A review of the nomenclature of the Cretaceous formations in the Ecuadorian Oriente Basin

Santiago Vaca [1] & Esthela Zambrano [1,2]

1 Departamento de Geología, EPN, Ap. 17-1-2759, Quito, Ecuador (vaksantiago@yahoo.com)
2 Dirección Nacional de Hidrocarburos, MEM, Ap.17-15-277-C, Quito, Ecuador (mazambrano@menergia.gov.ec)

KEYWORDS: Cretaceous Stratigraphy, Oriente Basin, Ecuador

This project is a result of detailed study of the Cretaceous stratigraphy in the Ecuadorian Oriente Basin (Fig.1). The analysis of approx. 30 well logs distributed in the basin has permitted to identify vertical and lateral facies shifts in a sequence stratighaphy model, and therefore to suggest a redefined nomenclature of the members of the Hollin and Napo Formations of the Oriente basin.

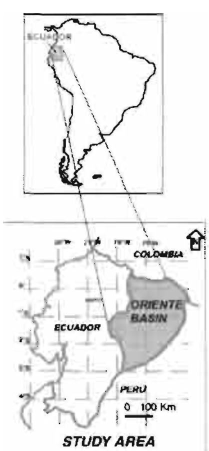

Fig 1.- Location of the Ecuadorian Oriente basin.

HOLLIN FORMATION: (? – Early Albian)

The Hollin Formation consists mainly in a typical fluvial sandstone with two minor marine members. Hollin overlies unconformable over Jurassic or Paleozoic rocks, and transitionally passes to the marine Napo Formation on top. The Hollin Formation members are:

Basal Sandstone Mb. (BSM) constitutes a salty water marginal marine reservoir, based on the SP log deflection [10]; in Tiguino-1 well, marine fossils are also reported [Mills, 1971 *in* 4] and shows an estuarine and distal fluvial environment at the Hollin- Loreto-Coca road outcrop [7]. Towards the eastern edge of the basin, this member presents a lateral change to calcareous facies, named ***Tambococha Mb.*** (TM) (Fig 2 y 3a). The Tambococha Fm. of M. Díaz [2], was reported as Medium Jurassic–Early Cretaceous age; nevertheless, this deposit also could be equivalent to the marine Peruvian Cushabatay Fm. of Valanginian age [10]. ***Main Sandstone Mb.*** (MSM) constitutes a distinctly fluvial "Braid Plain" deposit that deepens to the "Coastal Plain" [11] toward the top.

NAPO FORMATION: (Early Albian – Late Campanian)

The Napo Formation is characterized by full marine at least seven sequences of interbedded shales, limestones and sandstones (Fig. 2), represented in the following members:

Basal Sandstone Mb. (BSM) (known as Upper Hollin), is comprised of glauconitic sandstones of estuarine environment [7]. ***"C" Limestone Mb.*** ("C"LM) consists of limestones of confined marine setting [4]. ***Basal Shale Mb.*** (BShM), which is comprised of regressive marine shales that change vertically to calcareous facies within the deeper part of the basin, named ***"T" Limestone Mb.*** ("T"LM). The BShM and "T"LM present a lateral shift to sandstone facies toward the continent, named ***Basal "T" Sandstone Mb.*** (B"T"SM) (Fig. 2 and 3a). It is justified by pollens, that have been found at Tambococha-1 well [6] and likewise these are typical of BShM [Robertson Research, 1985 *in* 4]. ***Main "T" Sandstone Mb.*** (M"T"SM), represents a fluvial-deltaic environment in the eastern Oriente basin [4]. In the center of the basin, the P"T"SM is interpreted to be tidal channels and bars within an estuarine environment [7], created by flooding of the incised valley [11] (Fig 2 and

3b). The P"T"SM changes laterally to distal marine facies towards the western part of the basin [Rivadeneira, *pers. com.*]. ***Upper "T" Sandstone Mb.*** (U"T"SM) is a glauconitic sandstone interpreted as a tidal flat and interbedded subtidal mudstones flat in an estuarine environment [7]. ***"B" Limestone Mb.*** ("B"LM) is a carbonate deposit whose facies deepen toward the top [4]. It is a regional deposit, however at the eastern edge of the basin its equivalent would be a sandstone named ***"B" Sandstone Mb.*** ("B"SM) (Fig. 2 and 3b). ***"U" Shale Mb.*** ("U"ShM) it is a shale deposit prograding to ***"U" Limestone Mb.*** ("U"LM).

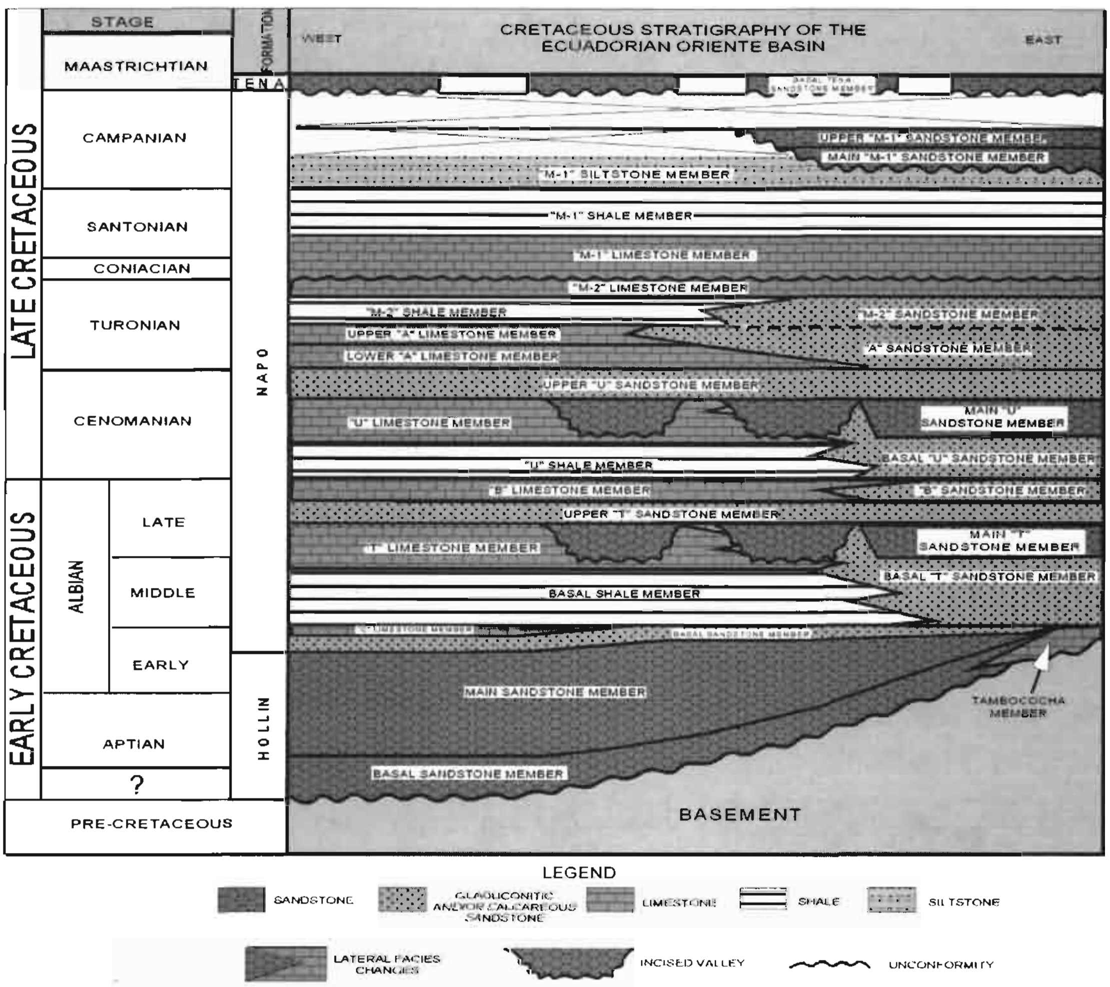

Fig.2.- Cretaceous stratigraphy in the Ecuadorian Oriente basin proposed in this paper, showing lateral and vertical facies relationships.

These deposits ("U"ShM and "U"LM) become sandier eastward of the basin, eventually grading transitionally into detrital facies called ***Basal "U" Sandstone Mb.*** (B"U"SM) (Fig. 2, 3b and 3c). ***Main "U" Sandstone Mb.*** (M"U"SM) and ***Upper "U" Sandstone Mb.*** (U"U"SM) show an environment and spatial distribution similar to P"T"SM and U"T"SM. ***Lower "A" Limestone Mb.*** (L"A"LM) records a low energy subtidal setting [4] whose distribution is restricted to the western center part of the basin (Fig. 2 and 3c). ***Upper "A" Limestone Mb.*** (U"A"LM) is composed of progradational carbonaceous deposits whose detrital equivalent to the east of the basin would be the ***"A" Sandstone Mb.*** ("A"SM) (Fig. 2 and 3c). ***"M2" Shale Mb.*** ("M2ShM) is deposited in the western and central part of basin, its equivalent toward the east is the ***"M-2" Sandstone Mb.*** ("M2"SM) (Fig. 2 and 3c) represented by glauconitic sandstones [4].

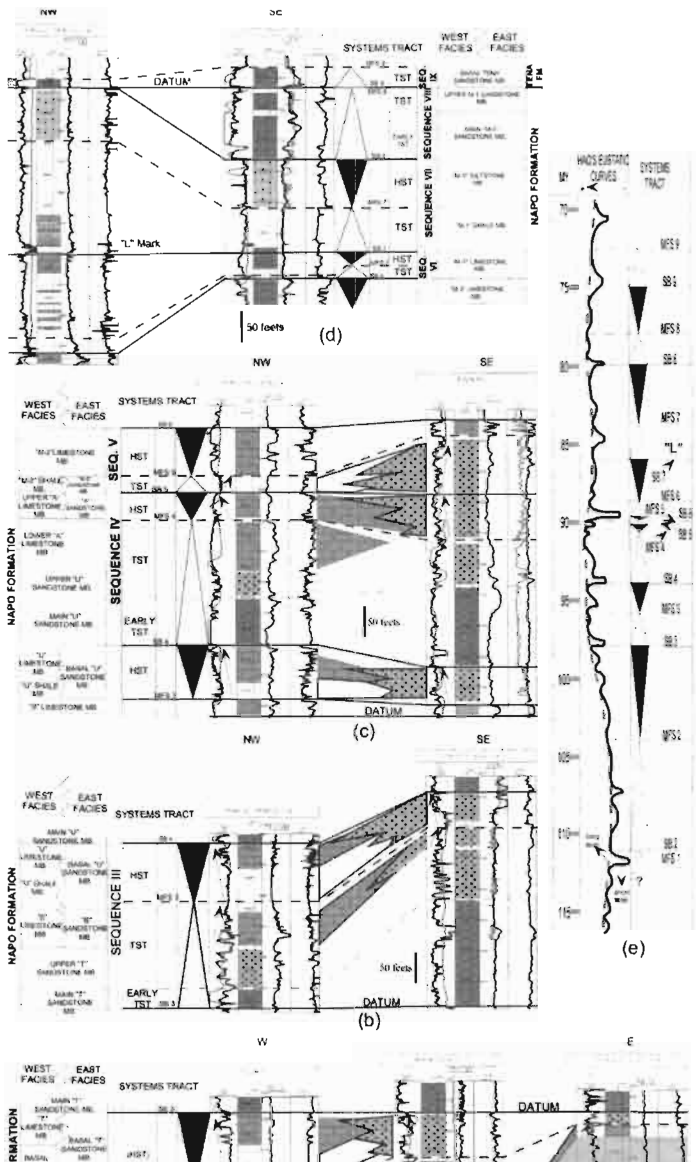

Fig.3.- Cross sections along the Oriente basin, showing lateral and vertical shifts and Sequence stratigraphy. (a) Sequences I and II; (b) Sequence III; (c) Sequences IV and V; (d) Sequences VI, VII, VIII and IX; (e) Sequence boundaries and maximum flooding surfaces correlated with global-cycle chart of Haq et al. (1987).

"M-2" Limestone Mb. ("M2"LM) is constituted by one calcareous deposit within progradational sets, which shifts progressively from a deep marine and confined setting to an open and shallow environment as it rises. It represents an excellent regional marker. ***"M-1" Limestone Mb.*** ("M1"LM) is a succession of shales, chalks and limestones [4] within an anoxic carbonated shelf, deepen in the base and with substantial shallowing at the top (Fig. 3d). ***"M-1" Shale Mb.*** ("M1"ShM) begins with a major regional radioactive marker evident everywhere in the Oriente basin named "L" Marker (Condensed Section) [4]. ***"M-1" Siltstone Mb.*** ("M1"SlM) (instead of Basal "M-1" Sandstone of Raynaud et al., 1993 *in* 4) which comprises clastic shelf mudstones of low energy [Raynaud et al., 1993 and Rivadeneira et al., 1995 *in* 4]. ***Main "M-1" Sandstone Mb.*** (M"M1"SM) is a fluvial sandstone deposit and tidal channel of estuarine environment (Don Simmons, *pers. com.*), that is restricted on the eastern part of the basin (Fig. 2 and 3d). In certain areas it could represent incised valley fills. ***Upper "M-1" Sandstone Mb. (U"M1"SM)*** consists of a sandstone interpreted to have been deposited in an estuarine environment, occasionally it is overlaid by black shales and/or coal layers (Don Simmons, *pers. com.*).

Basal Tena Sandstone Mb. (BTSM), is part of the Tena Formation, it is a discontinue sandstone deposit all over the basin (Fig. 2), that constitutes paleo valley fills at the base of an important transgression [Raynaud et al., 1993 *in* 4].

SEQUENCE STRATIGRAPHY

Due to global eustatic changes [3] sequence boundaries and maximum flooding surfaces have been identified (Fig. 3e). These allow us to define nine type "I" sequences in the Oriente basin according to [9]. These patterns are summarized in following description of sequences detailed in Table 1.

SEQUENCES	SYSTEMS TRACT	SURFACES AGES(*)	STRATIGRAPHY (W – E)		ORDER (**) SEQUENCES
IX	TST	MFS 9 → 72.5 Ma *(b)* SB 9 → 75 Ma	Basal Tena Sandstone Mb.	TENA FM.	THIRD ORDER
VIII	TST EARLY TST	MFS 8 → 78 Ma *(f)* SB 8 → 80 Ma	Upper M-1 Sandstone Mb. Main M-1 Sandstone Mb.	NAPO FORMATION	THIRD ORDER
VII	HST TST	MFS 7 → 83.5 Ma *(f)* *Condensed Section "L"*: 85.5 Ma SB 7 → 86 Ma	M-1 Siltstone Mb. M-1 Shale Mb.	NAPO FORMATION	SECOND ORDER
VI	HST TST	MFS 6 → 88.5 Ma *(b,e)* SB 6 → 89.75 Ma	M-1 Limestone Mb.	NAPO FORMATION	SECOND ORDER
V	HST TST	MFS 5 → 90 Ma *(b)* SB 5 → 90.25 Ma	M-2 Limestone Mb. M-2 Shale Mb. M-2 Sandstone Mb.	NAPO FORMATION	THIRD ORDER
IV	HST TST EARLY TST	MFS 4 → 90.5 Ma *(c,d)* SB 4 → 94 Ma	Upper A Limestone Mb. A Sandstone Mb. Lower A Limestone Mb. Upper U Sandstone Mb. Main U Sandstone Mb.	NAPO FORMATION	SECOND ORDER
III	HST TST EARLY TST	MFS 3 → 96 Ma *(b)* SB 3 → 98 Ma	U Limestone Mb. Basal U Sandstone Mb. U Shale Mb. B Limestone Mb. B Sandstone Mb. Upper T Sandstone Mb. Main T Sandstone Mb.	NAPO FORMATION	SECOND ORDER
II	HST TST	MFS 2 → 104 Ma *(b)* SB 2	T Limestone Mb. Basal T Sandstone Mb. Basal Shale Mb. C Limestone Mb. Basal Napo Sandstone Mb. Main Hollin Sandstone Mb.	NAPO FORMATION / HOLLIN FM.	SECOND ORDER
I	TST	MFS 1 → 111 Ma *(a)* SB 1 → Basement top	Lower Hollin Mb. Tambococha Mb.	HOLLIN FM.	?

BIOSTRATIGRAPHY AGES

a = Mills, 1971 *in* b
b = Jaillard *et al.*, 1997
c = Labogeo, 1994 *in* b
d = Vallejo *et al.*, 2002
e = Jaillard *et al.*, (*in press.*)
f = Raynaud *et al.*, 1993 *in* b

LEGEND

TST = Transgressive System Tract
HST = Highstand System Tract
MFS = Maximum Flooding Surface
SB = Sequence Boundary
△ Retrogradational Series
▽ Progradational Series
(*) Surfaces ages have been correlated with eustatic curves of Haq *et al.*, 1987
(**) After Duval *et al.*, 1992

Table 1: Sequence stratigraphy correlated with members of the Hollín & Napo formations and the basal Tena member

CONCLUSIONS

Sedimentation in the Ecuadorian Oriente basin was controlled by subsidence, global eustatic changes and regional as well as local tectonic events acting during the Cretaceous. These factors defined development and distribution of different petroleum systems (reservoir, source and seal rocks), stratigraphy and structural traps. Whereas sediments modify their facies depending of proximity or distance from the continent. We propose a nomenclature based on shoreline migration that permits to predict new potential plays, where there will have an ideal petroleum system and other places where this one there will be incomplete due to erosion, non deposition or lateral facies shifts.

This article has been supported by National Hydrocarbons Direction Minister of Energy and Mines,Quito –Ecuador.

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