SUBSURFACE STUDY OF THE PRECRETACEOUS REGIONAL UNCONFORMITY IN THE WESTERN DESERT OF IRAQ
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ABSTRACT

The Cretaceous units in the Western Desert of Iraq lie unconformably on the Jurassic, Triassic and Paleozoic units with a break in sedimentation that lasted from 30 to 200 m.y. This paper is concerned with the morphology, paleogeography, structure and mineralization potential of this regional unconformity. The study was based on surface and subsurface data, including deep wells, geological surveys and geophysical surveys.

The results show a highly irregular surface at the base of the Cretaceous units. The western part is a plateau which descends rapidly towards NE and E with an elevation difference of up to 4 km. A remarkable elongated positive zone exists in the west extending from SW to NE and coincides with the course of Wadi Horan on surface. The deepest parts of the unconformity surfaces are found in the Anah and Nukhaib grabens. The morphology of this erosional surface was structurally controlled; the western part was subjected to continuous uplifting since the Early Jurassic, whereas the grabens in the NE and E were activated in the Cretaceous. The morphology of this unconformity surface played a decisive role in controlling the paleogeography and basin configuration during the Cretaceous and Early Tertiary times. Moreover, the unconformity is a potential target for laterite development in favourable traps during wet periods in the Early Cretaceous.

Introduction

The aims of this study include construction of the subsurface morphology, structure, geology, mineralogenesis and paleogeography of the Cretaceous with older rocks erosional contact in the Western Desert of Iraq (Fig. 1) The study is based on data obtained from surface geological mapping (Jassim et al., 1990, Qassim et al., 1992, Qassim et al., 1993 and Al-Azzawi et al., 1996), deep wells for hydrogeological exploration (Blocks 4, 5 and 7) and for oil exploration (Oil Exploration Co., Iraq), aeromagnetic surveys (C.G.G., 1974), seismic surveys (Oil Exploration Co., Iraq) and satellite image interpretation (Al-Amiri, 1978). More than 230 documentation points from various sources (Fig. 2) were used to construct the following maps: structural contour map on the base of the Cretaceous
(Fig. 3), subsurface geological map of the unconformity surface (Fig. 4), isothickness map of the sedimentary cover overlying the unconformity surface (Fig. 5) and structural elements map of the area (Fig. 6).

The lineaments intersection density map (Fig. 7) prepared by Al-Amiri (1978) from LANDSAT image interpretation and the groundwater piezometric map prepared by Parsons (1957) were also used to support the results of this study. The potential laterites development in certain parts of the area was discussed and a model was prepared (Fig. 8). The paleogeographic development of the area from Late Triassic to Paleogene was updated on the basis of this study (Figs. 9-14). This work was conducted in the State Co. of Geological Survey and Mining as part of its research programme.

**Morphology of the pre-Cretaceous unconformity surface**

The erosional surface which marks the base of the Cretaceous units in the studied area is morphologically irregular with an elevation difference of about 4 km. (Fig. 3). The highest points (relative to sea level) are found in the SW (about 650 m. above sea level) forming an elongated SW-NE elevated zone generally coinciding with the course of Wadi Horan on surface and will be referred to as the Horan High in this paper. On the other hand, the lowest points are found in the NE part, within the Anah Graben (about 3400 m. below sea level in Anah well no. 2).

Generally, the unconformity surface descends from west to east. The highest slope is found in the NE part of the area (towards Anah Graben) reaching up to 10 m/km. The slope is gentler in the western part of the area, not exceeding 4 m/km (south of Rutba). In addition to these morphological features, there are two shallow depressions in the N and NE parts of the area, which were previously identified as the Damluk and Tinif troughs (Al-Bassam and Karim, 1992). They bound an elevated zone extending from Ga’ara towards west which was identified by the same authors as the Akashat platform.

The movement and isopiezometry of the groundwater in the shallow aquifers were studied by Parsons (1957) and by Arai (1990). It is interesting to note that the general direction of movement is from west to east with a remarkable water divide coinciding approximately with the Horan High. The groundwater movement is to the east in the eastern flanks of this zone and to the northwest in the western flank. The shallowest levels
of groundwater are found at this water divide, which correspond to the morphology of the pre-Cretaceous surface in this part of the area. A similar water divide was identified by Araim (1990), but not shown on Parsons map, which coincides with the Akashat platform.

Subsurface geology of the unconformity surface

The pre-Cretaceous subsurface geological map (Fig. 4) represents the geology of the pre-Cretaceous erosional surface where the Cretaceous units were laid down. It consists of Paleozoic, Triassic and Jurassic units.

Paleozoic units:- They cover the northern and southwestern parts of the area. The oldest of these units is Al-Tawil Formation (Devonian) which was found underlying the Late Cretaceous units in Al-Jalamid area, NW Saudi Arabia (Riddler et al., 1985). In the northern part of the area the Cretaceous units are underlain by Devonian-Carboniferous units (Swab well no. 1 in Syria), followed southward by Early Carboniferous units (Akas well no. 1 in Iraq), followed by Permocarboniferous units (Ga’ara and Wadi Swab in Iraq and Tinif well no. 1 in Syria).

The distribution of the Paleozoic units in the area indicates that they dip towards SE in the northern part, but little is known about the dip in the southern part. However, the general configuration suggest a synclinorium with an E-W axis passing in the middle of the area from Rutba to Traibeel.

Late Triassic units:- These are represented by the Mulussa and Zor Hauran formations. They were deposited after a break in sedimentation which lasted through the Early Triassic. The Late Triassic units were found underlying the Cretaceous units in all the subsurface sections south of Rutba-Amman highway, as well as in the Risha wells of Jordan. The truncation of the Paleozoic units by the younger Late Triassic units in the area (Fig. 4) suggests an angular unconformity between the two, which may be related to the movements associated with the initiation of the old Tethys. The dip of the Late Triassic units, shown in exposed sections is towards SE in the area south and east of Ga'ara depression, but little can be deduced about the dip of these units in subsurface.

Jurassic units:- Early, Middle and probably Late Jurassic units cover the pre-Cretaceous unconformity surface in the eastern part of the area (Fig. 4). They are found in exposed and subsurface sections; older units in the west and younger units in the east, having a general NE-SW strike and dip towards SE. They were intersected in all subsurface sections east of Rutba,
in the area south of Rutba-Km 160 highway, as well as east of Wadi Horan north of the highway. They are represented from older to younger by Ubaid, Hussainiyat, Amij, Muhaiwir and Najma (?) formations. The Jurassic units are missing in the western part of the investigated area.

Geology of the overlying units

The unconformity surface is overlain by Early Cretaceous (Aptian-Turonian) units in the area east of Rutba and east of Wadi Horan, exposed by two clastic-carbonate units (Nahr Umr-Ma'uddud and Rutba-Ms'ad formations). In the western and northern parts of the area however, the overlying units are of Late Cretaceous age or of Paleogene age. The longest gap exists in the eastern rim of the Ga'ara depression, where the Ga'ara Formation (Permo-carboniferous) is overlain directly by the Ratga Formation (Eocene). The Late Cretaceous and Paleogene units are of marine origin throughout. The former are expressed here by the Hartha, Tayarat and Digma formations (Campanian-Maastrichtian). The Shiranish Formation was encountered in the Anah and Nukhaib grabens (subsurface sections). A gap exists between Early and Late Cretaceous units which includes the Coniacian, Santonian and probably part of the Turonian. Furthermore, the Late Cretaceous units were laid down with an angular unconformity; they generally dip toward N and NW in the western part of the area and toward E and SE in the eastern part. This angular unconformity may be related to the movements associated with the opening of the New Tethys.

The Paleogene units expressed here by the Akashat, Umm Er Rsdhuma, Ratga, Dammam and some Oligocene formations cover most of the area, except along the axis of the Horan High where they are missing. Some Neogene units are exposed in the E and NE parts of the area, such as the Euphrates and the Nfayil formations.

It is worth noticing that the Late Cretaceous and Paleogene formations have different facies on each side of the Horan High. Digma, Akashat and Ratga formations are dominant in the western side, whereas Tayarat, Umm Er Radhuma and Dammam formations are dominant in the eastern side. The former are open marine, phosphrite-bearing units and the latter are reef, back-reef or lagoonal units in general.

 Thickness distribution of the overlying Cretaceous and Tertiary units

The Pleozoic, Triassic and Jurassic units are unconformably overlain
by variable thicknesses of Cretaceous and Paleogene units except in the Ga‘ara depression and the area to the east of it (the Jurassic Plateau) where older units form a window caused by erosion or non-deposition of the younger units. The isothickness map of the units overlying the pre Cretaceous unconformity (Fig. 5) shows thickness variation from zero to 1100 m. in the NE Prt of the area, increasing to 2000 m. in Anah well no. 1 and to about 3700 m. in Anah well no. 2. In the southern part of the area, the thickness of these units reaches to about 800 m. near the Nukhaib Graben. The thickness decreases drastically to 0-200 m. only along the axis of the Horan High where the Paleogene units are missing. It is also small on the Akashat Platform; not exceeding 100 m.

The thickness variation of the Cretaceous and Tertiary units conforms fairly well with the morphology of the underlying unconformity surface. Thicker sediments were laid down in the depressed zones and thinner sediments are found in the elevated parts. Moreover, some basinal units of Late Cretaceous age were encountered in the grabens of Anah and Nukhaib expressed by the Shiranish Formation. This indicates that the Cretaceous basin was much the same as the morphology of the underlying pre Cretaceous surface, at least in the Late Cretaceous time. The initiation and development of the Anah Graben is believed to have taken place sometimes in the Late Cretaceous (Fouad, 1997) and subsidence in the graben was contemporaneous with deposition, which allowed for the huge Cretaceous sedimentary column to develop in that area.

**Structural elements of the sedimentary cover**

The area has been influenced by many tectonic events that resulted in several fault systems, horst and graben structures, tilting of strata and uplifting. The structural development of the area has influenced the paleogeography, basin configuration and sedimentary regime throughout its geological history and appear to have played the main role in the morphological development of the pre Cretaceous unconformity surface.

The available field data show that the Paleozoic units dip towards S and SE and the Triassic, Jurassic and Early Cretaceous units dip towards SE. The Late Cretaceous and Paleogene units dip in the western part of the area towards N and NE (Ga‘ara-Syrian borders-Anah) and to the NW and W south of Rutba-Amman highway. In the eastern part of the area they dip towards SE, E and NE.
The structural elements map (Fig. 6) was prepared in this study on the basis of aeromagnetic survey (C.G.G., 1974), satellite image interpretation (Al-Ameri, 1978), surface geological mapping (Al-Mubarek and Amin, 1983, Buday and Jassim, 1984, Al-Azzawi et al., 1996) and gravity survey (Al-Kadhimi and Fttah, 1994). Several fault systems were recognized in the sedimentary cover:

**N-S faults:** These are believed to have originated by the rejuvenation of old fault lines in the basement related to the Hijaz Orogeny (faults no. 1-6). Some of these faults have contributed to the development of the Nukhaib Graben.

**NW-SE faults:** These faults, well expressed on surface, are believed to have originated along the old fault lines of the Najid Orogeny in the basement. They are especially expressed in the Horan area (faults no. 7-18). They are normal faults forming horsts and grabens and are 10-30 km. Long. Their influence is restricted to the Early Cretaceous and older units. These faults are younger than the N-S fault system. The reactivation of this system of faults seems to have taken place during the Late Kimmerian Orogeny.

**E-W and NE-SW faults:** The NE-SW fault system is the youngest in the area and may be related to the Late Cretaceous Laramide movements, which may have reactivated the older E-W fault system in the area. There are nine faults in the direction E-W (faults no. 22-30). The E-W fault system have contributed to the development of the Anah Graben in the NE part of the area, as well as the Damluk and Tinif troughs and the rapidly descending basin in the direction of Anah Graben via a series of normal step faults.

The lineaments study, based on LANDSAT image interpretation, resulted, among other things, in the construction of a lineaments-intersection density map (Fig. 7), which was prepared by Al-Amiri (1978). The map shows that the highest density of lineaments intersections is found mainly in a zone coinciding with the Horan High and extends from the Iraqi-Jordanian-Syrian borders in the SW to the Ga'ara depression in the NE and extends further to Qasr Muhaiahir. Al-Amiri (1978) concluded that this zone has a high potential for groundwater resources in view of the high secondary porosity and permeability of the Late Triassic carbonate units caused by the high density of fractures and faults intersection. Such features may also represent a potential area for karstification when favorable conditions prevail. A good example of such phenomenon is the
highly karstified zone of NE Hussainiyat (Fig. 7), near Qasr Muhaiwir, where the karst -bauxite deposits were developed. Such karstification is expected in the Mulussa and Zor Hauran carbonates (in subsurface) west of Rutba on the basis of similarity of lineaments-intersection density. Furthermore, the high lineaments-intersection density reflects active uplifting of the area; a conclusion reached by Al-Amiri (1978) who called this zone as the "Horan Anticline".

Minerogenic potential of the pre Cretaceous unconformity

The unconformity between the Cretaceous and older units lasted for considerale span of time during which the area was subjected to uplift and erosion under various climatic conditions. Numerous economic mineral deposits are known in the pre Cretaceous units exposed at the present-day land surface where Cretaceous units were not deposited or eroded (i.e Ga'ara and the Jurassic plateau east of it). Among these deposits are the kaolinitic claystone deposits and the sedimentary ironstone deposits of the Ga'ara and Hussainiyat formations and the heavy-minerals -bearing sandstones of the Amij Formation. The extension of these deposits in subsurface is expected below the Cretaceous and Paleogene cover where erosion could have provided fairly good aerial exposures before the Cretaceous units were laid down. Such extensions are expected west of the Ga'ara depression for the kaolinites and ironstones of the Ga'ara Formation and south of Rutba-Baghdad highway for the kaolinites, ironstones and heavy minerals sandstones of the Hussainiyat and Amij formations.

Apart of these pre Cretaceous mineral deposits, the Early Cretaceous deposits (not decisively found at the present-day surface) have a fairly good potential for stratiform Al- and Fe-type laterites development in subsurface. This potential is based on several facts and observations:-

1. The Barremian to Albian stages witnessed a tropical rain-forest climate in Iraq, based on palynological studies (Al-Amiri, 1994).

2. There are stratiform and karst bauxite deposits of Aptian age in Saudi Arabia and Syria (age ascertained by palynological studies) (Norris, 1980).

3. The NE Hussainiyat karst bauxites are believed to be of Aptian/Albian age (Al-Bassam, 1998).
4. Source rocks of suitable composition (kaolinitic claystones) were available in the older rock units (Ga'ara, Hussainiyat and Amij formations) which were exposed in the beginning of the Cretaceous period at topographically higher positions and could have been source areas for the Early Cretaceous continental sediments in lower areas.

5. Early Cretaceous continental deposits are expected to be preserved in the area south of Rutba-Km. 160 highway in view of the relatively gentle slope of the pre Cretaceous unconformity surface there (Fig. 8).

6. Field evidence on laterite formation (paleosols) exist at the contact between Cretaceous (Nahr Umr Formation-Albian) and older rock units (Al-Azzawi et al., 1996). Both Al-rich kaolinites with traces of bauxite minerals containing pisolites and pisolitic ironstones were found at the exposures of this contact in the area.

7. Topographic traps of structural origin (grabens) were available in the pre Cretaceous unconformity surface, having the same trend as that of the Anah Graben, but of much shallower character (Al-Bassam et al., 1999).

Subsurface karst bauxites are expected in the carbonates of the Late Triassic units (Mulussa and Zor Hauran formations) in the western and southwestern parts of the area (below Cretaceous and Paleogene cover) where maximum density of lineaments intersection was identified by Al-Amiri (1978). Kaolinitic source rocks were available in the Paleozoic units (especially the Ga'ara Formation) exposed in the Triassic and Jurassic times north of Rutba-Amman highway.

Favorable climatic conditions for laterization existed sometimes in the Late Triassic and Early Jurassic. There are clear evidence of a major event of chemical weathering at the close of Triassic and Early Jurassic in the Arabian Plate (Abed, 1979, Goldbery, 1979 and Valeton et al., 1983). This tropical weathering is reflected in the Western Desert of Iraq by the deeply weathered and highly karstified Ubaid Formation (Liassic), development of lateritic red beds in Arabia of Early Jurassic age (Abed, 1979) and the overwhelming presence of kaolinite and residual elements (Al, Fe and Ti) as well as the enrichment of Ga and absence of bases and alkalies in the laterites of the Hussainiyat Formation (Liassic) (Al-Bassam and Tmar-Agha, 1998).

**Paleogeography**

Marine and continental sediments covered the whole area of western
Iraq during the Paleozoic. Continental deposits, however, dominated the area in the Late Carboniferous and Permian, expressed as fluvial deposits of quartz-sand and kaolinitic clays (Tamar-Agha, 1986), filling a basin (flood plain) believed by Buday and Jassim (1987) to have originated from a N-S graben developed during the Hercynian movements. The climate was apparently warm and wet, evidenced by kaolinite as the dominant clay mineral and the frequent presence of ferricrete horizons (Blatt et al., 1980 and Tamar-Agha, 1986).

The Early Kimmerian movements resulted in the uplift of the area and tilting of the Paleozoic units; evidenced by the absence of the Early Triassic sediments in the area. However, the opening of the Old Tethys and related movements created a new paleogeographic setting where a marine basin was developed and marine deposits covered the whole area except the northern part (along the Syrian borders) where the area remained higher than sea-level at that time (Fig. 9). This positive land supplied clastics to the shallow parts of the Late Triassic sea (the clastics-rich facies of the Mulussa and Zor Hauran formations).

By the end of the Triassic period the influence of Horan High started to appear and control the paleogeography of the area. The western part, influenced by this positive zone, remained higher than the Jurassic sea level at all times (Fig. 10). The initiation of the Horan High, as a positive zone, coincided with the late stages of the Early Kimmerian movements. This positive zone extended throughout the western part of western Iraq and formed a source area for the Jurassic clastic units developed to the east of Horan High during sea regression episodes. Sea-level fluctuations in the Jurassic period resulted in several carbonate-clastics cycles. The Jurassic was shallow at all times in western Iraq (Hassan, 1984) and covered a gently inclined shelf. The climate was generally warm and arid except at certain intervals where wet climate prevailed evidenced by the lateritic ironstone and kaolinite deposits of the Hussainiyyat Formation (Al-Bassam and Tamar-Agha, 1998 and Al-Atia, 1999).

The Late Kimmerian movements at the end of the Jurassic were felt in this part of Iraq by a regional uplift coincided with a eustatic sea-level drop (Haq et al., 1987) and resulted in a regional break in sedimentation, erosion and exposure of the Jurassic, Triassic and Late Paleozoic units in the area. The first Cretaceous cycle in the studied area is probably of Early Barremian to Early Middle Aptian. The elevated parts of the area in the west were among the source areas that supplied clastics to the plain in the
east. The Arabian Shield in the south was another source area for the clastics in the Early Cretaceous (Buday, 1980).

Huge clastic sediments were transported at that time from the Arabian Shield and the elevated parts of the Stable Shelf evidenced by the Zubair Formation in southern Iraq. In the Early Aptian, shallow shelf marine carbonates were deposited on top of the Early Cretaceous clastics (Harris et al., 1984). The deposits of this cycle are expected to be found in subsurface in western Iraq, especially in the area south of Rutba-Km. 160 highway, forming the first (?) Cretaceous sediments in this part of the country. This cycle is capped in the Arabian Peninsula by a regional unconformity (Harris et al., 1984) that represents erosion or non-deposition and marks a significant lithological change from marine carbonates to clastic deposits. At that time the climate was wet and warm to very wet at intervals, evidenced by the formation of stratiform bauxites in Saudi Arabia and in Syria as well as the karst bauxites of Iraq; all are believed to be of Aptian age (Norris, 1980 and Al-Bassam, 1998). In addition to the palynological studies of Al-Amiri (1994) which revealed a rain-forest climate in samples from the Zabair Formation.

The Late Aptian- Turonian cycle is well defined in the Western Desert by two transgressive cycles of sandstone-carbonate, which covered the eastern parts of the studied area (Nahr Umr-Mauddud and Rutba-Ms'ad formations). The deposition of these cycles followed a period of subaerial exposure evidenced in the area by paleosols and ferricrete horizons at the contact between Nhar Umr and older units in exposed sections (Al-Azzawi et al., 1996). The sedimentation was inhibited in the western part of the area by the Horan High which remained a positive land during the whole of the Early Cretaceous and to the Early Turonian (Figs. 11 and 12).

The Late Cretaceous witnessed some remarkable events, following a depositional break that lasted throughout Late Turonian to Santonian. The slab-pull forces, due to the obduction of the Arabian Plate below Eurasia, resulted in the opening of deep grabens along old fault lines of E-W and NW-SE directions (Fouad, 1997). Marine transgression started in the Early Campanian (Hartha Formation) and covered the area except the elevated parts of Horan High. However, in the Late Campanian and specifically in the Maasrichtian, the whole area was submerged, except the Ga'ara and the Jurassic plateau east of it (Fig. 13). This time witnessed the first signs of the Tethyan phosphogenic event in Iraq, expressed as relatively thin
phosphorite horizons which remained restricted to the area west of Horan High suggesting open and free communication with the main Tethyan seabody. On the other hand, east of Horan High shallow and semi-restricted sea prevailed (frequently lagoonal).

The Horan High, though mostly submerged, acted as a basin-divide at that time with different marine facies on each of its flanks, especially during the Maastrichtian. The NE part of this elevated zone remained, however, a positive area of non-deposition to the end of the Cretaceous forming an island in the sea evidenced by the fluvialite clastics of the Marbat Beds (Late Cretaceous) in the Ga'ara depression (Al-Bassam et al., 1990). On the other hand, basinal units were deposited in the Anah Graben, which was a highly subsiding block in the Campanian and Maastrichtian (Fouad, 1997). The climate in the Late Cretaceous seems to have been warm and arid most of the time, as suggested by the dominant palygorskite and smectite clay minerals in the sequence.

The transgressive phase continued, after a short (?) hiatus, through the Paleogene, and the Horan High remained active in separating the depositional basin into an open marine in the west and northwest and shallow restricted marine (partly lagoonal) in the east. The main phosphogenic event in Iraq took place in the Paleocene, associated with remarkable high sea-level that brought basinal sedimentation to the shelf (Akashat and neighbouring areas). The Anah Graben was almost filled by sediments by the end of the Cretaceous, whereas the Tinif and Damluk troughs were still subsiding in the Paleogene, as evidenced by the frequent basinal facies (Aaliji and Jaddala facies) found in these depressed zones (Al-Bassam et al., 1990). However, two islands were probably still emerging at that time (Fig. 14).

The sea retreated after the Middle Eocene as a result of the uplift of the area and was restricted to the E and NE parts in the Oligocene and Miocene. The continuous subsidence in the Nukhaib Graben facilitated the deposition of some Pliocene and Pleistocene fresh-water deposits (Zahra Formation) in the depressed areas, unconformably overlying the Paleogene units (Al-Mubarek and Amin, 1983). The present-day landforms suggest that the Horan High is still active, as evidenced by the direction of wadis on both sides, and the high relief morphology of the land along its axis.

Conclusions

1. The Cretaceous units were laid down in western Iraq on a highly
irregular erosional surface with a relief difference of about 4km. The depositional break lasted from 30 to 200 m.y. The unconformity surface is characterized by an elevated zone in the western part (Horan High), initiated by the end of the Triassic and was further enhanced in the Late Cretaceous by the subsiding blocks in the northern and eastern parts of the area.

2. The thickness of the Cretaceous and Tertiary sediments in the area is highly variable (0-3700 m.). The variation in thickness is proportional to the morphology of the underlying erosional surface. This cover of sediments was encountered in the west, along the Horan High and thick sediments were deposited in the troughs.

3. The pre-Cretaceous unconformity surface and the overlying units are influenced by several fault systems, mainly of N-S, NW-SF, E-W and NE-SW directions. The structure of the area has played a decisive role in controlling basin configuration and paleogeography.

4. The depositional history of the area witnessed several important unconformities since the end of the Paleozoic, which can be related to epirogenic movements of regional character and also to eustatic sea-level fluctuations.

5. Laterites development (Fe- and Al-types) is expected in Early Cretaceous (Aptian) sediments in subsurface sections, especially in the area south of Traibeel-Km160 highway.

References


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Fig. 1: Location map.
Fig. (2) Topographic and Location map.
Fig. (3) Structure contour map on the base of the Cretaceous units
Fig. (4) Geological map of the Pre-Cretaceous erosional surface
Fig(5) Isothickness map of the Cretaceous and Tertiary units.
Fig. (7) Lineament intersection density map (Al-Amiri, 1978)
Fig. 8: Schematic cross section showing the possibility of shale-trap fault development.

Fig. 9: Palaeogeography of the Late Triassic.
Fig. (10)  Paleogeography of the Jurassic.

Fig. (11)  Paleogeography of the Late Aptian-Albian.
Fig. (12): Paleogeography of the Cenomanian-Turonian.

Fig. (13): Paleogeography of the Late Campanian-Maastrichtian.
Fig. (14) Paleogeography of the Paleogene