Late Cretaceous Upwelling in the Southwest of the Thetys Sea, a Case History From the Barinas Basin, Venezuela

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Abstract

New studies show evidence of repetitive upwelling events taking place in the southwestern margin of Thetys from the Turonian through the Maastrichtian. Based on comparative analyses of sedimentological and biotic characteristics, Zones II and III of the upwelling model (Jones et al., l983) are interpreted in seven subcropping sections analyzed along the northern border of the Barinas Basin, southwestern Venezuela.

The presence of laminated dark shales, phosphate pellets, and abundant fish debris, glauconite, diatoms, radiolarian and dinoflagellates, and biogenic chert, support the upwelling model within a continental shelf and with the upwelling center located over the mid-inner shelf.

The following biofacies were established: *Planktic Foraminifera Biofacies* associated to light yellow glauconitic wackestone-mudstone limestones, suggesting high productivity and well oxygenated marine conditions; *Buliminids and Planktic Foraminifera, Diatoms,Radiolaria and Calcareous Nannoplankton Biofacies* in dark grey calcareous shales and wackestone-mudstone, that we associated with Jones, 1983 Zone III and, *Diatoms, Radiolarian and Dinoflagellate Biofacies* in dark grey shales and dolomites interstratified with yellow-brown sandstone and black phosphorites, indicative of Zone II and *Fish debris Biofacies* associated with Zone III (Jones et al., 1983).

Low diversity and high abundance assemblages, typical of opportunistic species characterize the microfaunal associations. These assemblages are considered survivors of anoxic to dysoxic conditions due to the upwelling. The subsequent high productivity conditions, associated to high salinity and low oxygen level of the water mass, results in high mortality which is reflected by the presence of fish debris and phosphate nodules.
The biofacies succession shows a tendency of the upwelling to have changed from more distal during the Turonian-Coniacian to a more proximal location during the Santonian-Maastrichtian.

Introduction

There are several interpretations concerning the sea-level history and causes of anoxia (Jeans et al., 1991; Paul et al., 1994; Douglas, 1998). One of the main causes of these anoxic events is the upwelling system, caused by paleoceanographic currents, which introduce rich nutrient water masses producing high paleoproductivity episodes.

Jones et al., l983 model considers that the response of phytoplankton in space and time to nutrient fields generated during an upwelling event, characterizes the potential source rock intervals.

Several Oceanic Anoxic Events (OAEs) have been recognized during the Cretaceous. One of the most pronounced and best studied is the Cenomanian-Turonian, which has became a model of an anoxic event caused by a sea-level rise. (Arthur et al., 1987)

The purpose of this paper is to prove the applicability of the Northern Hemisphere upwelling model proposed by Jones et al., l983 in younger events that have been identified in the Barinas Basin.

To improve our understanding of the Late Cretaceous upwelling system in Venezuela, we require multi-disciplinary studies in our main sedimentary basins: the Maracaibo and Eastern Venezuelan basins to setting up a

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high-resolution inter-regional correlation. The results of our study in the Cretaceous of the Barinas basin are a contribution to this effort.

The lithostratigraphy and location map of the basin is shown on figure 1

Geologic setting

The studied area is located in the Barinas-Apure basin, southwestern Venezuela, and its tectonic history as related to the present study is characterized by a preliminary phase (which spanned from the Jurassic to the late Cretaceous) marked by a progressive evolution starting with an extension of the Caribbean-Tethyan passive margin at the edge of the South American plate, and attributed to the fragmentation of Pangea.

In Barinas-Apure this initial phase is represented by the transgresive facies of the Guayacan Member of the Escandalosa Formation and La Morita and Quevedo members of the Navay Formation, which are correlated with the worldwide eustatic changes of the sea level.

This initial phase was followed by the collision and obduction of the Pacific Volcanic Arc with the South American plate, during the late Cretaceous-Paleogene time.

The collision transformed the passive margin into an active belt, creating a foreland basin with an associated forebulge in the Barinas area, where the regressive facies of the Burguita Formation were deposited (Parnaud et. al., 1995). (Figure 1)

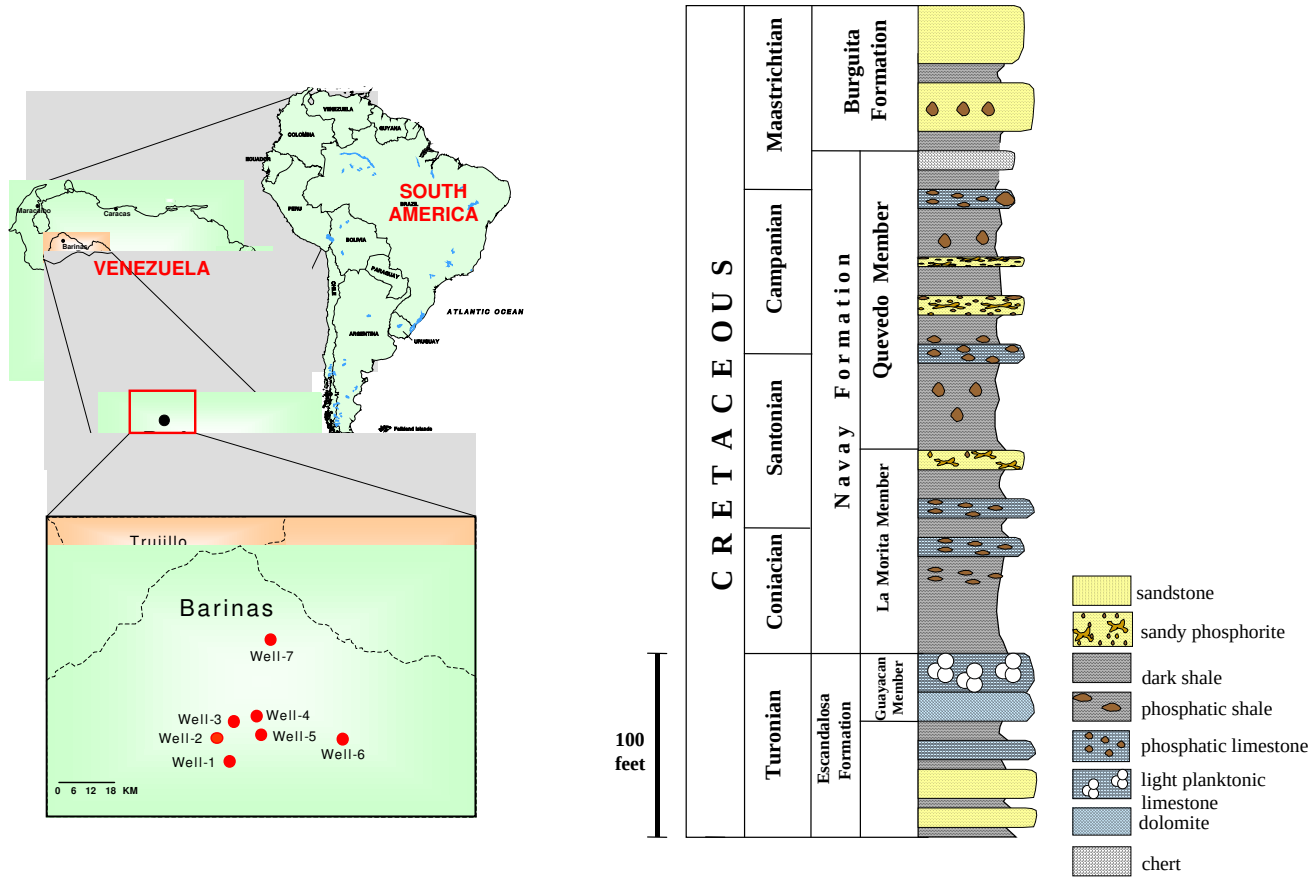

Figure 1.- Location map, and general lithostratigraphy of the studied area

Methodology

High resolution stratigraphical, biostratigraphic and lithologic analyses of the Turonian-Maastrichtian section were done in cutting and core samples from all the rock types (limestones, phosphorites, sandstones and shales) in seven subcropping sections. These analyses included the following:
- Sedimentologic descriptions of all the samples.
- Foraminifera analyses of washed residues and thin-sections, as well as, calcareous nannoplankton and Palynological analyses of 200 cutting samples and 14 core samples.
- Geochemical analyses (TOC and Rock Eval pyrolisis) were carried out on 140 cutting samples.

Sample preparation methods were the standard for each discipline.

Results

Based upon the lithologic descriptions, foraminifera, diatom, radiolarian, fish fragments, nannoplankton, dinoflagellates and phosphates content, four association were identified; three of these associations are correlative to the Jones model for upwelling in the northern Andean Turonian-Maastrichtian section, and one is not related with the model.

The characteristics of these key associations are the following:

Key Association P ("Phosphorites")

The lithology is represented by dark gray shales and phosphorites. The biological association is mainly composed of fish teeth, bone fragments, scales, phosphate nodules, scarce *Buliminid* forams and some specimens of *Astacolus* sp. *Quadrum* sp, *Watznaueria* sp and *Micula* spp nannoplankton platform assemblages, alternating with P>G (Peridinioids > Gonyaulacoids) dinoflagellate assemblages. The TOC varies from 0.81-2.80%. We correlate this association with Jones,1983 upwelling **Zone III**.

Key Association LSS ("Laminated siliceous shales")

The lithology is represented by dark gray mainly laminated shales and bedded chert. The biological association contains predominantly diatoms and radiolaria, scarce planktic and buliminids forams, *Thoracosphaera* sp and *Watznaueria* sp nannoplankton association, and P>G (Peridinioids > Gonyaulacoids) dinoflagellates assemblages. The TOC varies from 0.98-1.61%. %. We correlate this association with Jones,1983 upwelling **Zone II**.

Key Association DCS ("Dark Calcareous shales")

The lithology is represented by dark gray shales mainly laminated and limestone partially dolomitized.
The biological association contains abundant, benthic and planktonic forams represented by *Bulimids and* some specimens of *Gavelinella* sp and *Gyroidina* sp, *Heterohelix* sp and *Hedbergella* sp; low diversity assemblages of *diatoms* and *radiolaria*; diagenetically deteriorated, very poor *Micula* spp nannoplankton assemblages, alternating with P>G (Peridinioids > Gonyaulacoids) dinoflagellate assemblages and phophate nodules. The TOC varies from 0.21-4.6%. %. We correlate this association with Jones,1983 upwelling **Zone III**.

Key Association LCL ("Light colour limestones")

The lithology is represented by recrystallized, partially dolomitized light limestones.
The biological association contains very abundant, low diversity planktic foraminifera assemblages represented by the genera *Hedbergella* , *Heterohelix* and *Whiteinella*; with very poor benthic assemblages, represented by scarce buliminids alternating with P=G or G>P (Gonyaulacoids > Peridinioids) dinoflagellates assemblages. No nannoplankton or extremely poor *Watznaueria* assemblages were present. The TOC varies from 0.17-4.7%
No correlation with Jones (1983) was possible. This association represents high productivity, well oxigenated normal marine conditions.

Upwelling Evolution in the Barinas Basin

Based on these key associations, four maps were made in order to show the biological and sedimentological spatial distribution of the upwelling system in the studied area (Figure 2)

The studied sequence begins within the Turonian, characterized by a light color limestone, which corresponds to times of enhanced surface water productivity in eutrophic conditions (Key Association LCL). It belongs to the Guayacan Member of the Escandalosa Formation which spread over all the studied area. (Figure 2a).
These open marine conditions tend to increase to the southwest according to the lithologic and biostratigraphic features observed in the samples.

During the Coniacian-Santonian, over this limestone was laid an interval of laminated calcareous dark shales (Key Association DCS), sedimented in anoxic to dysoxic (oligotrophic) conditions, with faunas characterized by high abundance, low diversity and small size of benthic and planktonic foraminifera, corresponding to the La Morita Member of the Navay Formation, which represents one of the most important maximum flooding surfaces defined in the Barinas-Apure basin (Parnaud et al., 1997; Figure 2b).
One of the main characteristics of this level is the total anoxia in certain areas of the basin, indicated by total absence of benthonic and planktonic organisms.

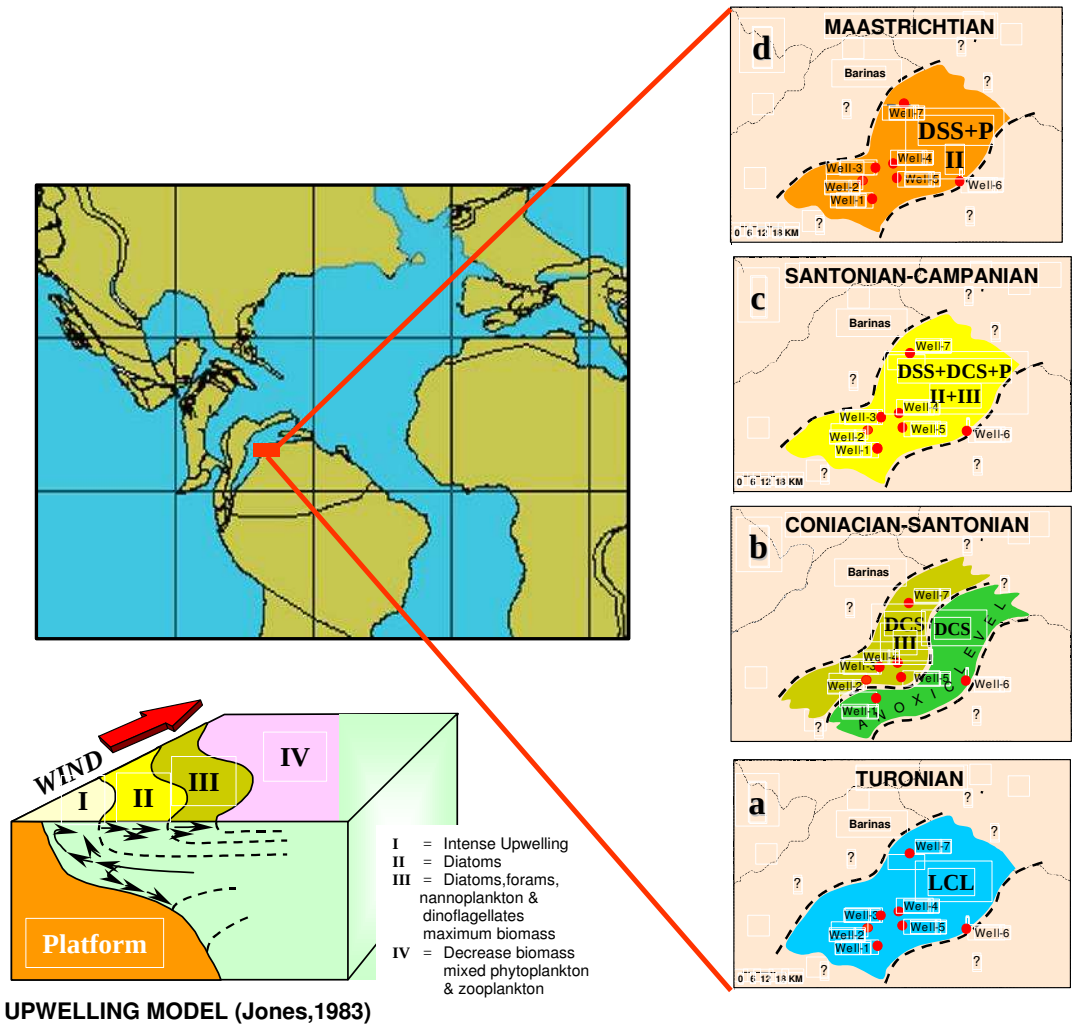

Figure 2.- Maps showing the distribution of the biofacies and its relation with the upwelling system

This event could be correlated with the global event OAE2 (Oceanic Anoxic Event) (Premoli, 1999), which corresponds with the Cenomanian-Turonian boundary, being a little younger, and the authors propose to be nominated OAE2a or Morita anoxic Event in the Barinas basin.

During the Santonian-Campanian, the upwelling system shows a sequence of mainly laminated dark siliceous shales intercalated with chert, phosphorites, thin phosphatic limestones and sandstones (Key Associations LSS and P), abundant diatom and radiolarian association are present and are the major indicators of eutrophic conditions and high productivity (Douglas, 1998; Luciani et. al, 1999). It corresponds to the Quevedo member of the Navay Formation (Figure 2c). This interval is associated with the proximal zone II with intercalations of phsphoritic facies which are associated to the Zone III, located offshore on the shelf.

The Maastrichtian is represented by a sequence that is characterized mainly by sandstones intercalated with thin laminated dark shales associated to the proximal zone II (Key Association LSS); it corresponds to the Burguita Formation (Figure 2d).

Conclusions

***** Alternation of four key associations based on faunal and floral assemblages, as well as on lithology and TOC content, characterize the Turonian - Maastrichtian section of the southwest Thetys Sea in the Barinas Basin area.

***** The comparison of the associations described in this paper with the description given by Jones, 1983, for the upwelling model zones, shows striking coincidences with three of our associations: P, DCS and DSS.

* One of the key associations (LCL) has no similitude with the above mentioned zones, and it has been interpreted as representing the sedimentation from a well oxygenated high productivity marine water mass, not included in the upwelling model.

***** The evolution of the upwelling in space and time shows a seaward migration of the zones from the Turonian through the Coniacian - Santonian, with a maximum preserved productivity in the Turonian-Santonian interval.

***** The presence during the Santonian-Maastrichtian of siliceous (chert) and phosphatic rich sediments, both characteristic products of high paleoproductivity eutrophic conditions, indicates changes in the paleoceanography of the latest Cretaceous at the southwestern Thetys platform, probably related with the closing of the connection to the Barinas Basin Gulf.

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