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SUMMARY AND CONCLUSIONS

The purpose of the present study was to carry out a stratigraphic framework of Tertiary and Upper Cretaceous sediments based on biostratigraphy, high resolution well log correlations, and as well to provide interpretations of the depositional environments. In addition, several paleogeographic maps, associated with net sand and sand/shale ratio maps are provided. An interpretation in term of sequence stratigraphy is proposed.

The datations and the paleoenvironments of 22 wells from the Monagas province have been reinterpreted with biostratigraphical techniques. The result is an homogenisation of the data, presented on a synthetic breakdown for each well. We noted remarkable changes of environmental types between the Cretaceous and the Tertiary, at the Paleocene-Eocene boundary and especially at the Eocene-Oligocene transition (hiatus). The lower Miocene illustrates clearly a rapid increase upwards of the rate of sedimentation (thickening upwards of 4 biozones , each representing the same time bracket). The paleogeographical trends become clearer upwards, with more marine conditions Northwards in the Oligocene and North-Eastwards in the lower Miocene. The results have been used for sedimentological correlations and for a better evaluation of depositional conditions and regional trends

A sedimentological quick look of cores has been performed for 10 wells. The observed facies indicates presence of different depositional environments which are marine shales, shoreface/delta-front and delta plain deposits.

Because of the evolution through time of the North American plate from a **passive margin** (Upper Cretaceous to Upper Eocene) into an **active margin** resulting from the tangential displacement and collision of the Caribbean plate along the North American plate, it results that the area has seen important changes of the paleogeography.

During the Upper Cretaceous to Upper Eocene the coast line was approximately oriented East-West. The rivers were flowing toward the North. Because of low accommodation related to low subsidence, shoreface sandstones and sand channel fills are stacked. A depositional model is proposed consisting of shoreface/delta-front reworked by low efficient tidal currents, with a braid-delta plain composed of stacked channel fills.

During the Upper Oligocene, the tangential displacement of the Caribbean plate induced an East-West subsiding zone and the creation of a **paleo** Orinoco river which was flowing West-East. The Upper Oligocene sediments observed in the area correspond to the deltaic deposits. The present day Orinoco delta is thought to be an analog for the Upper Oligocene deltas. The delta plain deposits correspond to sand channel fills in the distributaries, and to some sandy splays. In the lower delta-plain, large distributaries are located in the South of the delta and to the North sandy and muddy sandy channel fills (?) may correspond to tidal channel fills; in the delta-front, a complex of mouth-bars develops at the mouth of the main distributary channels reworked by tidal currents and along the interdistributary area beach/shoreface complexes are present.

The correlations are proposed for the Upper Cretaceous to the Upper Oligocene and are based on 15 markers named M14 to M0, and two sequence boundaries SB68(?) and SB(30). The markers were dated based on the biostratigraphical study, and defined in the fully cored FUL-13 well. Based on the facies observed on the cores, the depositional environments were indicated on each cross-section for each cored interval. For the not cored interval, based on GR log pattern, an interpretation of environment was proposed.

For each stratigraphic interval defined at top and bottom by a marker, net-sand, sand/shale ratio maps were carried out. In addition, the paleoenvironments were added on each maps based on the depositional environments indicated on each cross-section.

16 paleogeographic maps with net sand and sand/shale ratio isocurves are provided. They illustrate clearly the depositional environment evolution through time in relation with the tectonic and the change of the relative sea level.

1 - INTRODUCTION

The Norte Monagas area is a prolific hydrocarbon area located in the Eastern part of Venezuela (fig. 11). Important fields are located in the area (fig. 15) such as: Furrial, Boqueron, Orocual and the recent discovery Jusepin. These fields mainly produce from Oligocene through Upper Cretaceous formations.

The purpose of this study is to carry out a **stratigraphic** framework of Tertiary and Upper Cretaceous sediments based on **biostratigraphy**, high resolution well log correlations, and as well to provide interpretations of **the depositional environment** of Upper Cretaceous, and Lower Tertiary mostly clastic sediments. In addition several paleogeographic maps, associated with netsand and sand/shale ratio maps are provided. An interpretation in term of **sequence stratigraphy** is proposed.

The data available for the present study consist of biostratigraphic records, core photographs, some cores and logs (gr, ild, sonic, density, neutron, SP, SN) (fig 15).

The present day **structural framework** exhibits the collision and tangential displacement of the Caribbean Plate along the South American plate (fig 12 and 13). From Upper Cretaceous to Tertiary, the Northern part of the South American plate has been in an evolution from a passive margin into an active margin. In the Norte Monagas area up to the Upper Eocene, the area was a passive margin as indicated by a subsidence diagram (fig. 16) of well J-479X (the sedimentation ratio is low 36'/Ma. from SB 68 to M9 marker). From the Middle to Upper Oligocene the sedimentation rate (102' / Ma.) was more important related to the initiation of the collision, and to a more important subsidence (evolution into a foreland) (fig.13). During the Lower Miocene the subsidence was even more important (sedimentation rate = 1560'/Ma. from M3 to base NN4, and 2828' /Ma. for NN4) which indicates the evolution into a foredeep. At the end of the Lower Miocene the collision, in the Norte Monagas area, resulted in several phases of thrusting. The overthrust structures present in Furrial, Orocual or Jusepin fields are considered as paraautochtonous zone, the shortening related to the thrusts beeing relatively minor while the displacement of the strata North of the Pirital thrust, is thought to be more important in the allochtonous zone (Fig. 14).

2 -BIOSTRATIGRAPHY

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INTRODUCTION

Objectives

The reinterpretation of biostratigraphic data from the Monagas province was decided to provide the sedimentologists, involved in sequence stratigraphy, with reliable datations and paleoenvironmental reconstructions. This helped the correlations and the identification of paleogeographical trends, making possible a better reservoir mapping, a more precise prediction of prospective intervals and areas.

The interval of interest is mainly between the lower Miocene and the Eocene, but data have been collected already from the middle Miocene down to the Cretaceous. The Nannopaleontology proved good results in dating the Neogene and the upper Paleogene. Foraminifera are helpful in dating the Paleogene and for paleoenvironmental diagnoses. Palynology is often useful in nearshore to continental facies, from the base of the Miocene downwards.

Material reinterpreted

Following wells have been reinterpreted :
Chaguaramal-1X (Fig. 2.1. CHL-2)
Chaguaramal-2X (Fig. 2.2. CHL-2)
Corozo-1 (Fig. 2.3. COL-1)
Corozo-2 (Fig. 2.4. COL-2)
Cotoperi-1X (Fig. 2.5. COT-1X)
Furrial Norte-1 (Fig. 2.6. FN-1)
Furrial 2 (Fig. 2.7. FUL-2)
Furrial-13 (Fig. 2.8. FUL-13)
J 476-X (Fig.2.9.)
J 479-X (Fig. 2.10)
JGE-28 (Fig. 2.11. JGE-28)
JX-9 (Fig. 2.12. JX-9)
MRC-1E (Fig. 2.13. MRC-1E)
Orocual 25 (Fig. 2.14. ORC-25)
Orocual 54 (Fig. 2.15. ORS-54)
Orocual 55 (Fig. 2.16. ORS-55)
Orocual 59 (Fig. 2.17. ORS-59)
Orocual 63 (Fig. 2.18. ORS-63)

Quiriquire-647 (Fig. 2.19. QQ-647)
Quiriquire-648A (Fig. 2.20. QQ-648A)
San Vicente-1 (Fig. 2.21. SVL-1)
San Vicente-2X (Fig. 2.22. SVL-2X)

The reports made available are generally based on cutting samples and often on scattered intervals, according to the first operational interest of that time. Few of them indicate the observations sample by sample (Range charts) : intervals with their content are indicated. The casing shoe positions are generally not taken into account for the caving problems, in the original interpretations ; neither the use of the masterlog to identify favourable lithologies to be processed nor the control of bit changes on this log (caving problems) are traditional in these studies. The reinterpretation tried to inject this information, together with new data : as a matter of fact, the nannopaleontology proved recently a good efficiency in shallow water environments where planctonic foraminifera are scarce or absent. Additional work was performed with this technique in those wells where no or scattered data existed : the procedure practicized by Lagoven selects the cuttings before the mounting of slides, this meaning that the integrity of "geological" assemblages is preserved. The procedure used by Intevep is less precise and complicates the sample interpretation, because the cuttings are not sorted before the preparation and the assemblages of in situ and caved cuttings are mixed in the slides, this being avoided by the Lagoven procedure, which is not more time consuming.

The informative quality of resulting reinterpretation can be quoted as follows:
- Good key wells : SVL-1X, J 476-X, COT-1X JGE-28 ORS-55, QQ-467.
- Fair well reinterpretation : Ful-2, Ful-13, COL-2X, CHL-2X, ORS-63 ORC-25.
- Insufficient data for a fair reinterpretation : MRC-1E, JX-9, CHL-1X, ORS 59.

The "Carapita" problem

A particular interest was dedicated to the Carapita formation and to the boundary with underlying formations : this is particularly important to evaluate the Oligo-Miocene boundary, which is generally observed here under nearshore facies. The traditional use of foraminiferal biozones is thus not really adapted to solve the datation problems in this interval : nannofossils provide however useful markers in these shallow water environments. The Carapita formation (Middle Miocene to lower Miocene) is in fact heterogeneous in this area, because the upper part (middle Miocene to topmost lower Miocene) remains under deep marine outer shelf/slope facies, while the lower part was deposited under middle to nearshore shelf facies : this was only recently underlined (STENAM project) when biostratigraphical studies combined their observations with the lithofacies on cuttings. Dip geophysical profiles in the Onado area also show this phenomenon which cannot be readed from profiles, taken in the faulted eastern areas (Jusepin). A major facies change was thus recognised within the NN 4 nannoplankton biozone (topmost lower Miocene), possibly related with a short time gap in some areas. However, the traditional use of the biozonation based on the original definition of the Carapita formation was applied in the present area, where the Carapita formation does not correspond with the original description. The main result of this is that biostratigraphers tried to find planktonic foraminiferal biozones where no planktonics could occur, except caved juvenile specimens from the middle Miocene, taken for lower Miocene rare but "in situ" specimens. The stratigraphical interpretations based on these data are thus subject to aleatory fluctuations and the ages proposed are often too old (Oligocene for lower Miocene) : in fact the biostratigraphers oriented themselves with rather diachronic lithological facies changes (see herebelow the letter classification of the Carapita fm.).

The Carapita formation was first defined on Stainforth work (1953), revised by Sowers for less marine facies (1957) and by Lamb (1963) on a faulted fied section near Santa Ines (Estado Sucre)(see Maria del PILAR STIFANO SANDIAGO, 1993, Estratigrafia de la formacion Carapita en su seccion tipo y en la seccion del pozo ORS 52.-Tesis Univ. Central Caracas) : this section is rich in planktonic foraminifera, but does not represent the full extent of the formation, which was thus defined with well data for the upper and the lower parts. Stainforth defined planktonic foraminiferal biozones (letter classification A to E), for which lateral equivalents have been created by Lagoven, for the areas where these planktonics are scarce or even absent. These equivalents are defined by benthonics or even with lithological criteria, easily recognised in operational work but certainly diachronic : Carapita D should be clayey, E more sandy and F glauconitic. Furthermore, at the time of Stainforth, the original biozones were parallelized with the Oligocene stratotype, a wrong attribution recognised later to be in fact mostly Miocene: these adaptations leaded the operational interpretators to propose older ages as they are in fact.

The main results

Ages are generally interpreted from the presence of markers ; some time gaps are observed. Paleogeographic considerations depends both on the representativity of the sampling of each epoch by the wells and on the tectonical reduction of surfaces. The paleogeographic mapping (present positions) shows that the open sea was located at the N-NE of the area during the Tertiary. The Cretaceous needs a palinspastic reconstruction to be understood, the shallower areas being apparently to the north.

- The lower Miocene

  A minor time gap might exist sometimes in the lowermost levels. This is in relation with a regional thinning downwards of the biozones (especially Nannofloras), indicating globally slower sedimentation rates downwards.

  Inner shelf facies prevail in the SW (Ful, Col, SVL, Jusepin area, CHL-1X ?), middle shelf is observed more to the north (COT-1X, JX-9 ?, CHL-2X, ORS 54 and 55, ORS-63 ? and ORC-25 ?). The slope facies is present in the N and NE (JGE-28 and QQ-467).

- The upper Oligocene

  It is present is all the wells, some minor time gaps might exist a the top. Inner shelf facies is present in the SW (Ful-13, COL-2X , J 476-X ?, MRC-1E ?) ; middle shelf deposits are more scattered, between South and north areas (Ful-2, Ful-13, COL-2X, CHL-1X ?, CHL-2X ?, ORS-55 ?, ORS-54, ORC-25 ?). Outer shelf areas are better defined (SVL-1X, COT-1X, JX-9, JGE-28). Only one well seems to be on the slope (QQ-467).

- The middle Oligocene
  It is rarely documented. The lower Oligocene is apparently missing, together with the top of the Eocene.

- The middle Eocene
  It is not represented on all the wells. An inner shelf facies was present in the south (COL-2X, SVL-1X). Middle shelf facies are slightly more northwards (COL). Outer shelf conditions are well marked (J-476-X, JGE-28). The slope is documented at the NE (ORC-25).

- The Paleocene
  It is sporadically represented, under generally deep marine facies on the slope (JX-9, JGE-28, QQ-467).

- The Cretaceous
  It is only sporadically documented and difficult to correlate level by level. Inner shelf facies are questionably present in the south (Ful-13 ,, COL-2X ?). Middle shelf deposits are more certainly defined in the N-NE areas (JGE-28, ORC-25, QQ-467). Outer shelf facies are represented in the centre of the studied area (J-476-X).