Petroleum Res. J. Vol. 15 (2003); P. 23–32, 15 Figs.

Late Cretaceous Stratigraphy and Palaegeography of Zaltan Platform (Concession 59), South Central Sirt Basin, Libya

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التتابع الطبقي والجغرافية القديمة بمنطقة مسطح زلطن بعقد الامتياز 59 جنوب وسط حوض سرت – ليبيا

ميلود أبو قارص و محمود البكاي

ينتشر التتابع الطبقي التابع للعصر الطباشيري العلوي فوق معظم أجزاء حوض سرت الرسوبي، ويحتوي على طين بحري وحجر جيري، ويمتد عمره الجيولوجي بين زمن التوروني وحتى المستريختي.

تنقسم التتابعات الطبقية في منطقة الدراسة إلى خمسة تكاوين واضحة المعالم ومميزة، ويعزي توزيعها إلى الجغرافيا القديمة لطبوغرافية المناطق السائدة وقت الترسيب ويمكن ترتيب هذه التكاوين تصاعدياً على النحو التالي:

الحجر الرملي التابع إلى عصر ما قبل الطباشيري العلوي، متبخرات تكوين إيثيل (التوروني) والمتكون من مسطحات مياه ضحلة ومحصورة، تكوين الرشمات الذي يمتد عمره من الكونياكيان إلى السانطوني والمتكون من رواسب بحرية ضحلة مفتوحة ومحمية جزئياً، تكوين سرت الطيني وهو مسطح ضحل ومحصور وأخيراً الحجر الجيري لتكوين الواحة التابع للعصر الماستريختي وهو مسطح جيري ضحل.

إثناء الزمن الطباشيري العلوي ارتفع منسوب سطح البحر وتقدم باتجاه الجنوب فوق صخور القاعدة الجرانيتية أو فوق الحجر الرملي للعصر ما قبل الطباشيري العلوي وإبان العصر السانطوني وبداية العصر الكمباني تقدم البحر تدريجياً ليغمر معظم مناطق الواحة والدفة.

أما في نهاية الطباشيري العلوي أي خلال زمن المستريختي فقد استمر البحر في التقدم باتجاه الجنوب وغمر معظم المرتفعات القديمة وذلك على إمتداد مسطح زلطن. وخلف هذا جزيرتين غير متصلتين كمناطق غير مغطاة تعرفان اليوم بحقل الواحة وحقل الدفة، وتم بناء أحزمة جيرية حولهما بسبب تقدم البحر إلى الأعماق وكجزء من هذه المرحلة تكونت السحنات الجيرية المعروفة بسحنات خزان الواحة النفطي الجيري حيث تغيرت جانبياً باتجاه مركز الحوض إلى تتابع طبقي من رواسب طينية تعرف بتكوين سرت الطيني.

Abstract: *The Upper Cretaceous stratigraphic sequences are widespread over the whole of Sirt Basin and consist of marine shale and limestone, ranging in age from the Turonian up to the Maastrichian. The sequences, in the study area (Zaltan platform), are divided into five clearly recognizable formations and their distribution is related mainly to the palaeogeography of the pre-existing topography. In ascending order they are; Pre-upper Cretaceous sandstone, evaporitic Turonian Etel Formation (shallow water restricted platform), Coniacian/ Santonian Rachmat Formation (shallow open marine, slightly protected), Campanian Sirte Shale (shallow*

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restricted platform) and Maastrichian Waha Limestone (shallow carbonate platform).

Upper Cretaceous sea transgressed towards the south either over the basement and granite wash or over Pre-upper Cretaceous sandstone. It encroached gradually on the Al Wahah and Ad Deffah areas at the close of Santonian and the beginning of Campanian time. During Maastrichian time, sea continued to transgress southwards and covered most of palaeohighs in the Zaltan platform. Two separated islands were left uncovered, forming the palaeohigh (Al Wahah and Ad Deffah field area). The carbonate belts around them grew narrower as the sea got too deep for the carbonate deposition. Carbonate facies, known as Waha reservoir facies, were developed on the highs and changed laterally basinward into shally sequence deposits of the Sirte Shale.

INTRODUCTION

The study area is located in the south central part of the Sirt Basin (Fig.1). It covers Concession 59 including Al Wahah, Ad Deffah fields and Al Harash area in Zaltan platform. This study was carried out in order to further understand the subsurface geology and the palaeogeographic distribution of the Late Cretaceous stratigraphic sequences. It includes from base to top; the Pre- upper Cretaceous, Etel, Rachmat, Sirte Shale, Waha Limestone and Kalash Formation. The relation between structural system and facies development in the Zaltan platform is also considered.

The present study is based on subsurface well logs data, collected and analyzed from twenty five wells located in Concession 59 of the Al Wahah, Ad Deffah field areas. Regional geological cross-sections, palaeogeographic maps and schematic block diagrams were also constructed for this purpose.

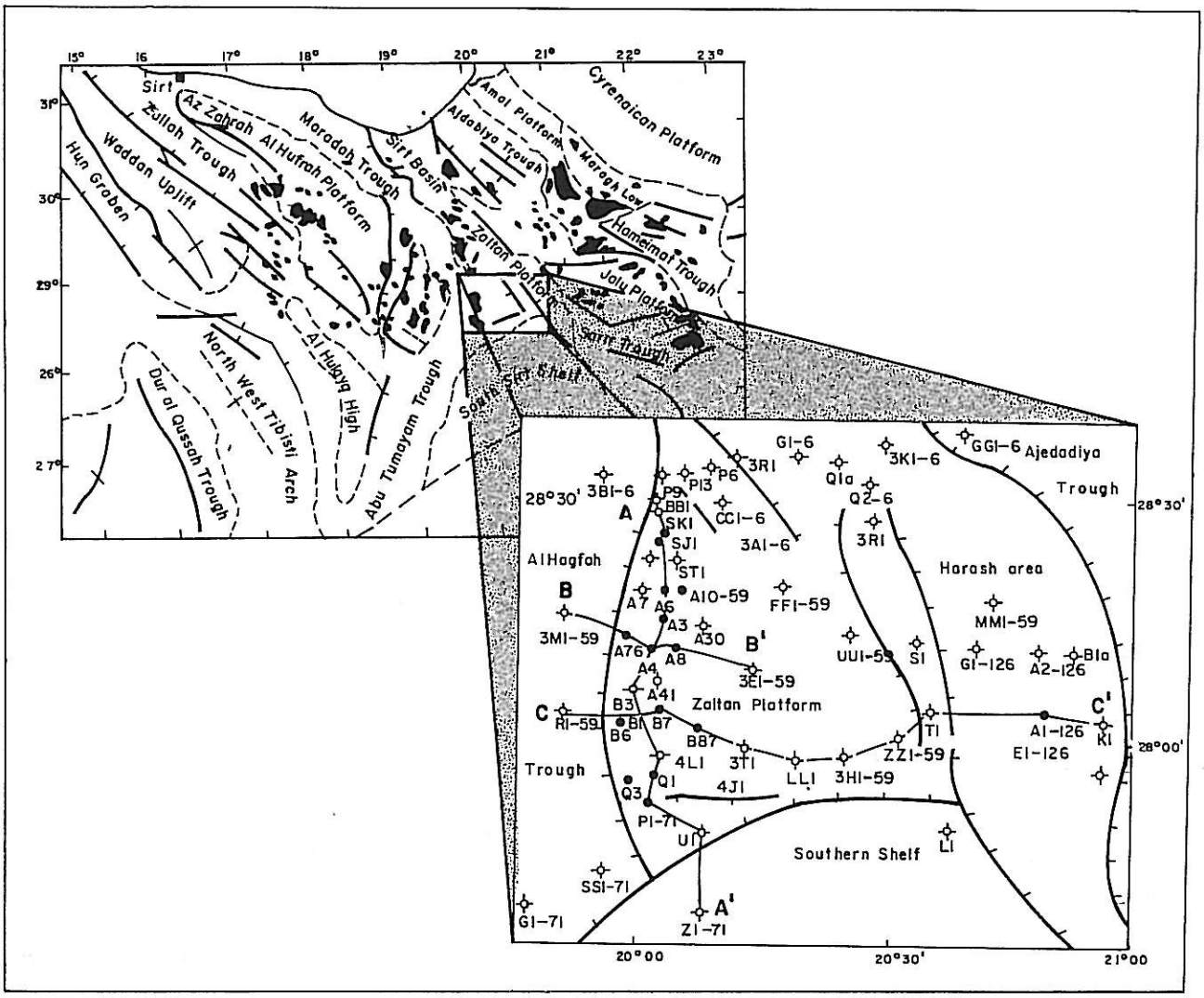

Fig. 1. Map showing the major tectonic elements and location of wells and cross sections in the studied area.

GEOLOGICAL SETTING AND STRATIGRAPHY

The Mesozoic and Tertiary sequences of the Sirt Basin were formed in a tensional regime with large-scale area of uplift and subsidence, associated with normal faulting and a noticeable absence of compressional folds. The absence of Upper Paleozoic and Lower Mesozoic sediments suggests that the area was domed, faulted and eroded during the Late Mesozoic (Lawson, 1988).

The widespread distribution of the Maastrichtian carbonate facies over much of the platform and basin areas suggests that the tectonics were relatively inactive during the Maastrichtian time (Gumati and William, 1985).

In the study area, the Zaltan platform has a NW-SE trend parallel to Al Hagfah trough. It gets wider towards the southern portion of the basin and is tilted down towards the east while the depth of the basement is comparatively deeper to the north (Fig.1).

The geological history of the Sirt Basin, during the Upper Cretaceous period, demonstrates that there has been a gradual onlapping over the fault - block topography by marine sediments. At the very end of the Late Cretaceous, almost all the topographic eminencies were completely buried and shale and carbonates were deposited during the Late Cretaceous time. Abrupt lateral facies changes are apparent from Platform areas toward the deeper troughs along with steep down dip thickening (Fig. 2). Contemporaneous faulting along structural elements and normal step faults probably assisted these conditions.

The regional geological setting and distribution of the Upper Cretaceous sediments is illustrated (Figs. 3 -12). Figures 11,12 and 13 exhibit the relationship between the sedimentary patterns and structural features of the central part of the study area.

PALAEOGEOGRAPHICAL DISTRIBUTIONS AND DEPOSITIONAL HISTORY

Pre-Upper Cretaceous

Nubian Sandstone

The term Nubian Formation or Nubian Sandstone was first applied for a widespread, non-marine sandstone sequence that is well exposed in Nubia, in the Nile Valley of Upper Egypt. Nubian Sandstone was used informally in Libya to cover a broad group of poorly dated detritus sediments representing a major clastic body that had shaped the pattern of distribution and thickness in the study area (Figs.3 and 4). The Nubian Formation in the Sirt Basin was divided into three members namely an upper sandstone member, middle shale and lower sandstone member (Abdulgader, 1996). These continental deposits reach a thickness of more than 800 feet in well P1-71. It unconformably overlies the basement on the eastern - side and south-central part of the Zaltan platform and is absent in the basement palaeohigh of Al Wahah - Ad Deffah ridge (Fig. 4).

Thick sequence of Nubian Sandstone is widespread, over the south and east of Ad Deffah, Al Wahah and Al Harash areas, and extend to the south of Ad Deffah area, which fill a large graben at wells P1-71 and U1-71 (Fig. 4). The Lower and Upper Sandstone members represent fluvial sedimentation that has taken place under regressive conditions

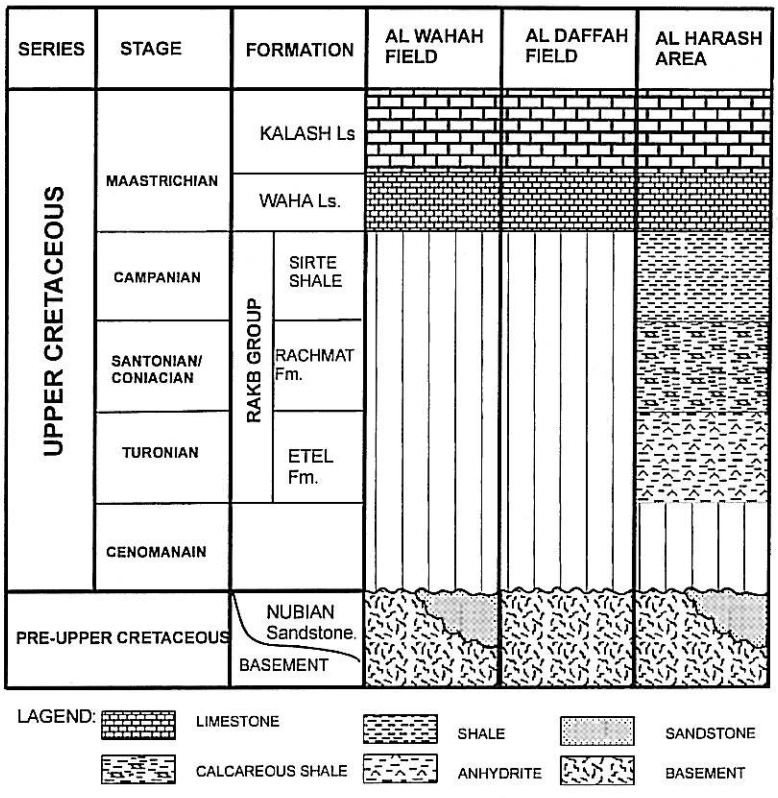

Fig. 2. General stratigraphy of the study area.

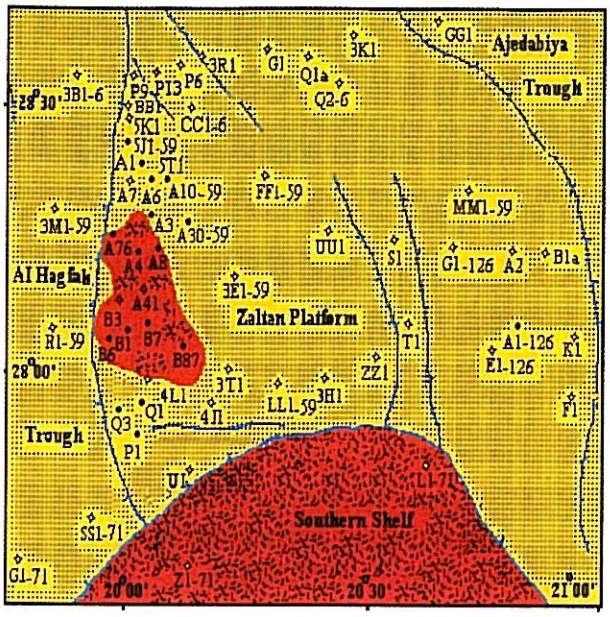

Fig. 3. Palaeogeographic map of pre-Upper Cretaceous sandstone in Zaltan platform.

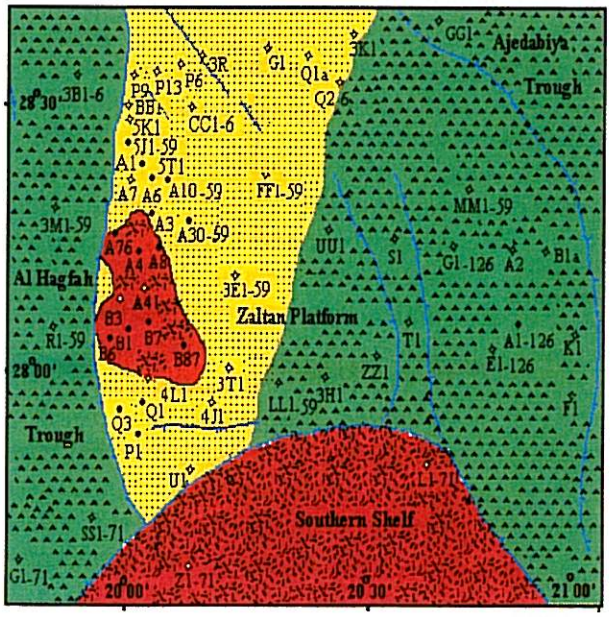

Fig. 4. Palaeogeographic map of Etel Formation in Zaltan platform.

(El-Hawat.1996). On the other hand, Middle Shale Member may represent deposition in lagoon during the time of maximum sea level rise or still- stand stage.

During the Cenomanian time, shallow restricted platform deposits (Lidam Formation) represent the first marine transgression episode that was related to a global rise of sea level and tectonic subsidence. Locally over the central parts this shallow restricted platform deposits onlapped the continental clastic of Nubian Formation.

Upper Cretaceous

Rakb Group

Etel Formation (Turonian Age):

Barr and Weegar (1972) introduced the name and the type section, which is located in the subsurface in well O2-59. The formation is widespread across the study area and its thickness increases gradually from 50 feet at well LL1-59 up to 330 feet at wells U1- 59 and ZZ1-59. It reaches more than 1365 feet at the Al Hagfah and Ajdabiyah troughs, but it is absent on the regionally high areas of Al Wahah and Ad Deffah field areas (Fig. 4). Lithologically it is composed of Anhydrite interbedded with dolomitic limestone, shale and sandstone. The upper contact is placed at the top of the anhydrite below the shale or carbonates of the Rachmat Formation (Fig. 2), which conformably overlies the Etel Formation. In the Zaltan platform, the Etel Formation is transgressive over older formations and unconformable overlies the Nubian Sandstone. It becomes slightly less restricted in the eastern side of the study area where the dolomite rocks are commonly interbedded with anhydrite, southward the Turonian Etel sequence bordered by the basement palaeohighs, is known to geologists as the southern shelf. In general, the Etel Formation is deposited in arid climatic, shallow water restricted platform and subtidal and intertidal with low energy protected environment (Fig. 9).

Rachmat Formation (Santonian / Coniacian)

The Rachmat shale, according to Barr and Weegar (1972), contains Santonian - Coniacian shales and its type section was located in well O2-59. It's thickness in the Zaltan platform ranges between 120 to130 feet in wells ZZ1-59, 3H1 and LL1-59. It gets thicker towards the east in the deep trough area and, is absent on the ridge of Al Wahah and Ad Deffah areas (Fig. 5).

In the study area, the lithology of the Rachmat Formation consists of dark gray green shale with minor limestone, sandstone and occasional dolomite interbeds in the lower part (Barr and Weegar, 1972). The lower boundary is conformable with the Etel Formation and the upper boundary is conformable to disconformble with the Campanian - Maastrichtian Sirte Shale (Fig. 2). The overall distribution of the pre-existing palaeohighs during Santonain-Coniacian time was similar to that of the Turonian time, except

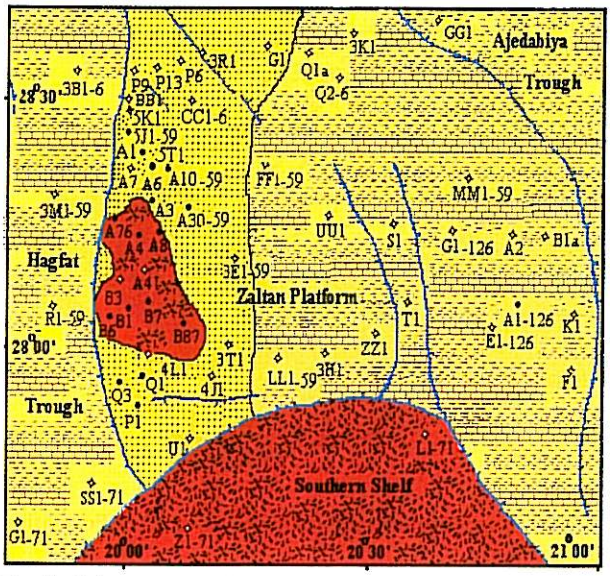

Fig. 5. Palaeogeographic map of Rachmat Formation.

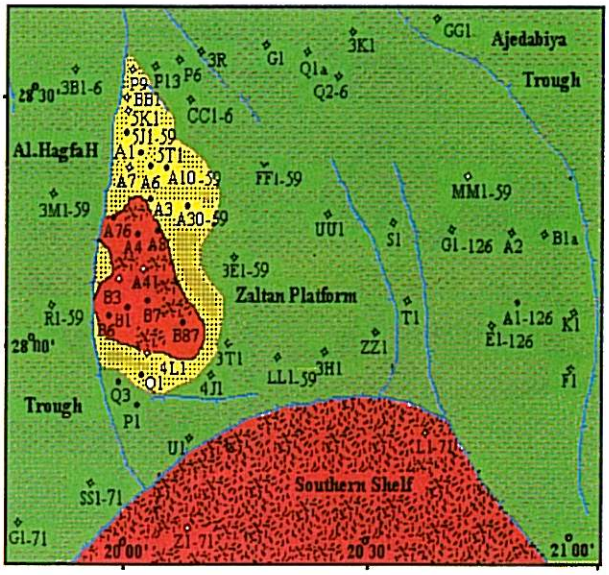

Fig. 6. Palaeogeographic map of Campanian Sirte Shale in Zaltan platform.

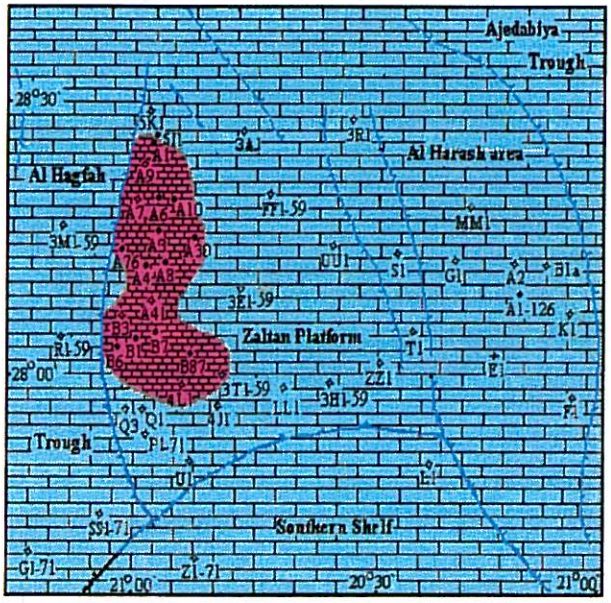

Fig. 7. Palaeogeographic map of Maastrichtian Waha and Kalash formations.

that the Rachmat Formation was deposited in less restricted conditions where carbonate and shale predominated. It is encountered in the wells drilled in the central area of the Zaltan platform and also in Al Hagfah and Ajdabiyah troughs (Fig.10). A gentle gradual thinning westward toward the Al Wahah - Ad Deffah ridge suggests the existence of a gentle slope shelf during the deposition of the Rachmat Formation.

Sirte Shale (Campanian):

The Sirte Shale is dominantly a shale sequence with thin limestone interbeds. It attains an average thickness of about 270 feet and increases towards the eastern part of the Zaltan platform. In the western portion of the study area it is getting gradually thinner towards the regional high of Al Wahah and Ad Deffah field area (Fig. 6). It conformably overlies the Upper Cretaceous (Santonian/Coniacian) Rachmat Formation and in the northeastern part of the study area, the Sirte Shale grades laterally and overlies the Pre- Upper Cretaceous continental sandstone. The upper boundary is conformable with the Maastrichtian Kalash Limestone (Fig. 2). At the close of Santonian and the beginning of Campanian time Al Wahah and Ad Deffah ridge remained subareally exposed separating the Ajdabiyah trough to the east from Al Hagfah trough to the west at an early stage of their subsidence. Widespread gradual transgression extended shale deposition covering the area of study except at the regional highs (Hammuda, 1980).

Shallow restricted environmental setting dominated the whole region of the central basin in the Zaltan platform and deposited thick sequences of Sirte Shale in the Al Hagfah, Ajdabiyah troughs. This shale is interpreted as shallow restricted platform that is characterized by the dominance of dark - grey shale and sandy limestone in the lower part.

Waha and Kalash Limestone (Maastrichtian)

The Waha Limestone exhibits its maximum thickness at well A76-59 along the margin of the Al Wahah and Ad Deffah areas of the Zaltan platform and thins towards the northern and southern parts of the Zaltan platform. In other places it overlies the basement rocks

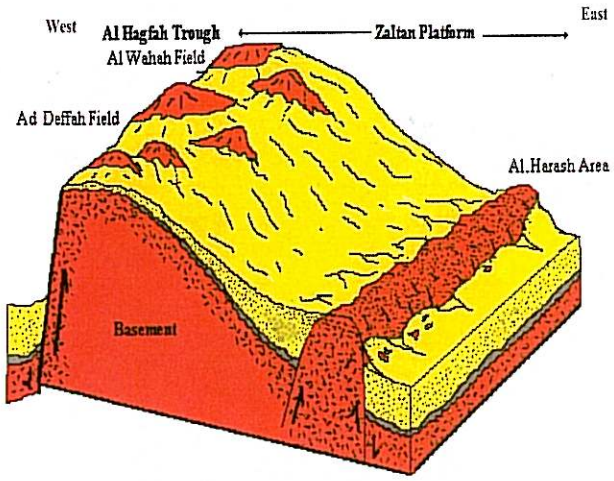

Fig. 8. Depositional model of pre-Upper Cretaceous sandstone (schematic).

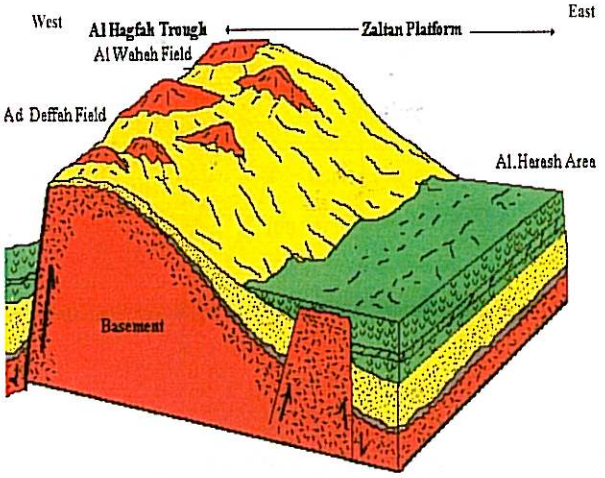

Fig. 9. Depositional model of Turonian Etel Formation (schematic).

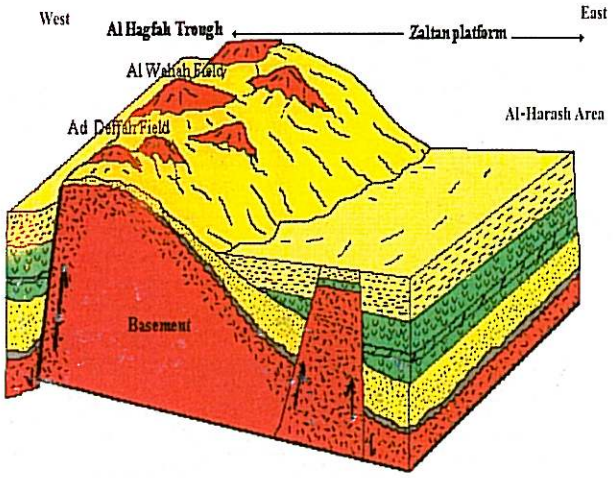

Fig.10. Depositional model of Santonian / Coniacian Rachmat Formation (schematic).

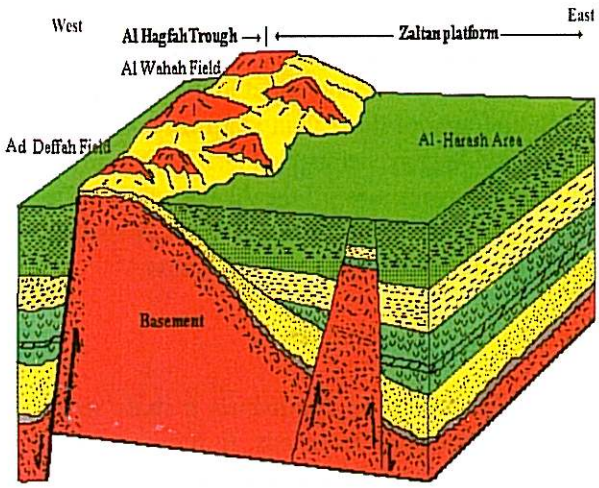

Fig. 11. Depositional model of Campanian Sirte Shale (schematic).

and is conformably overlain by an unusually thinly developed Maastrichtian Kalash Limestone (Figs.13, 15). In Ad Deffah field area, Defa Limestone overlies the Waha Limestone; the latter is underlain by the basement rocks (Fig.13). It ranges in thickness from 145 feet to 200 feet in Ad Deffah field area at wells B1, B2, B7 and B87-59. Widespread distribution of the Maastrichtian Waha carbonate facies over much of the Zaltan Platform and surrounding areas suggests that tectonics were relatively inactive during the Maastrichtian (Hammuda, 1980). (Figs. 7 and 12).

In the southern part of the Zaltan platform, Waha Limestone is the principal reservoir in Al Wahah field (Fig.15). Here it is composed of a skeletal calcarenite onlapping the structurally high area and was subjected to winnowing, creating excellent reservoir conditions. It is restricted to the platform areas because of its shallow - water, high- energy depositional environment. (Wenneker *et al*, 1996).

Kalash Limestone is widely recognized over much of the Sirt Basin and is well defined in its type section at well E1-57. It is conformably overlies the Sirte Shale and Waha Limestone and it is overlain by Paleocene Hagfa Shale or Lower Sabil Carbonates. Abundant foraminifera fauna defined its age and indicated that the kalash Limestone was deposited in an open sea, probably neritic conditions during Maastrichtian age. Because of its widespread distribution it has characteristic signature on the wire line logs. For this reason it was used as the datum line on the top of Kalash Limestone. Towards the south, the Kalash Limestone is distal, more shaly and it onlaps the southern shelf and gradually disappears through non-deposition (Wenneker *et al*, 1996).

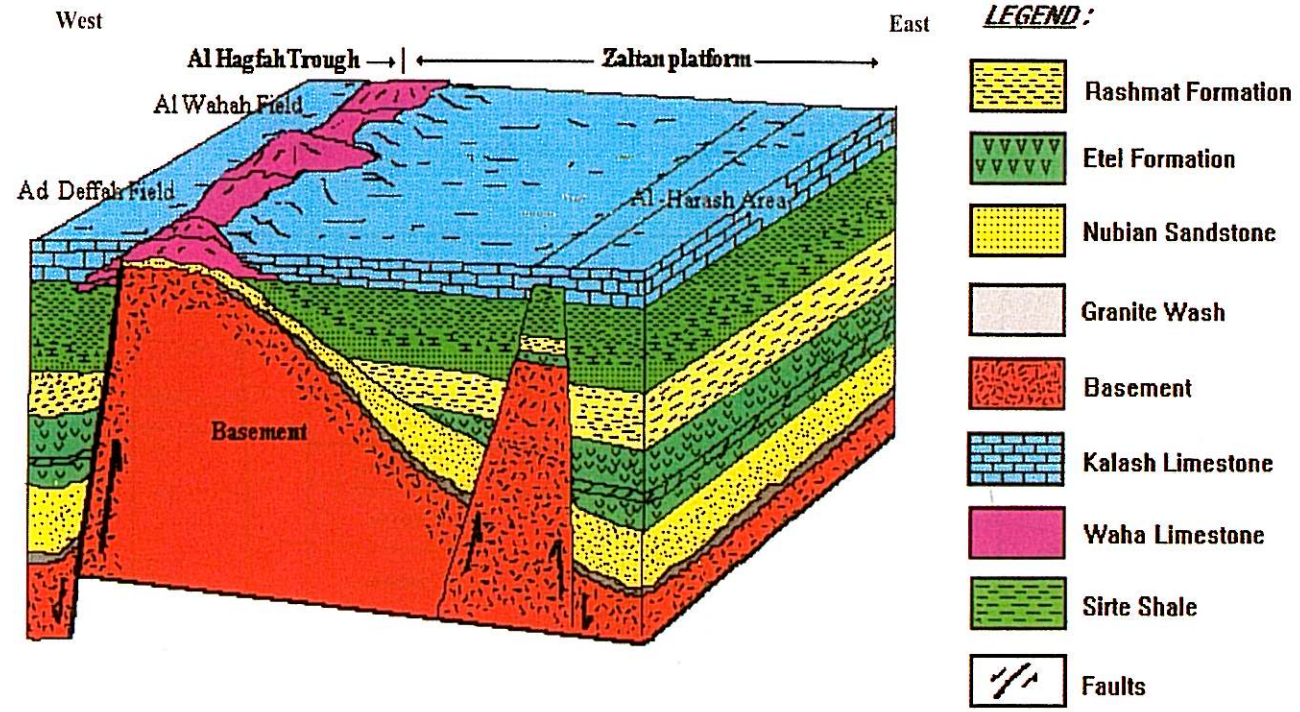

Fig. 12. Depositional model of Maastrichian Waha and Kalash formations (schematic).

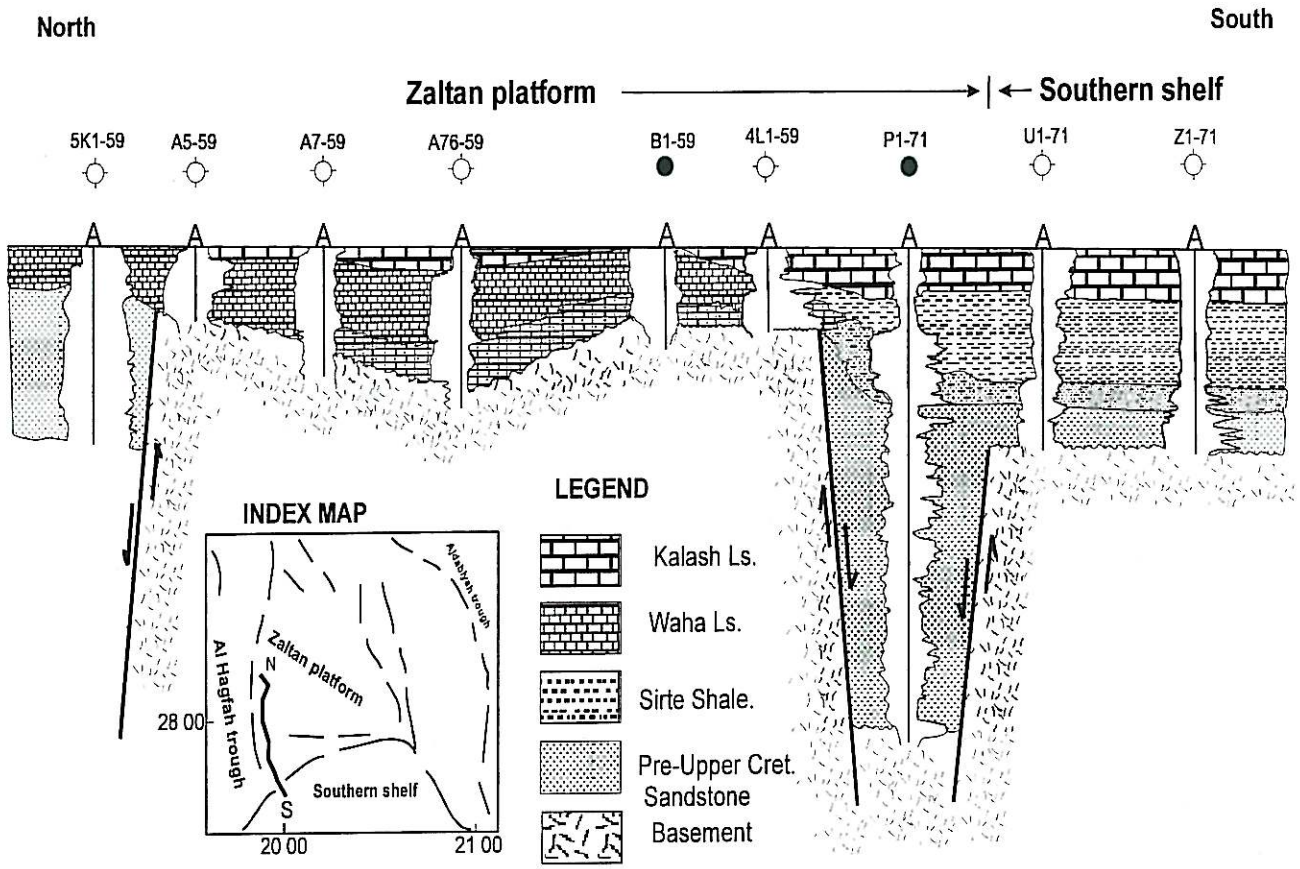

Fig. 13. N-S structural cross-section over Zaltan platform.

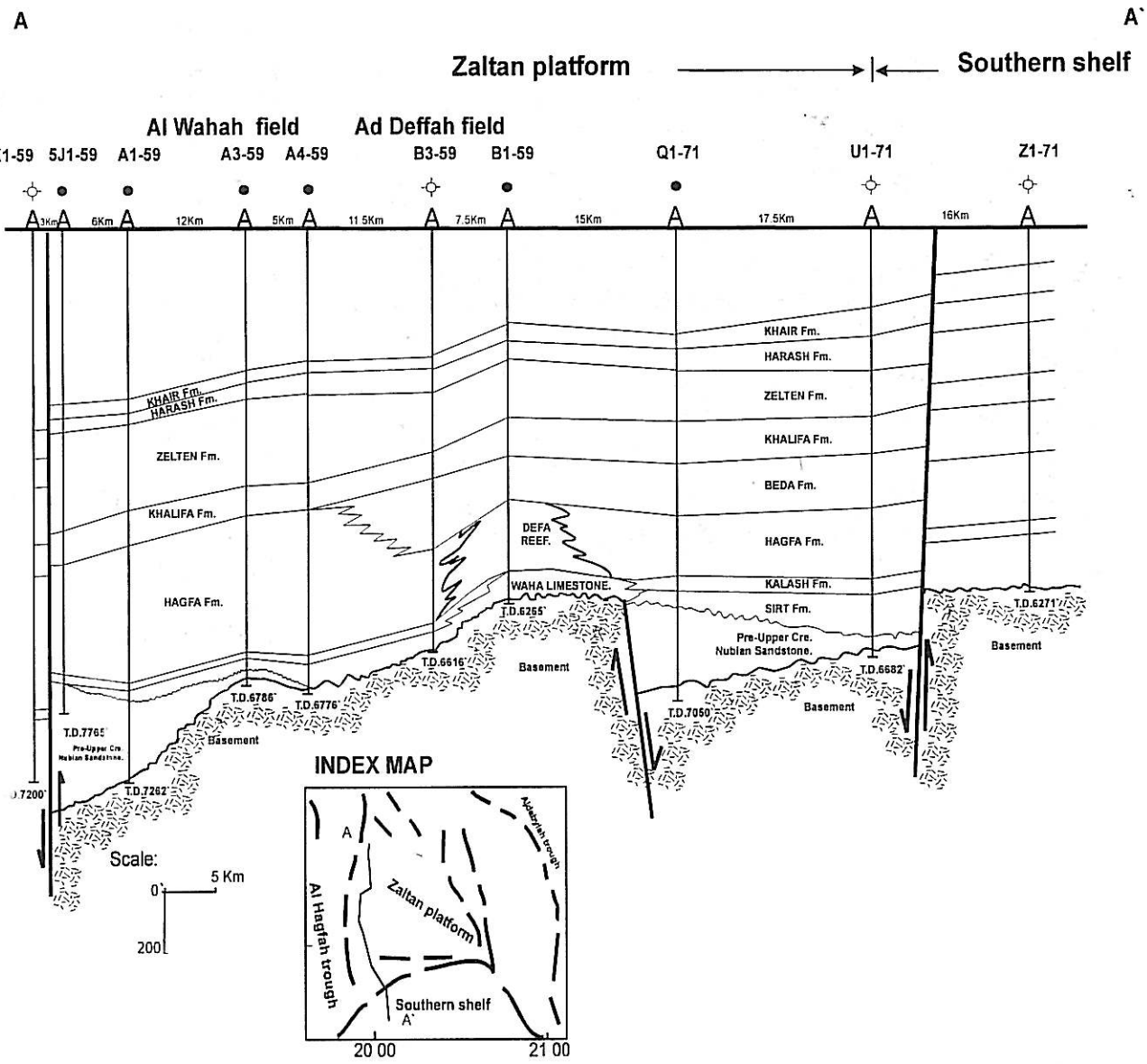

Fig. 14. Cross-section across Al Wahah and Ad Deffah fields, Zaltan platform.

DISCUSSION AND CONCLUSION

The distribution of the lithostratigraphic rock units was related mainly to the palaeogeography of the pre-existing topography. They are: Pre-Upper Cretaceous sandstone, evaporitic Turonian Etel Formation, Coniacian / Santonian Rachmat Formation (shallow open marine, slightly protected). Campanian Sirte Shale (shallow restricted platform). Maastrichtian Waha Limestone (shallow carbonate platform). The Paleocene and Eocene sequences comprise Hagfa Shale, Beda and Khalifa formations, Zeltan Limestone, Harash and Khier formations.

Shales and carbonates were deposited during all stages of the Upper Cretaceous as a lateral time equivalent facies. It was developed in the western palaeotopography high of the Zaltan Platform area towards the deeper trough, east of the Harash area. Contemporaneous faulting assisted the thickening.

During the Upper Cretaceous time southward advancing seas, encroached gradually on the Al Wahah and Ad Deffah areas which remained emergent until the end of Early Campanian time.

At the close of Santonian stage, the Zaltan platform remained subaerialy exposed separating the Ajdabiyah trough to the east from the Al Hagfah trough to the west at an early stage of their subsidence. The area of Al Wahah and Ad Deffah fields existed at this time as an island or peninsulas surrounded by Pre-Upper Cretaceous sandstone (Nubian Sandstone) which was

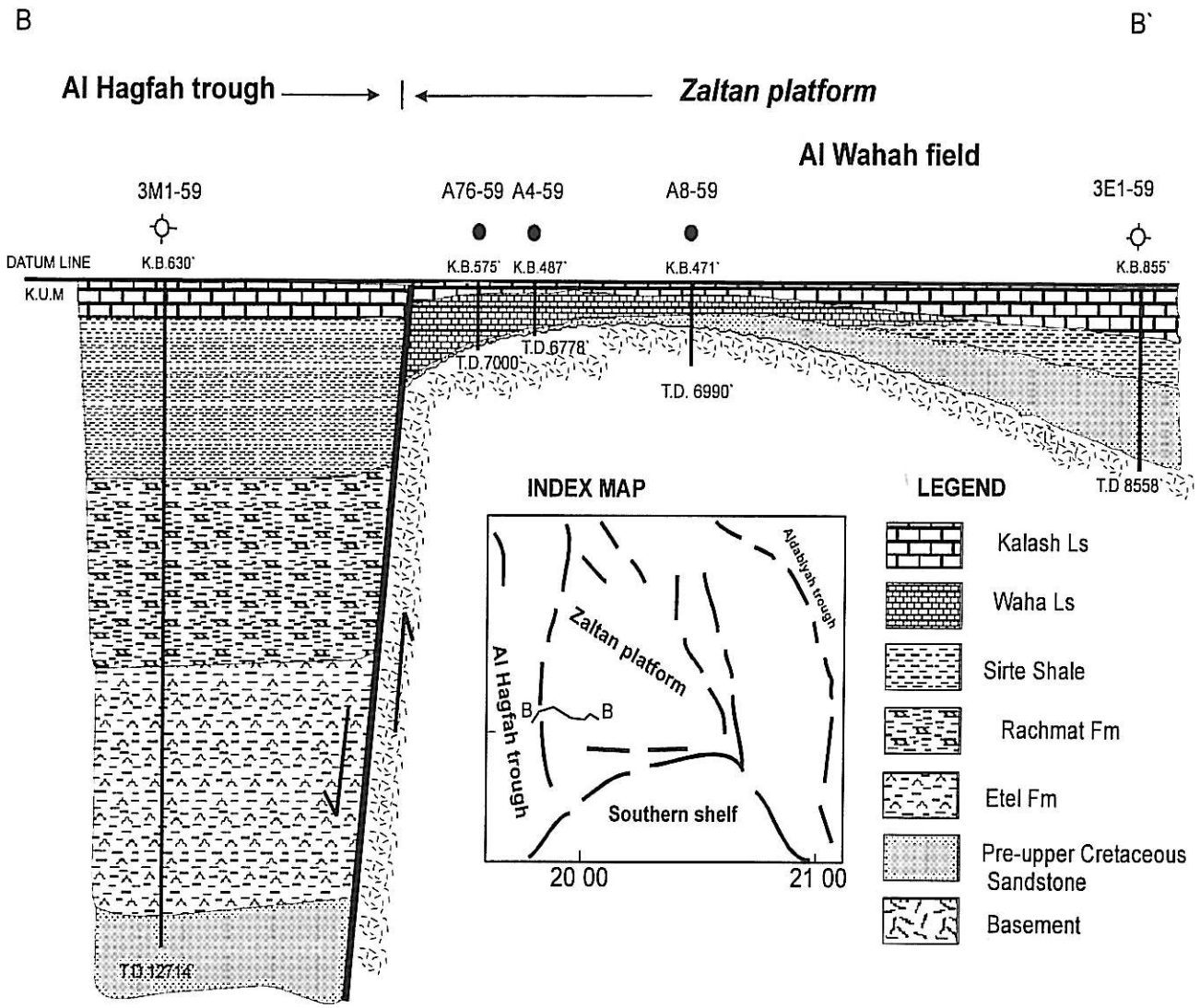

Fig. 15. Cross-section across Al Wahah field, Zaltan platform.

deposited east of Ad Deffah-Al Wahah area and south of Ad Deffah field. Furthermore, seas advanced toward the south at the Early Campanian stage resulted in a sea connection between Ajdabiyah and Al Hagfah troughs.

During Late Campanian and Early Maastrichtian times seas transgressed over Ad Deffah - Al Wahah ridge and reworked pre-existing sands from high areas and redeposited them as marine shoreline calcareous sands.

During Maastrichtian time the sea continued to transgress southwards onto the peninsula until Al Wahah ridge was separated from Ad Deffah ridge forming two separate islands, while the carbonate belts around them grew narrower as the sea got too deep for carbonate precipitation. Rudist carbonate facies developed on the highs. These deposits are well known as Waha reservoir facies in this area.

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REFERENCES

Abdulgader. G, 1996. Sedimentology and reservoir heterogeneities of the Nubian Formation, south eastern Sirt Basin, Libya. In: *Geology of Sirt Basin*, **II**. 223- 249. Elsevier, Amsterdam.

El Hawat, Ahmed. S ,1996. The Nubian sandstone in Sirt Basin and its correlatives. In: *Geology of Sirt Basin*, **II**. 3 - 30. Elsevier, Amsterdam.

Barr. F. T and Weegar, A, 1972. *Stratigraphic Nomenclature of the Sirte Basin, Libya.* Publication of Petroleum Exploration Soc. Tripoli, Libya, P.179

Bergig. K. A ,1991. *Al Wahah Oil Field, Case History.* Unpublished report, *Petroleum Research Centre*, Tripoli, Libya.

Butt. A. A, 1986. Upper Cretaceous biostratigraphy of the Sirt Basin, Libya. *Revue de paleobiolgie,* **5**(2) 175-191.

Gumati Y. D. and William. H, 1985. Early Tertiary subsidence and sedimentary facies - northern Sirte basin, Libya. *Am. Assoc. Petrol. Geol.* **69** No.1. 39- 52.

Hammuda. O. S, 1980. Sediments and palaeogeography of the Lower Campanian sand bodies along the southern tip of Ad Deffah -Al Wahah, Sirt Basin. *In: Symposium on the Geology of Libya* Tripoli, Libya, 509-520, London Academic Press.

Lawson. W. G, 1988. *Progress Report On North Al Wahah And Al Wahah Field Areas*, (internal report), *Waha Oil Company,* Libya. 23 p.

Wennekers J. H, Wallace F. K. and Abugares. Y. I. 1996. The geology and hydrocarbon of the Sirt Basin: *Synopsis. In: Geology Sirt Basin.* **II**, 3–56, Elsevier, Amsterdam.