SEQUENCE STRATIGRAPHY OF THE CRETACEOUS ECUADORIAN ORIENTE BASIN: TECTONIC AND SEDIMENTARY EVIDENCES OF AN EARLY FORELAND DEFORMATION

Howard WHITE [1], Roberto BARRAGAN [2], Frederic CHRISTOPHOUL [3], Patrice BABY [4] and Marco RIVADENEIRA [5]

1) Kerr McGee Oil and Gas Corporation, 16666 NorthChase, Houston, Texas 77060
2) Amerada Hess Production Gabon, P.O.Box 20316, Libreville, Gabon-Africa, rbarragan@hess.com
3) Laboratoire des Mécanismes de Transfert en Géologie, 38 rue des 36 ponts, 31400 TOULOUSE
4) IRD (UR104), 38 rue des 36 ponts, 31400, Toulouse, baby@cict.fr
5) Petroproducción, Apartado Postal 17.12.857, Quito, Ecuador

Key Words: Oriente Basin, LST, TST, HST, MFS, sedimentary cycle, tectonic inversion

INTRODUCTION

The Cretaceous section of the Ecuadorian Oriente Basin (Hollin, Napo, and Basal Tena formations), located on the eastern flank of the Andean Cordillera (Fig. 1), exhibits features well suited to a sequence stratigraphic framework. They are characterized by a cyclic sequence of limestones, shales and sandstones whose deposition and distribution were controlled by relative sea level changes (White et al., 1995). The cyclic Cretaceous Hollin-Napo-Basal Tena succession has been subdivided into five, third order stratigraphic sequences associated to the global eustatic chart of Haq et al. (1987). Figure 2 illustrates the inferred depositional sequences within the Hollin-Napo-Basal Tena sandstone intervals positioned opposite to the significant sea level drops.

Within a sequence stratigraphic framework, relative sea level controls basinal accommodation space and excerpts regional controls over sediment distribution. The base of each sandstone interval represents a sign of basinward shifting of facies and is thus classified as a sequence boundary.

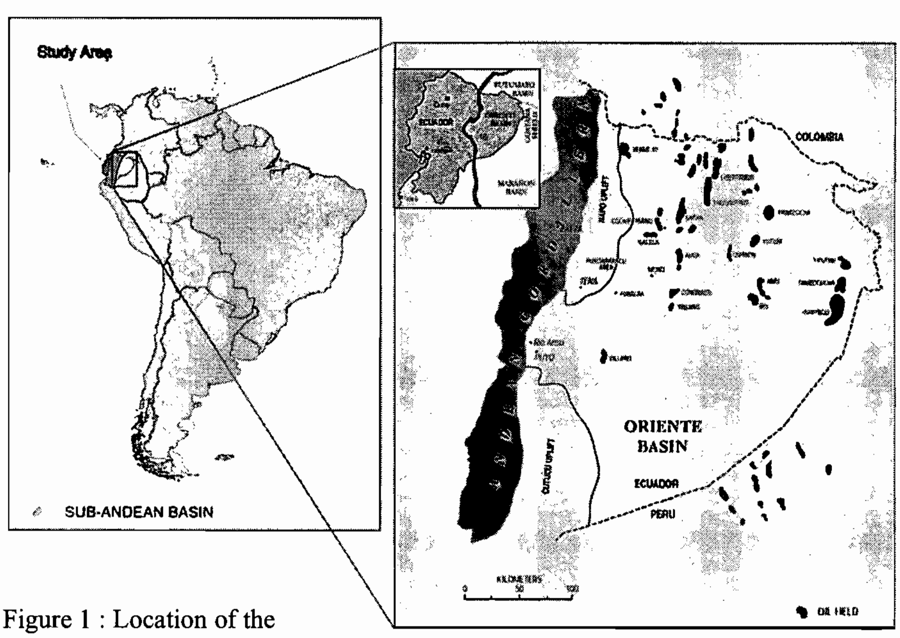
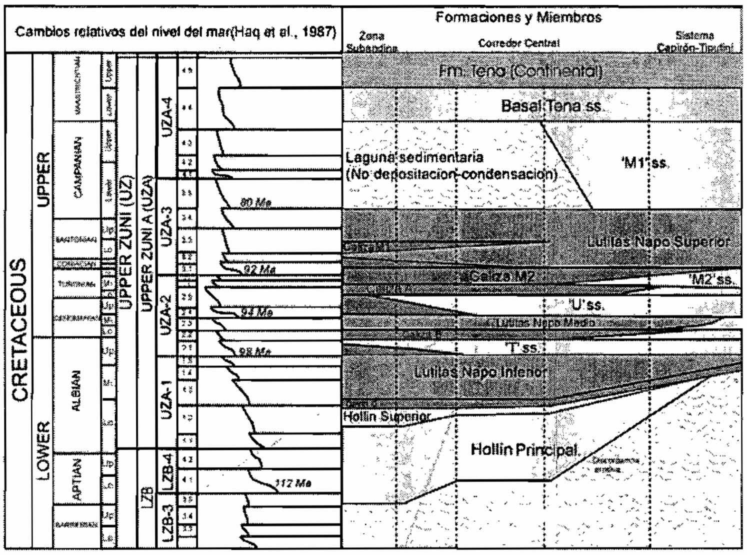


Figure 1 : Location of the study area



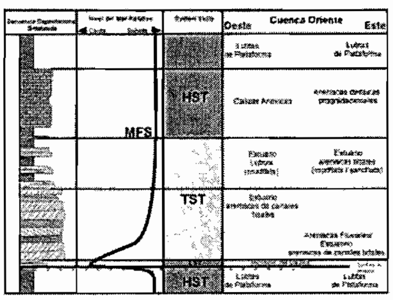


Figure 2 : Cretaceous sedimentary cycles of the Oriente basin and the relationship to the eustatic curve from Haq et al. (1987). Biostratigraphic ages from Jaillard (1997) ; Faucher et al., 1971)

Figure 3 : Ideal sedimentary sequence in the Cretaceous section, Orietne Basin (modfied from Gardner, 1995)

The ideal sedimentary cycle is the record of a completed base-level transit cycle (Gardner, 1995) (Fig 3). It starts with the channeled sands transported from an east-southeast source. These channel sands were deposited within the incised valley, typically within tidal-influenced fluvial environments. Once the estuary is filled, successive deposits spill over the valley margins and reflect the overall transgression of marine facies back toward the east (TST-transgressive system tract). Interbeded tidal- influenced sandstones, thicker shales and thin limestones give way to thick limestone accumulations and marine shales (HST- high stand system tract). This ideal cycle is recognized in the Hollin-Napo-Basal Tena units (Fig. 4). Thus:

Sedimentary cycle I (upper Aptian - Upper Albian): It corresponds in classic stratigraphic terms to the Main Hollin and Upper Hollín formations, Lower Napo Shale, and Basal T Sandstone units. The Main Hollín alluvial braidplain prograded westward across the Oriente during sea level lowstand conditions. The transgressive tidal shoreline and shallower marine shelf deposition occurred during Upper Hollín (TST), from west to east eventually through the entire Oriente Basin shelf. The maximum flooding surface (MFS), recording the transition to highstand condition, occurred during deposition of the Lower Napo Shale. The capping Basal Napo T marine shelf dominated sandstones parasequence prograded westward over the entire Oriente Basin and represents the highstand system tract (HST) of the first sedimentary cycle.

Sedimentary cycle II (upper Albian -middle Cenomanian): It corresponds to the Main 'T' sandstone, Upper 'T'

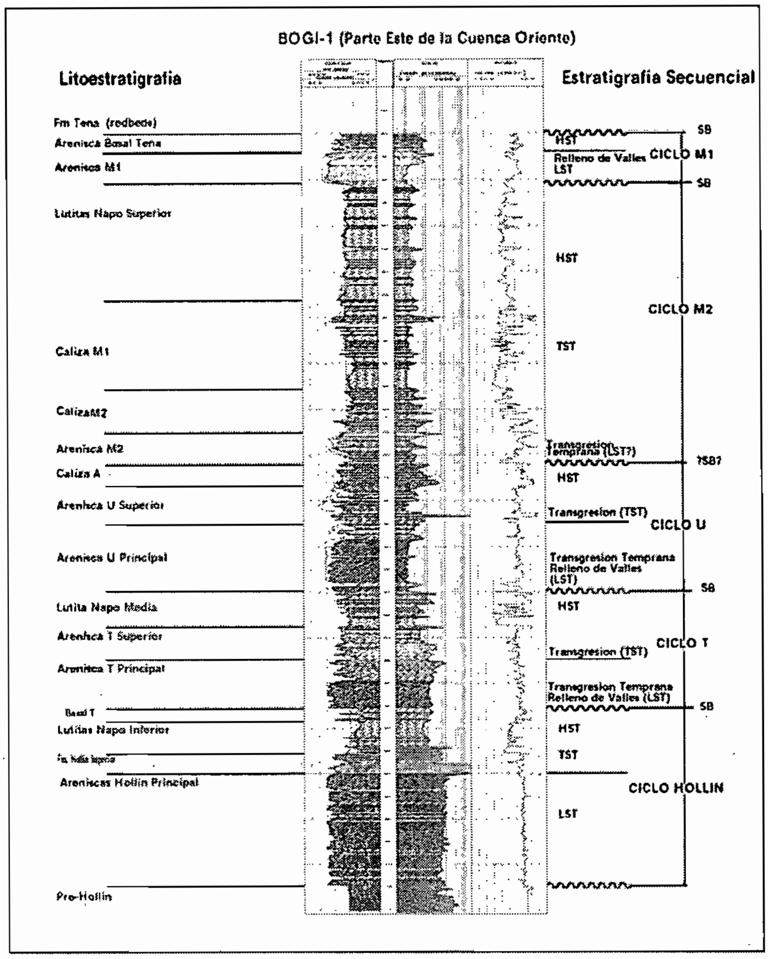


Figure 4 : Sedimentary cycles defined within the Cretaceous section of the Oriente Basin

Sandstone, 'B' limestone and the capping Middle Napo Shale units of the Napo Formation. Sea level drop during the Upper Albian (≈ 98 my) creating a major sequence boundary and an erosive drainage network subsequently filled by the main T incised valley sandstones during early transgressive sea level rise. Overlying are the transgressive to highstand deposits of the Upper T, the Napo B limestone and Middle Napo Shale.

Sedimentary cycle III (lower/middle Cenomanian – lower Turonian?): It consists of the Main 'U' sandstone, Upper 'U' sandstone and 'A' limestone units of the Napo formation. Subsequent sea level drops during the midle Cenomanian (≈94 my) created another erosional sequence boundary at the top of Middle Napo Shale. The Main U Sandstone represents the subsequent incised valley fill deposited during early transgression. Limestone packages of the A limestone represents highstand carbonate deposition on the open marine shelf.

Sedimentary cycle IV (Turonian – Campaniano Inferior): The M2 cycle includes the 'M2' Sandstone, the 'M2' Shale and M2 Limestone plus the capping M1 Limestone and Upper Napo Shale. In the western-central basin, the M2 sedimentary cycle is completely marine shelf without any coarse terrigenous input. Equivalent shorelines to alluvial clastics for the M2 interval are confined to the eastern Oriente Basin and Marañon Basin (Barragán, 1999) and are interpreted as lowstand to early transgressive system. The M2 and M1 Limestones and the Upper Napo Shale reflect the major transgressive and highstand deposits.

Sedimentary cycle V (Campanian-lower Maastrichtian?): It is formed by the fluvial 'M1' Sandstone evident only in the eastern part of the basin and the Basal Tena sandstones that progradated over the entire basin. The 'M1' Sandstone (in the east/southeastern basin) represents early transgressive incised valley fill. Part of the M1 cycle has been preserved as an entirely sedimentary section (eastern part of the basin) while to the west active tectonism continued to create surfaces of stratigraphic discontinuity. The Basal Tena sandstone is interpreted to represent the final episode of Napo sedimentary infill and document tide-dominated deltaic facies within a rapidly prograding highstand depositional system (HST). After the Basal Tena progradation, Oriente Basin marine conditions were replaced by a non-marine (continental) foreland basin setting.

Although the sequence IV and V shows a complete base-level sedimentary transit cycle (Gardner, 1995), they exhibits distinctive tectonic synsedimentary features (Fig. 4), and active volcanism that records the first phase of basin inversion of pre-Cretaceous structures (Baby et al., 1999). The difference from the previous sedimentary cycles is the fact that Upper Napo Cretaceous sediments are condensed or almost absent in the sub-Andean zone as a consequence of a ravinement and starving event associated with late Cretaceous tectonism.

CONCLUSIONS

Within the Albian-Maastrichtian section, five third-order sequence stratigraphic intervals have been identified in the Ecuadorian Oriente Basin. They represent the Hollín-Napo-basal Tena depositional system that document westerly shoreline shifts across the Oriente Basin and vertical changes in facies which interrupt otherwise consistent marine shelf sedimentation. Seismic sections, regional well log correlations and facies distribution reveal key synsedimentary features and active volcanism attesting a tectonic control during Upper Napo deposition (M2 limestone to Basal Tena Fm). We conclude that from the Aptian to Turonian, the Oriente Basin existed as the expression of a pre-tectonic cratonic passive margin under eustatic influence (White et al., 1999), and from the Turonian to Maastrichtian, the basin underwent a syntectonic period and/or the beginning of the Andean foreland system recording the first phase of basin inversion of pre-Cretaceous structures (Baby et al., 1999) where eustatic influence is still present.

REFERENCE

Baby, P., Rivadeneira, M., Christophoul, F., and Barragán, R., 1999. Style and timing of deformation in the Oriente Basin of Ecuador. Extended Abstract *ISAG99*, Gottingen. 68-72.

Barragán, R., 1999. Relations entre Volcanisme, Tectonique d'inversion et Sedimentation dans le Bassin Cretace Equatorien, *Ph.D Thesis,* Laboratoire de Dynamique de Bassins, Universite Paul Sabatier, Toulouse III, Toulouse, France. 223p.

Gardner, M., 1995. Tectonic and eustatic controls on the stratal architecture of mid-Cretaceous stratigraphic sequences, central western interior foreland basin of North America. *SEPM Special Publication*, **52**, 243-281.

Haq, B.U., Hardenbol, J., and Vail, P.R., 1987. Chronology of sea levels since the Triassic. *Science*, **235**, 1156-1167.

Jaillard, E., 1997. Síntesis Estratigráfica y Sedimentológica del Cretáceo y Paleógeno de la Cuenca Oriental del Ecuador: *Petroproduccion – Orstom*, 163 p.

White, H. J., Skopec, R., Ramirez, F., Rodas, J., and Bonilla, G., 1995. Reservoir characteristics of the Hollin and Napo formations, western Oriente basin, Ecuador, *in* Tankard, A. J., Suárez S. R., and Welsink, H. J., eds., Petroleum basins of South America: *American Association of Petroleum Geologist* Memoir **62**, 573–596.

White, H., Barragan, R., Jordan, D., Robbs, E., and Ramirez, F., 1999. Predictability of reservoir facies within a sequence stratigraphic framework, Oriente Basin, Ecuador. *AAPG Annual Convention*, San Antonio Texas, A149

Géodynamique andine
Andean Geodynamics
Geodinámica Andina

Résumés étendus
Extended abstracts
Resúmenes expandidos

Organisateurs **Organizers** **Organizadores**

Institut de recherche pour le développement Paris

Université Paul Sabatier Toulouse France

Institut de recherche pour le développement

2002

ISAG

UNIVERSITE PAUL SABATIER TOULOUSE III

GÉODYNAMIQUE ANDINE
ANDEAN GEODYNAMICS
GEODINAMICA ANDINA

5th International Symposium on Andean Geodynamics

Université Paul Sabatier, Toulouse, France,

16-18 Septembre 2002

Résumés étendus
Extended abstracts
Resúmenes ampliados

Organisateurs / Organizers / Organizadores

Institut de recherche pour le développement

Université Paul Sabatier

IRD

INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT

Paris, 2002

COMITÉ D'ORGANISATION
COMITE ORGANIZADOR
ORGANIZING COMITTEE

P. Baby (IRD-Toulouse), J. Darrozes (Univ. Paul Sabatier-Toulouse), J. Deramond (Univ. Paul Sabatier-Toulouse), B. Dupré (CNRS-Toulouse), J.-L. Guyot (IRD-Toulouse), G. Hérail (IRD-Toulouse), E. Jaillard (IRD-Quito), A. Lavenu (IRD-Toulouse), H. Miller (Univ. München), T. Monfret (IRD-Géoscience Azur), G. Wörner (Univ. Göttingen)

Comité scientifique et représentants nationaux
Comité Científico y Representantes Nacionales
Scientific Advisory Board and National Representatives

R. Armijo (IPG, Paris), J.-P. Avouac (CEA, Paris), R. Charrier (Univ. Chile, Santiago), J.-Y. Collot (IRD, Géoscience Azur), L. Dorbath (IRD, Strasbourg), S. Flint (Univ. Liverpool), B. France-Lanord (CNRS, Nancy), L. Fontboté (Univ. Genève), Y. Gaudemer (Univ. Paris VII), R. Gaupp (Univ. Jena), F. Hervé (Univ. Chile, Santiago), T.E. Jordan (INSTOC, Cornell), J. Mojica (Univ. Bogotá), O. Oncken (Univ. Potsdam), L. Ortlieb (IRD, Bondy), R.J. Pankhurst (Brit. Antartic Surv.), V. Ramos (Univ. Buenos Aires), P. Ribstein (IRD, Paris), C. Robin (Univ. Clermont-Ferrand), S. Rosas (Univ. Lima), F. Sàbat (Univ. Barcelona), M. Schmitz (FUNVISIS, Caracas), R. Suárez Soruco (YPBF, La Paz), M. Rivadeneira (Petroproducción), W. Winkler (ETH, Zürich).

APPUIS FINANCIERS
FUNDINGS
APPOYO FINANCIERO

L'organisation de l'ISAG 2002 et les bourses accordées à un certain nombre de collègues latino-américains ont été possibles grâce au soutien financier de l'IRD (notamment de la Délégation à l'Information et à la Communication), de la région Midi-Pyrénées, de l'Université Paul Sabatier et de l'Andean Comittee de l'ILP.