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Stratigraphic chart of the sedimentary basins of Costa Rica, Central America [1]

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Abstract

Costa Rican sedimentary rocks deposited since the Campanian are subdivided into supergroups, groups, subgroups, and formations. The Curime, Boruca and Cerere supergroups are unconformity-bounded units. The preexisting number of formations is considerably reduced. The remaining rock units described in this paper are defined by their depositional environment, using differential sedimentologic criteria. The use of sequence stratigraphic terminolgy is discussed.

Resumen

La evolución de las distintas cuencas a partir del Campaniano es relacionada con el contexto morfotectónico. Tres supergrupos, delimitados por discordancias regionales son definidos, a saber: Curime, Cerere y Boruca. La litoestratigrafía se ha simplificado considerablemente, al utilizar una filosofía agrupadora. El número de formaciones se reduce notoriamente, abarcando mayores rangos paleogeográficos y/o temporales. Las unidades de roca se definen por criterios genéticos y se utiliza el diagnóstico diferencial para distinguir entre ellas. Se analiza el uso de la estratigrafía secuencial en Costa Rica, en particular lo vinculado a los superciclos de segundo orden.

INTRODUCTION

The main objective of this paper is to present a new edition of the Stratigraphic Chart of Sedimentary Basins of Costa Rica. Research undertaken by the first author began in the late seventies in order to gradually and patiently obtain a general consensus on a stratigraphic concept which would be accepted by most geologists working in Costa Rica. As to stratigraphic criteria to be used in geological maps, very little agreement existed at that time. Most descriptions referred to local sedimentary successions but seldom defined facies, interpretated sedimentary environments, or established a context with the development of the corresponding sedimentary basin. Since the late eighties, however, much progress has been made towards an understanding of Costa Rican stratigraphy in terms of structural and morphodynamic control on facies distribution and architecture of sedimentary basins.

Lithostratigraphic charts for Costa Rica have been published by SPRECHMANN (1982, 1984a, b). Since the last publication, a wealth of new data has

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accumulated (e.g., BAUMGARTNER et al., 1984; SPRECHMANN et al. 1987 and in press; SEYFRIED et al., 1987, 1991; DENYER & ARIAS, 1991). Despite the introduction of modern sedimentological concepts, poorly (or randomly) defined stratigraphic units continue to be introduced into Costa Rican stratigraphy.

Since 1988, the authors of this paper coordinate a working group of 18 geologists in the task of standardizing Costa Rican stratigraphy. The stratigraphic chart published in this paper is the fifth version produced by this working group and the authors are well aware of the fact that it will not be the last one. The coordinators are responsible for the correlation between the different basins. As to the definition of individual stratigraphic units, references are made within the lithostratigraphic chart. Time-stratigraphic delimitations of lithostratigraphic units are placed according to information provided by the working group (including unpublished reports).

We suggest that further publications on aspects of Costa Rican stratigraphy be made in the *Revista Geológica de América Central* which is regularly published by the *Escuela Centroamericana de Geología de la Universidad de Costa Rica*. We recommend that these publications should include the complete bibliography on the subject, including unpublished reports.

THE STRATIGRAPHIC CHART OF THE SEDIMENTARY BASINS OF COSTA RICA

The vertical axis of the chart is a time and not a thickness axis. We emphasize the common lack of reliable biostratigraphic data, due to the often very poor preservation of fossils. Along the horizontal axis, the chart is divided into 3 segments, according to the proposal made by Seyfried et al. (1991): North Costa Rica Arc Segment, b) Dissected Zone of Central Costa Rica, and c) South Costa Rica Arc Segment. These segments are tectonic units shown on Fig. 1. Deformation events refer to data published by STREBIN (1982), M.M. GURSKY (1988), BAUMGARTNER et al. (1984), and ASTORGA et al. (1991). DL1 corresponds to a tectonic uplift in Paleocene time recognized by Calvo & Bolz (1992). On the right side, the well-known HAQ et al. (1988) curve is placed for easier cross-reference with relative changes of sea level. The Nicoya Complex and its related sedimentary units are not included in this chart. For reasons of scale, some members of certain formations, some informal or supraformational units as well as most of the younger lacustrine sediments have also been omitted.

SEDIMENTARY BASINS

In 1960 and 1962, DENGO presented a stratigraphic study for the Pacific coastal area and central valley of Costa Rica. His first units were rather empirically defined, as a consequence of the hitherto poor knowledge of Costa Rican geology. Some of DENGO's early definitions of sedimentary basins have remained more or less unaltered since (e.g.: Valle Central, Osa-Burica, Térraba, Limón), but others have changed considerably. New basins have been added (Tárcoles Trough, SEYFRIED et al. (1991); Nicoya Basin, ASTORGA et al. (1991); Parrita Trough, SEYFRIED et al. (1991); Quepos Basin, ASTORGA et al. (1991). The name *Limón Basin*, traditionally used in Costa Rican stratigraphy, has been changed by FERNANDEZ (1987) and ASTORGA (1991) into *North* Limón Basin and *South* Limón Basin. In order to avoid confusion, these names have been changed by SEYFRIED et al. (1991) into Nicaragua Graben and Tortuguero Trough (substitutes for north Limón basin) and Baja Talamanca Trough (substitute for south Limón basin).

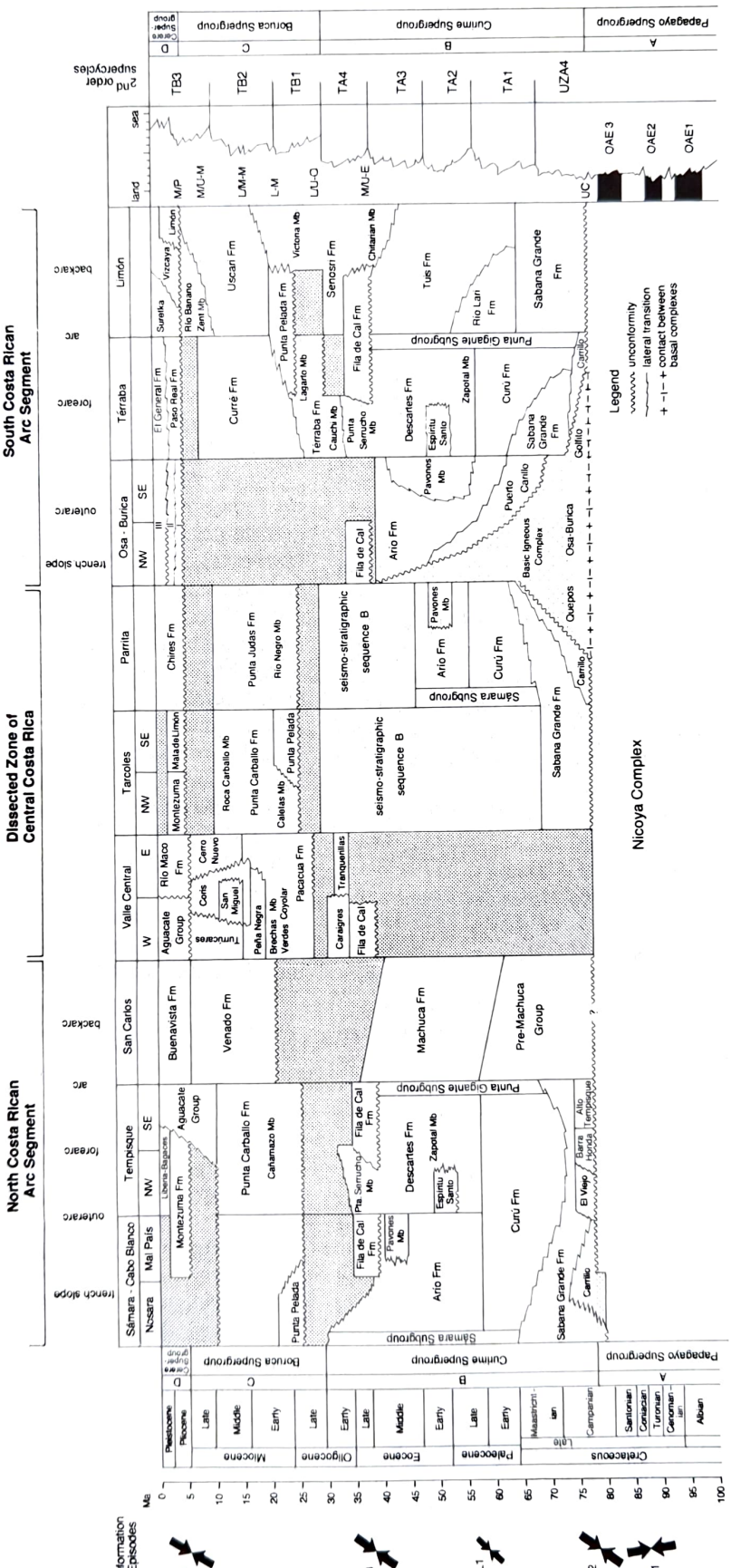
Fig. 1: Lithostratigraphic correlation of sedimentary rocks in Costa Rica.

The working group which contributed to this table was composed of the following persons:
ARIAS, OSCAR; ASTORGA, ALLAN; BARBOZA, GUILLERMO; BOLZ, ANGELA; BOTTAZZI, GIOVANNI; CALVO, CLAUDIO; CAMPOS, LOLITA; CHINCHILLA, ANA LEYLA; DENYER, PERCY; FERNÁNDEZ, ALBERTO; GONZÁLEZ, GERMAN; LAURITO, CESAR; OBANDO, JORGE; OBANDO, LUIS; SPRECHMANN, PETER; VALVERDE, RONALD.

Deformation episodes have been compiled after STREBIN (1982), M.M. GURSKY (1988), BAUMGARTNER et al. (1984), ASTORGA et al. (1991), and CALVO & BOLZ (1992). Relative change of coastal onlap, second-order supercycles, and geochronology are redrawn after HAQ et al. (1988). Oceanic anoxic events (OAE): after ASTORGA (1990, 1993). The formations of the Osa-Burica Basin (I: Peñitas; II: Burica: III: Armuelles) belon to the Charco Azul Group.

Unconformities: UC: upper Campanian; M/U-E: mid/upper Eocene; L/U-O: lower/upper Oligocene; L-M: lower Miocene; L/M-N: lower/mid Miocene; M/U-M: Mid/upper Miocene; M/P: Miocene/Pliocene.

Stippled areas: hiatuses.


North Costa Rican Arc Segment
Dissected Zone of Central Costa Rica
South Costa Rican Arc Segment
trench slope
outerarc
forearc
arc
backarc
Sámara - Cabo Blanco
Nosara
Mal País
Montezuma Fm
Liberia-Bagaces
Tempisque
Aguacate Group
Punta Carballo Fm
Cahamazo Mb
Fila de Cal Fm
Pta. Samucho Mb
Descartes Fm
Zapotal Mb
Espíritu Santo
Pavones Mb
Ario Fm
Punta Pelada
Curú Fm
El Viejo
Barra Honda Limestone
Sabana Grande Fm
Camilo
Sámara Subgroup
Punta Gigante Subgroup
San Carlos
Buenavista Fm
Venado Fm
Machuca Fm
Pre-Machuca Group
Valle Central
W
E
Aguacate Group
Turrucares
Coris
San Miguel
Peña Negra
Brechas Mb
Verdes Coyolar
Caragres
Tranquenitas
Fila de Cal
Río Maco Fm
Cerro Nuevo
Pacacua Fm
Tarcoles
NW
SE
Montezuma
Malade Limón
Roca Carballo Mb
Punta Carballo Fm
Calelias Mb
Punta Pelada
Parrita
Chires Fm
Punta Judas Fm
Río Negro Mb
seismo-stratigraphic sequence B
Ario Fm
Pavones Mb
Curú Fm
Sámara Subgroup
Osa - Burica
NW
SE
Fila de Cal
Ario Fm
Pavones Mb
Basic Igneous Complex
Puerto Carillo
Osa-Burica
Quepos
Sabana Grande Fm
Camilo
Térraba
El General Fm
Paso Real Fm
Curré Fm
Punta Pelada Fm
Lagarto Mb
Terraba Fm
Caucho Mb
Punta Samucho Mb
Descartes Fm
Espíritu Santo
Zapotal Mb
Fila de Cal Fm
Curú Fm
Sabana Grande Fm
Golfito
Camilo
Punta Gigante Subgroup
Limón
Suretka
Río Banano
Zent Mb
Uscari Fm
Limón
Vizcaya
Victoria Mb
Senosri Fm
Chitaran Mb
Tuis Fm
Río Lari Fm
Sabana Grande Fm
Camilo
land
sea
M/P
M/U-M
LM-M
L-M
LU-O
M/U-E
UC
TB3
TB2
TB1
TA4
TA3
TA2
TA1
UZA4
OAE 3
OAE2
OAE1
2nd order supercycles
Cover Supergroup
D
Burica Supergroup
C
Curima Supergroup
B
Papagayo Supergroup
A
Nicoya Complex
Legend
unconformity
lateral transition
contact between basal complexes
Deformation Episodes
D4
D3
DL-1
D2
D1
Ma
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cretaceous
Late
Middle
Early
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian

DEFINITION OF SUPERGROUPS AND GROUPS

The different lithostratigraphic units deposited unconformably on the Nicoya Complex, are grouped into 3 supergroups: a) Curime, b) Boruca and c) Cerere. They overlie the Papagayo Supergroup defined by BAUMGARTNER et al. (1984), which includes the Nicoya Complex sensu lato. The boundaries between these supergroups are marked by regional unconformities (unconformity-bounded units cf. MIALL 1990: 119).

The supergroups correspond to megasequences A, B, C and D as defined by geologists of RECOPE (ASTORGA et al. 1991) on the basis of geophysical data. These megasequences are informal units. Megasequences A and B correspond to megacycle sets, megasequence C to a supercycle set, and megasequence D to a set of third-order cycles (*cf*. HAQ, HANDERBOL & VAIL, 1988). The stratigraphic concept of Fig. 1 is compatible with the available geophysical data.

The Curime Supergroup consists of deep water sediments and neritic carbonates. It is delimited by two regional unconformities and ranges from the late Campanian (UC) to the transition from early to late Oligocene (L/U-O). Two groups were introduced to distinguish between deep water clastic and neritic carbonate rocks:

a) *Garza Group* (SPRECHMANN 1982, 1984a, b), or Garza Supergroup (BAUMGARTNER et al., 1984; ASTORGA, 1987; SPRECHMANN et al., 1987). The Garza Group is made up by deep water sediments deposited between the UC and the L/U-O regional unconformities. This lithostratigraphic unit should be used when mapping within the pelagic limestones of the Sabana Grande Formation and the fine-grained turbidite facies (Curu Formation). The reduced scale does not allow the inclusion of the name Garza Group on Fig. 1.

b) The *Alto Tempisque Group* comprises the neritic limestones of the late Campanian (CALVO, 1987; SPRECHMANN et al., 1987 and in press). For this group a formal chronostratigraphic unit named *Alto Tempisquense Stage*, was created (SPRECHMANN et al., 1987 and in press).

The Boruca Supergroup contains neritic and nearshore deposits delimited by the L/U-O and the Miocene/Pliocene (M/P) regional unconformities.

The Cerere Supergroup comprises the neritic, nearshore and continental sedimentation of the Plio-Pleistocene. In the Osa-Burica Basin turbidites are also present. This unit is underlain by the M/P boundary regional unconformity.

Each supergroup contains lithostratigraphic units defined on depositional environments. In addition, the use of unconformity-bounded supergroups avoids the problems which plague the Mal País Supergroup of BAUMGARTNER et al. (1984). This unit is extremly diachronous, ranging from Campanian to late Miocene/Pleistocene, and is subdivided into chronostratigraphically delimited lithostratigraphic units. The age-diagnostic criteria, however, were not accurate (SPRECHMANN, 1984b). No subdivision of the Mal País Supergroup into episodes, phases, spans or clines was made (*cf.* MIALL, 1990 : 86).

The units plotted in the stratigraphic chart of Costa Rica are strictly based on lithostratigraphy, according to HEDBERG's recommendations. These are based on observable lithologic features which are readily observed during field mapping, including composition, grain-size and, if possible, also some basic sedimentological information such as types of sedimentary structures and cyclic sequences (MIALL, 1984 : 74).

For the definition of lithostratigraphic units a clustering method is used (with emphasis on common features caused by similar depositional environments) rather than a splitting method (which has been the common stratigraphic practice in Costa Rica). Under this premise, the following changes are introduced:

a) BAUMGARTNER et al. (1984) defined 4 new turbiditic formations, and incorporated 3 previously existing ones in the Sámara Group. In this paper only 3 formations consisting of turbidites are recognized, having a larger paleogeographic extension (Curú, Arío and Descartes formations).

b) The Fila de Cal Formation is characterized by limestones with larger foraminifera; it now substitutes many obsolete lithostratigraphic terms (unidad El Cajón, Las Animas de Turrialba, Parritilla Formation, Caliza Punta Cuevas, Cabo Blanco Formation, etc.).

REMARKS ON SOME LITHOSTRATIGRAPHIC UNITS

In this paper the *Brecha Carrillo Formation* is used according to its original definition (SPRECHMANN, 1982, 1984a, b).

CALVO (1987) states that the *Loma Danta Member* (unidad Loma Danta, *cf.* RIVIER, 1983, 1984) of the *Curú Formation* represents Paleocene allodapic limestones, formed by reworking of neritic limestones from the *Barra Honda* and *El Viejo* formations. The *Loma Danta Member* correlates with the *Sapoá Formation* of southwestern Nicaragua (CALVO, 1987).

The *Lutitas Silíceas de Bahía Murciélago Member* which previously has been incorporated into the *Sabana Grande Formation* (BAUMGARTNER et al., 1984; ASTORGA, 1987), is now incorporated into the *Loma Chumico Formation* of the *Papagayo Supergroup* (ASTORGA, 1990; 1993).

The *Calizas Pelágicas de Punta Blanca Member* is eliminated. Consequently, the *Sabana Grande Formation* contains nothing else than pelagic limestones.

We believe that the *Sabana Grande Formation* extends into the the subsurface of the Limón Basin, being equivalent to the *Changuinola Formation* of FISHER & PESSAGNO (1965).

The Río Lari Section in the Limón Basin (FISHER & PESSAGNO, 1965) is regarded as a formal unit, named *Río Lari Formation* (cf. CALVO & BOLZ, 1992). The same authors correlated the *Río Lari Formation* with the *Arío Formation*. BOTAZZI et al. (1993) consider this unit a member of the *Tuis Formation*.

In cases where the *Curú Formation* cannot be distinguished from the *Arío* or *Descartes Formations* the use of the terms *Sámara* and *Punta Gigante Subgroups*, respectively, is recommended.

Time-stratigraphic units in Upper Cretaceous rocks of the Térraba Basin are established in analogy to the Golfito area.

The *Pre-Machuca Group* has been established by WEYL (1980, fig. 61) and ELF PETROLEOS REPORT (1968-1972).

In the Osa-Burica Basin, the *Salsipuedes Formation* is considered a synonym of the *Arío Formation*.

Allodapic limestones (e.g., *Punta Serrucho Member*) are age-equivalent to certain autochthonous limestones (e.g., *Fila de Cal Formation* stratotype). However, allodapic limestones should be incorporated into the same formation as the accompanying silicoclastic turbidites. Examples of allodapic limestones found in formal and informal lithostratigraphic units are known from the following localities: Punta Serrucho, Pavones, Bahía Drake, Peñón de Arío, Espadilla, Punta Sámara, and Loma Danta [*cf.* RIVIER (1983); BAUMGARTNER et al. (1984); OBANDO (1986); CALVO (1987); ASTORGA (1987); BOLZ (in prep.)].

Lithofacies and microfacies of the Middle and/or Upper Eocene *Fila de Cal Formation* are remarkably uniform throughout the entire isthmus. Therefore, no field criteria for recognizing differences between Middle and Upper Eocene limestones can be provided; micropalaeontological evidence, however, does exist.

Limestones with large foraminifera have been deposited in different settings at different times. The following criteria may serve as a guide to distinguish between different units:

- the *Espíritu Santo Formation* (Upper Paleocene-Lower Eocene, CALVO & BOLZ, 1991) can be identified by a low diversity among the larger foraminifera and by the occurrence of the index fossil *Ranikothalia bermudezi* (PALMER) *sensu* BUTTERLIN (1981),
- the *Fila de Cal Formation* (Middle-Upper Eocene) commonly presents the highest diversity among larger foraminifera
- the *Punta Pelada Formation* (Upper Oligocene-Lower Miocene) is easily recognized by the fact that it contains Miogypsinidae. It is underlain by an angular unconformity, and overlain by estuarine or deltaic deposits (CALVO, 1987).

The hiatus which corresponds to the regional unconformity which underlies Upper Oligocene rocks represents an hiatus of 6 Ma (CALVO, 1987: 122).

The stratigraphic chart (Fig. 1) does not include formal lithostratigraphic units defined in subsurface sections because the necessary information is not available. For the same reason, the informal unit *El Real* is excluded from the present edition. Lithostratigraphically, the *El Real unit* can be correlated with the *Montezuma Formation* (Pliocene, CALVO, 1987).

STRATIGRAPHY AND SEQUENCE STRATIGRAPHY

During the last decade, an increasing number of publications considered sequence stratigraphic aspects of the Costa Rican sedimentary record (e.g., SEYFRIED et al., 1987; ASTORGA, 1987; CALVO, 1987; LAURITO, 1988; SCHMIDT, 1989; KOLB, 1990; SEYFRIED et al., 1991, SCHMIDT & SEYFRIED, 1991; KOLB & SCHMIDT, 1991; WINSEMANN & SEYFRIED, 1991; WINSEMANN, 1992; von EYNATTEN, SCHMIDT & WINSEMANN, 1992; AMANN, 1993). The crucial problem with these sequence stratigraphic interpretations, however, is the poor biostratigraphic control of almost all sedimentary rocks exposed on land. Most age determinations are restricted to higher chronostratigraphic categories. This seriously hampers correlation of sequence boundaries.

CONCLUSIONS

The present edition of the Stratigraphic Chart of the Sedimentary Basins of Costa Rica has been synthesized by a team of 18 geologists with vast experience in mapping sedimentary rock units in the different basins recognized in Costa Rica.

The stratigraphic chart is based on a time scale and subdivided into the existing sedimentary basins. Sediments deposited in these basins are divided into 3 supergroups: *Curime*, *Boruca* and *Cerere*. The boundaries of these supergroups are regional uncorformities.

Groups and subgroups were introduced to simplify terminology and to reveal genetic relations between depositional environments. The number of formations has been considerably reduced as compared to current practice.

The stratigraphic concept of the chart is com-

patible with the available geophysical data. Within certain limits, objective lithostratigraphic units can be correlated with interpretive sequence stratigraphic units.

The lithostratigraphic units shown in Fig. 1 are also used in a hitherto unpublished edition of 3 geologic maps of Costa Rica, presented as posters at the 1990 Congreso Geológico de América Central in San José, Costa Rica, by the exploration staff of the Costa Rican oil company Recope (Geologic map of Costa Rica, 1:500.000; Geologic map of the Limón Sur Basin, 1:200.000; Geologic map of the Térraba Basin, 1:200.000).

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