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Interpreted sequence stratigraphy of the Los Jabillos, Areo, and (subsurface) Naricual formations, Northern Monagas area, Eastern Venezuela Basin

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Resumen

Las diversas posiciones estratigráficas que se han asignado en la literatura a las formaciones Los Jabillos, Areo y Naricual (subsuelo), así como las ambigüedades bioestratigráficas involucradas, han resultado en confusión entre los geólogos desde hace largo tiempo. La Formación Los Jabillos es considerada de edad Oligoceno a pesar de contener comúnmente fauna Eocena. La confusión puede resolverse al considerar la sedimentación de estas unidades desde el punto de vista de estratigrafía secuencial.

La Formación Los Jabillos contiene dos secuencias estratigráficas de edad Oligoceno temprano. Estos sedimentos se depositaron en el margen de la plataforma externa de un margen pasivo. Los sistemas encadenados ("systems tracts") están constituidos por (1) una cuña clástica asociada al margen de la plataforma ("lowstand shelf margin wedge") y (2) depósitos de relleno de valle excavado ("incised valley fill"), pertenecientes al sistema transgresivo. La cuña clástica está asociada al descenso del nivel del mar hace 33 millones de años (Ma), mientras que el valle excavado está asociado al descenso del nivel del mar global hace 30 Ma y posterior ascenso. Estos sistemas encadenados están contenidos dentro de secuencias sucesivas depositadas entre 36 Ma (límite Eoceno-Oligoceno) y 29 Ma, edad que coincide con una superficie de máxima inundación dentro de la Formación Areo. La Formación Areo es un equivalente lateral de la Formación Los Jabillos. La Formación Areo está solapada ("downlapped") por la parte superior de la Formación Naricual (subsuelo), un equivalente lateral de las arcillas de la parte inferior de la Formación Carapita (Zona F).

Las confusas relaciones bioestratigráficas se pueden explicar si consideramos un complejo arrecifal en el margen de la plataforma en el Eoceno, representado por el Miembro Tinajitas de la Formación Caratas. Las bajadas del nivel del mar que ocurrieron entre el Eoceno tardío y el Oligoceno temprano fueron responsables de la erosión o disolución de este complejo arrecifal. Los remanentes erosivos de este margen de plataforma pasiva permanecieron en el fondo marino mientras la plataforma subsidía rápidamente. La deposición glauconítica de la Formación Areo está asociada a los sistemas transgresivos y de alto nivel. Durante la subida del nivel del mar entre 30 y 29 Ma estos parches arrecifales fueron retrabajados y abundante fauna Eocena rellenó las superficies transgresivas asociadas con rellenos de valles excavados (Formación Los Jabillos). Lateralmente durante el mismo período, las arcillas (Formación Areo) se depositaron en el talud y en el margen de la plataforma durante los períodos de inundación. La contínua transgresión del Oligoceno, causada por la acelerada subsidencia de la cuenca, provoca la migración del quiebre de la plataforma y fuerza a los sedimentos de plataforma de la parte superior de la Formación Naricual (subsuelo) a retrogradar hacia el suroeste.

Palabras Claves: *Cuenca Oriental de Venezuela, Norte Monagas, Formaciónes Areo y Los Jabillos, Estratigrafía Secuencial*

Abstract

Faunal inconsistencies and variable stratigraphic positions of the Los Jabillos, Areo, and (subsurface) Naricual formations have confused stratigraphers for a long time. The Los Jabillos Formation is considered to be Oligocene in age even though Eocene age fauna are commonly found within it. By considering the deposition from a sequence stratigraphic point of view, the confusing stratigraphy of these formations may be reasonably explained.

The Los Jabillos Formation is interpreted to include two stratigraphic sequences of the Early Oligocene. These were deposited along a passive margin outer shelf. The systems tracts comprise (1) a lowstand Shelf Margin Wedge (SMW), and (2) Incised Valley Fill (IVF) sediments of the transgressive systems tract. The former relates to the 33 million year global sea-level drop while the latter relates to the 30 million year sea-level drop and subsequent rise. These systems tracts lie within successive sequences deposited from the Oligocene-Eocene boundary (36 million years) upwards in time to the 29 million year maximum flooding surface found within the Areo Formation. The Areo Formation is a lateral equivalent of the Los Jabillos Formation. It is downlapped by the upper portion of the (subsurface) Naricual Formation, a lateral equivalent of the shales of the lower Carapita Formation (Zone F).

The confusing faunal relationships are best explained by considering an Eocene shelf margin reef complex (the Tinajitas Member of the Caratas Formation). During global sea-level drops from the Late Eocene through Early Oligocene, the reef complex was incised by dissolution or erosion. Reef remnants on the incised shelf margin remained on the sea floor as the shelf rapidly subsided. Glauconites of the Areo Formation were deposited during each sea-level rise and highstand. Ravinement of remnant patch reefs during the 30 Ma to 29 Ma sea-level rise deposited abundant reworked Eocene fauna from nearby flooded reef tops along the transgressive surfaces of the incised valley fill sediments (Los Jabillos Formation). Laterally time-equivalent shales (Areo Formation) were deposited on the slope and on the shelf during maximum flooding events. Continued transgression in the Late Oligocene due to accelerated basin subsidence forced downlapping shelf sediments of the (subsurface) upper Naricual Formation to retrograde southwestward.

Key words: *Eastern Venezuela Basin, Northern Monagas, Areo and Los Jabillos formations, Sequence, Stratigraphy.*

Introduction

In the northern Monagas area of the Eastern Venezuela Basin the association of Eocene faunas within the sandstones of the Caratas and the Los Jabillos formations has admittedly been confusing to stratigraphers for many years (Hedberg and Pyre 1944; Hedberg 1950; Renz 1957; Stainforth 1971; Gonzalez de Juana et al. 1980). In outcrop the Los Jabillos Formation has been considered either a sandy facies of the (Oligocene) Areo Formation (Lamb 1964) or a "lateral facies" of the (Eocene) Tinajitas limestone (Hedberg 1950). In the subsurface the Los Jabillos Formation contains a fauna that is transitional into overlying Areo shales such as in the well JGE-31, yet it also contains a definite Eocene fauna, *Asterocyclina,* in a nearby well, ORC-16A. Today, it is generally believed that the Eocene faunas are reworked and an Early Oligocene age for the Los Jabillos Formation is now accepted. How are these reworked faunas logically explained?

Also in the subsurface of northern Monagas, the stratigraphic position of the Areo Formation with respect to the Naricual and Carapita formations seems cloudy. The uppermost oil productive sandstones in El Furrial Field were studied by Gutierrez (1988) who considered them to belong to the Naricual Formation on the basis of their stratigraphic position between the Areo Formation and the Carapita Formation. But to the east of El Furrial field in the Quiriquire field, the Areo Formation, clearly identified by the fauna of the outcrop type section, lies directly beneath the Carapita Formation. The Naricual sandstones are missing. Considering such relatively abrupt stratigraphic variations in northern Monagas, where do the Los Jabillos and Naricual formations actually fit within the stratigraphy?

This paper attempts to explain such confusing faunal and stratigraphic enigmas by considering them from a sequence stratigraphic point of view. All of the formations of this discussion are recognized as belonging to a passive continental margin wedge which was later disrupted by south-directed thrusting along the Pirital fault at the end of the Early Miocene. Except for accelerated basin subsidence in the form of simple downbending, tectonics is believed to have played very little part in varying the stratigraphy. In this paper, the stratigraphic variations and faunal inconsistencies are interpreted to be the result of several relative sea-level fluctuations on the shelf.

The formations of northern Monagas, originally identified as lithostratigraphic units primarily from outcrop studies, were later found to be diachronic when biostratigraphic zones were applied in subsurface studies from well samples. The sequence stratigraphic analysis which follows interprets these diachronic units within the context of genetically related stratigraphic units (sequences) and their depositional systems tracts which formed as a result of global sea-level cycles during the Oligocene.

Most of the seemingly confusing relationships can be explained within the context of known Eocene to Oligocene biostratigraphy and relative sea-level drops followed by rises that affected the passive margin depositional shelf, shelf break, and upper slope during this time. It requires considering a passive margin shelf on which the Oligocene strata were deposited as it underwent simple downbending and regional marine transgression due to tectonism. The global sea-level fluctuations during the Oligocene when combined with the downbending were responsible for developing such confusing faunal relationships and "lateral" stratigraphy by eroding a deeply incised mixed clastic and carbonate platform which had a shelf margin reef complex, the Tinajitas Member of the Caratas Formation.

A brief review of the lithostratigraphy and biostratigraphy

As originally defined, the lithostratigraphic units of northern Monagas and some of their biostratigraphy are briefly reviewed as follows:

The (Eocene) Caratas Formation consists of siltstones and glauconitic, sandstones (Hedberg 1937). Locally developed bioclastic limestones constitute the upper Tinajitas Member (Salvador 1964). Although the Caratas Formation is generally considered to be Eocene in age, lower segments may also be Paleocene. The Tinajitas Member is generally thought to be Middle Eocene in age (Galea 1985) with the Late Eocene missing. But Late Eocene planktonic foraminifera have been identified in exposures northeast of the San Francisco fault (Contreras and Hernandez 1980) and in the well QGE-33 (Furrer, personal com.). The lower contact of the Caratas Formation is transitional with the underlying Vidoño Formation, but the upper contact is an unconformity (Gonzalez de Juana et al.1980.)

The overlying Los Jabillos Formation is identified as the predominantly sandstone lithologic unit that lies stratigraphically beneath the Areo shale and unconformably over (where present) the Tinajitas limestone member of the Caratas Formation (Gonzalez de Juana et al.1980). Macsotay et al. (1986) dated the Los Jabillos Formation as Early to Middle Oligocene based on mollusks, and Rosales (1967) interpreted its depositional environment as inner platform, littoral marine with a fluvial influence.

The Areo Formation is a glauconitic shale unit that is diachronic throughout the Oligocene from the *Cassigerinella chipolensis-P. micra* Zone through *G. ampliapertura* and *G. opima opima* to the *G. ciperoensis ciperoensis* Zones (Lamb 1964). In places it is a lateral equivalent of the Los Jabillos Formation. Elsewhere it overlies the Los Jabillos Formation. Areo shales are found in both shelf and slope positions but they are faunally richer on the outer shelf, slope, and basin floor.

The Naricual Formation in the subsurface of northern Monagas is unlike that of the type location in outcrop (Socas 1991). In the subsurface of northern Monagas at El Furrial field, Gutierrez (1988) described the lower contact of the Naricual Formation as conformable and transitional with the underlying Areo Formation. He described its upper contact as transitional into shales of the Carapita Formation. In later studies on well cores, Isea et al. (1993) redefined the El Furrial oil pay section. They defined three units referring to them as simply "upper", "middle" and "lower" units. They included a glauconitic section, considered by Gutierrez (1988) to be the Areo Formation, within their "middle" unit and included the sandstones he considered Los Jabillos and Caratas formations within the "lower" unit. In addition, they described the "middle unit" as lying unconformably on fluvial sandstones of probable Cretaceous age rather than on the Los Jabillos and Caratas formations. They considered the Paleocene and Eocene beds to be missing at El Furrial.

At El Furrial field, depositional environments of the Naricual sandstones (better referred to as the El Furrial sandstones) are considered to be coastal margin, inner neritic tidal channel, coastal barrier, and distributary channel mouth bar deposits having a greater marine influence towards the top of the section (Isea et al. 1993). Planktonic foraminifera are few, but where present, this fauna place the "upper unit" of sandstones within the Late Oligocene, the *G. ciperoensis ciperoensis* planktonic zone. Recent research by Intevep geoscientists suggests that the upper unit sandstones may in fact be Early Miocene in age.The shales of the "middle unit" likewise belong to the *G. ciperoensis ciperoensis* Zone, but the glauconite at the base of the "middle unit" lacks age-definitive fauna. It may have variable ages as explained below. The "lower unit" of Naricual sandstones also lacks age-diagnostic fauna, but these sandstones are now believed to belong to the Cretaceous.

Sequence stratigraphic perspective

Interpretation of stratigraphic sequences and the depositional systems tracts which formed as a result of fluctuations in relative sea level is largely dependent on position with respect to the shelf, slope, and basin floor. These positions are determined by the paleobathymetry. The depositional shelf break which separates shelf from slope deposits may migrate throughout geologic time in response to both tectonics and the sediment supply. Migration of the depositional shelf break will be reflected in the stratigraphic section encountered in drilled wells which can be considered essentially vertical penetrations into the basin geohistory as shown by the stratigraphy within the well.

Paleogeographic setting

The changing paleobathymetry of the strata in the wells in northern Monagas shows that the passive margin sediments of the formations described above were deposited along a foundering outer shelf and upper slope (Fig.1). A south- to southwest-migrating shelf break resulting from simple downbending may account for the seemingly abrupt changes in the stratigraphy. A sequence stratigraphic analysis of the sedimentary sections in three key wells located in northern Monagas at the depositional shelf break (Fig. 2) serves to illustrate and lends a perspective which explains many of the previously confusing stratigraphic relationships among these formations. In these wells, the well log sequence stratigraphy (Vail and Wornardt 1990) illustrates the global fluctuations

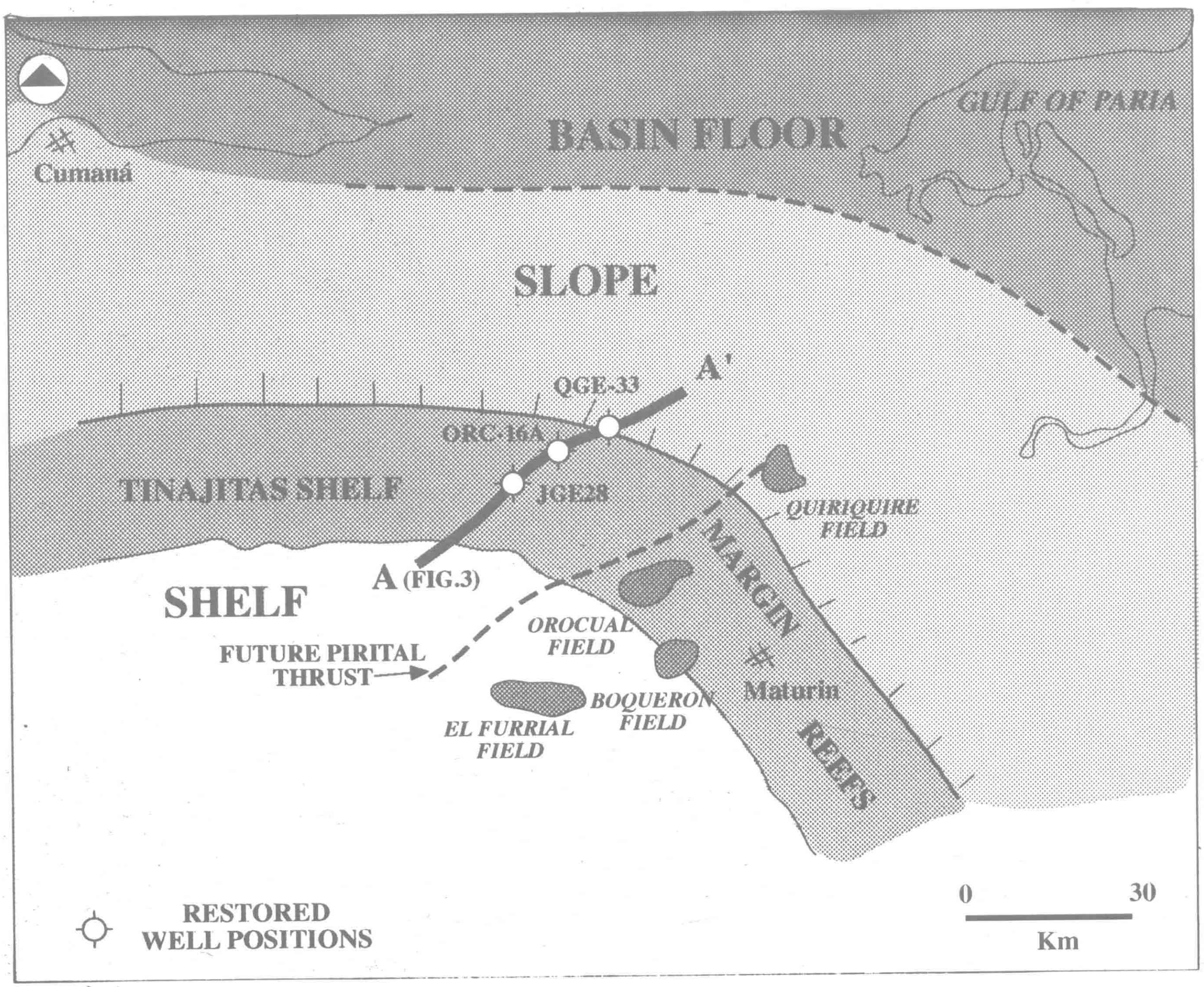
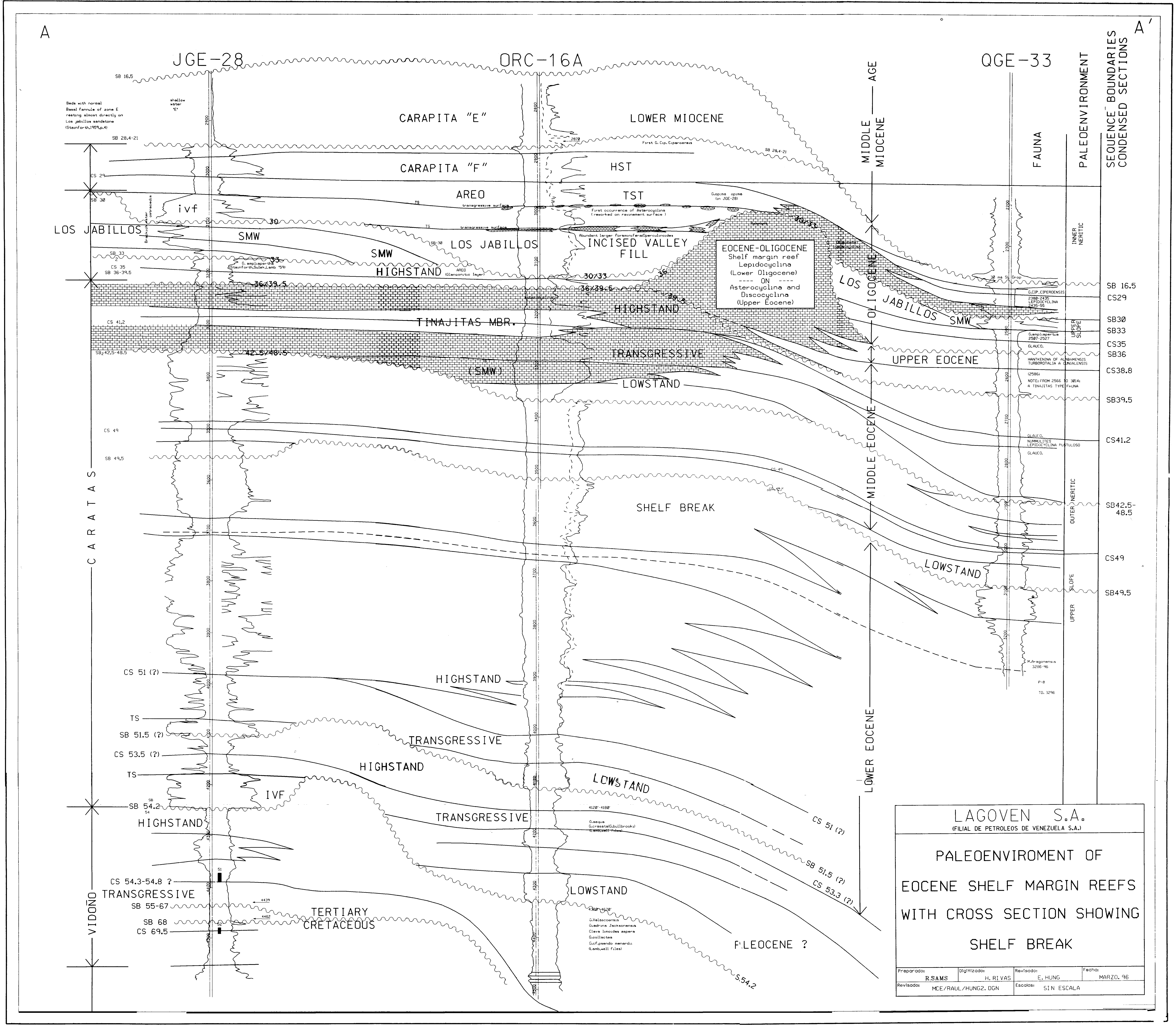


Fig. 1
Paleogeographic sketch of Eocene platform showing depositional environments


A
A'
JGE-28
ORC-16A
QGE-33
AGE
MIDDLE MIOCENE
OLIGOCENE
UPPER EOCENE
MIDDLE EOCENE
LOWER EOCENE
FAUNA
PALEOENVIRONMENT
SEQUENCE BOUNDARIES CONDENSED SECTIONS
CARAPITA "E"
LOWER MIOCENE
CARAPITA "F"
HST
AREO
TST
ivf
LOS JABILLOS
SMW
LOS JABILLOS
INCISED VALLEY FILL
HIGHSTAND
EOCENE-OLIGOCENE
Shelf margin reef
Lepidocyclina
(Lower Oligocene)
---- ON ----
Asterocyclina and
Discocyclina
(Upper Eocene)
LOS JABILLOS SMW
TINAJITAS MBR.
HIGHSTAND
TRANSGRESSIVE
(SMW)
LOWSTAND
CARATAS
SHELF BREAK
LOWSTAND
INNER NERITIC
UPPER SLOPE
OUTER NERITIC
UPPER SLOPE
SB 16.5
CS29
SB30
SB33
CS35
SB36
CS38.8
SB39.5
CS41.2
SB42.5-48.5
CS49
SB49.5
CS 51 (?)
HIGHSTAND
TS
SB 51.5 (?)
TRANSGRESSIVE
CS 53.5 (?)
HIGHSTAND
TS
LOWSTAND
IVF
SB 54.2
HIGHSTAND
TRANSGRESSIVE
CS 54.3-54.8 ?
TRANSGRESSIVE
SB 55-67
SB 68
CS 69.5
VIDOÑO
TERTIARY
CRETACEOUS
LOWSTAND
PALEOCENE ?
CS 51 (?)
SB 51.5 (?)
CS 53.3 (?)
S.54.2
LAGOVEN S.A.
(FILIAL DE PETROLEOS DE VENEZUELA S.A.)
PALEOENVIROMENT OF
EOCENE SHELF MARGIN REEFS
WITH CROSS SECTION SHOWING
SHELF BREAK
Preparado: R.SAMS
Digitizado: H. RIVAS
Revisado: E. HUNG
Fecha: MARZO. 96
Revisado: MCE/RAUL/HUNG2.DGN
Escala: SIN ESCALA

in relative sea level from the Late Eocene through the Early Oligocene. Biostratigraphic correlation of these strata southwestward to the El Furrial field utilizing the 29 Ma maximum flooding surface as a datum permits reconstruction of the passive margin paleogeography illustrated in Figure 1 for the end of the Eocene.

From the Eocene to the Early Oligocene a shelf position is indicated at El Furrial field with the shelf break to the north. The slope position is indicated in well QGE-33 immediately to the north and east of wells JGE-28 and ORC-16A. The Orocual and Boqueron fields also occupy positions on the shelf, but they are nearer to the shelf break than El Furrial field as suggested by the presence of the Tinajitas shelf margin reef facies within the strata of these fields.

At a position clearly on the depositional shelf, such as in the El Furrial field, the Areo Formation is very thin and the Los Jabillos Formation in places may even be absent with glauconites of the Areo Formation lying directly on Cretaceous age shelf sandstones as interpreted by Isea et al. (1993). The Areo Formation in this position is composed of glauconitic sediments most typical of maximum flooding events and their accompanying condensed sections (Aguado 1993).

The Areo Formation of Gutierrez (1988), as well as the strata both above and below it, were cored in well FUL-13 in El Furrial field. In this well the Areo Formation is within the "middle" unit of Isea et al. (1993) It is composed of only a few tens of feet of sandy shale and 50 feet of almost pure glauconite. Three vertically separated samples of the glauconite section were dated radiometrically in 1992. Results showed a variety of dates ranging from 33.6 Ma (Oligocene) to 42.6 Ma (Eocene) with a margin of error of ± 1.1Ma. Thus, Gutierrez's Areo Formation here is a diachronic unit that extends in time from Middle Eocene until Early Oligocene. This glauconite section will be referred to hereafter informally as the Areo glauconite member to distinguish it from younger Areo shales in the overall diachronic section which includes the *G. ciperoensis ciperoensis* Zone. Within the Areo glauconite member occurs a 2 foot limestone (Fig. 3) which is either a dislodged block or a very thin, insitu bedded remnant of the dissected shelf margin reef facies. In the Boqueron field, 20 km to the northeast and nearer to the depositional shelf break, Aguado (1993) reported a correlative glauconitic condensed section (60 feet thick) "resting erosively on a carbonate platform" but having a second condensed section above it. This younger condensed section consists of highly altered pelletal glauconite separated from the older condensed section below by only 25 feet of shale and silt. While Aguado assigned no dates to these condensed sections, within sections of the Areo Formation along the outer shelf and upper slope as at Orocual field and in the Quiriquire field respectively, the planktonic foraminifera are sufficiently abundant within the formation to establish an age for the correlative strata. At these positions the Areo Formation as a whole is known to extend through three Oligocene biochronozones, namely: the *G. ampliapertura*, *G. opima opima,* and *G. ciperoensis ciperoensis* zones (Salvador and Stainforth 1968). But the correlative glauconitic member of the Areo Formation contains only the biochronozone *G. ampliapertura* of the Early Oligocene. In a core from the well *QGE-33 at* the shelf break (Figs. 1 and 2), the Areo Formation is similarly identified by its fauna between 2507 and 2527 feet. In this well the Eocene-Oligocene boundary appears to be conformable. A very thin section of glauconitic sandstones below the Areo Formation but above the Eocene-Oligocene contact with the Caratas Formation is referred to as "Los Jabillos" based on its stratigraphic position (M. Furrer 1992, personal communication).

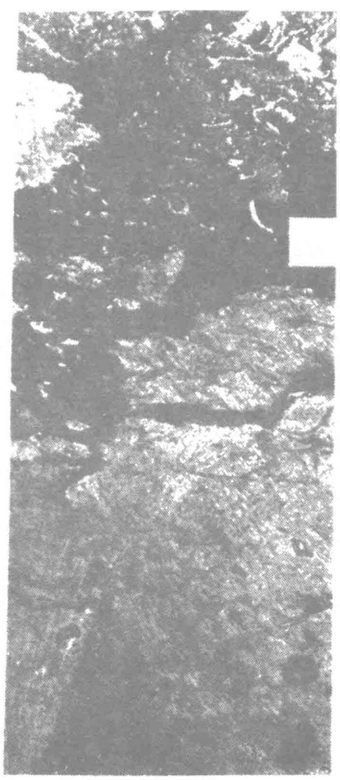


Fig. 3
Photo of limestone block within the Areo glauconite from core in FUL-13

Application of the Mesozoic-Cenozoic Cycle Chart

The Mesozoic-Cenozoic Cycle Chart of Haq et al. (1988) identifies six third order global sea-level cycles within the Oligocene. Based on the biostratigraphy in northern Monagas wells, these cycles have been recognized in the following sequences and systems tracts:

Cycle TA4.4

The presence of the <u>*G. ampliapertura*</u>

biochronozone in QGE-33 on the upper slope assigns a date to the Areo glauconitic member of between 35 and 33 Ma. These dates are in agreement with the upper (and younger) radiometrically determined ages in the glauconites at El Furrial, specifically those above the limestone bed. Based on the correlation of these dates then, the condensed sections of the Areo glauconitic member in the FUL-13 should include the 35 Ma condensed section indicating a maximum flooding surface over the Eocene shelf limestones during the earliest Oligocene. The 36 Ma sequence boundary at the end of the Eocene is apparently conformable on the slope in QGE-33, but it truncates the Late Eocene sediments on the shelf in wells JGE-28 and ORC-16A and incises the reefal limestones of the Tinajitas Member of the Caratas Formation (Fig. 2).

The uppermost seven feet of the glauconitic member above the limestone cored in the FUL-13 is characterized by 7-10 feet of leached moldic porosity and an oxidized sideritic zone. This leached and oxidized zone indicates subaereal exposure and is therefore interpreted as a lowering of sea-level. Incision of shelf sediments from this lowering of sea-level is lacking because the glauconites grade upwards into the overlying shales. A drop in sea-level which does not incise the shelf is a characteristic of a type II unconformity (Van Wagoner et al.1988). This type II sequence boundary is interpreted to be the 33 Ma sequence boundary based on its stratigraphic position next above the 35 Ma condensed section and 36 Ma sequence boundary of cycle TA 4.4.

The correlation of Areo glauconites that contain *G. ampliapertura* with the Areo glauconite radiometric dates in the member above the limestone bed also shows that from the shelf edge at well QGE-33 to the shelf position at El Furrial field, the 35 Ma condensed section has overlapped eroded beds of the Late Eocene which are present in the well QGE-33 but not present at El Furrial field (Fig. 4). The Late Eocene at El Furrial field is thus missing by erosion or dissolution of the carbonates. At El Furrial the Areo glauconite member, as mentioned earlier contains remnants of shelf limestone. The sharp, flame-like, vertical contact between the limestone and the glauconite (Fig. 3) suggests dissolution and is possibly a karst surface. Older glauconite of Early to Middle Eocene age (42 Ma) lies below the limestone. Thus any Late Eocene sediments that may have been deposited on the platform have since been removed either by erosion or dissolution during the sea-level lowstand at the end of the Eocene. This erosional or karst surface marking the Eocene-Oligocene boundary is the 36 Ma sequence boundary of cycle TA 4.4.

Had these sediments been removed by erosion rather than dissolution, a lowstand systems tract of the removed and redeposited sediments should be present basinward. This systems tract has not been found. Therefore an interpretation in favor of dissolution is preferred over an erosion surface.

Cycle TA4.5

At Orocual field, the correlative glauconite member of the *G. ampliapertura* Zone is present but thinner than it is at El Furrial field. At this position the glauconite member lies unconformably on the Eocene Tinajitas Member of the Caratas Formation. But here the glauconite is overlain by several hundred feet of limey deltaic sands which are not present at El Furrial field. Based on their stratigraphic position these sands would be included within the Los Jabillos Formation. They are in turn overlain by Areo shales that include the fauna of the later Early Oligocene biochronozones, i.e., *G. opima opima* and *G. ciperoensis ciperoensis*. The sandstones would therefore be properly called Los Jabillos based upon their stratigraphic position, but they are younger than the Areo glauconite member. Within the deltaic sandstones, age-diagnostic planktonic foraminifera are lacking, however, calcareous nannoplankton within the ORC-52 well in Orocual field are identified as Eocene to Early Oligocene in age (M. Castro 1993, personal communication). Thin limestone interbeds containing *Operculinoides* are also to be found within the predominantly sandstone section. These outer shelf deltaic deposits of the Los Jabillos Formation are interpreted as the lowstand shelf margin wedge (SMW) systems tract that lies above the type II 33 Ma sea-level drop of cycle TA 4.5 (Fig. 4). At Boqueron field, the Areo glauconite member also occurs at the base of these deltaic sandstones of the shelf margin wedge. The subsequent relative sea-level rise and 32 Ma condensed section may be present in wells at Boqueron and in those at Orocual field, but it is not defined by a glauconite layer or a faunally rich transgressive shale wedge. Rather, it is identified by a thin shale break within the predominantly sandy log pattern. At the shelf edge position, a much thinner section of Los Jabillos sandstones lies above the Tinajitas

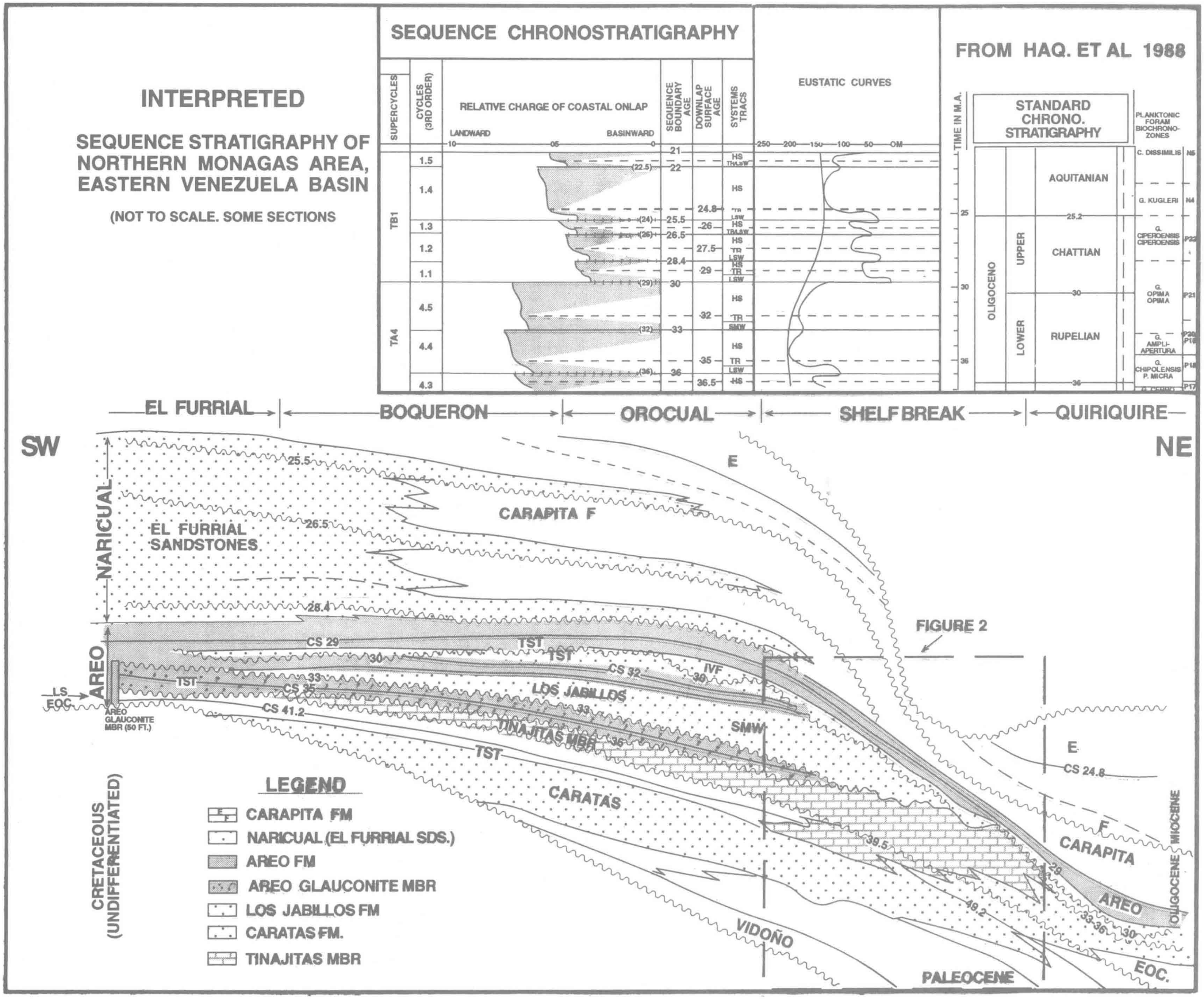


Fig. 4
Diagramatic cross section through El Furrial-Boqueron-Orocual fields to the depositional Shelf break

limestone member of the Caratas Formation in the JGE-28, ORC-16A, and QGE-33 wells (Fig. 2). There the 32 Ma condensed section has been truncated by the next youngest sequence bounding unconformity. Likewise the highstand systems tract of this sequence seems to be missing by erosion from the overlying 30 Ma sequence boundary.

Cycle TB1.1

In the ORC-16A (Fig. 2), the Los Jabillos sandstones are transitional into overlying Areo shales of the *G. ciperoensis ciperoensis* Zone. In this well the sandstones of the Los Jabillos Formation are interpreted as incised valley fill (IVF) of the transgressive systems tract following the 30 Ma sea-level drop of cycle TB1.1. The overlying Areo shale of the *G. ciperoensis ciperoensis* Zone forms the 29 Ma condensed section at the top of the transgressive systems tract. Based on the biostratigraphy, these shales are also clearly younger than the Areo glauconitic member and belong to the Late Oligocene. In well JGE-28 they contain *G. opima opima*. Thus at the shelf edge (and in more basinward positions than at El Furrial field), the sands identified as Los Jabillos by their stratigraphic position result from the lowstand shelf margin wedge, highstand, and transgressive incised valley fill deposits of cycles TA4.5 and TB1.1 (Fig. 4).

A correlation of the 29 Ma maximum flooding event and its condensed section described above with a condensed section in the FUL-13 in El Furrial field is possible based on the biostratigraphy of the earliest portion of the *G. ciperoensis ciperoensis* Zone. In FUL-13 at the top of four feet of Areo shale above the Areo glauconite member, a distinct erosional surface is overlain by coarse conglomerate. This erosion surface is interpreted as the 30 Ma sequence boundary. The erosion surface is overlain by a fossil-rich condensed section of the Late Oligocene *G. ciperoensis ciperoensis* Zone. This condensed section is interpreted as the 29 Ma condensed section and is correlatable throughout the northern Monagas area. It is important to note also that these sediments are older than the sands of the "upper unit" of the subsurface Naricual Formation which lie immediately above the Areo shales and 29 Ma condensed section at El Furrial.

Tectonic downbending

At El Furrial field, above the glauconites in the core of the Ful-13, as mentioned earlier only four feet of Areo shale is present beneath the 30 Ma sequence boundary. The erosion surface of the 30 Ma sequence boundary has truncated all but this four feet of the transgressive systems tract of the 32 Ma sea-level rise and all of the highstand systems tract of cycle TA4.5 which should have included sandstones of the Los Jabillos Formation. On the shelf at the El Furrial position then, the Late Eocene and all of the Early Oligocene sediments except the glauconites and four feet of shale are missing. Four posibilities exist: (1) the highstand sediments were never deposited on the platform, i.e., they pinch out; (2) they are truncated between Orocual and El Furrial fields on a tilted carbonate platform; (3) the platform has been deeply incised along its shelf margin; or (4) a combination of (2) and (3) is also likely.

At Orocual and Boqueron fields, however, 700-800 feet of the Los Jabillos sandstones remain, suggesting that tectonic downbending has preserved some of them here beneath wave base during the 30 Ma sea-level lowstand. At the shelf edge (Figs. 1 and 2) the Tinajitas reefs must also have foundered beneath wave base until they were exposed by the 30 Ma sea-level drop. As relative sea-level rose the reefs were ravined at wave base, and their Eocene faunas were reworked into the incised valley fill of the Los Jabillos shelf margin sandstones (Fig. 2).

The overlying sandstones of the Naricual Formation in El Furrial field interfinger to the northeast at Boqueron and Orocual fields with the shales of the Carapita Formation (Zone F) which contain the later portion of the *G. ciperoensis ciperoensis* Zone. At Quiriquire field in the upper slope position these strata thin and downlap onto the Areo Formation (Fig. 4).

The interpreted sequences and their systems tracts together with those missing by erosion or dissolution suggest the following scenario: downbending of the shelf margin began at the end of the Middle Eocene and continued concurrently with drops in relative sea level. Tectonic downbending caused Early Eocene sandstones (Caratas Formation) of the delta system to retrograde southwestward leaving a clastic-free environment that favored carbonate platform development (Tinajitas Member). Continued downbending eventurally extinguished reef growth at the shelf margin, but during Oligocene sea-level lowstands, the delta system progaded to the shelf margin depositing first a shelf margin wedge (33

Ma) followed by incised valley fill (30 Ma-29 Ma) of the Los Jabillos Formation. Areo glauconites and shales transgressed during the highstands. The depositional shelf break then retreated to a position between Orocual field and El Furrial field during the Late Oligocene. Coastal margin deposits of the Naricual Formation back-stepped during the successive cycles of the Late Oligocene (cycles TB 1.2 and TB 1.3) in response to continued downbending. These deposits interfingered with outer shelf and upper slope deepwater shales of the Carapita Formation (Zone F). They were finally transgressed during the Early Miocene sea-level rise as the shelf continued its subsidence. The combination of simple tectonic downbending with a southwestward shift in the depositional shelf break and sea-level fluctuations during the Oligocene thus explains the confusing stratigraphic relationships among these lithostratigraphic units.

Conclusions

By considering migrating shelf and upper slope positions within the sequence stratigraphic framework provided by the Mesozoic-Cenozoic Cycle Chart of Haq et al. (1988), the following may be concluded:

1. The Los Jabillos and Areo formations comprise at least two stratigraphic sequences within the Early Oligocene. Systems tracts of the Los Jabillos Formation comprise (1) deltaic and shore zone sediments of a lowstand shelf margin wedge (SMW) that follows the 33 Ma sea-level drop, and (2) variable thicknesses of Incised Valley Fill (IVF) sediments of the transgressive systems tract that followed the 30 Ma sea-level drop and subsequent rise. The lateral time equivalent shales and glauconites of the Areo Formation comprise transgressive systems tracts and maximum flooding events during these cycles.

2. These systems tracts lie within successive stratigraphic sequences that range in age from the Oligocene-Eocene boundary upwards in time to the 29 Ma maximum flooding surface of cycle TB1.1 at the end of the Early Oligocene.

3. Within the El Furrial field the maximum flooding surface of cycle TB1.1 (29 Ma condensed section) occurs in the middle unit of the Naricual Formation and is correlatable to the shelf break and upper slope positions now found in the section on the hanging wall of the Pirital thrust.

4. The 36 Ma sea-level drop that initiates the Oligocene may have been characterized by karst development, and rather than forming lowstand deposits as in the succeeding 33 Ma and 30 Ma sea-level drops, formed only very a thin, sandy, glauconitic section along the upper slope.

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