. 8).

In the opposite W side of the basin, in today's Upper Magdalena Valley, the Early Maastrichtian sea level fall deposited also a coarsening upwards succession, which includes the Buscavida Formation and La Tabla Formation. The Buscavida Formation (GUERRERO *et al.* 2000: p. 78-83, plate 9) includes 90-170 m of a coarsening upward succession that includes biomicrites and impure (muddy) biomicrites of foraminifers, bivalves, and fish spines, along with a few terrigenous mudstones. In its type locality near Piedras the unit measures 90 m, and the most common lithology is packstone-texture impure (muddy) biomicrite, with a gradual upward increase in the amount and size of terrigenous mud particles, so that some terrigenous mudstones are present in the upper part of the unit. A very minor amount of thin to medium beds of phosphatized packstone biomicrites with sharp lower boundaries was also detected. The formation is thicker toward the axis of the basin, in the E side of the Guaduas Syncline, where it reaches 160-170 m thickness. The age of the Buscavida Formation is well documented in the older part of the Early Maastrichtian with a varied and abundant assemblage of planktic foraminifers, including the *Globotruncanella havanensis* and the *Globotruncana aegyptiaca* biozones (GUERRERO *et al.* 2000: p. 83, plates IV and V). The sedimentary environment was considered as transitional from shallow ramp to upper offshore.

The La Tabla Formation (PORTA 1965, 1966; GUERRERO *et al.* 2000: p. 83-87, plate 10) includes the relatively coarse grained strata that gradually overlie the Buscavida Formation. The unit measures 5-90 m and includes a coarsening upward succession of fossiliferous lithic arenites and sandy biosparites, with conglomeratic sandstone and pebble conglomerate toward the top of the unit. In its type section in the Piedras area measures 90 m that begin in the lower part of the unit with very fine-grained sandstones. These are calcite cemented, matrix free, and include variable amounts of foraminifers and bivalve fragments. As with all the other formations of the Upper Magdalena Valley succession, rock fragments of volcanic and metamorphic nature dominate the terrigenous content, derived W from the Ancestral Central Cordillera. Grain size increases in a gradual manner up to very coarse-grained sandstone and conglomerate of granules and medium pebbles. The unit is thinner toward the axis of the basin in the E where, in the E side of the Guaduas Syncline, only has 5 m and eventually disappears. The added thickness of the Buscavida and La Tabla Formation is always around 180-190 m, so that one unit becomes thicker as the other one thins, depending on the position of the section in relation with the W border of the basin. The age of the La Tabla Formation is placed in the younger part of the Early Maastrichtian, in the lower part of the *Gansserina gansseri* biozone (GUERRERO *et al.* 2000: p. 87, plate V). Sedimentation took place in a shallowing upward succession of lower to upper shoreface and backshore dune environments. The unit constitutes a very important reservoir of hydrocarbons in the Upper Magdalena Valley, including the Guaduas Syncline in the NE extreme of it. In some areas the interval is informally and non-accurately referred to the upper part of the "cimarrona formation" and also as the upper part of the "monserrate formation".

Lower part of the Guaduas Alloformation (GUERRERO *et al.* 2000). Retrogradational and aggradational strata of Late Maastrichtian age.

The lower part of the Guaduas Alloformation includes strata deposited during relatively fast sea level rise (TST) and high sea levels (HST). The base of the unit is placed in a transgressive surface (TS) at or near the Early Maastrichtian / Late Maastrichtian boundary. The Guaduas Alloformation includes the Guaduas Formation in the Bogotá area and the E foothills of the Eastern Cordillera. In the Upper Magdalena Valley it does include the Seca Formation. The Guaduas Alloformation is well dated in the Late Maastrichtian and Early Paleocene interval with dynoflagellates, pollen, spores, benthic foraminifers, and planktic foraminifers (Sarmiento 1992b; Martínez 1995; Guerrero & Sarmiento 1996; Sarmiento & Guerrero 2000; Guerrero *et al.* 2000).

The Guaduas Formation (Hettner 1892; Hubach 1951) includes the approximately 700 to 1000 m of relatively fine-grained strata, mainly mudstones and coals, which in the type locality near Guatavita overlie the sandstones of the Guadalupe Group and underlie the sandstones of the Cacho Formation. Hubach (1951) defined accurately the boundaries of the formation, indicating the presence of exploitable coals and black mudstones with ammonites, along with minor beds of sandstone in the lower part of the unit. The upper part of the formation was characterized by reddish, purple and multicolored mudstones with minor sandstone beds. A reference section of the Guaduas Formation near Bogotá was studied by Sarmiento (1992a), who indicated a thickness of 1100 m. The lower 400 m of the unit include Late Maastrichtian palynomorphs (Sarmiento 1992b) in a lithology dominated by black mudstones and coals, with a lesser amount of sandstone interbeddings. The upper 700 m of the formation are characterized by the gradual appearance of red beds and the disappearance of coals, along with the increasing presence of fining upward successions a few meters thick.

The lower part of the Guaduas Formation is interpreted here as marine dominated, in estuarine, shallow offshore, and minor shoreface environments, which evolved in the Early Paleocene upper part of the unit to coastal plain and fluvial environments of anastomosed and meandering rivers. Only the lower part of the Guaduas Formation is considered here of retrogradational and high aggradational nature, to include a TST and a HST. It seems that this very thick succession includes minor oscillations of short-term relative sea level changes that most probably correspond to parasequences. These are difficult to correlate laterally and probably even more difficult to date with biostratigraphy.

In the opposite W side of the basin, the equivalent strata are included in the Seca Formation (Porta 1965, 1966; Guerrero *et al.* 2000: p. 87-90, plate 11). The unit is similar to the Guaduas Formation from the Bogotá area, except that the interbedded sandstones have a lithic nature; it also has a lower part dominated by gray mudstone and an upper part dominated by reddish and multicolored mudstone. The lower part of the Seca Formation has an estimated thickness of 300 to 400 m and also a very clear marine influence, resulting from relatively fast sea level rise over the previous upper shoreface and coastal plain environments of the La Tabla Formation. The lower part of the Seca Formation contains coal beds and a rich assemblage of benthic foraminifers, with a very minor presence of planktic foraminifers. Minor beds of glauconitic sandstones are also interlayered with the gray mudstone and claystone that constitute the bulk of this lower part. Age of the lower part of the formation was determined as Late Maastrichtian with foraminifers and palynomorphs (Guerrero *et al.* 2000). Sedimentary environments include mainly estuarine lagoons, interdistributary bays, and shallow offshore settings; a few intervals include sandstones deposited in the lower shoreface and shallow offshore domains during sporadic storm events.

The dark gray to black mudstone and claystone of the lower part of the Guaduas Alloformation constitute a very effective regional seal to the hydrocarbons that have migrated from underlying source rocks to the reservoir sandstone and conglomerate of the Upper Guadalupe Alloformation.

HYDROCARBON EXPLORATION

The understanding of the paleogeography of the Cretaceous Colombian Basin as located in an elongated back-arc setting bounded on the E by the Guyana Shield, and on the W by a volcanic/metamorphic arc has very important implications in hydrocarbon exploration (Guerrero *et al.* 2000). The most important ones are that coarse-grained reservoir rocks are present on both, E and W sides of the basin, can be followed along the paleo - shorelines in a NNE direction, and get thinner and finer grained toward the axis of the basin. The reservoirs on the W side of the basin are more calcareous than the ones on the E side of it, because source area of terrigenous detritus on the W consisted of a narrow belt with a reduced extent, when compared with the Guyana Shield.

The important Cretaceous reservoirs are included in progradational (RST) to aggradational (LST) coarse-grained strata deposited during the Early Albian, Cenomanian, Early Campanian and Early Maastrichtian. The most important and better known are those included in the Upper Guadalupe Alloformation (Early Maastrichtian), which contains the San Luis Formation in the E foothills of the Eastern Cordillera, and the La Tabla Formation in the Upper Magdalena Valley. The second one in importance is the Upper Sandstone Member of the Caballos Formation in the Upper Magdalena Valley, which is part of the Lower Une Allomember of Early Albian age. The third unit of importance is the Lower Guadalupe

Alloformation, which includes the San Antonio Formation in the E foothills of the Eastern Cordillera, and the El Cobre Formation in the Upper Magdalena Valley.

The Early Albian and Cenomanian coarse grained units corresponding to the Lower and Upper Sandstone Members of the Une Alloformation in the E side of the basin have been relatively unexplored but could constitute important reservoirs. It is also the case of the Cenomanian sandstones included in the Upper Une Allomember (Hondita Formation) from the Upper Magdalena Valley.

As indicated by GUERRERO *et al.* (2000), the precise location of the axis of the basin is a very important piece of information, to predict changes in lithology and in thickness of the reservoirs. Such axis has to be determined by considering provenance of sediments from the E (quartz arenite affinity) or from the W (lithic and calcareous affinity) sides of the basin. In some exploratory areas such as the Guaduas Syncline (W of Bogotá), the fossiliferous sandstones and conglomerates of the La Tabla Formation get thinner and finer grained toward the E, up to the point where they disappear within a narrow belt a few km wide.

CONCLUSIONS

Sequences from the Cretaceous Colombian Basin were deposited in time spans of 9 to 17 Ma and are considered of second order. Third order sequences deposited in intervals of less than 3 to 5 Ma are not always present and have had little correlation potential within the basin because of the lack of biostratigraphic resolution. Parasequences are present in some sections that include minor oscillations between shoreface and shallow offshore strata, but dating and correlation potential is even less than in third order sequences. Because of this, the sequences of primary importance within the Cretaceous succession from Colombia are the second order sequences, which allow correlation of reservoirs and source rocks at different points of ancestral shorelines, and also in opposite E and W sides of the basin.

Despite the complex interaction of eustasy, basin subsidence and sediment supply at different localities, the synchronous ages of sequences on both sides of the basin indicate that relative sea level signal was dominated by eustatic sea level change. Back-arc basin subsidence was approximately balanced by sediment supply or local interaction of them was generally of less magnitude than long term eustatic sea level rise or fall.

Maximum thickness of 5 km of Cretaceous strata in the central and E sides of the basin indicate subsidence values of 50 to 60 m / Ma, meanwhile that in the W side of it (in the UMV) subsidence was about half of that value and maximum thickness of Aptian to Maastrichtian strata was only 1.8 km.

ACKNOWLEDGMENTS

Dr. Kristian Soegaard from Norsk Hydro Research Center (Norway), Professor Dr. Carlos Villarroel from the Universidad Nacional (Colombia), and Exploration Geologist Martha Suárez from Ecopetrol (Colombia) reviewed earlier versions of this paper and made valuable comments that helped to improve the text and figures.

The results presented here are part of the projects "Stratigraphy of the rocks with petroleum potential from the Colombian Andes", "Micropaleontology and magnetostratigraphy of the rocks with petroleum potential from the eastern side of the Eastern Cordillera" and "Petrographic characterization of the Cretaceous and Tertiary succession from the Colombian Andes".

REFERENCES CITED

BURGL, H. (1956): Catálogo de las Amonitas de Colombia. Parte I, Pulcheliidae.- Boletín Geológico Instituto Geológico Nacional, v. 4, no. 1, p. 1-119.

CÁCERES, C. & ETAYO, F. (1969): Bosquejo geológico de la región del Tequendama. 1er Congreso Colombiano de Geología, Opúsculo guía excursión pre-congreso, 22 p.

CAMPBELL, C. (1962): A section through the Cordillera Oriental of Colombia between Bogotá and Villavicencio.- Fourth Annual Field Conference of the Colombian Society of Petroleum Geologists and Geophysicists. Published in 1979 as: *Geological Field-Trips Colombia 1959-1978*, p. 89-118.

CAMPBELL, C. & BURGL, H. (1965): Section through the Eastern cordillera of Colombia, South America.- GSA Bulletin, v. 76, no. 5, p. 567, 589.

CORRIGAN, H. (1967): The geology of the Upper Magdalena Basin (Northern Portion).- VIII Annual Field Conference, Colombian Society of Petroleum Geologists and Geophysicists. Reprinted in 1979 in p. 221-251 of CSPGG *Geological Field Trips Colombia, 1959-1978.*

ERLICH, R., MACSOTAY, O., NEDERBRAGT, A. & LORENTE, M. (2000): Birth and death of the Late Cretaceous "La Luna Sea", and origin of the Tres Esquinas phosphorites.- Journal of South American Earth Sciences, v. 13, p. 21-45.

ETAYO, F. (1968a): Sinópsis estratigráfica de la región de Villa de Leiva y zonas próximas.- Boletín de Geología UIS, no. 21, p. 19-32.

ETAYO, F. (1968b): El Sistema Cretáceo en la región de Villa de Leiva y zonas próximas.- Geología Colombiana, no. 5, p. 5-74

ETAYO, F. (1979): Zonation of the Cretaceous of central Colombia by ammonites.- Publ. Geol. Espec. Ingeominas, no. 2.

ETAYO, F. (1985): Paleontología estratigráfica del Sistema Cretácico en la Sierra Nevada del Cocuy, in F. Etayo, and F. Laverde, eds, Proyecto Cretácico.- Publicaciones Geológicas Especiales del Ingeominas, no. 16.

FABRE, A. (1985): Dinámica de la sedimentación cretácica en la Sierra Nevada del Cocuy (Cordillera Oriental de Colombia), in F. Etayo, and F. Laverde, eds, *Proyecto Cretácico*.- Publicaciones Geológicas Especiales del Ingeominas, no. 16.

FOLLMI, K., GARRISON, R., RAMIREZ, P., ZAMBRANO, F., KENNEDY, W. & LEHNER, B. (1992): Cyclic phosphate-rich successions in the Upper Cretaceous of Colombia.- Palaeogeography, Palaeoclimatology, Palaeoecology v. 93, p. 151-182.

FORD, A. & HOUBOLT, J. (1963): Las microfacies del Cretáceo de Venezuela occidental.- International Sedimentary Petrography Series, v. 6, p. 1-59, 55 pl.

GARNER, A. (1926): Suggested nomenclature and correlation of the geological formations in Venezuela.- American Institute Min. and Metall. Eng., p. 677-684.

GONZÁLEZ, C., ITURRALDE, J. & PICARD, X. (1980): *Geologia de Venezuela y de sus cuencas petrolíferas*.- Caracas, Ediciones Foninves, t. 1, 414 p.

GUERRERO, J. (2002): A proposal on the classification of Systems Tracts: Application to the Allostratigraphy and Sequence Stratigraphy of the Cretaceous Colombian Basin. Part 1: Berriasian to Hauterivian.- Geología Colombiana, no. 27, p. 3-25.

GUERRERO, J. & SARMIENTO, G. (1996): Estratigrafía física, palinológica, sedimentológica y secuencial del Cretácico Superior y Paleoceno del Piedemonte Llanero. Implicaciones en exploración petrolera.- Geología Colombiana, no. 20, p. 3-66.

GUERRERO, J., SARMIENTO G. & NAVARRETE, R. (2000): The stratigraphy of the W side of the Cretaceous Colombian Basin in the Upper Magdalena Valley. Reevaluation of selected areas and type localities including Aipe, Guaduas, Ortega, and Piedras.- Geología Colombiana, no. 25, p. 45-110.

HEDBERG, H. (1931): Cretaceous limestone as petroleum source rock in northwestern Venezuela.- AAPG Bulletin, v. 15, no. 3, p. 229-244.

HEDBERG, H. & SASS, L. (1937): Synopsis of the geologic formations of the western part of the Maracaibo Basin, Venezuela.- Bol. Geol. Min., t. 1, no. 2-4, p. 71-112.

HERNGREEN, G. & DUEÑAS, H. (1990): Dating of the Cretaceous Une Formation, Colombia and the relationship with the Albian-Cenomanian African–South American microfloral province.- Review of Palaeobotany and Palynology, v. 66, p. 345-359.

HETTNER, A. (1892): Die Kordillere von Bogotá.- Peterm. Mitt., Erg.-Bd. 22, Heft 104, p. 1-131.

HUBACH, E. (1931a): Exploración en la región Apulo – San Antonio – Viotá.- Boletín Minas y Petróleos, t. 4, no. 25-27, p. 41-60.

HUBACH, E. (1931b): Geología petrolífera del Departamento de Norte de Santander.- Servicio Geológico Nacional, Informe no. 176. Also published in: 1993, Compilación de los Estudios Geológicos Oficiales en Colombia, t. 12.

HUBACH, E. (1945): La región de Panga Panga al NE de Choachí (Cundinamarca).- Compilación de Estudios Geológicos Oficiales de Colombia, t. 6, p. 27-37.

HUBACH, E. (1951): Estratigrafía de la Sabana de Bogotá y alrededores.- Servicio Geológico Nacional, Informe no. 785. Also published in: 1958, Boletín Geológico Instituto Geológico Nacional, v. 5, no. 2, p. 93-112.

HUBACH, E. (1953): Condiciones geológicas de las variantes de carretera en la región de Arcabuco-Barbosa-Oiba, Deptos Santander y Boyacá.- Servicio Geológico Nacional, Informe no. 952.

HUBACH, E. (1955): Los daños por deslizamiento en el estribo izquierdo del puente viejo de San Gil.- Instituto Geológico Nacional, Informe no. 1097, p. 1-5.

HUBACH, E. (1957): Contribución a la unidades estratigráficas de Colombia.- Instituto Geológico Nacional, Informe no. 1212.

JULIVERT, M., BARRERO, D., BOTERO, G., DUQUE, H., HOFFSTETTER, R., NAVAS, J., PORTA, J DE., ROBBINS, R., TABORDA, B., TÉLLEZ, N. & ZAMARREÑO, I. (1968): *Lexico Estratigráfico, Colombia*.- IUGS v. 5, fasc. 4a, part 1, 651 p.

KEHRER, L. (1937): Some observations on Cretaceous and Precretaceous beds in the south-western and northern central parts of Venezuela.- Boletín Geol. Min., t. 1, no. 2-4, p. 47-70.

LIDDLE, R. (1928): *The Geology of Venezuela and Trinidad*.- Forth Worth, Texas, 552 p.

MARTÍNEZ, J. (1995): Microfósiles del Grupo Guadalupe y la Formación Guaduas (Campaniano - Maastrichtiano) en la sección de Tausa, Cundinamarca, Colombia.- Ciencia, Tecnología y Futuro, v. 1, no. 1, p. 65-81.

MARTÍNEZ, J. & VERGARA, L. (1999): La sucesión paleoambiental del Cretácico de la región de Tequendama y oeste de la Sabana de Bogotá, Cordillera Oriental Colombiana.- Geología Colombiana, no. 24, p. 107-147.

MOJICA, J. & MACIA, C. (1983): Características estratigráficas y edad de la Formación Yaví, Mesozoico de la región entre Prado y Dolores, Tolima, Colombia.- Geología Colombiana, no. 12, p. 7-32.

MORA, A., VENEGAS, D. & VERGARA, L. (1998): Estratigrafía del Certácico Superior y Terciario Inferior en el sector norte de la cuenca del Putumayo, Departamento del Caquetá.- Geología Colombiana, no. 23, p. 31-77.

MORALES, L., PODESTA, D., HATFIELD, W., TANNER, H., JONES S., BARKER, M., O´DONOGHUE, D., MOHLER, C., DUBOIS, E., JACOBS, C. & GOSS, C. (1958): General Geology and oil occurrences of Middle Magdalena Valley, Colombia.- AAPG *Habitat of oil symposium*, p. 641-695.

NOTESTEIN, F., HUBMAN, C. & BOWLER, J. (1944): Geology of the Barco Concession, Republic of Colombia, South America.- GSA Bulletin v. 55, p. 1165-1215.

PATARROYO, P. (1997): Barremiano Inferior en la base de la Formación Paja, Barichara, Santander – Colombia.- Geología Colombiana, no. 22, p. 135-138.

PATARROYO, P. (2000): Distribución de amonitas del Barremiano de la Formación Paja en el sector de Villa de Leyva (Boyacá, Colombia). Bioestratigrafía.- Geología Colombiana, no. 25, p. 149-162.

PEREZ, G. & SALAZAR, A. (1978): Estratigrafía y facies del Grupo Guadalupe.- Geología Colombiana, no. 10, p. 6- 85.

POLANIA, H. & RODRIGUEZ, G. (1978): Posibles turbiditas del Cretáceo Inferior (Miembro Socotá) en el área de Anapoima.- Geología Colombiana, no. 10, p. 87-113.

PORTA, J. de (1965): Estratigrafía del Cretácico Superior y Terciario en el extremo S del Valle Medio del Magdalena.- Boletín UIS, no. 19, p. 5-50.

PORTA, J. de (1966): La geología del extremo S del Valle Medio del Magdalena entre Honda y Guataquí (Colombia).- Boletín UIS, no. 22/23, p. 5-347.

RENZ, O. (1960): Geología de la parte sureste de la Península de la Guajira (República de Colombia).- Boletín Geológico Ministerio Minas Hidrocarburos, public. esp. 3, memoria. 3 congreso geología venezuela, t. 1, p. 317-349.

RENZ, O. (1982): *The Cretaceous ammonites of Venezuela*.- Basel, Birkhauser Verlag, 132 p., 40 pl.

RENZONI, G. (1963): Apuntes acerca de la litología y tectónica de la zona al este y sureste de Bogotá.- Boletín Geológico, Servicio Geológico Nacional, v. 10, no. 1-3, p. 59-79.

RENZONI, G. (1967): Geología del Cuadrángulo J-12 Tunja.- Ingeominas, Informe no. 1546. Also published in: 1981, Boletín Geológico de Ingeominas, v. 24, no. 2, p. 31-48.

RENZONI, G. (1968): Geología del Macizo de Quetame.- Geología Colombiana, no. 5.

ROD, E. & MAYNC, W. (1954): Revision of Lower Cretaceous Stratigraphy of Venzuela.- AAPG Bulletin, v. 38, no. 2, p. 193-283.

ROLLINS, J. (1965): *Stratigraphy and structure of the Guajira Peninsula, northwestern Venezuela and northeastern Colombia*.- University Nebraska Studies, no. 30, 103 p.

SARMIENTO, G. (1992a): Estratigrafía y medios de depósito de la Formación Guaduas.- Boletín Geológico de Ingeominas, v. 32, p. 1-44.

SARMIENTO, G. (1992b): Palinología de la Formación Guaduas (estratigráfica y sistemática).- Boletín Geológico de Ingeominas, v. 32, p. 45-126.

SARMIENTO, G. & GUERRERO, J. (2000): Palinología del Santoniano Tardío al Maastrichtiano del piedemonte llanero colombiano. Correlación con el paleocinturón tropical.- Geología Colombiana, no. 25, p. 111-147.

SUTTON, F. (1946): Geology of Maracaibo Basin, Venezuela.- AAPG Bulletin, v. 30, no. 10, p. 1621-1741.

TCHEGLIAKOVA, N., SARMIENTO, G. & GUERRERO, J. (1997): Bioestratigrafía y paleoecología de los foraminíferos bentónicos de la Formación Chipaque y el Grupo Guadalupe. Turoniano-Maastrichtiano del Piedemonte Llanero de los Andes Colombianos.- Geología Colombiana, no. 22, p. 103-119.

ULLOA, C. & RODRÍGUEZ, E. (1991): Memoria Explicativa de la Plancha 190 – Chiquinquirá.- Ingeominas, 26 p.

ULLOA, C., RODRÍGUEZ E., ACOSTA, J. & MARTÍNEZ I. (1993): Mapa Geológico escala 1: 100.00 de la Plancha 227 – La Mesa.- Ingeominas.

VERGARA, L. (1994): Stratigraphic, micropaleontologic and organic geochemical relations in the Cretaceous of the Upper Magdalena Valley, Colombia.- Giessener Geologische Schriften, no. 50, p. 1-179.

VERGARA, L. (1997): Stratigraphy, foraminiferal assemblages and paleonvironments in the Late Cretaceous of the Upper Magdalena Valley, Colombia. (Part 1).- Journal of South American Earth Sciences, v. 10, no. 2, p. 111-132.

VERGARA, L. & GUERRERO, J. (1996): Significado estratigráfico secuencial de algunos depósitos basales del Cretácico en Colombia: Caso de las Fromaciones Yaví y Tibasosa.- Geología Colombiana, no. 20, p. 133-140.

VERGARA, L., GUERRERO, J., PATARROYO, P. & SARMIENTO, G. (1995): Comentarios acerca de la nomenclatura estratigráfica del Cretácico Inferior del Valle Superior del Magdalena.- Geología Colombiana, no. 19, p. 21-31.

VERGARA, L. & RODRÍGUEZ, G. (1997): The Upper Cretaceous and Lower Paleocene of the Eastern Bogotá Plateau and Llanos Thrustbelt, Colombia: Alternative appraisal to the nomenclature and sequence stratigraphy. Geología Colombiana, no. 22, p. 51-79.

VERGARA, L., RODRÍGUEZ, G. & MARTÍNEZ, I. (1997): Agglutinated foraminifera and sequence stratigraphy from the Chipaque Formation (Upper Cretaceous) of El Crucero section, Colombia, South America.- Micropaleontology, v. 43, no. 2, p. 185-201.

VILLAMIL, T. (1998): Chronology, relative sea-level history and a new sequence stratigraphic model for basinal cretaceous facies of Colombia.- SEPM Special Publication, no. 58, p. 161-216.

Manuscript received, March 2002.