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Structural and Lithostratigraphic evolution of Al Baraka Oil field, Komombo Basin, Upper Egypt as deduce from 2D seismic lines and well logging data

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Abstract

Twenty 2D seismic lines were interpreted with three well velocities and time-depth trace conversion to characterize the different stratigraphic tops of Komombo basin and to highlight the major structural elements. Five depth structure contour maps were constructed on the tops of Pre-Cambrian Basement, Neocomian, Aptian and Albian/Cenomanian sequences. The interpretations of depth structure contour maps show two main fault trends: NW-SE and NE to ENE directions. The NW-SE trend is the dominant one, creating a half-graben system with two major bounding faults. The northeast one is downthrown to the southwest, while the southwestern bounding fault is downthrown to the northeast.

The restoration of the structure patterns and sediment fill evolution in Komombo basin is attempted using the 2D seismic lines in background, integrated with the well data (Al Baraka-1 and Komombo-3). A series of flattened profiles on top of Pre-Cambrian Basement, Neocomian, Barremian, Aptian, Albian/Cenomanian, Turonian, Coniacian/Santonian, and Campanian/Maastrichtian successions supported the identification of basin dimensions during its development through the main tectonic phases.

Keywords: Komombo basin, Al Baraka Oil Field, Seismic Interpretation, Structure, Lithostratigraphic, Upper Egypt.

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1. Introduction

Komombo concession area is located in Upper Egypt about 570 km south of Cairo and 65 km NNW of Aswan Town and covers an area around 11, 446 km². The area is well served by a paved road to Cairo, Aswan and the Red Sea Coast and by air connections through Aswan airport to Cairo. Al Baraka Oil Filed occupies the eastern part of the Komombo basin. It lies between latitudes 24° 38` and 24° 40` 30`` N, and longitudes 32° 46` and 32° 50` 30`` E (Fig.1), It is one of a series of intracontinental rift basins straddling the river Nile such as the Beni Suef and Asyut basins (Bosworth et al. 2008).

The study area is located on the eastern part of the Komombo basin (Fig. 1). It was part of a larger former Repsol concession which was relinquished in 2001 after the drilling of three wells in this area. These wells are located in a NW–SE trending half graben. After Centurion obtained exploration rights on Komombo block in 2004, additional 2D seismic and 3D seismic acquisition and processing were done. Despite this, the geologic evolution, geometry, and petroleum system of the basin remain poorly understood [1] and the basin still represents a unique petroleum activity in South Egypt.

The aim of the present study is to integrated 2D seismic data and wire-line logs of selected wells to construct the structure-tectonic maps. This is to characterize the different stratigraphic tops in the Komombo basin fill sequence. The detailed structural elements and the reconstruction of the evolution history and basin fill will be highlighted in order to understand the petroleum system in this new basin.

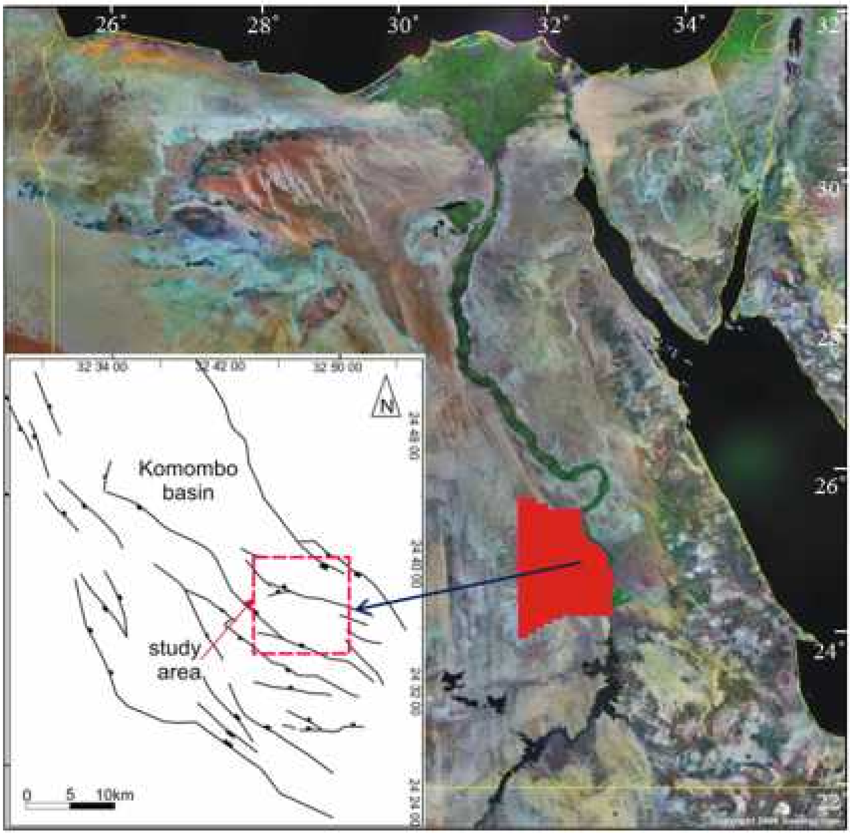

Fig 1: Landsat map of Egypt showing the study area within Komombo basin, Upper Egypt

2. Regional Tectonic Setting

Mesozoic Rift basins are primary targets for hydrocarbon exploration in North and Central Africa [2] and [3]. Some of these cratonic rifts are filled with sedimentary sequences ranging from non-marine lacustrine facies to fully marine systems (Fig. 2). It is obvious that the sedimentary patterns of Jurassic to lower Tertiary sequences appear to have been influenced by to main Tethyan tectonic forces; the sinistral shear during late Jurassic to Early Cretaceous and the dextral shear during the late Cretaceous to Paleocene [4]. In the South Western Desert of Egypt bouguer gravity and aeromagnetic data show large elongated structural lows, similar to the size of Gulf of Suez or larger, which are fault controlled grabens [5], [6] and [3]. These grabens were defined as faulted rifts by [7] that stopped at the second or the third evolutionary stages (e.g. Komombo, Nuqura and Kharit basins). The re-evolution of these basins will support better understanding of hydrocarbon potentialities in these systems. As stated above the Kom Ombo Basin is an extensional rift basin of Early to Late Cretaceous age in southern Egypt (Fig. 1). The Komombo basin appears to be a half graben (Fig. 2), probably developed in an extensional stress regime originated in Central and North Africa with the opening of South Atlantic during the Early Cretaceous [8]. The main bounding fault of the Komombo Basin is located to the northeast and trending NW–SE, while the subordinate faults are mainly synthetic and of the same trend (Fig.2). The basin contains up to 4 km of strata, principally clastics (sandstone and shales) with minor shelf carbonates in the upper part (Fig. 3). The cratonic rift basins are formed by the stretching and faulting of continental lithosphere [9], [10], [11], [12], [13], among other).

3. Stratigraphy

A stratigraphic of non-marine Cretaceous strata from SW Egypt and NW Sudan is given by surface and subsurface correlations, including definition and description of given formations. The exposed continental and transitional marine Cretaceous succession of the Komombo basin (SW Egypt) comprises from bottom to top, the Six Hills, Abu Ballas, Sabayaa, Maghrabi and Taref formations, which cover a Late Jurassic? to Turonian age [14] and [15]. The stratigraphy of the Komombo Basin has been established in a number of studies and published article during the last few years, predominantly based on the investigations of the surface geology beginning with the works of [14] and [15].

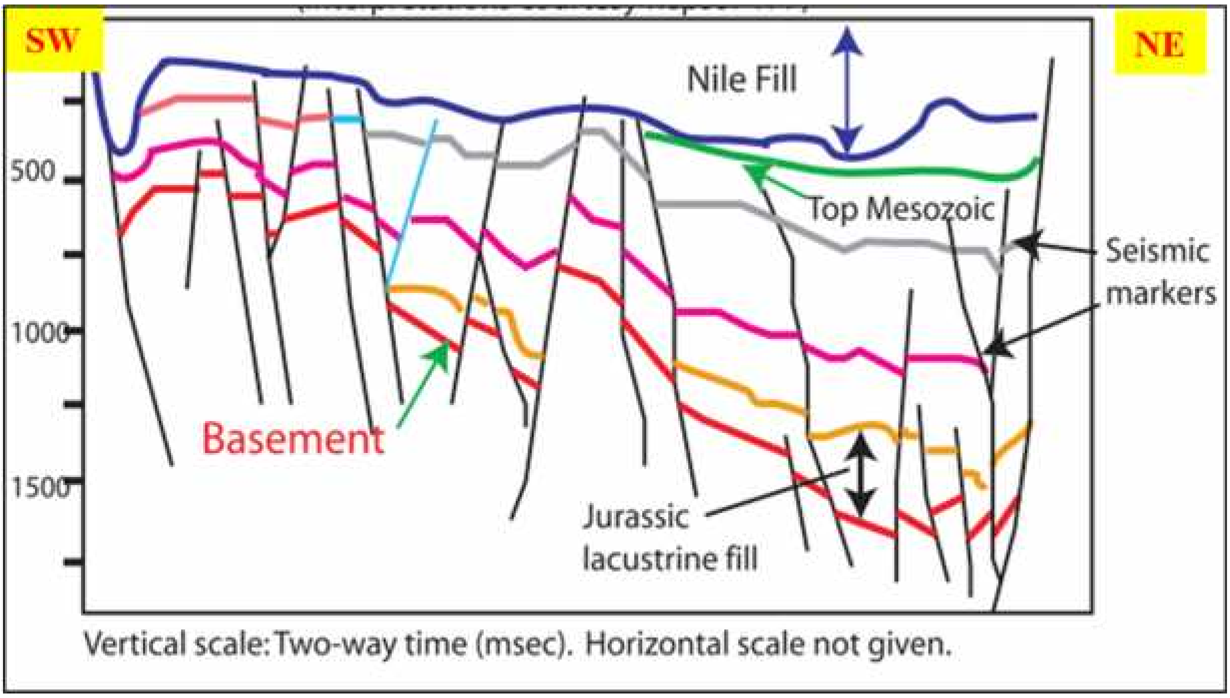

Fig 2: Interpreted geo-seismic line tracing, representative line from Kom Ombo Basin [16].

In the present study the stratigraphic column for Al Baraka oil field was constructed through integrating the biostratigraphic zonation, and lithostratigraphic analyses and correlation of the penetrated successions supported by wire-line logs (electric and radioactive log analysis). The biostratigraphic zonation was principally carried out through palynostratigraphic investigation since the foraminiferal examination indicated that the studied successions are barren of foraminifers with existence only of rare insignificant non-marker forms at very scattered intervals. The detailed palynological description and biostratigraphic zonation were carried out for the study wells (Al Baraka-1, Al Baraka SE-1 and Komombo-3) [17]. Age dating from the three wells penetrating the Cretaceous section is based on regularly-spaced drill-cutting samples and selected core-chips for high resolution biostratigraphic zonation [17]. These biostratigraphically investigated wells highlighted the age of the sedimentary cover on top of the Pre-Cambrian basement and their depositional environment (Table 1).

The biostratigraphic interpretation proved that the Komombo succession belongs to the Cretaceous (Hauterivian-Maastrichtian age). No older age could be detected for the study wells [18]. The palaeoenvironmental diagnosis for the analyzed units was carried out based on their palynological composition. It has generally shown that during the Hauterivian-Barremian time the prevailing environment was non-marine to lagoonal/intertidal. By the advent of Aptian time intertidal to littoral conditions started to prevail with an overall transgressive trend culminated by the prevalence of outer shelf conditions during the Campanian-Maastrichtian. However, a relatively regressive episode occurred during the Coniacian-Santonian time.

Updated stratigraphic column for Komombo basin and Al Baraka oil field area is shown (Fig. 3). Two major inter-formational stratigraphic breaks were detected in the studied successions; lacunae were recognized between Neocomian and Barremian around 3 million years and between Aptian and Albian sequences of around 14 million years. In addition to the main break represented by the time gap between the Pre-Cambrian Basement and the Neocomian sediments as non-deposition or major erosional phases and between the Cretaceous sequence and the overlying Paleocene sediments due to regional uplift event on the area. Also these time gaps as unconformities between the different sedimentary cycles [17].

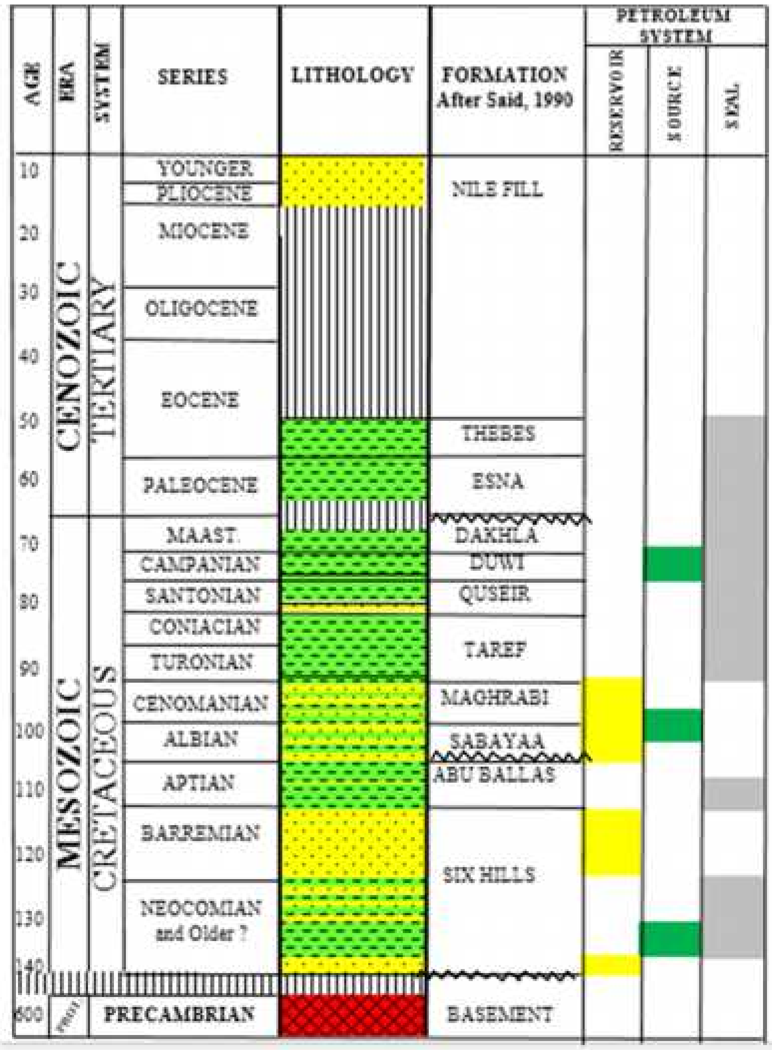

Fig 3: Generalized Stratigraphic Chart for Al Baraka Area [17].

4. Seismic Interpretation

Seismic reflection is generally the well-known method, which routinely used by oil and gas industry to delineate the subsurface structures within sedimentary rocks at great depths. The seismic interpretation methods are very important for petroleum exploration to detect the suitable locations of the exploratory wells, as well as for the development and evaluation of oil fields.

The initial step in the seismic interpretation process is to tie geological horizons to seismic reflectors. The next step is to pick the seismic horizons by continuity through characters of interest, and detect the structural elements. The most important step in this process is to follow a loop that allows us to check the reflectors interpretation. The two lines, at an intersection at the same place, must agree there. Interpreting key seismic reflectors, fault patterns and contouring of depth values of key horizons in a significant way represent the final step [19].The available seismic data sets will be used to achieve the goals of the present study, including twenty 2D seismic lines, four wells data and three vertical seismic profiles (VSP), these data were provided by (GANOPE) (Fig. 4). Twelve of the seismic lines are oriented in NW and NNW direction (Dip line) and the other eight lines are oriented in the NE direction (Strike line).

Table 1: AlBaraka-1 well Palynostratigraphic Summary [18]

AlBaraka-1			
Interval		Palyno-datum	Age
Top (ft)	Bottom (ft)		
1466.00	2620.00	Senegaliniu bicavatum / Andalusiella polymorpha / Trichodinium castanea	Campanian-Maastrichtian
2620.00	2890.00	Odontochitina operculata	Early Campanian
2890.00	3480.00	Foveotricoipites gigantoreticulatus/ Droseridites senonicus	Coniacian-Santonian
3480.00	3930.00	Undefined	Undetermined
3480.00	3800.00	Undefined	Turonian (Based on stratigraphic position)
3800.00	4640.00	Classopollis spp. / Crybelosporites pannuceus/ Inaperturopollenites spp.	Albian-Cenomanian
4640.00	4760.00	Undefined	Aptian (Based on stratigraphic position)
4760.00	7310.00	Undefined	Barremian (Based on stratigraphic position)
7310.00	7790.00	Aequiitriradites spinulosus	Barremian
7790.00	8560.00	Cupressacites Oxycedroides / Impardecispora apiverrcuata	Hauterivian
8560.00	8712.00	Undefined	Basement

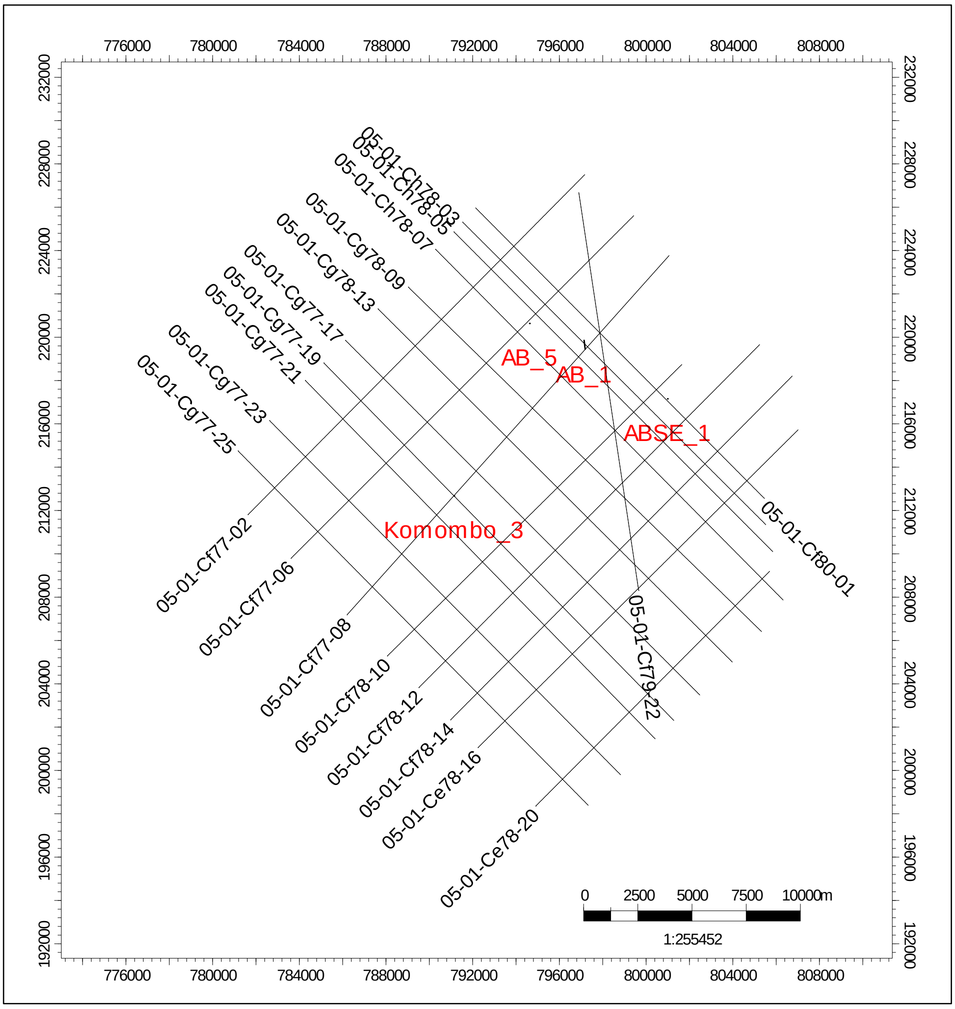

Fig 4: Base map showing 2D seismic lines and the location of the used wells.

5. Depth Structure Contour Maps

Five horizon tops were picked in the study area, including Pre-Cambrian Basement complex, Neocomian B, Neocomian C, Aptian, and Albian/Cenomanian, The depth of the tops surfaces of theses horizons related to sea level was estimated and structure contour maps for these surface were constructed. The structural elements traced from maps are discussed below (Fig. 5).

5.1. Top Pre-Cambrian Basement Depth Structure Contour Map

From analysis of the twenty seismic lines in addition to well logging and tops data, the basement depth values in the basinal area are -8031 ft. as reached in Al Baraka-1 well, -8046 ft. in Al Baraka SE-1 well and -3490 ft. in Komombo-3 well. Generally the interpreted top Basement depth values range from -9300 ft. in the eastern corner of the study area to -2400 ft. in the north and to -2900 ft. in the southwestern and western parts (Fig. 6). The depth structural contour map of the top Pre-Cambrian Basement surface shows two main fault systems extending in NW-SE and NE-SW directions. The NW-SE trending faults system is the dominant on the top basement and the deeper levels in the basin that play the main structural role (Fig. 6).

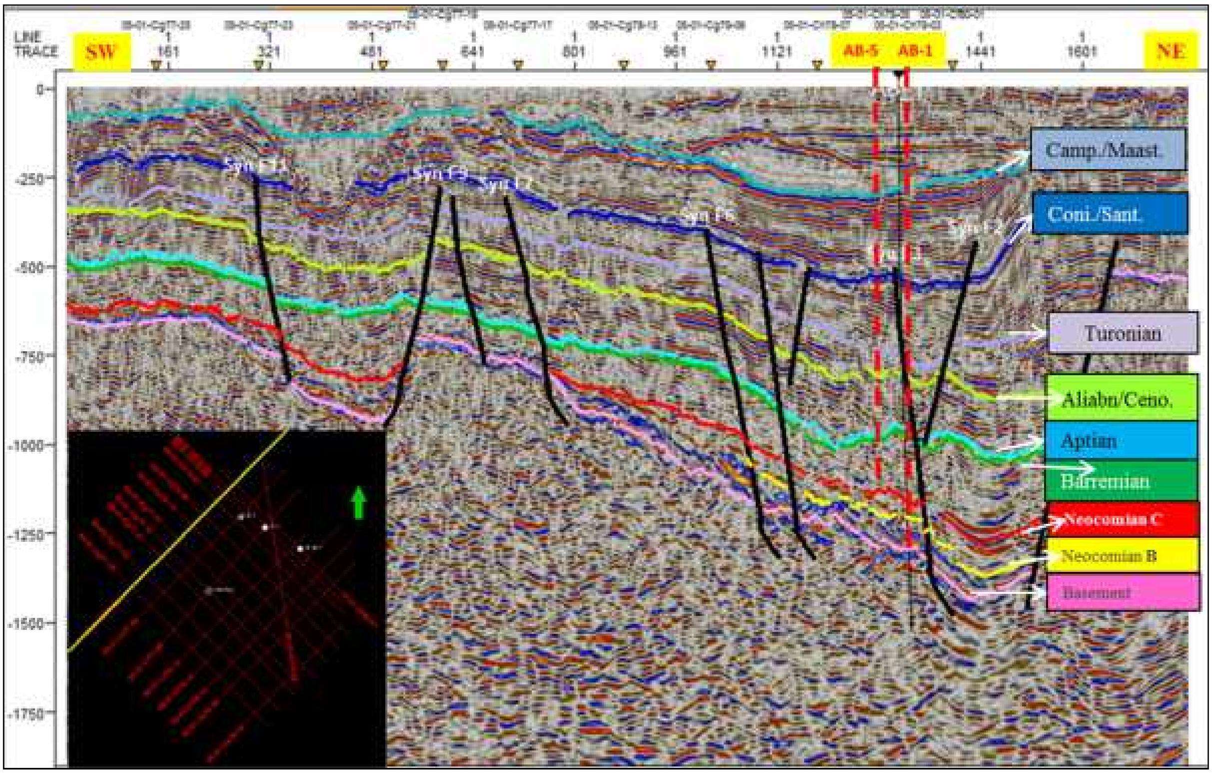

Fig 5: Interpreted Seismic time section for 05-01-Cf77-02 Line Komombo Basinal Area, Egypt

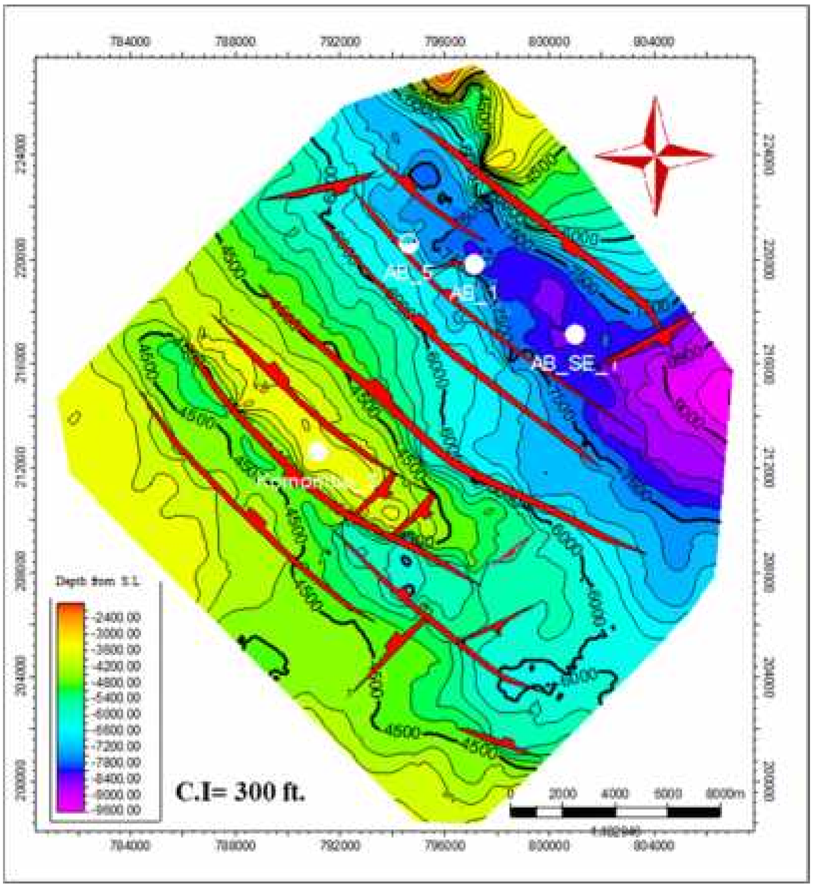

Fig 6: Top Basement depth structure contour map

5.2. Top Neocomian (B) (Lower Six Hills Fm.) Depth Structure Contour Map

The Neocomian (B) depth as recorded in value -7536 ft. in Al Baraka-1 well and at depth -7680 ft. in Al Baraka SE-1 well. However the depth values as deduced from the 2D seismic section range from -8400 ft. in the eastern corner to -4800 ft. in the western corner of the study area. In Komombo-3 well to the west of the study area the Neocomian (B) section is missing most probably due to paleo-structural highs during the deposition (Fig. 7). As the basement depth structure contour map, the Neocomian (B) depth structure contour map shows the same two main fault trends (NW-SE and NE to ENE). This NW-SE trending faults is the dominant on the top Neocomian (B) sequence and the deeper levels in the basin (Fig. 7).

5.3 Top Neocomian (C) (Lower Six Hills Fm.) Depth Structure Contour Map

The Neocomian (C) is recorded at depth -7158 ft. in Al Baraka-1 well and at depth -6790 ft. in Al Baraka SE-1 well. However the depth values as deduced from the 2D seismic section range from -7800 ft. in the eastern corner to -2600 ft. in the western corner of the study area. In the Komombo-3 well Neocomian (C) is not recorded probably due to structural Paleo-highs (horst block) (Fig. 8). The top of the Neocomian (C) depth structure contour map shows the main fault systems (NW-SE and NE to ENE). The NW-SE faults are the dominant on the top Neocomian (C) sequence and in the deeper levels.

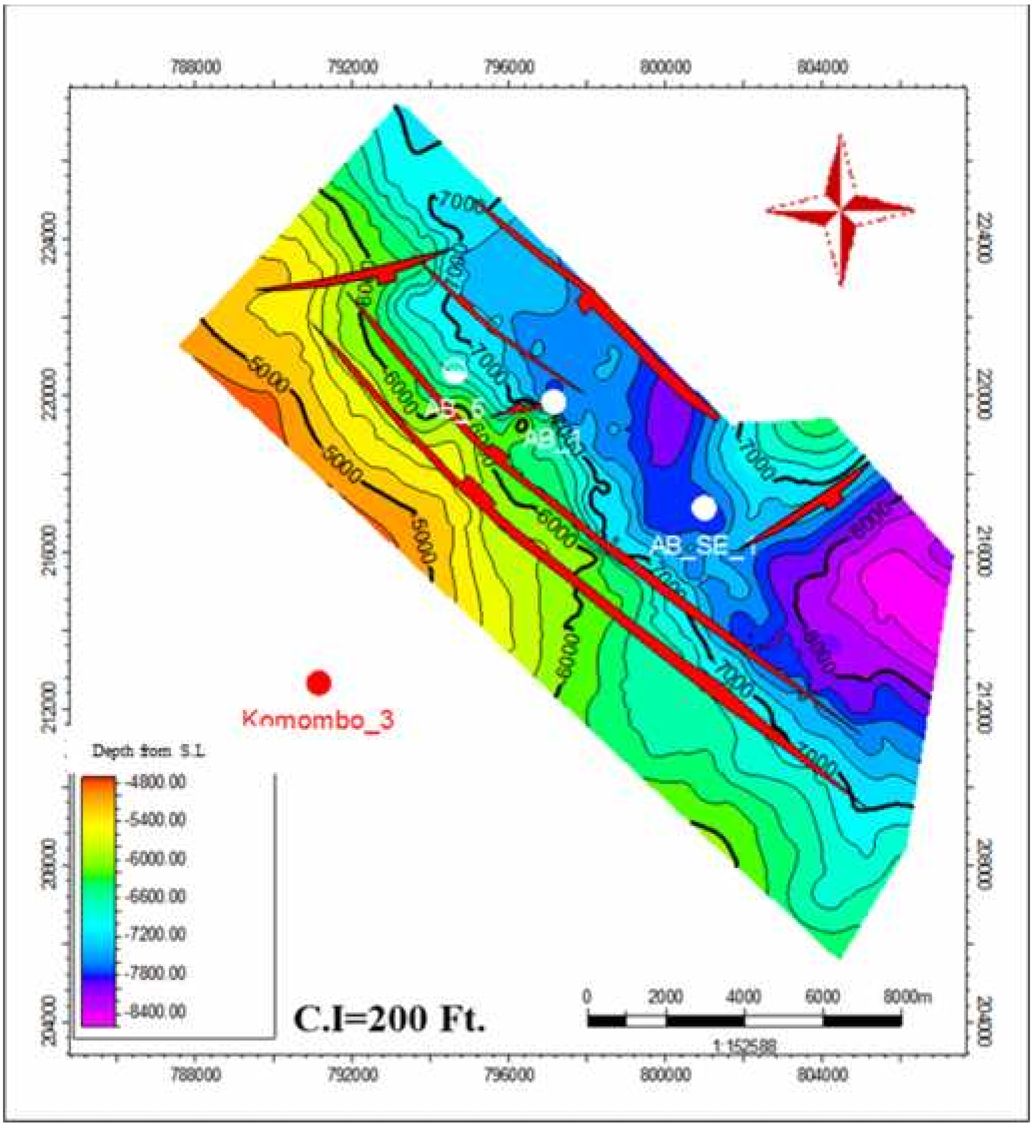

Fig 7: Top Neocomian (B) depth structure contour map

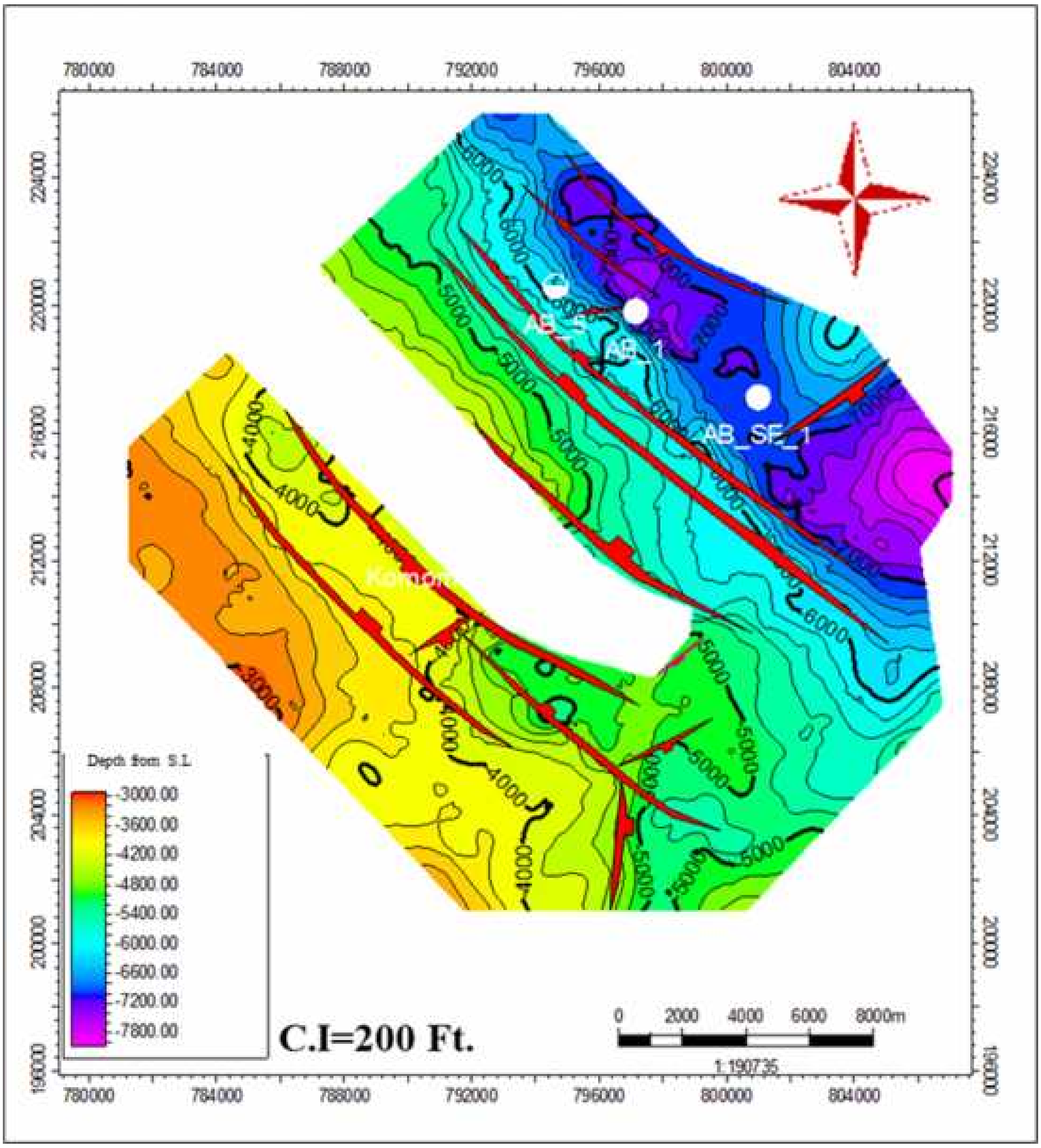

Fig 8: Top Neocomian (C) depth structure contour map

5.4 Top Aptian (Abu Ballas Fm.) Depth Structure Contour Map

The top of Aptian sequence (Abu Ballas Formation) would be reached at depth values -4061 ft. in Al Baraka-1 well, -4106 ft. in Al Baraka-5 well, -4355 ft. in Al Baraka SE-1 well and -3225 ft. in the Komombo-3 well. Accordingly the interpreted depth values range from -5400 ft. in the eastern and south parts of the study area to -2000 ft. in the northeastern corner and to -3200 ft. in the western part (Fig. 9). Top of Aptian depth structural contour map shows the main fault systems NW-SE and NE- ENE directions. This NW-SE trending faults is the dominant on the top Aptian sequence (Fig. 9).

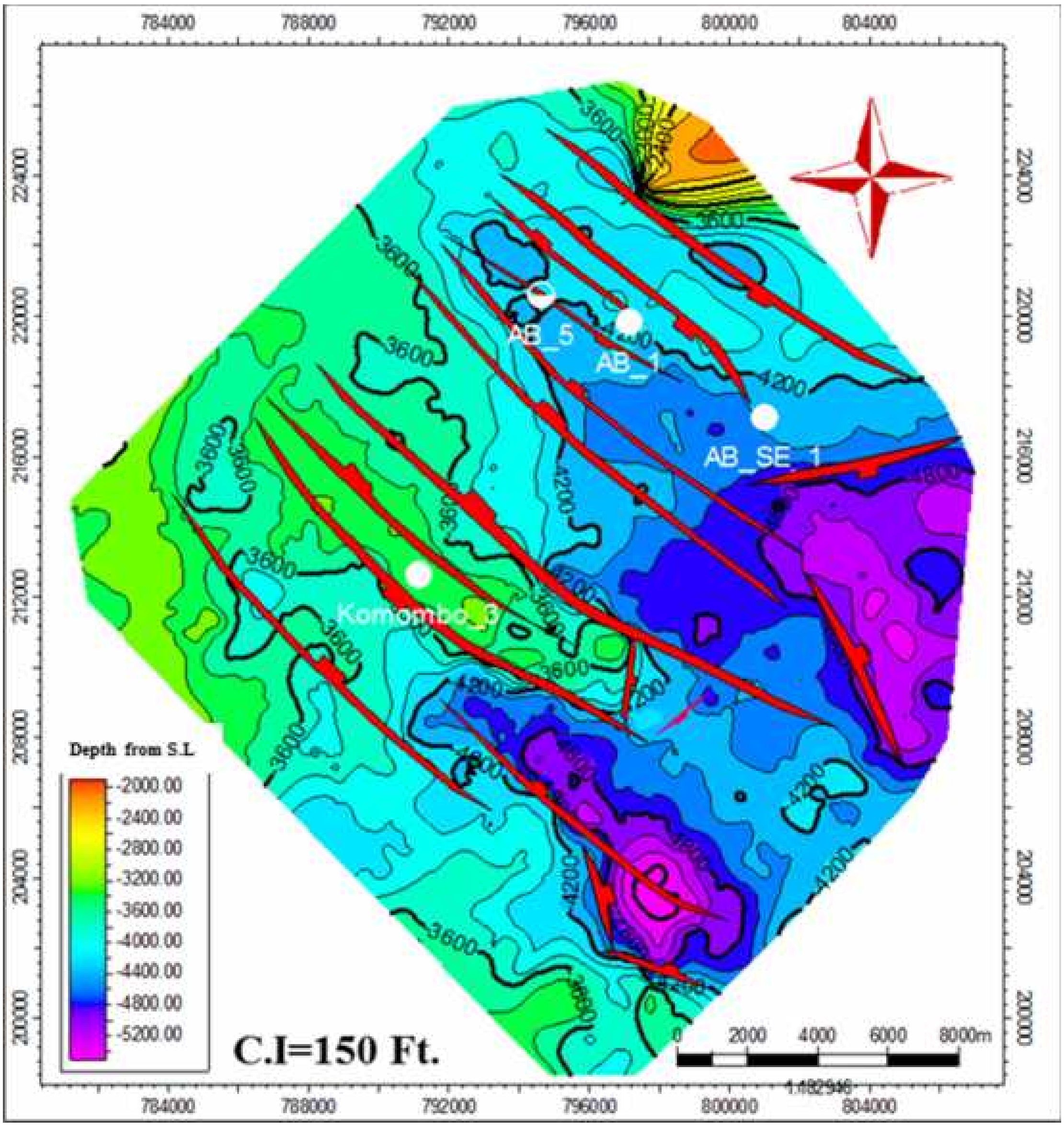

Fig 9: Top Aptian (Abu Ballas Formation) depth structure contour map

5.5 Top Albian/Cenomanian (Sabayaa/Maghrabi Fm.) Depth Structure Contour Map

The top of Albian/Cenomanian sequence (Sabayaa/Maghrabi formations) would be reached at depth values -3234 ft. in Al Baraka-1 well, -3170 ft. in Al Baraka-5 well, -3036 ft. in Al Baraka SE-1 well and -2242 ft. in the Komombo-3 well. However the depth values range from -4000 ft. in the eastern corner of the study area to -1500 ft. in the north corner and to -2100 ft. in the western corner (Fig. 10). Top of Albian/Cenomanian depth structural contour map shows the fault trends are directed towards NW-SE and NE to ENE. This NW-SE trending faults is the dominant on the top Albian/Cenomanian sequence (Fig. 10).

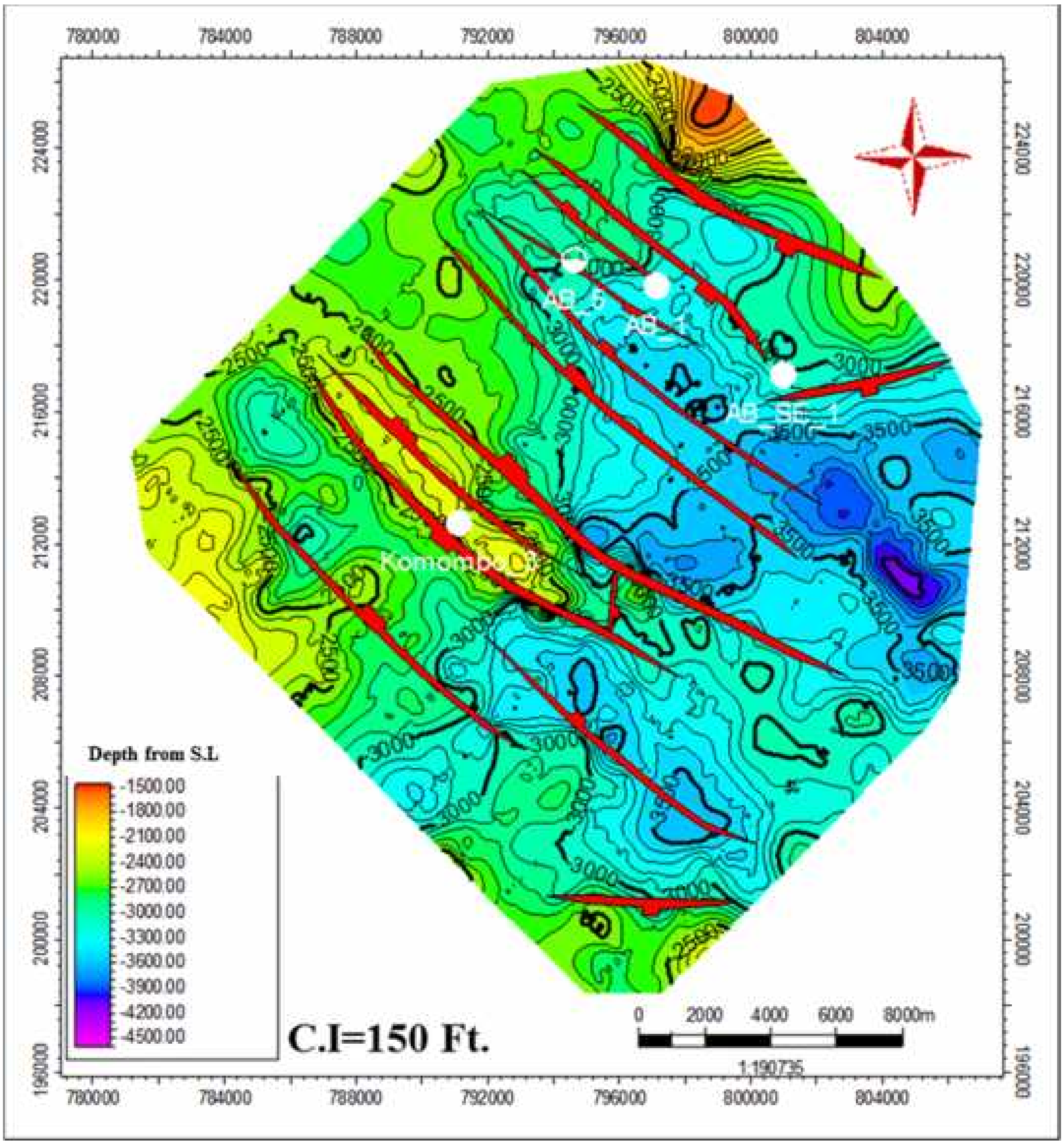

Fig 10: Top Albian/Cenomanian depth structure contour map

6. Paleo-structural Evolution

Structural restoration is attempted using the 2D seismic lines in background integrated with the well data to trace the Komombo basin evolution. A series of flattened sections are constructed on top of selected formation boundaries to identify the possible basin dimensions during evolutionary phases, firstly the Neocomian (A&B) were deposited non-conformably above the Pre-Cambrian basement complex. The Neocomian (A&B) section is mainly of alluvial fan deposits associated with lacustrine facies [17], affected by many growth faults in the NW-SE trend. The width of basin through Neocomian (A&B) was about 25900 ft. (Fig. 11). On the other hand the Isopach map of Neocomian (A&B) shows a variable thickness ranging from 100 ft. to 900 ft. The maximum thickness of Neocomian (A&B) is encountered in the eastern part of the study area, whereas, the minimum thickness is exhibited in western and northwestern parts of the study area (Fig. 12).

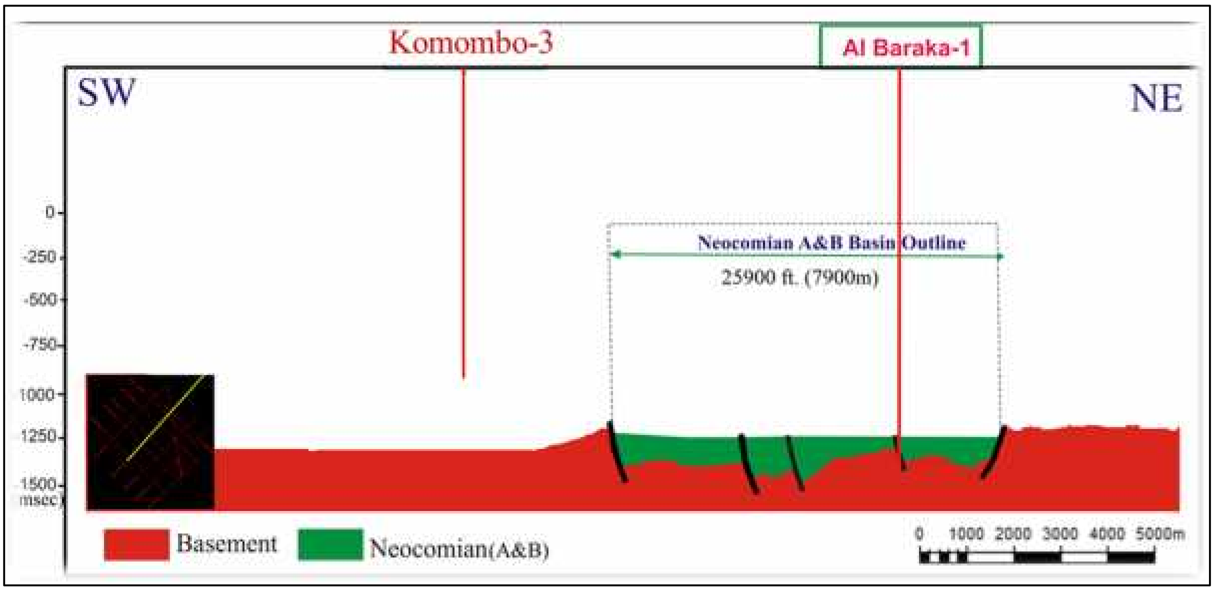

Fig 11: Structure Cross Section in the dip direction in Komombo basin datum on top Neocomian (A&B) sequence

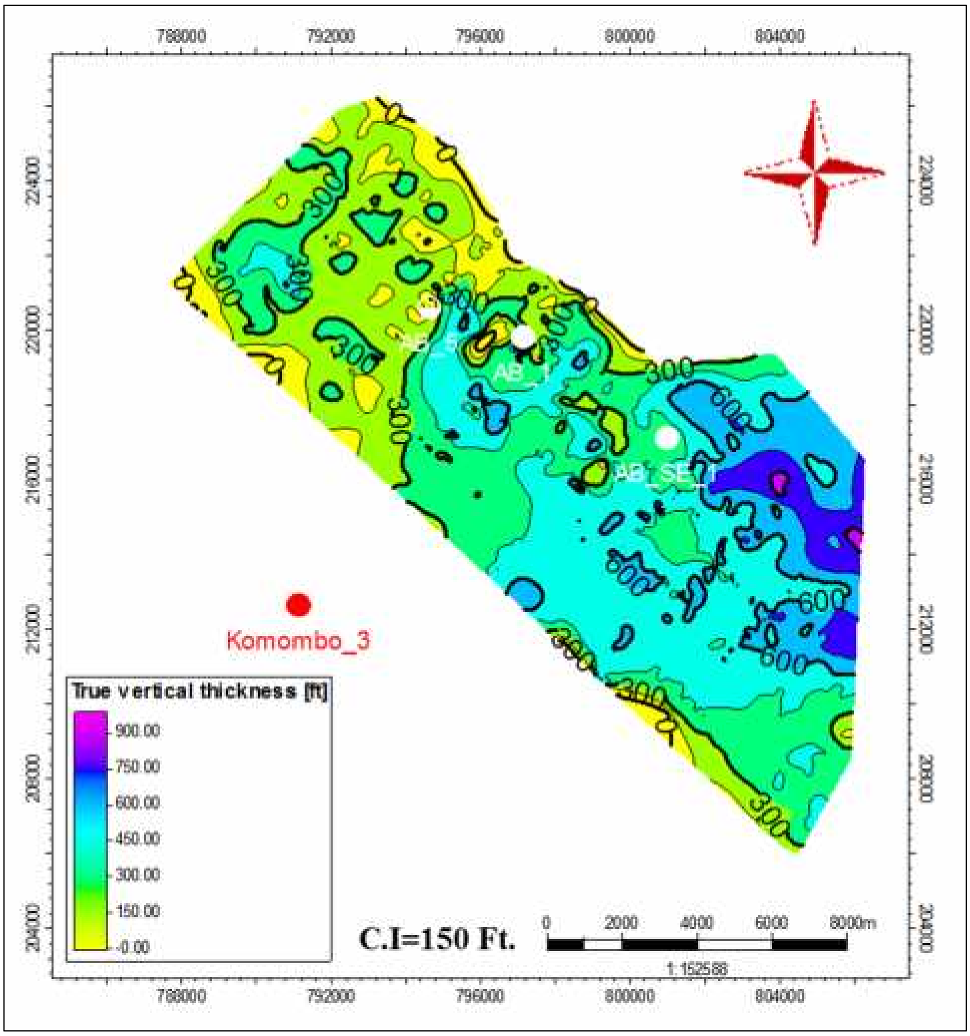

Fig 12: Isopach contour map of Neocomian (A&B)

The Neocomian (C) deposited overlain Neocomian (B) which represents the main siliciclastic reservoir in Komombo basin, the Neocomian (C) thickness ranges from 370 ft. in AB-1 well to 710 ft. in ABSE-1, being affected by many faults along the NW-SE direction. During that time the width of Komombo basin extended to more than 53140 ft. (Fig. 13), indicating continuous rifting stages. Be sides, the Isopach map of Neocomian (C) shows a variable thickness ranging from 400 ft. to more than 1400 ft. The maximum thickness is encountered in its eastern part of the study area. Meanwhile, it exhibits the minimum thickness in the western and northwestern parts of the study area (Fig.14). The development of growth faults increased the extension of Komombo basin. This caused more basin subsidence toward the east and leading to creation of a new sub basin (Mini basin) in the area west of Komombo-3 well (Fig 13). Barremian sequence (Upper Six Hills) was deposited above Neocomian C and reflecting increased thickness due to growth fault west of Komombo-3 well (Fig 15).

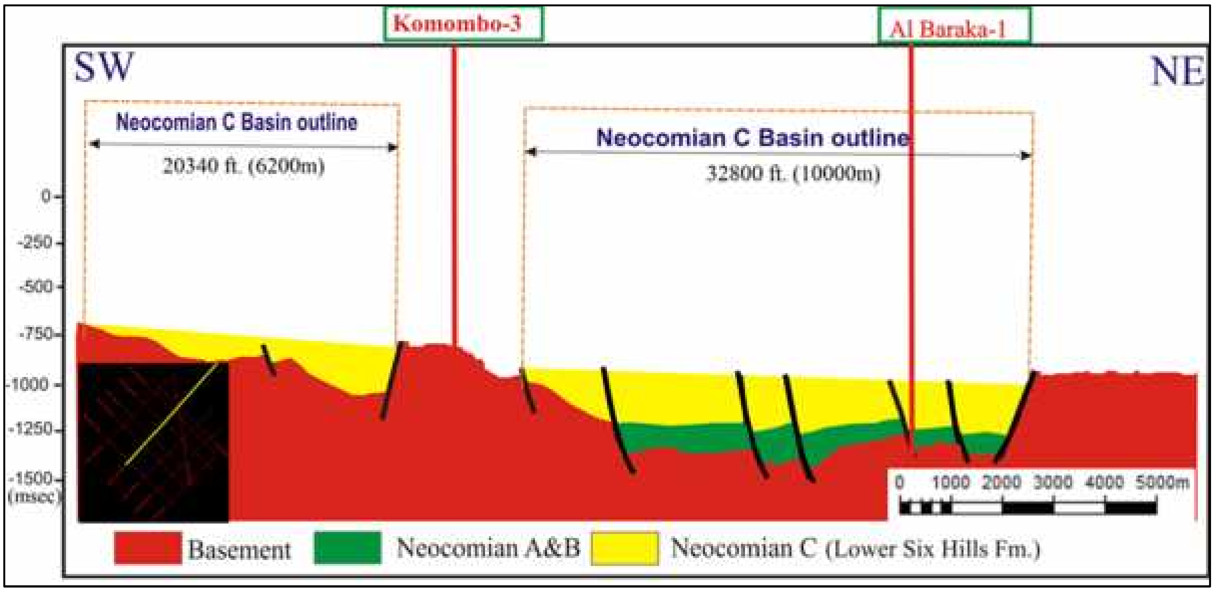

Fig 13: Structure Cross Section in the dip direction in Komombo basin datum on top Neocomian (C) sequence

The Barremian (Upper Six Hills) thickness decreased in the area around Komombo-3 due to uplifting (horst block) during deposition, or it might be eroded after deposition and increased in the area east of Komombo-3 gradually toward the east reaching its maximum thickness in the basin depocenter, Barremian sediment thickness varies in the drilled wells from 3030, 2480 and 145 ft. in AB-1, ABSE-1 and Komombo-3 respectively. Also the Komombo basin width increased to more than 62650 ft. (Fig. 15). The Isopach map of Barremian shows a variable thickness ranging from 200 ft. to more than 4000 ft. The maximum thickness is recorded in the northern part of the study area, whereas, the minimum thickness is detected in the central part (Fig. 16).

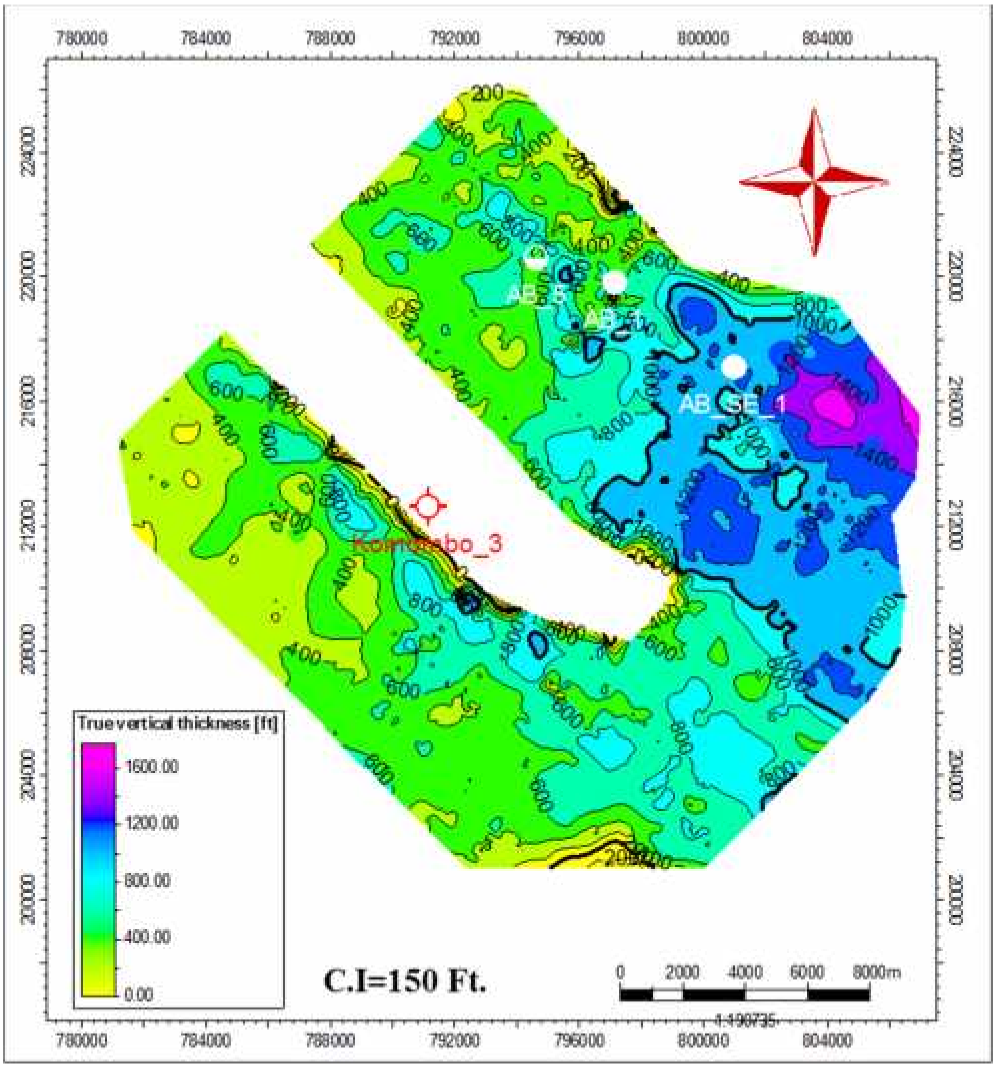

Fig 14: Isopach contour map of Neocomian (C)

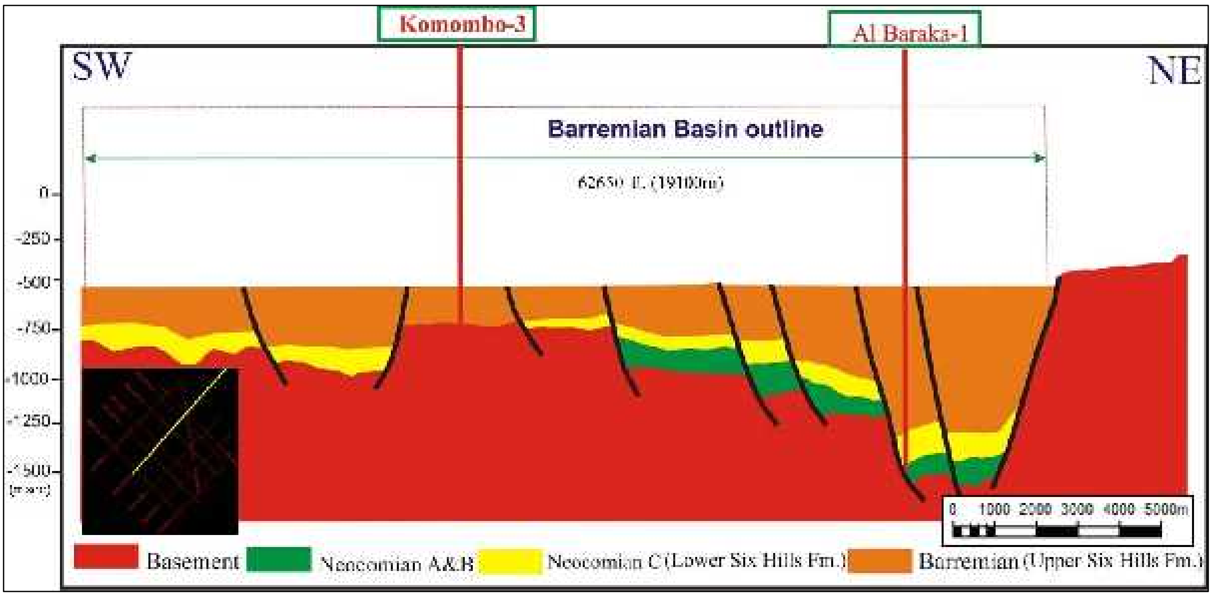

Fig 15: Structure Cross Section in the dip direction in Komombo basin datum on top Barremian sequence

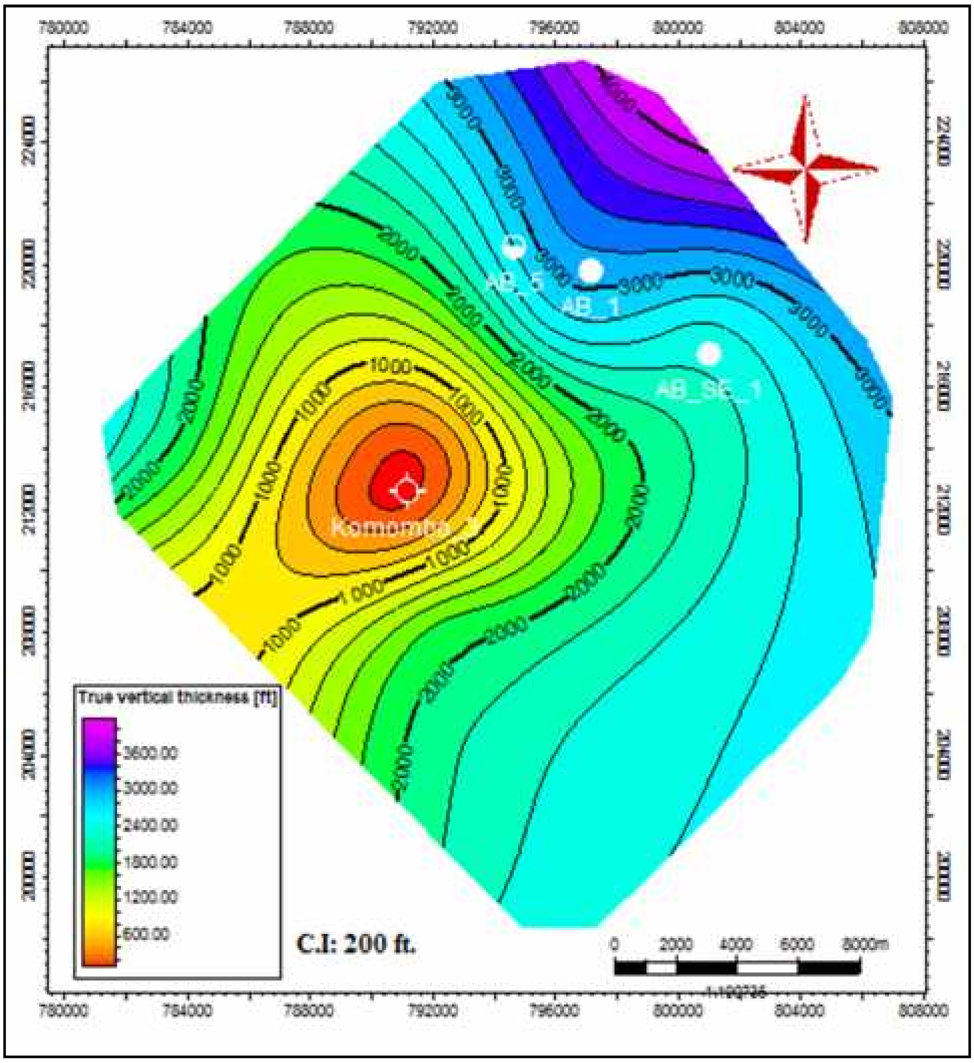

Fig 16: Isopach contour map of Barremian

At the beginning of Aptian, the sea rise took place and covered the south Western Desert and representing the first major transgressive phase and reached the study area which depositing the Aptian (Abu Ballas Formation), which extended laterally along the whole area. Aptian section has a uniform thickness about 140 ft. During that time the width of Komombo basin at was approximately the same width during the Barremian time of more than 62650 ft. (Fig.17). The Isopach map of Aptian (Abu Ballas Fm.) shows a variable thickness ranging from 120 ft. to 148 ft. The maximum thickness of Aptian is encountered in the eastern part of the study area. Meanwhile, it exhibits the minimum thickness in the central and northeastern parts of the study area (Fig. 18).

The Albian/Cenomanian sequences were accumulated above Aptian (Abu Ballas Formation) whereas Albian/Cenomanian (Sabayaa/ Maghrabi) thickness ranges from 830 ft. in AB-1 to 1325 ft. in ABSE-1, 980 ft. in Komombo-3 and 935 ft. in Al Baraka-5 wells, increasing gradually in the area east of Komombo-3 well reaching its maximum thickness in basin depocenter. During that time the width of Komombo basin in this area extended to about 72820 ft. (Fig.19). The Isopach map of Albian/Cenomanian shows a variable thickness ranging from 450 ft. to 1350 ft. The maximum thickness of Albian/ Cenomanian is encountered in the eastern part of the study area. Meanwhile, it exhibits the minimum thickness in the western, southwestern and northeastern parts of the study area (Fig. 20).

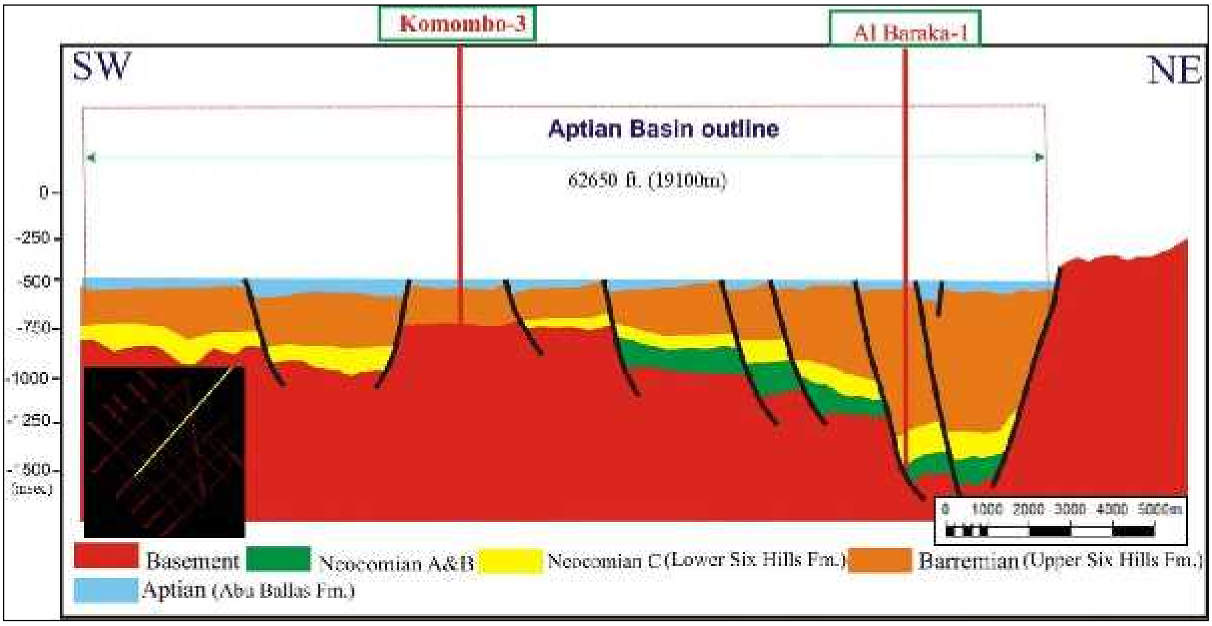

Fig 17: Structure Cross Section in the dip direction in Komombo basin datum on top Aptian sequence

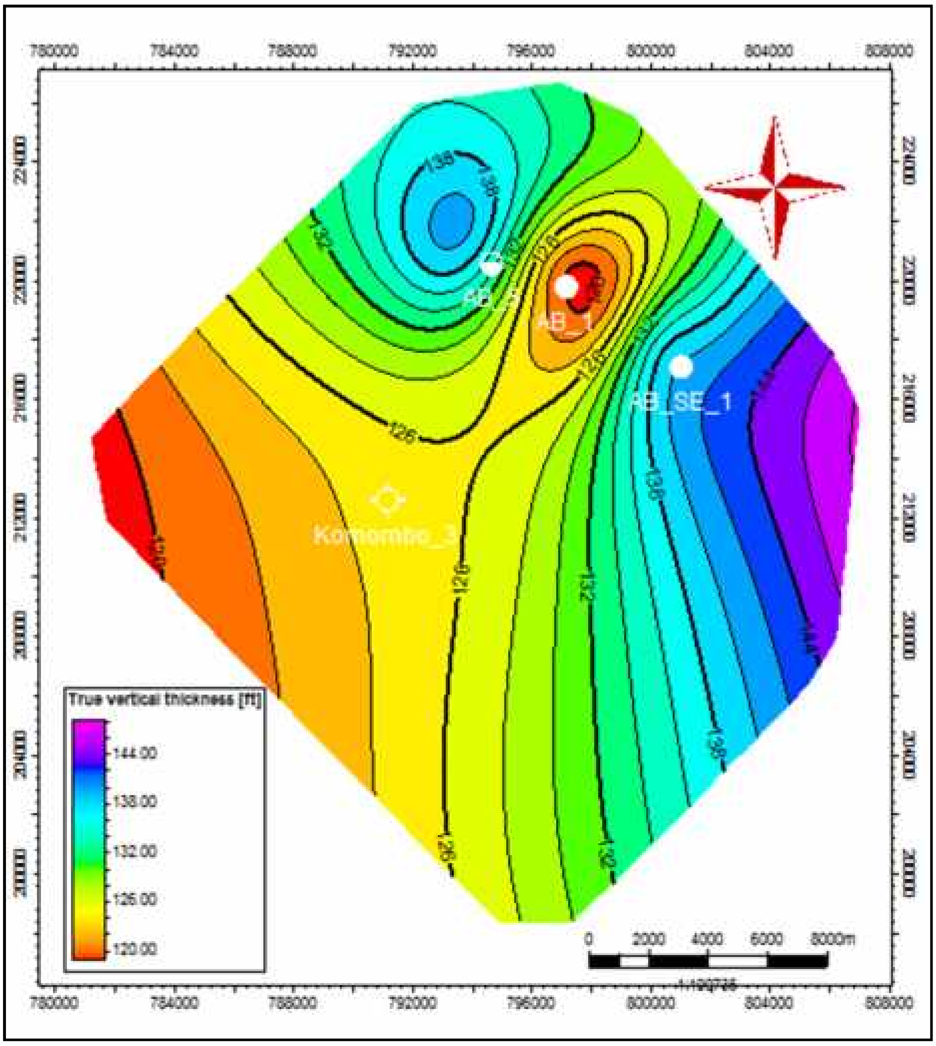

Fig 18: Isopach contour map of Aptian

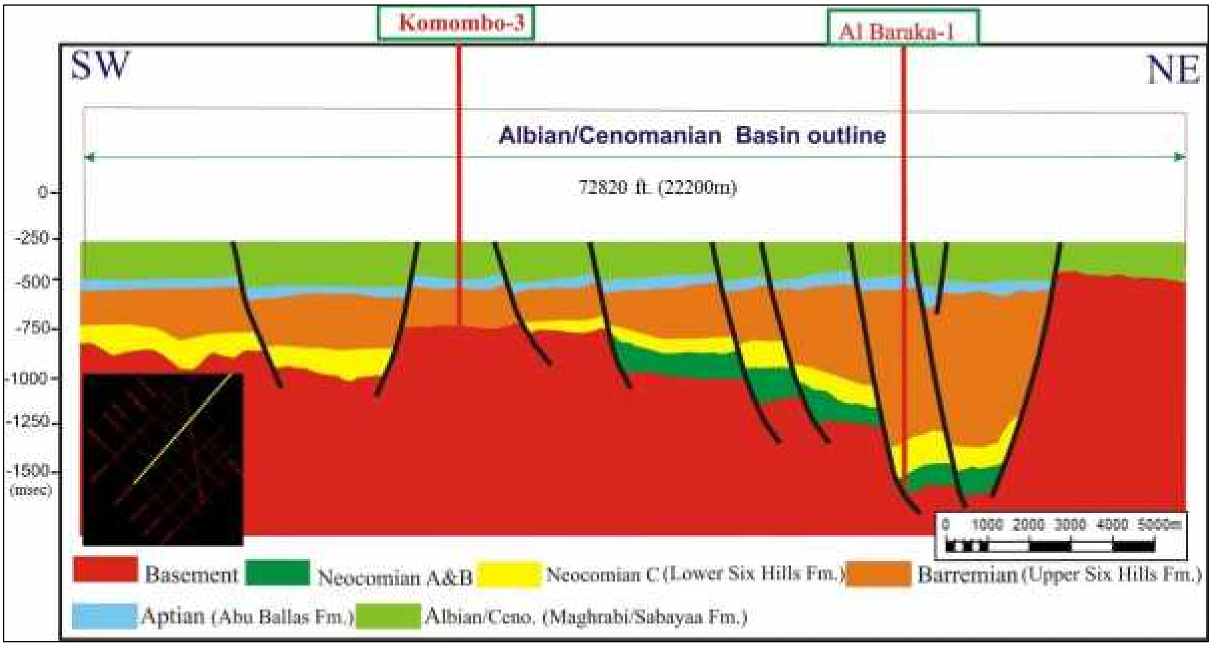

Fig 19: Structure Cross Section in the dip direction in Komombo basin datum on top Albian/Cenomanian sequence

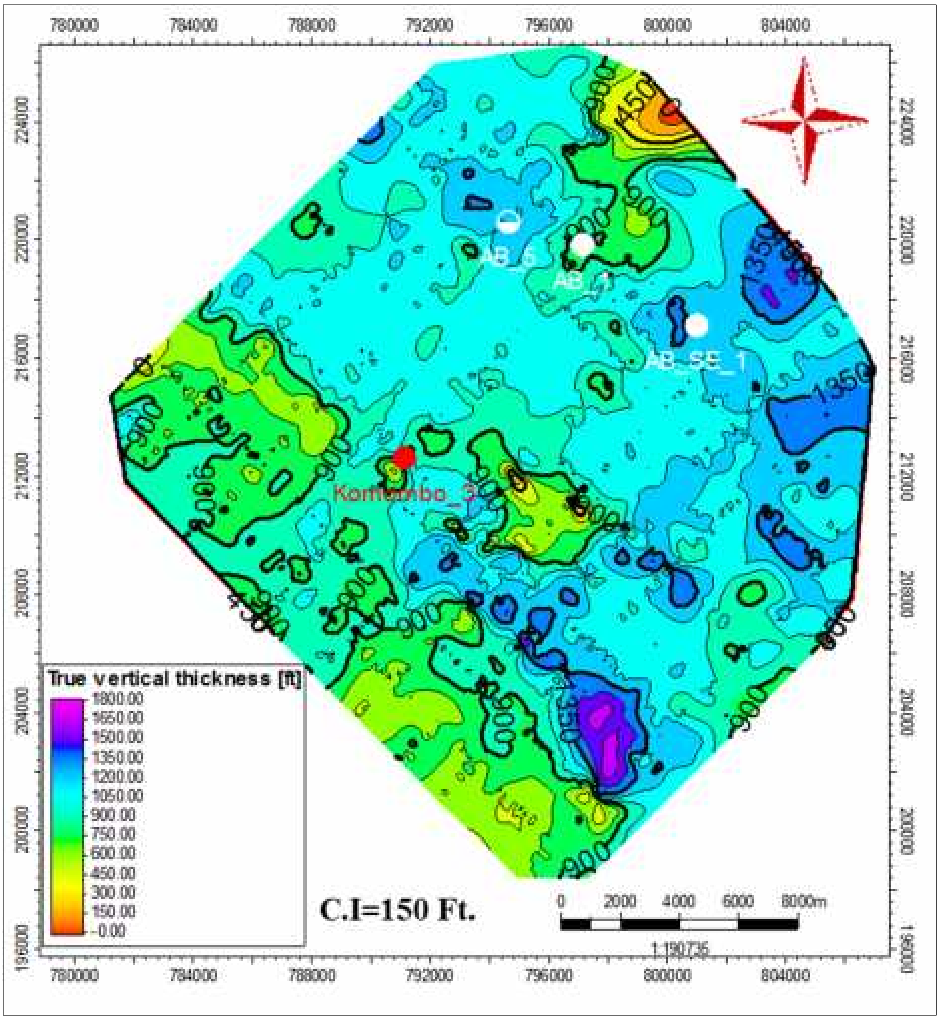

Fig 20: Isopach contour map of Albian/Cenomanian

The Turonian deposit (Lower Taref Formation) was overlaying Maghrabi Formation. The Turonian thickness ranges from 310 ft. in AB-1 to 610 ft. in ABSE-1, 205 ft. in Komombo-3 and 575 ft. in Al Baraka-5 wells, decreased in the area around Komombo-3 due to uplifting (horst block) of the area during deposition and increased in the area east of Komombo-3 gradually toward the east. During that time the width of Komombo basin at was approximately the same width adds that during the Albian/Cenomanian time of more 72820 ft. (Fig. 21).

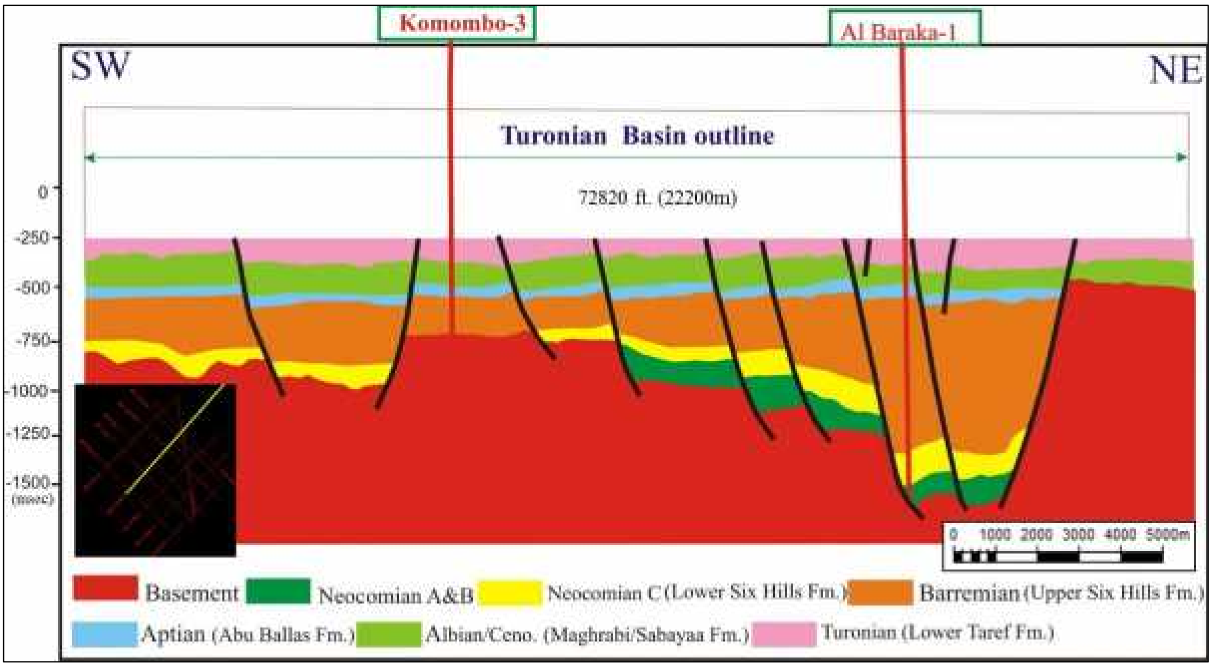

Fig 21: Structure Cross Section in the dip direction in Komombo basin datum on top Turonian sequence

The Coniacian/Santonian (Upper Taref and Quseir formations) sequences were accumulated above Turonian cycle (Lower Taref Formation) whereas Coniacian/Santonian thickness ranges from 575 ft. in AB-1 to 825 ft. in ABSE-1, 660 ft. in Komombo-3 and 505 ft. in Al Baraka-5 wells. During that time the width of Komombo basin at was approximately the same width adds that during Turonian time of more 72820 ft. (Fig. 22).

Same as the Coniacian/Santonian sequence, the Campanian/Maast. Sequences (Duwi & Dakhla formations) were overlying the Coniacian/Santonian deposits. The Campanian/Maast. thickness ranges from 1415 ft. in AB-1 to 810 ft. in ABSE-1, 1080 ft. in Komombo-3 and 1040 ft. in Al Baraka-5 wells. During that time the width of Komombo basin was approximately the same width during time Coniacian/Santonian of more 72820 ft. (Fig. 23). After that Alluvium deposits accumulated above Campanian/Maast. and recorded the maximum thickness in Al Baraka -1 and Al Baraka-5 wells about 1470 and 1550 ft. respectively (Fig. 24).

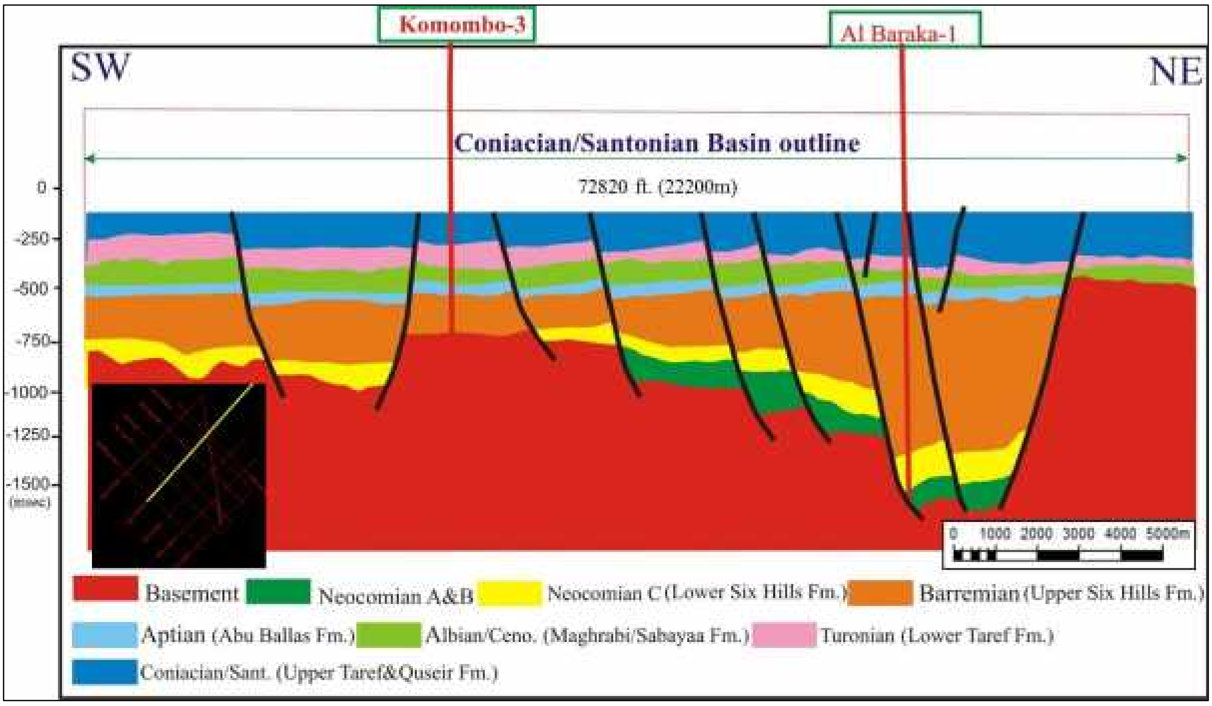

Fig 22: Structure Cross Section in the dip direction in Komombo basin datum on top Coniacian/Santonian sequence

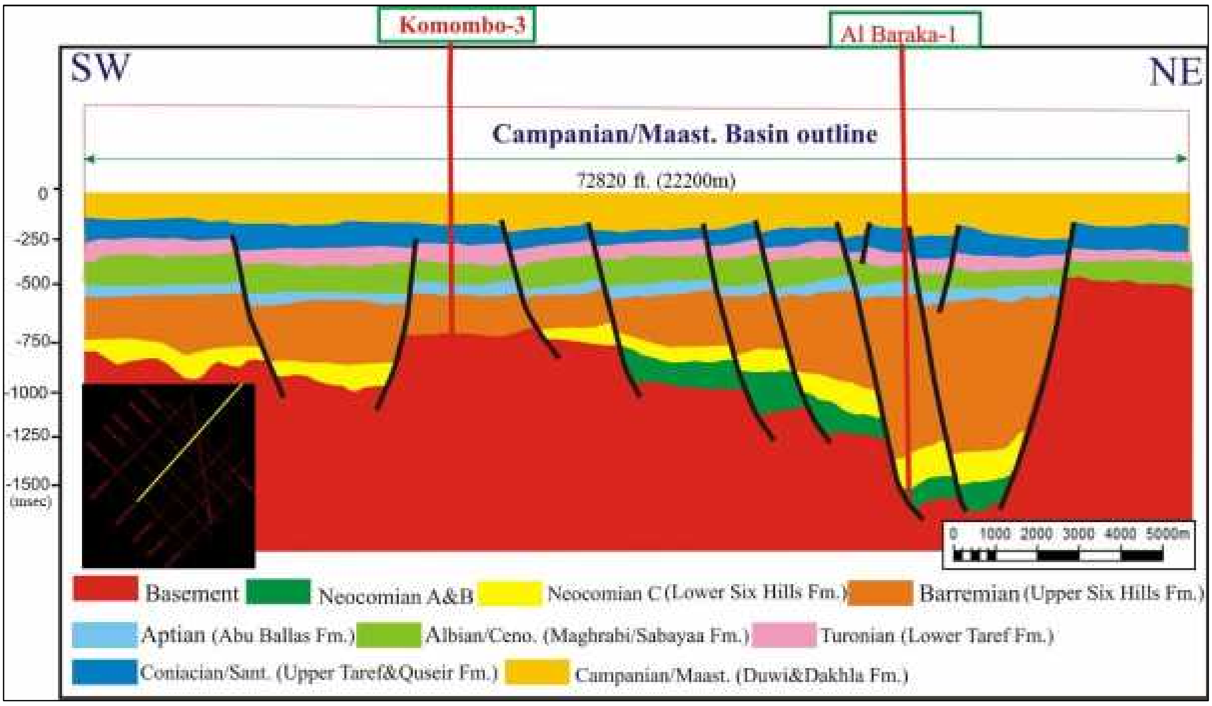

Fig 23: Structure Cross Section in the dip direction in Komombo basin datum on top Campanian/Maast. sequence

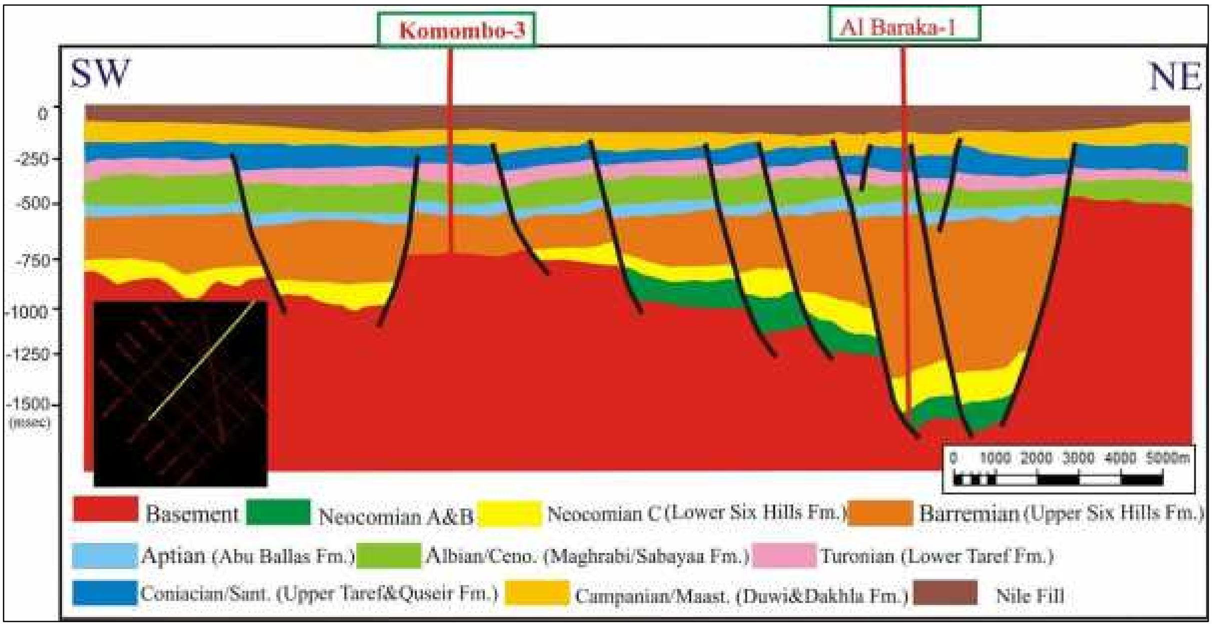

Fig 24: Structure Cross Section in the dip direction in Komombo basin at present day

7. Conclusion

Komombo basin in Upper Egypt is a half-graben system and contains thick non-marine sediments deposited during Early Cretaceous to Barremian followed by marine deposition during Albian /Cenomanian (sandstones and shales) and later shales and marine limestones during Late Cretaceous and early Tertiary.

The interpretation of depth structure contour maps show two main fault trends directed in the NW-SE and NE to ENE directions. The NW-SE trend is the dominant one, creating a major half-graben system, and bounded by two major faults striking in a NW direction, while the NE trend is downthrown to the southwest. The SW bounding fault is downthrown to the northeast.

The restoration of the structure patterns and sediment fill evolution in Komombo basin using the 2D seismic lines in background, integrated with the Al Baraka-1 and Komombo-3 wells data helped in tracing the evolution of the basin is considering to identify the basin dimension during the development and evolution phases.

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