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Tectonostratigraphic Evolution and Prospectivity of the Logone Birni Basin, North Cameroon – Central Africa

I. Introduction

The Logone Birni Basin (LBB) is an intracratonic basin that formed in response to the Gondwana break-up and subsequent separation of the South American and African plates. It covers an approximate area of 27,000 km² in the northern part of Cameroon, in Central Africa. The LBB belongs to the West and Central African Rift System (WCARS) described by Genik in 1992 (Figure 1). Significant oil discoveries have been made in sedimentary basins belonging to the WCARS as is the case for the Doba Basin in Chad. The later is thought to contain one billion barrels of recoverable reserves which are the reason for the construction of the Chad /Cameroon pipeline. From the aerogravity and aeromagnetic interpretation, the LBB is subdivided into three sub-basins from north to south (Figure 2) : the ***Makary Subbasin*** or ***Northern Logone Birni Basin (NLBB)***, the ***Zina Subbasin or Central Logone Birni Basin (CLBB)*** and the ***Yagoua Subbasin*** or ***Southern Logone Birni Basin (SLBB)***. The Makary and Zina subbasins are separated by the ***Kousseri Platform***. The present investigation covers only the NLBB and the CLBB where sufficient seismic data are available.

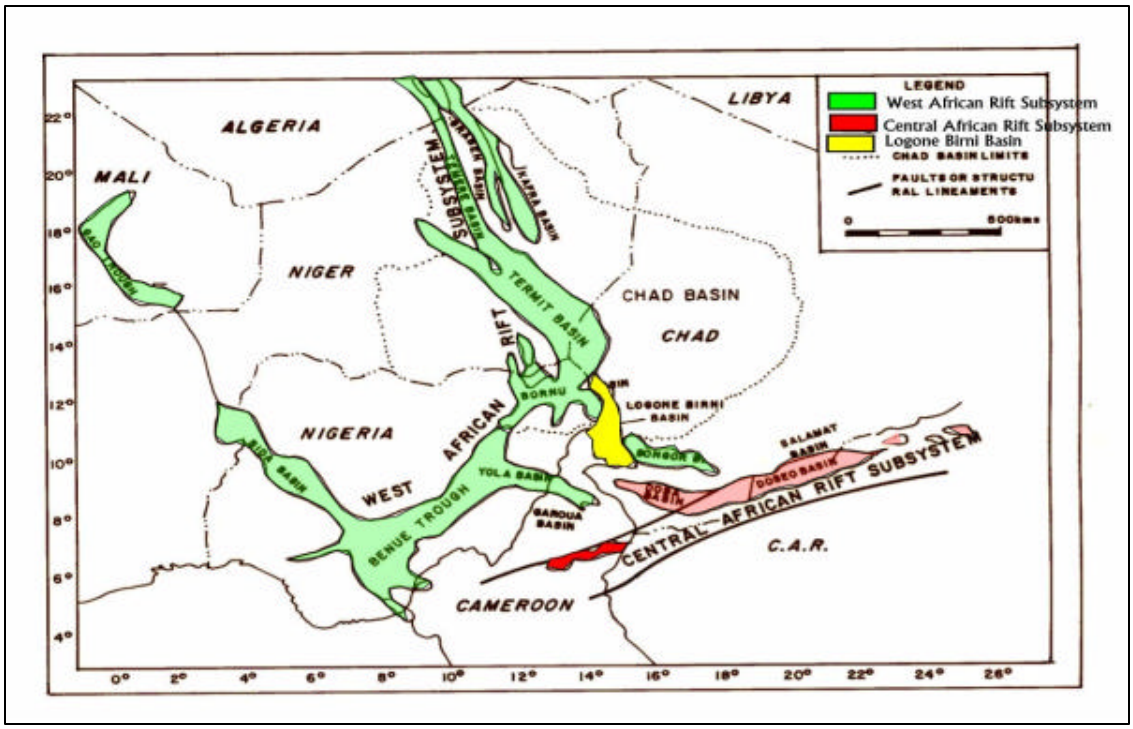
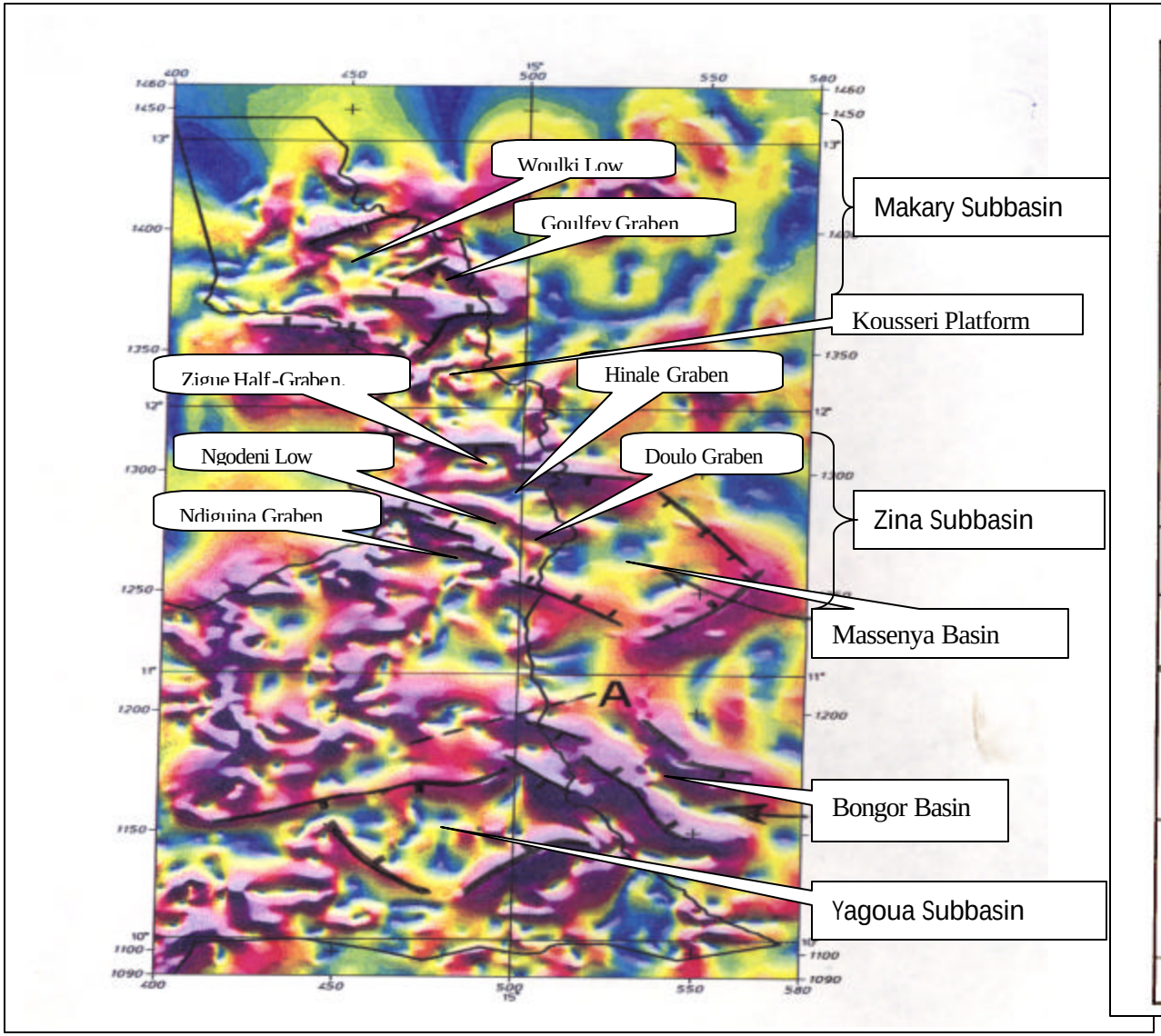
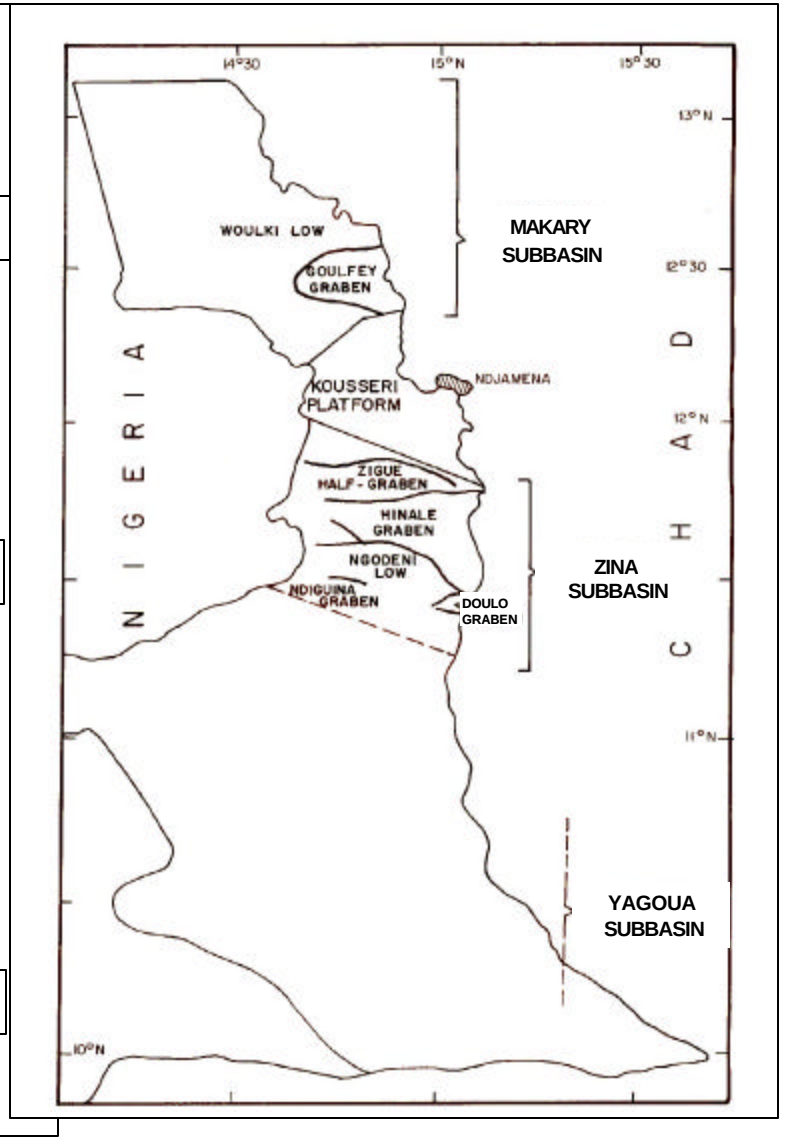


Figure 1 *: Logone Birni Basin within the West and Central African Rift System (modified after Genik, 1992)*



Horizontal gradient of the isostatic residual gravity (reinterpreted after Geophysical Technology, 1995)



(Seismic derived map)

<u>Figure 2</u> : Subbasins and Depocenters of the Logone Birni Basin

II. Evolution of the Logone Birni Basin

On the basis of structural and stratigraphic seismic interpretation and the regional geology, three main evolutionary phases are differentiated (Figure 3) :

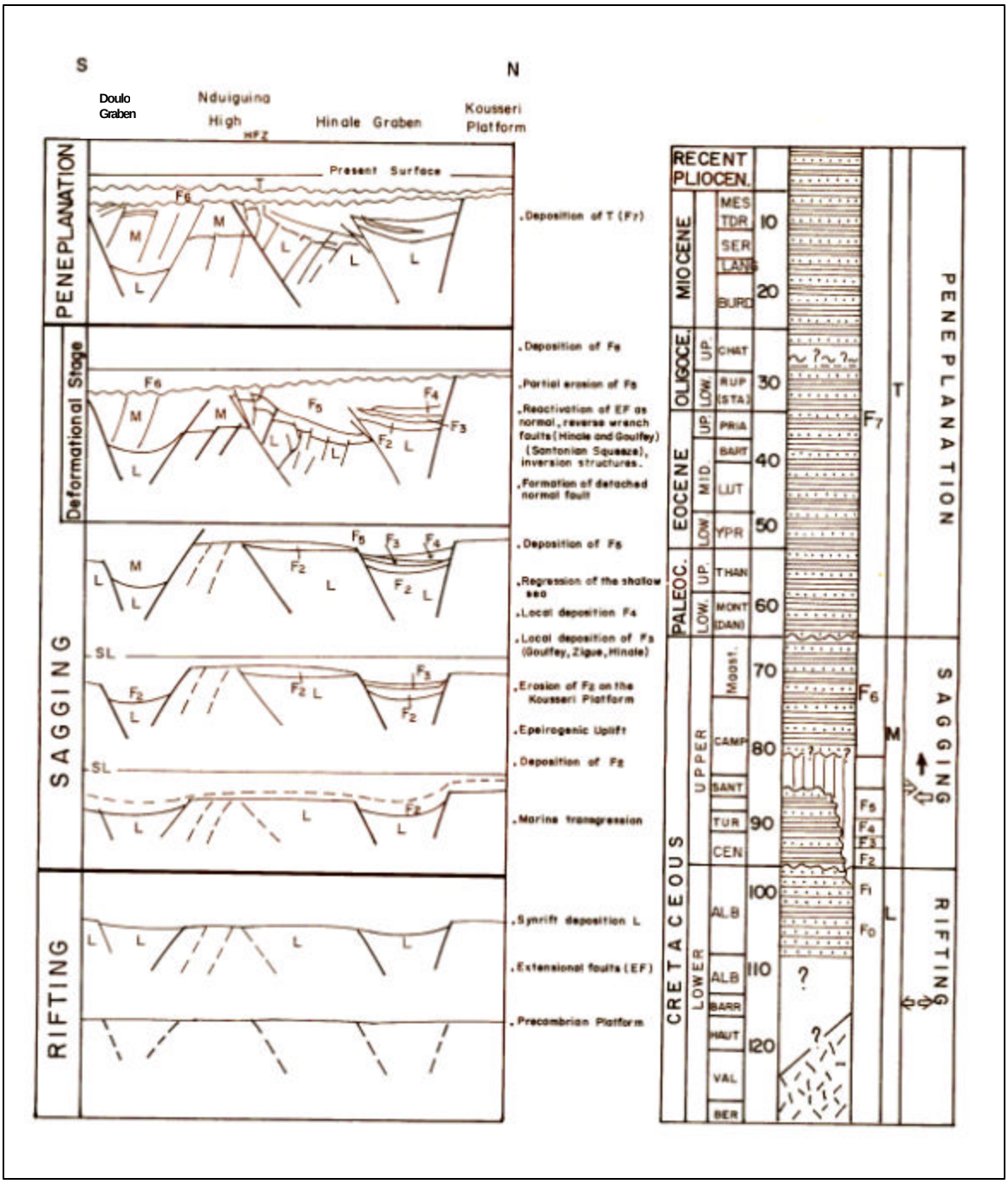
1. The ***Lower Cretaceous Rifting Phase,*** equivalent of the rifting phase 1 of Genik (1992) during which the extensional faults formed and the megasequence L was deposited. Six depocenters are identified (Figure 2) : in the NLBB, the Woulki Low which probably deepens towards the Lake Chad to the west and the Goulfey Graben to the east ;in the CLBB, from north to south : the Zigue Half-Graben, the Hinale Graben, the Ngodeni Low and the Ndiguina Graben. To the east, the Ngodeni Low becomes a small graben: the Doulo Graben. Between the two subbasins (NLBB and CLBB) lies the Kousseri Platform. The Hinale Graben is separated from the Ngodeni Low by the Zigague High. By analogy to the WCARS, the rifting phase in the LBB is Lower Cretaceous in age. The ***Albian*** or ***Lower Cretaceous Unconformity*** marks the end of rifting phase I in this basin (Figure 5C).

2. The ***Upper Cretaceous Sagging Phase*** is the equivalent of the rifting phase 2 of Genik (1992). During this phase, megasequence M was deposited. The region was invaded by the sea allowing the deposition of the seismic intervals F_2 and F_4. As the sea regressed, F_5 was deposited and the detached normal fault present to the west of the Hinale Graben formed (Figure 5B). Afterwards, the area was submitted to transpressional stresses that induced the formation of half flower and flower structures respectively in the Hinale Graben and the Goulfey Graben (Figures 5A and 5C). In fact, some of the initial extensional faults were rejuvenated either as wrench faults, normal faults or reverse faults. In addition, inversion structures occurred also in the Doulo Graben (Figure 4). This represents the ***Deformational Stage*** of the LBB which is the equivalent of the Santonian Squeeze of Genik (1992). The deformational stage was terminated by a regional erosional unconformity, the ***Santonian Unconformity*** (Figures 4 and 5). The sagging phase that lasted during the Upper Cretaceous ended with the deposition of seismic interval F_6. The upper boundary of the Sagging Phase is marked by the ***Maastrichtian*** or ***Upper Cretaceous*** or ***Base Tertiary Unconformity*** (Figure 5).

3. The ***Tertiary-Quaternary Peneplanation Phase,*** equivalent of the Tertiary-Quaternary post-rift phase of Genik (1992), put in place megasequence T which is sub-horizontal all over the study area (Figures 4 and 5). It overlies the Maastrichtian Unconformity. The horizontal aspect of T and the fact that it is not affected by the faulting indicate that it represents a post sagging phase hereby referred to as the ***Peneplanation Phase***. Therefore, T likely represents the products eroded from the neighboring surrounding uplifted areas.

Megasequence T is not affected by the Cretaceous faulting. It appears clearly that the Tertiary rifting phase III of Genik (1992) encountered in the CARS is absent in the LBB. In addition, the expected presence of marine intervals (seismic intervals F_2 and F_4) attests that the LBB is transitional between the WARS and the CARS. Genik in 1992 differentiated the West African Rift Subsystem and the Central African Rift Subsystem. The WARS contains marine deposits whereas the CARS is characterized by the exclusive presence of continental deposits and the rifting phase III of Genik (1992).

The Makary Subbasin is the southern continuation of the chadian Termit Basin whereas the Zina Subbasin is the western extent of the chadian Massenya Basin.



T : Megasequence T
M : Megasequence M
L : Megasequence L
F_0 to F_7 : interpreted seismic intervals

<u>Figure 3</u> : Tectonostratigraphic Evolution of the Logone Birni Basin

III. Prospectivity

The prospectivity of the LBB is defined by the expected presence of shale and sandstone intervals which could represent potential source/seal rocks (F_2, F_4) and reservoirs (F_1, F_3, F_5, F_6, F_7) respectively (Figure 3). In addition to these units of the megasequences M and L, any sand or shale interbedded unit of the whole sedimentary pile could also act as either a reservoir or a source/seal bed respectively. Unconformities can also be sealing.

A Lower Cretaceous and an Upper Cretaceous plays were therefore identified. Both plays contain interesting prospective features (Figures 4 and 5) associated with the wrench faulting (flower structures), detached normal fault (roll-over anticline), tilted blocks (onlap on the fault plan), pinchouts under Santonian Unconformity, inversion structures, Upper Cretaceous channels, and Lower Cretaceous fan.

It is worth to note that no hydrocarbon seepage has been located in the basin. This may be an indication of the presence of good sealing in the study area. In this event, the hydrocarbons ever generated and migrated would have been properly and efficiently trapped.

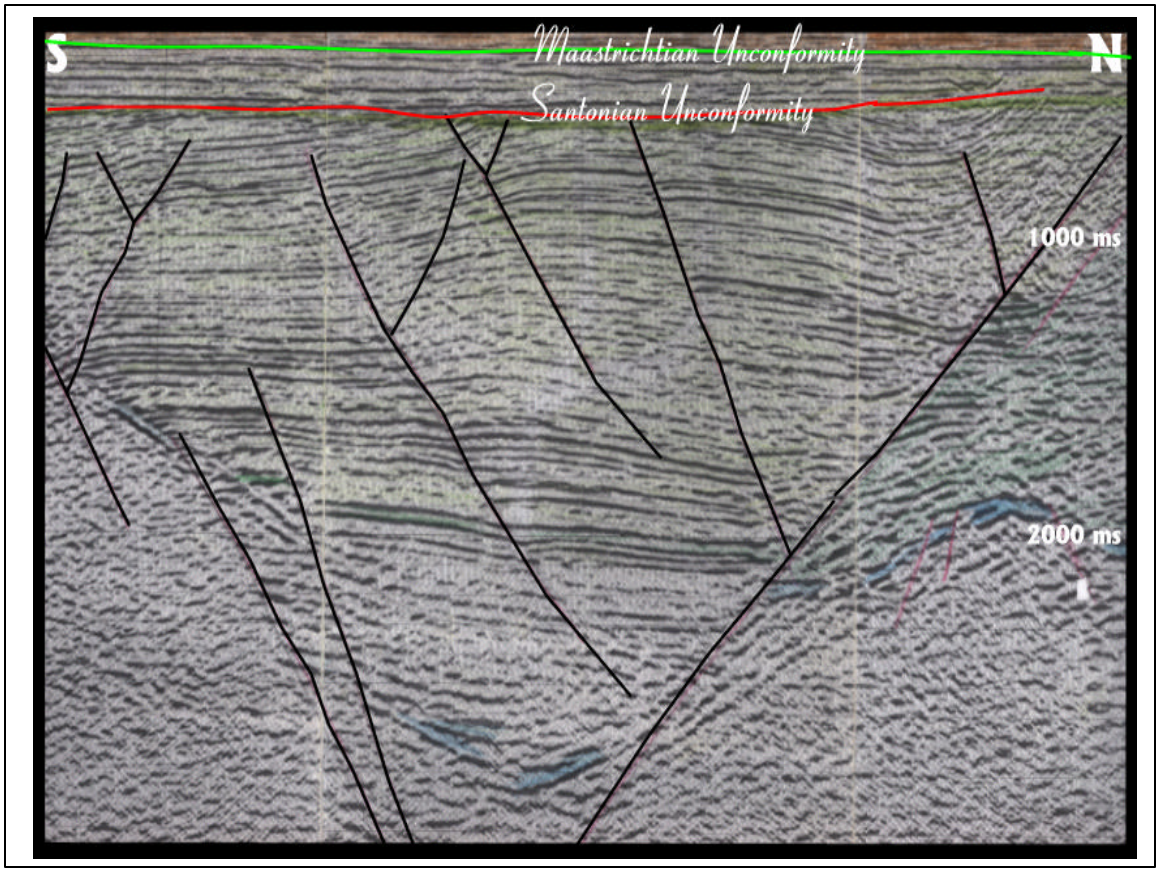
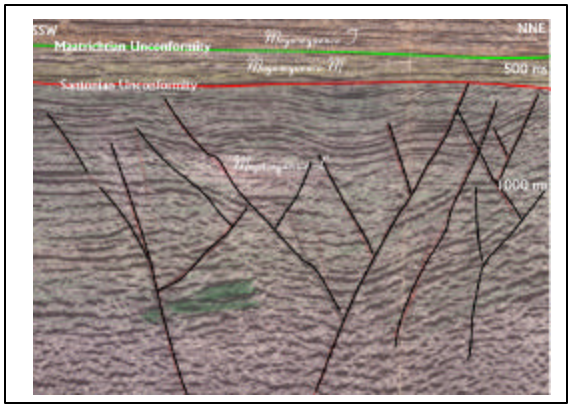
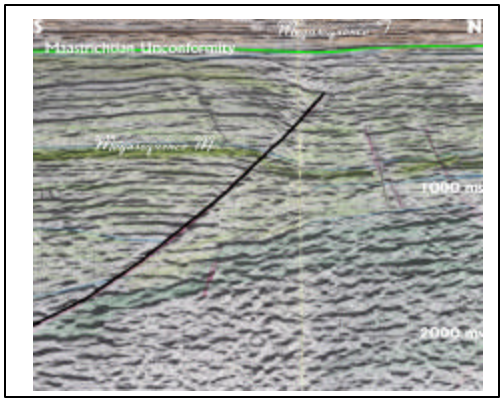


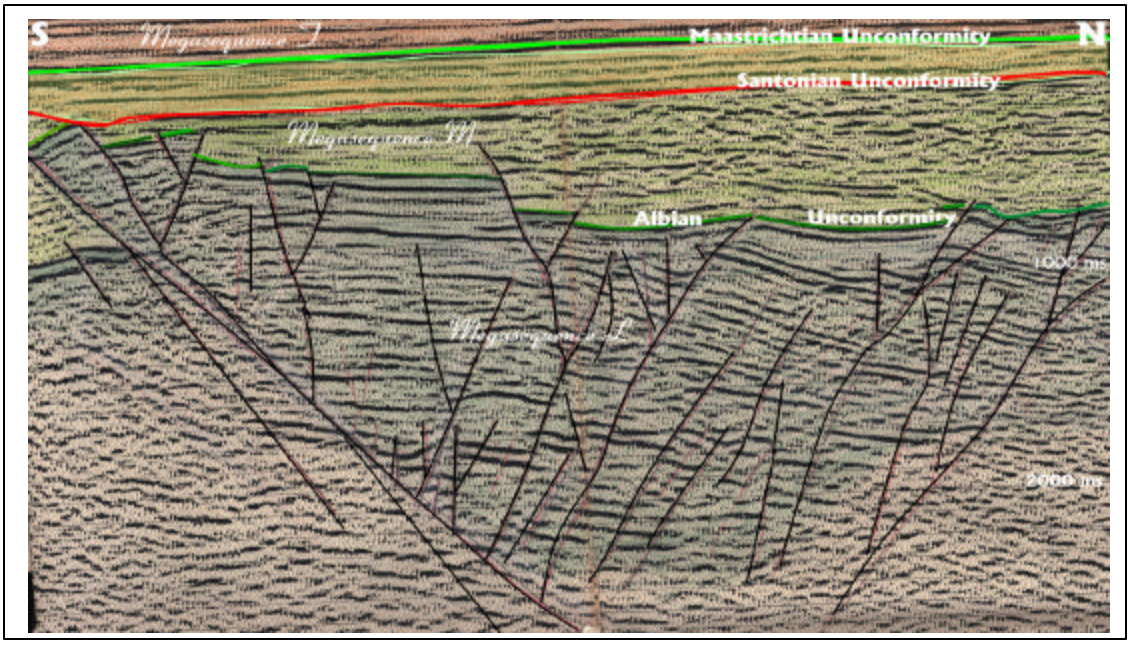
***Figure 4* : Inversion Structures within the Doulo Graben**



A. Flower structures
Goulfey Graben (Makary Subbasin)



B. Roll-over structure
Hinale Graben (Zina Subbasin)



C.: Half-flower structure in the Hinale Graben

<u>Figure 5</u> : Some interesting prospective features present in the LBB

IV. Conclusion

The Logone Birni Basin is an intracratonic rift basin transitional between the WARS and the CARS. It evolved into three main phases : the Lower Cretaceous Rifting Phase, the Upper Cretaceous Sagging Phase comprising the Santonian Deformational Stage and the Tertiary-Quaternary Peneplanation Phase.

Two petroleum systems are distinguished : the Lower Cretaceous play and the Upper Cretaceous play. Speculative cumulative recoverable reserves in the Zina Subbasin exceed 100 billions barrels. Hydrocarbons discoveries in the neighboring basins belonging to the WCARS enhance the probability of hydrocarbon occurrence in the LBB.