# PALEOCENE SEQUENCE DEVELOPMENT IN THE IRAQI WESTERN DESERT

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Received: 12/ 08/ 2013, Accepted: 18/ 06/ 2015
Key words: Paleocene, Sequence, Biozones, 3rd order cycle, Iraq


## ABSTRACT

The Paleocene succession in the Iraqi Western Desert, represented by Akashat Formation, is developed through six third order cycles. Local tectonism and eustacy caused the subdivision into several cycles. The K/T boundary is represented by a transgressive surface; correlated with the major Global Paleocene Transgression. The Early Paleocene succession was mainly controlled by the eustatic component and the resultant eustatic subsidence. During the Middle Paleocene; a major transgression had caused the extension of the basin eastward and shows interbedding of basinal-deep-shallow open marin facies reflecting minor relative sea level fluctuation. The Late Paleocene consists of a retrogradational pattern of deep or basinal facies of the TST bounded by a maximum flooding surface (MFS); this MFS is determined by marls rich with planktonic foraminifera of Late Paleocene age (*Globanomalina pseudomanirdii* Zone). This cycle ends up with a characterastic zone of coprolites rich with oysters, *Operculina* spp., *Nummulites deserti*, *Lenticulina* sp., and Late Paleocene planktonic (keeled).


## تطـور تتـابع الـپاليوسـين في الصحراء الغربيـة العراقيـة

**بثينة سلمان محمد الجبوري و علي داود گيارة**


**المستخلص**

يتمثل تتابع الپاليوسين في الصحراء الغربية العراقية بتكوين عكاشات ويتوضح ترسيب التكوين بستة دورات ترسيبية من الدرجة الثالثة، وهي تمثل فترات ارتفاع وثبات لمستوى سطح البحر. أثرت التكتونية المحلية والجغرافية القديمة على الدورات الترسيبية وادت الى تغيرات طفيفة في مستوى سطح البحر. يمثل حد التماس بين الكريتاسي والثلاثي سطح تقدم بحري يتوافق مع التقدم البحري العالمي خلال عمر الپاليوسين. ان التغير الواضح في ليثولوجية تكوين عكاشات والتغير في المحتوى الحياتي أدى الى تمييز العديد من السحنات الدقيقة والتي ترسبت في عدة بيئات رسوبية ضمن المنحدر البحري.

تأثر تتابع الپاليوسين الأسفل بتذبذب مستوى سطح البحر المحلي ويفصل سطح الأنغمار الأقصى بين عمر الدانيان والسلاندين، تأثر الپاليوسين الأوسط بتقدم بحري كبير وأدى الى ترسيب السحنات الحوضية والعميقة والبحرية الضحلة، بينما تمثل تتابع الپاليوسين الأعلى بدورة تراجعية انتهت بتكون سحنة الرف الداخلي.


## INTRODUCTION

The Paleocene succession in the Western Desert is represented by the Akashat Formation, which has an economic importance due to its phosphorite resources. The Akashat Formation is added to the stratigraphic column of Iraq. Formaly, the succession was considered to be Umm Er Radhuma Formation. The difference in lithological composition, facial development

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and paleogeographical distribution between Akashat and Umm Er Radhuma formations were recognized by Buday (1980) and Buday and Hak (1980) who called it as phosphatic facies of Umm Er Radhuma Formation, Jassim *et al.* (1984) called it Akashat Formation and Al-Bassam and Karim (1997) announced it officially as Akashat Formation.

Many studies concerning the Paleocene deposits have been accomplished in the Iraqi Western Desert. Herinafter some of them:

- During the period (1976 – 1983) many biostratigraphic and paleontologic studies were carried out by the paleontological labrotary staff of the regional geological survey for the eastern part of the Western Desert (Al-Mutter, 1976; Amer, 1977; Karim, 1977 and Al-Mubarak and Amin, 1983).
- Jassim *et al.* (1984) named the phosphatic facies of Umm Er Radhuma Formation, as Akashat Formation and was announced offically by Al-Bassam and Karim (1997).
- Karim in (Karim and Jassim, 1986) studied the biostratigraphy and environmental reconstraction of the Paleocene sequance in the Western Desert.
- Al-Bassam (1987) studied the facies and depositional environment of the Upper Cretaceous – Lower Tertiary phosphorite bearing sequence in the Western Desert.
- Al-Bassam *et al*. (1990) did the detailed geological survey of the Upper Cretaceous – Lower Tertiary phosphorite bearing sequence in the Western Desert.

The main aim of the present study is to interpret sequence development and basin evaluation by means of detailed petrographic and facies analysis for paleoenvironmental interpretation. 70 samples were collected from four subsurface sections drilled within the studied area by the Yougslave Team and GEOSURV (Fig.1).

The biostratigraphic study includes the determination of the main biozones to aid the sequence stratigraphic subdivisions and boundaries. Sequence stratigraphic analysis is the main tool to clarify the effect of local tectonism and eustacy on the development of the succession and basin evaluation.

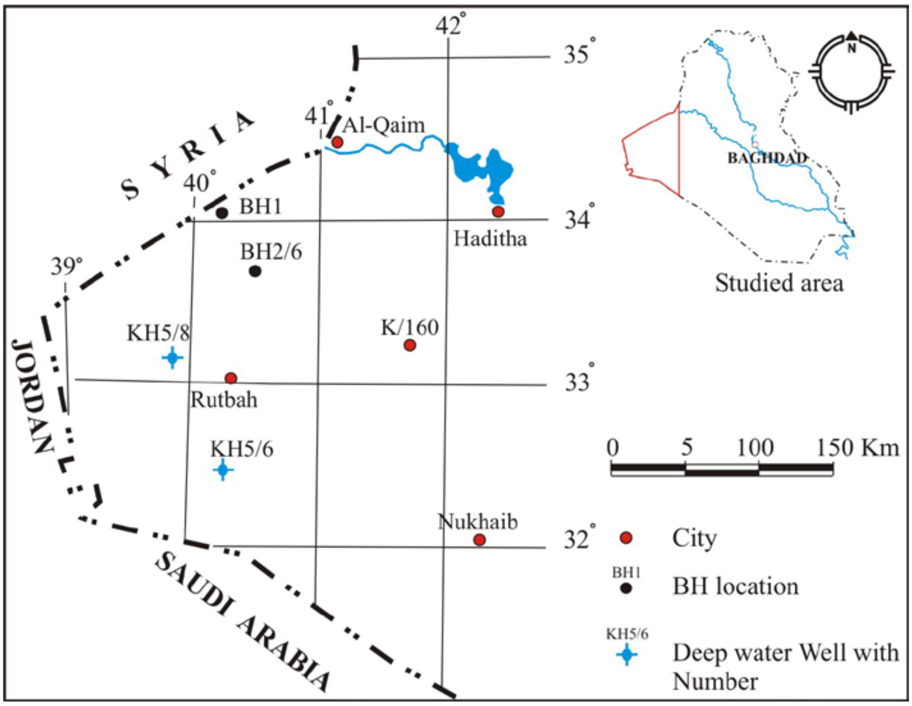


Fig.1: Location map

## TECTONIC EVOLUTION

Continued oceanic spreading of the Atlantic, Mediterranean and Indean Oceans, resulted in the continuing subduction along the northeastern margin of the rapidly closing Neo-Tethys (Sharland *et al*., 2001) (Fig.2). During the Early Paleocene to Late Eocene (67 – 34 Ma), the Arabian Plate was still attached to the African Plate with broadly compressive Neo-Tethys margin and a string of inherited deep foreland basin along the northeastern margin. At the end of this period, the fragmentation of Africa – Arabia was initiated with the onset of limited thermal uplift and rifting in the Red sea area (op.cit). During the Early Paleocene to Late Eocene, eustatic sea level was generally high with high frequency regressive events (Haq *et al*., 1988).

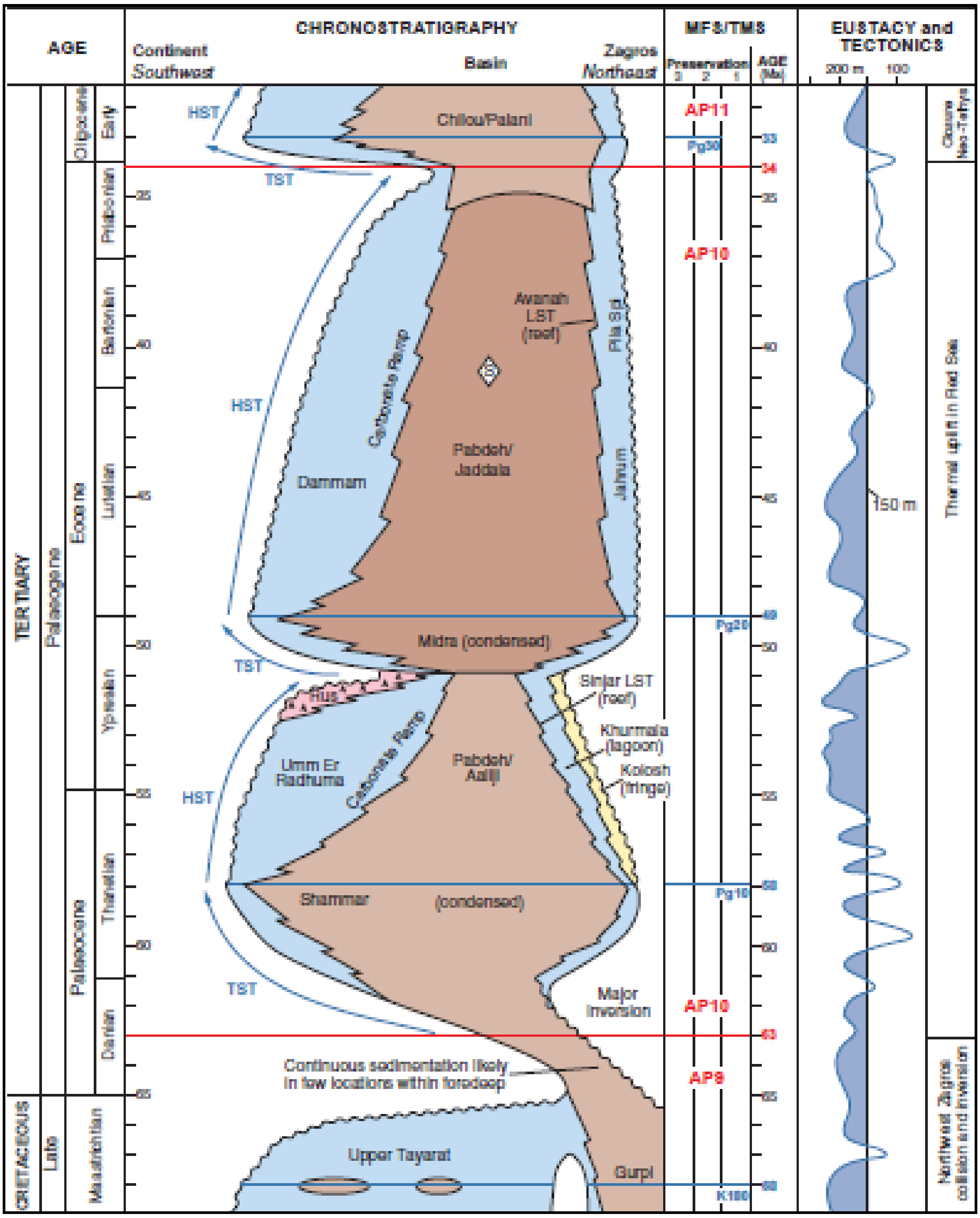


Fig.2: Paleocene – Eocene Megasequence $AP_{10}$ (Sharland *et al*., 2001)

The Paleocene – Eocene sequence can be correlated with megasequence $AP_{10}$ suggested by Sharland *et al*. (2001) (Fig.2). The lower boundary of the succession marks the end of a major Cretaceous collision, that is the tectonics and ophiolite obductions on the northern and northeastern Arabian Plate margin. Whereas, the upper boundary, dated 34, Ma marks both the oneset of Red Sea rifting between Africa and Arabia (Beydoun and Sikander, 1992 and Beydoun *et al*., 1992) and the first continent-continent crush between the Arabian Plate and Eurasia along the Zagros suture collision and uplift in the Zagros causing a southwestwards shift in facies belts marking the oneset of the final closure of the Neo-Tethys (Beydoun, 1991 and 1998 and Goff *et al*., 1995).

## CRETACEOUS/ TERTIARY (K/T) BOUNDARY

The Cretaceous/Tertiary (K/T) boundary is conveniently placed near one of the most dramatic and catastrophic biological events in the history of our planet. This boundary is marked by the depletion of a large percentage of world's biota and turnover in a relatively short time and rapidly (Kent, 1977; Berggren and Miller, 1988; Haq, 1991; Norris *et al*., 1999; Gallala, 2013 and Rodrigues *et al*., 2014). Less than 25% of Late Cretaceous species survived into the Tertiary.

The idea of the presence of Danian in the Iraqi Western Desert was not believed; the Iraqi geologists used to believe the occurrence of a hiatus between the Cretaceous and Tertiary. The Danian in Western Iraq was first reported by Ctyroky and Karim (1971); Karim in Jassim *et al*. (1984); Karim and Jassim (1986); Karim in Al-Bassam *et al*. (1990) and Al-Jibouri (2003). In the present study, the K/T is seemingly conformable (KH5/6, KH5/8, BH1 and BH2/6) and represent a transgressive boundary (TS) as correlated with Global Paleocene Transgression.

## FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT

The interpretation of the depositional environment of the Paleocene succession was based on petrographic and microfacies studies of the thin sections for the studied boreholes. The Akashat Formation consists of different lithologies: marl, phosphate, phosphatic limestone, chalky limestone and sandy limestone, with varied fauna of planktonic and benthonic foraminifera, shark teeth, bone fragments, molluscas and algae, so the formation was deposited under different subenvironments on the carbonate platform (Fig.3) and as follows from the base:

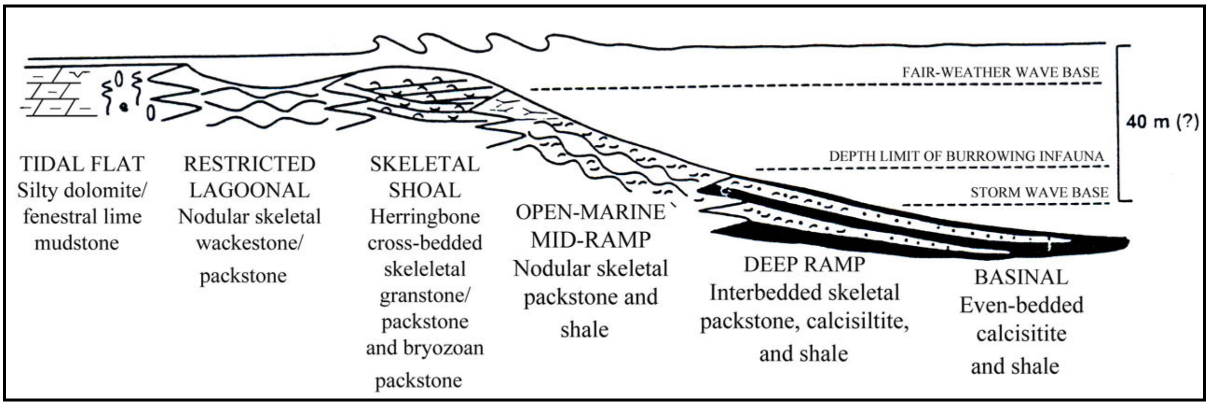


Fig.3: Idealized ramp to basin profile (Pope and Read, 1997)

- **Traifawi Member (Early Paleocene)**

The Traifawi member represents a sedimentary cycle that always starts with clay and chalk or silicified chalk rich with planktonic foraminifera followed by phosphatic or phosphorite horizons; burrows (horizontal and vertical) are abundantly found in the clayey fine sediments which represent a period of slow sedimentation always filled with phosphate intraclast (Al-Bassam *et al*., 1990). This member was deposited under deep ramp to basinal environment. This environment is characterized by the following microfacies:

– Planktonic mudstones (Fig.4-1 and 2): Slightly with phosphate pellets and rare terrigneous material. Planktonic forams such as *Globigerina dubjergensis*, *Subbotina triloculinoides* and *Chilgumbelina* sp., associated with deep water benthonic forams such as *Bulimina* sp., *Cibicides* sp., and *Valvulineria* sp. This facies was observed in BH1, BH2/6 and KH5/6.

– Peloidal phosphatic foraminiferal wackestones – packstones (Fig.4-3): This facies consists of about 22 – 45% forams mostly planktons (Globigerinds) and some benthonics like *Bulimina* sp., *Cibicides* sp., *Siphogerina* sp., *Gabonella* sp., and ostracods. Phosphate grains occur as pellets, rarely as intraclasts and bone fragments. Biomolds with calcite cement, chert nodules were found at different levels. This facies was recognized in BH2/6, KH5/6 and KH5/8.

- **Hirri Member (Middle Paleocene)**

This member is bounded by two main shelly horizons rich with bivalves such as *Venericardia* sp., *Cardita* sp., each represents a shoal environment and characterized by the following microfacies:

– Shelly phosphatic packstones (Fig.4-4): This facies is represented by abundant macrofauna like *Venericadia* sp., *Cardita* sp., *Cardium* sp. with phosphate pellets and oolites in calcite cements. The upper part contains many planktonic and benthonic forams like *Marozovella angulata*, *Globorotalia pseudobulloides*, *Subbotina triloculinoides*, *Valvulinaria ravni*. The matrix of the lower part is dolomitized and moldic pores are filled with calcite cement. This facies was recognized in BH1, BH2/6 and BH5/8.

The absence of Middle Paleocene keeled spinose planktonic foraminifera like *Globorotaia fraagi*, *Praemurica uncienata* may be due to the cool marine conditions caused by frequent pulses of upwelling currents (Kelly *et al*., 1998).

– Peloidal phosphorite microfacies (Fig.4-6): This microfacies is restricted to the middle part of Hirri Member. It is usually associated with (D) microfacies. The phosphate peloids are well sroted (up to 60%) without terrigeneous material and no cement. It seems that this facies was developed under moderate energy in the outer shelf on the upper slope of the ooidal-bivalve shoals.

– Ooidal, cortoidal phosphatic packstones (Fig.4-7): Phosphate oolites and cortoids (38 – 54%) and phosphoclasts are the main components of this facies; planktonic often forms the nuclii of oolites, the phosphoclasts are mainly bones.

This facies represent the most important economic phosphorite unit where almost the economic phosphorite deposits of Iraq are located, especially below the shelly microfacies. It is usually well sorted and relatively fine grained. The well sorted phosphate grains suggest a dynamic factor (wave action) and the presence of algae suggest a photic zone indicating that this facies was most dominant in intertidal inner platform and was developed into an offshore shoals by tidal action building up at the base of the bivalve shoal growth. This microfacies is widely distributed and recorded in all the studied sections.

– Globigerinal packstones (Fig:4-8 and 9): This microfacies is interbedded with the peloidal phosphorite and includs frequent chert horizons the main constituents of this facies are planktonic forams such as *Globorotalia pseudobulloides*, *Morozovella angulata*, *Subbotina triloculinoides* and it is bitumineous.

It represents deposition in deep ramp lower slope environments. (Pope and Read, 1997 and Posamentier *et al*., 1988) and represents a maximum sea transgression.

Microfcies B, C and D of the Hirri Member show a cyclic nature in assending order within the succession, repeated three times throughout. This cyclic succession is bounded from above and below by microfacies A.

- **Dwaima Member (Late Paleocene)**

This member is characterized by the presence of chalky limestones and papery calcareous claystones and phosphorite (ooides, peloids and intraclasts) followed by fossiliferous horizons. This member was deposited in open marine (middle ramp) and deep ramp environments and represented by the following microfacies:

– Foraminiferal phosphatic packstones (Fig.4-10): This facies is rich with planktonic and benthonic forams, some of them are heavily noded and keeled, like *Morozovella valascoensis*, *Mor*. *acuta*, *Mor*. *aequa*, *Mor*. *apanthesma*, *Globorotalia irrorata*. The aforementioned globorotalids indicate warm marine conditions tropical-subtropical and normal salinity of mid ramp. (Bradshaw, 1959; Be, 1959; 1960; 1964; Silter, 1972; Murry, 1973 and Hultberg and Malmgren, 1986). The benthic fauna found with the former planktonics are *Nodosaria menili*, *Frondicularia phosphatica*, *Vaginulina* sp., *Vaginulopsis midwayensis*. *Lenticulina turbinata*. These fauna may reflect deposition on the bathyal upper slope. (Murray, 1973; Berggren and Aubert, 1975). This facies is recorded in section BH2/6.

– Globigerinal wackestones-packstones: Small planktonic forminifera such as *Subbotina triloculinoids*, *Globigerina valascoensis* and other *Globigerina* spp., constitute the major components of this facies. The abundance of *Globigerins* and absence of *Globorotalia* spp. (within *Morozovella*. *valescoensis* Zone) indicate cold temperate marine currents affecting the area caused by upwelling (Kelly *et al*., 1998). This facies represents a deep basinal environment prevailed during the Late Paleocene.

– Coprolitic shelly packstones (Fig.4-11): This microfacies is restricted to the upper part of the Dwaima Member (uppermost part of Akashat Formation), where a characteristic zone of coprolites rich with oyster and shell fragments occurred with many benthonic foraminifera like *Opericulina* sp., *Nummulites deserti*, *Lenticulina* sp., with rare keeled planktonic forams (as in BH2/6). It is usually coarse grained and poorly sorted and consists of 1 – 3 cm long coprolites, bone fragments and shark teeth with or without terrigenous clastics. This facies represents deposition in a moderate energy open inner ramp setting.

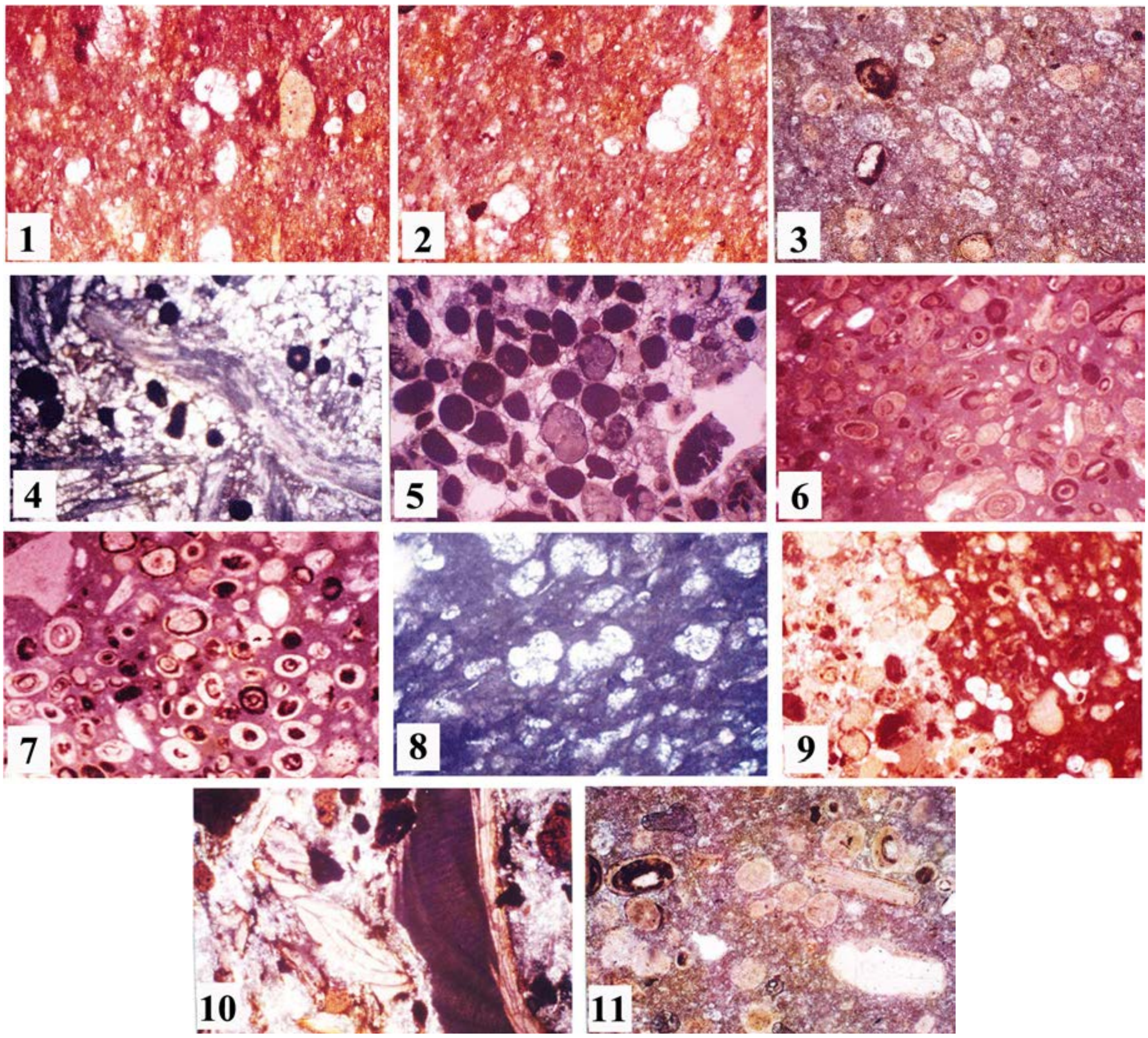


Fig.4: Microfacies of Akashat Formation:

1. **and 2.** Planktonic mudstone, Traifawi Member, BH1, Depth 150 m X45
3. Peloidal phosphtic foraminiferal wackestone, Traifawi Member, BH1, Depth 105 m X45
4. Shelly phosphtic packstone, Hirri Member, BH2/6, Depth 65 m X30
5. Ooidel, cortoidal phosphtic packstone, Hirri Member, BH2/6, Depth 55 m X30
6. Peloidal phosphorite, Hirri Member, BH5/8, Depth 100 m.X30
7. Ooidel, cortoidal phosphtic packstone, Hirri Member, BH5/8, Depth 75 m X30
8. Globigerinal packstone, Hirri Member, BH5/8, Depth 90 m. X45
9. Peloidal phosphorite and globigerinal packstone, Hirri Member, BH1, Depth 85 m X30
10. Foraminiferal phosphtic packstone, Dwaima Member, BH2/6, Depth 30 m X25
11. Coprolitic shelly packstones, Dwaima Member, BH2/6, Depth 30 m X30

**PALEOCENE BIOZONES**

The Planktonic foraminiferal zonation of the Paleogene from areas around the world; as well as the recent deep sea drilling project in the Atlantic and Pacific oceans, and the Mediterranean sea have been established by Loeblich and Tappan (1957); El-Naggar (1966); Berggren (1969, 1970 and 1971); Postuma (1971); Krasheninnkov and Hoskins (1973); Bang (1977 and 1979); Bolli and Kransheninkov (1977); Kureshy (1979); Kalia and Kintso (2006) and Hadavandkhani and Sadeghi (2010).

The Paleocene sequence in Iraq is identified and characterized by rich planktonic and benthonic foraminifera with ostracods and shell fragments of gastropods (Fig.5). The Akashat Formation (Paleocene) was divided for the first time by Jassim *et al*. (1984); Al-Hashimi and Amer (1985); Karim in Karim and Jassim (1986) and Karim in Al-Bassam *et al*., (1990) into many biozones. These are described from bottom upwards:

- ***Globigerina daubjergensis*** **Zone**

The first appearance of this index species marks the beginning of new period in the geological time (Tertiary). Many new genera appear for the first time with the index species as *Chilogumbelina* sp., *Globorotalia* sp. Several planktonic forams of Upper Cretaceous disappear completely at the K/T, like *Globotruncana* spp., *Heterohelix* spp., and *Rugoglobigerina* spp.

Many other planktonic fauna are present with the nominate taxon; *Globanomalina campressa* (PLUMMER), *Globorotalia pseudobulloides* (PLUMMER), *Glt. trinidadensis* BOLLI, *Praemurica imitata* SUBBOTINA, *Globigerina haynesi* NAGGAR, *Subbotina triloculinoides* PLUMMER *Chilogumbelina midwayensis* (CUSHMAN) and *Guembelitria cretacea* (CUSHMAN). Benthonic fauna present within this zone are: *Gabonella* sp., *Lenticulina turbinata* PLUMMER, *Valvulineria ravni* REUSS, *Bulimina* sp. and *Anomalinoides midwayensis* BROTZEN.

This zone is of Danian age (El-Naggar, 1966 and Bang, 1977 and 1979) and represents the Traifawi Member of Akashat Formation and recorded at depth 39 m in BH2/6. In KH5/6, the Danian age is represented by the following two zones.

– *Globorotalia pseudobulloides* zone.
– *Globorotalia trinidadensis* zone.

These two zones are included in Zone $P_1$ of Premol-Silva and Bolli (1973) and Bang (1979).

- ***Globorotalia pseudobulloides*** **Zone**

This zone is identified by the first appearance of *Grt. pseudobulloides* to the first appearance of *Grt. trinidadensis* Zone with first appearance of *Globigerina daubjergensis, Eauglobigerina danica*, *Globanomalina compressa* associated with *Subbotina triloculinoides, Globigerina hayncsi*, *Globorotalia quadrata*, *Chilogumbilina* sp., *Praemurica imitata* and benthonic foraminifera *Gabonella* sp. (the last appearance of this genus is Upper Danian), *Lenticulina* sp. *Bulimina* sp. This zone is identified at depth 150.6 – 142.5 m in BH1.

- ***Globoratalia trinidadensis* Zone**

This Zone is identified by the first appearance of *Globorotalia trinidadensis* BOLLI, with continuous appearance of *Grt*. *pseudobulloides* (PLUMMER), *Globigerina daubjergensis*, *Globanomalina compressa*, *Grt*. *quadrate*, *Praemurica imitata*, *Subbotina triloculinoides*, with the same association of benthonic forams of the previous zone. This zone is identified and recorded at depth interval 142.5 – 121.0 m in BH1.

- ***Globorotalia angulata* Zone**

With the nominate taxa, an abundant occurranes of *Globorotalia pseudobulloides* PLUMMER and *Glt*. *quadrata* WHITE, *Globigerina haynesi* El-NAGGAR, *G. velascoensis* (CUSHMAN), *Subbotina triloculinoides* PLUMMER and many benthonic foraminafera association as *Lenticulines midwayensis* (PLUMMER), *Bulimina* sp., *Valvelinaria ravni*, *Cibicides* sp., and rich ostracods. This zone is assigned to the Middle Paleocene (El-Naggar, 1966, Bang 1977 and 1979; and Karim and Jassim 1986). It is represented by the Hirri Member of Akashat Formation (Al-Bassam *et al*., 1990) and records a prominence in many of the studied sections, as BH2/6.

- ***Globorotalia velascoensis* Zone**

This zone is characterized by the abundant occurrence of *Globorotalia velascoensis* (CUSHMAN) and abundant occurrance of heavily nodded and keeled planktonic forminfera, as *Globorotalia acuta* TOULMIN, *Glt*. *aequa* CUSHMAN and RENZI, *Glt. esnaensis* (LEROY) *Grt. irrorata* LOEBLICH and TAPPAN., *Glt. woodi* EL-NAGGAR, *Glt. pusilia laevigata* BOLLI., *Glt. occulosa* LOEBLICH and TAPPAN and *Subbotina triloculinoides* PLUMMER. Benthonic fauna are *Frondicularia phosphatica* (REUSS), *Vaginulopsis midwayensis* (FOX and ROSO), *Astacolus gladuis* (PHILIPS), *Nodosaria macneili* CUSHMAN, *Valvulinarra ravni* BROTZEN, *Lenticulina midwayensis* CUSHMAN and PONTON, *Lenticulina wilcocensis* LEROY, *Vaginulina* sp. and *Bulinmina* sp.

This zone represents Late Paleocene age (Permol- Silva and Bolli, 1973; Stainforth *et al.*, 1975; Toumarkin and Luterbacher, 1985 and Berggren and Miller, 1988) and represents the Dwaima Member of the Akashat Formation (Al-Bassam *et al*., 1990).

In KH5/6, *Globorotalia pseudomanardii* Zone is recorded at depth (121.0 – 96.8) m before *Globorotlia velascoensis* Zone, which is identified at depth (96.8 – 85.8 m), so the *Globorotalia pseudomenardi* Zone ($P_4$) is assigned as Early Upper Paleocene and *Globorotalia velascoensis* Zone is of Late Upper Paleocene ($P_5$ and $P_{6a}$) (Berggren, 1969; Berggren and Miller, 1988; Blow, 1979; Stainforth *et al*., 1975 and Toumarkine and Lutorbacher 1985).

In KH5/8, *Globorotalia velascoensis* Zone is recognized at depth 68 – 47 m with rich *Globorotalia* spp. and *Globigerina* spp. and rich benthonic foraminifera, as *Frondicularia phosphatica*, *Lenticulina midtwayensis*, *L. wilcoxensis*, *Bulimina* sp. At the uppermost part of Akashat Formation, at depth 46 – 43 m, due to the presence of *Nummlites deserti* and *Discocyclina* sp., an uppermost Early Paleocene is adopted for this part.

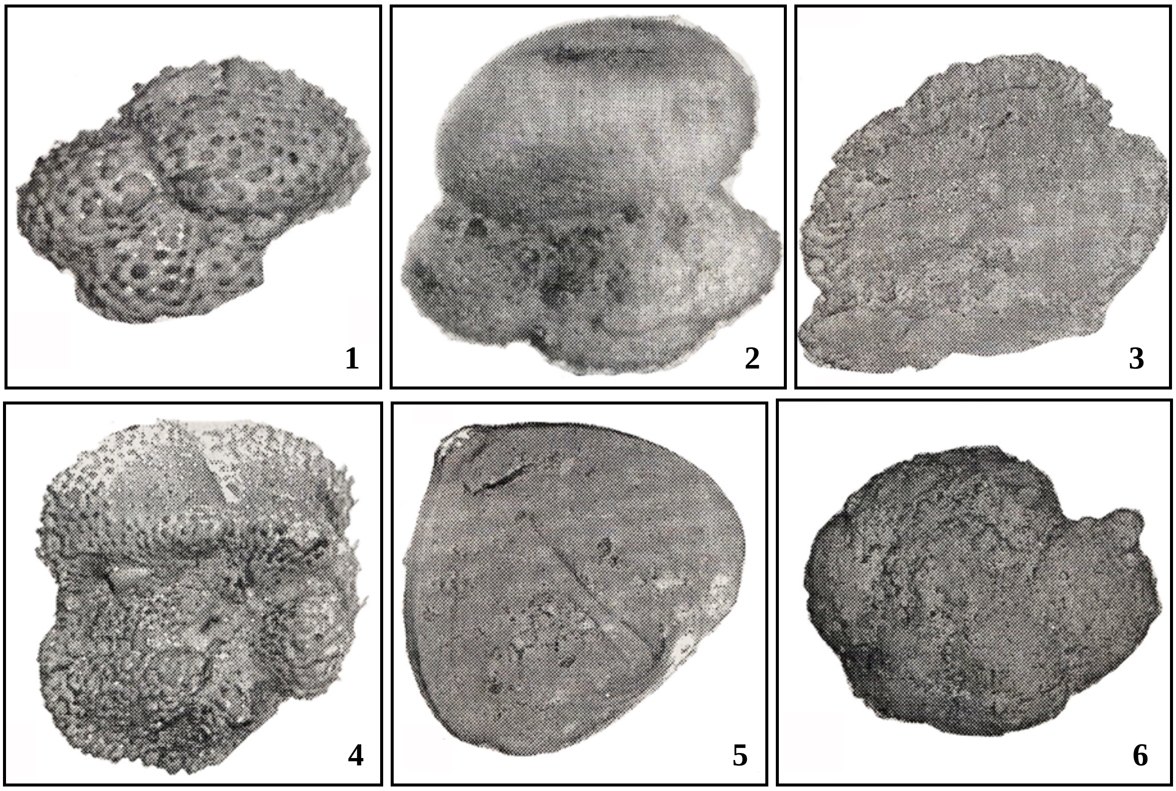


Fig.5: Index fossils of Akashat Formation

**1.** *Globigerina daubjeragensis*, X250, BH1, depth 120 m
**2.** *Globorotalia pseudobulloides*, X200, KH5/6, depth 135 m
**3. and 4.** *Globorotalia valescoensis*, X7.5, BH2/6, depth 35 m
**5.** *Frondicularia phosphatica*, X.32, BH2/6, depth 33 m
**6.** *Valvulineria ravni*, X.85, KH5/6, depth 53 m

**PALEOCENE SEQUENECE DEVELOPMENT**

The depositional sequence of the Early Paleocene (Danian) is represented by four 3$^{rd}$ order cycles (A, B, C and D) (Figs.6-9). Cycles A, B and C, can be recognized in the section of BH1; each cycle consists of a relatively thick basinal facies of TST and thin deep facies of HST; they represent successive episoides of long sea level rise and relatively short episode of stillstands. The age of these cycles is correlatable with *Globigerina daubjergensis* Zone.

The Early Paleocene started with a deeper and cooler environment; relative to that of the Upper Cretaceous. This change in environment was of a global character (Paleocene Transgression) (Haq, 1991, Posamentier *et al*., 1988 and Sharland *et al*., 2001). The higher sea level might be assissted by a local subsidence (block movements) along rejuvinated faults in the area west of Rutba – Hail Arch. (Al-Bassam and Karim, in Al-Bassam *et al*., 1990). The activation of these block movements during the Paleocene was the main controlling factor on cyclicity of the above succession.

Cycle D extends into the Middle Paleocene, where a maximum flooding surface (MFS) separates the Danian from Selandian. The transgressive basinal facies changes into the deep and shallow open marine facies of the HST. This fluctuation is manifested eastwards towards the inner platform by the successive parasequences of TST (deep or shoal facies) and HST (shoal or shallow open facies).

The Middle Paleocene is represented by the upper part of cycle D and cycle E, which can be divided into three 4$^{th}$ order cycles ($E_1$, $E_2$ and $E_3$). Cycle E, generally consists of a relatively thick transgressive shoal, deep, and basinal facies followed by a thin shallow open marine facies of the HST. The overall shallowing can also be noticed in $E_1$, $E_2$ and $E_3$ in the west, where the fluctuation ranges from basinal-deep-shallow open ($E_1$), basinal-shallow open ($E_2$) and shallow open-shoal ($E_3$) it reflects the minor relative sea level fluctuations which are also due to local tectonism. To the extreme west, at KH5/6, cycle E is missing, where deposition of the Middle Paleocene ceases in the uplifted area.

The Late Paleocene is represented by one third order cycle (F). This cycle consists of a retrogradational pattern of deep or basinal facies of the TST bounded by a maximum flooding surface (MFS), which can be correlated with $Pg_{10}$ of Sharland *et al*. (2001), dated 56.5 Ma and MFS of Haq *et al*. (1988). This MFS is determined within the planktonic foraminifera-rich marls of Late Paleocene age (biozone $P_4$) *Globorotalia pseudomanirdii* Zone of Blow (1979).

The HST is represented by a prograding deep-shallow open marine facies. This cycle can also be divided into two third order cycles (F1 and F2). The cycle ends by the development of an intertidal coprolitic shoal, which passes basinwards into phosphatic nummulitic shoal.

## PALEOCENE/ EOCENE BOUNDARY

The Late Paleocene – Early Eocene Boundary throughout the studied area is clearly conformable and represents a TS boundary and is marked by an uppermost horizon of coprolitic bed sometimes rich with oysters and Late Paleocene larger foraminifera and planktonics, followed by the nummulitic limestone of the Lower Ypresian.

## PALEOCENE BASIN EVOLUTION

The Early Paleocene of west Iraq, represented by the Traifawi Member of Akashat Formation, was deposited in a narrow intrashelf basin extending to the Southern Desert along the Rutba – Hail Arch. The depositional setting is typical of a distally steepened ramp, where deposition occurs in a shoal-open marine to deep and basinal sediments in the northeast. The deposition of this succession was controlled mainly by the paleogeography of the conformable upper boundary of the Late Maastrichtian, as well as by the isostatic subsidence resulted from the major eustatic sea level rise at the beginning of the Paleocene. This subsidence might be also related to a new phase of local tectonic activity (Mitchum *et al*., 1977; Van Wagnoor *et al*., 1988 and Nystuen, 1998).

During the Middle Paleocene, another major transgression enlarged the basin farther to the east of the studied area and the development of another NE – SW trending paleohigh occurred, probably due to block movements, which separated the intrashelf basin. This led to deposition of mainly shallow open to shoal facies (Hirri Member), which intercalated with deep ramp facies (Globigerinal packstones). The intercalation was due to the sea level fluctuation, which had caused many subcycles.

The Late Paleocene in the Western Desert is characterized by higher rate of subsidence within the intrashelf basin and narrower positive area, where the deposition of the Dwaima Member, of open marine and deep facies, took place. This succession came to an end by the development of inner shelf shoal coprolites shelly packstone, which passed basinwards into phosphatic nummulitic shoal.

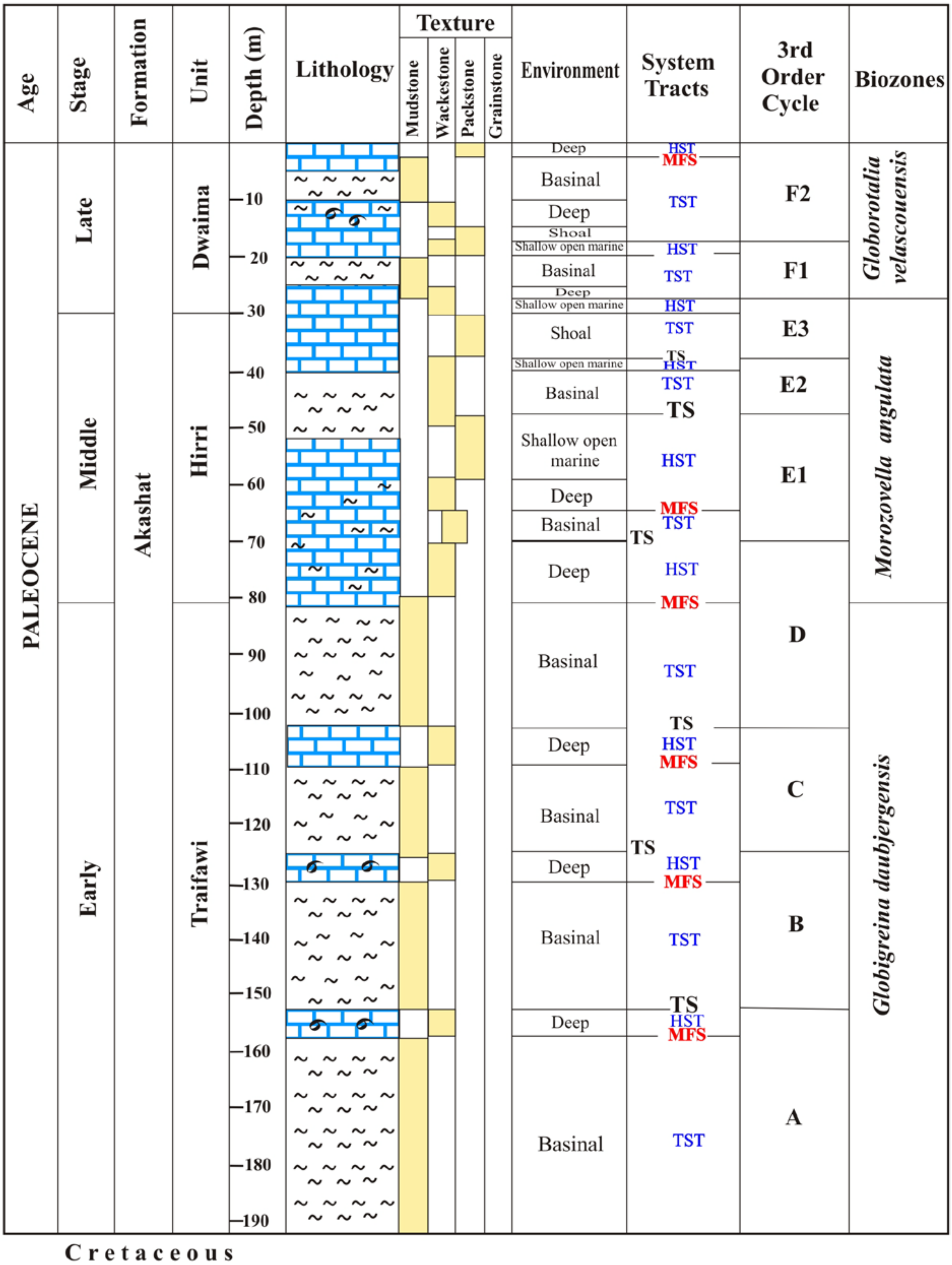


Fig.6: Facies stacking pattern and sequence stratigraphic subdivision of BH1

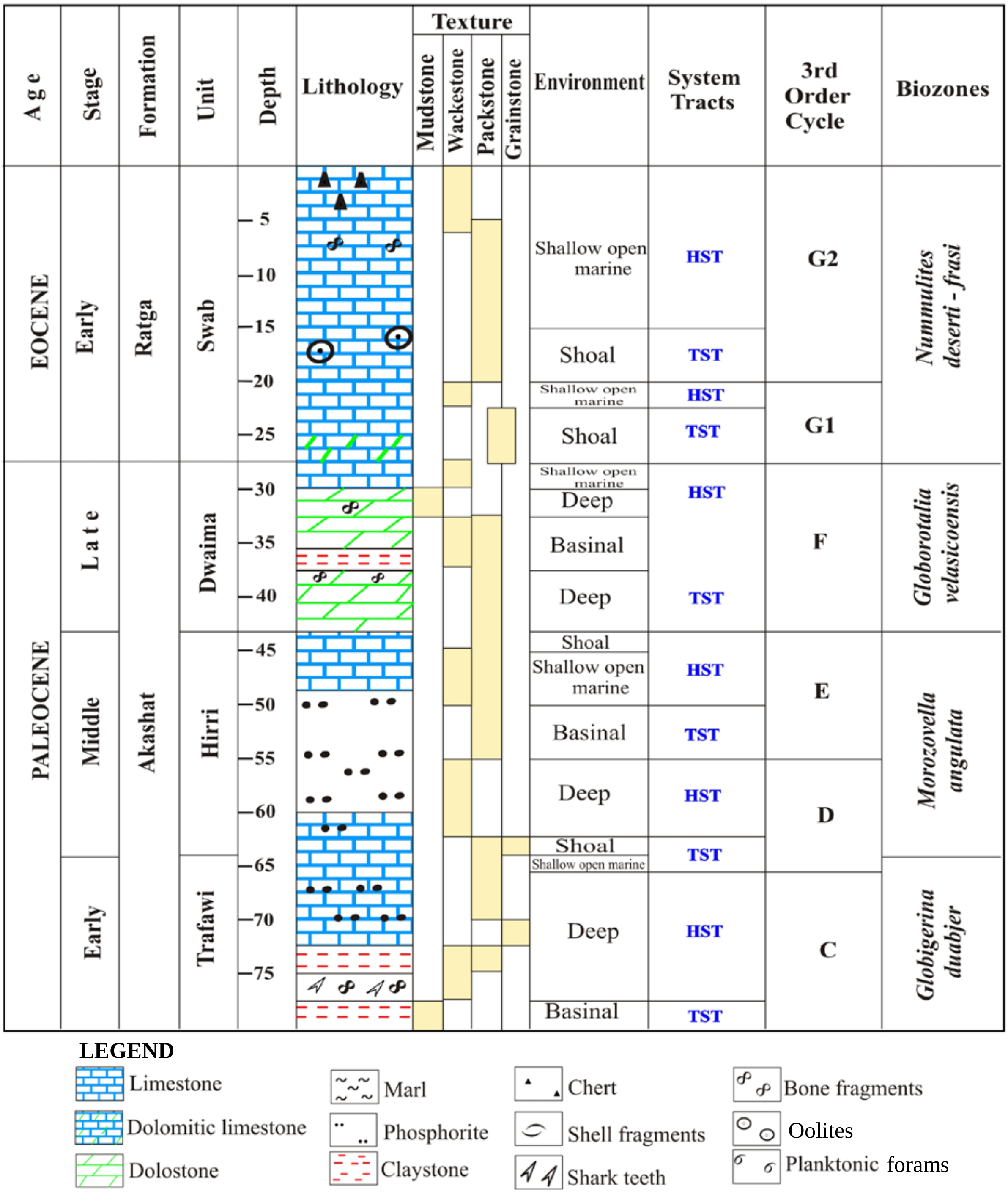


Fig.7: Facies stacking pattern and sequence stratigraphic subdivision of BH2/6

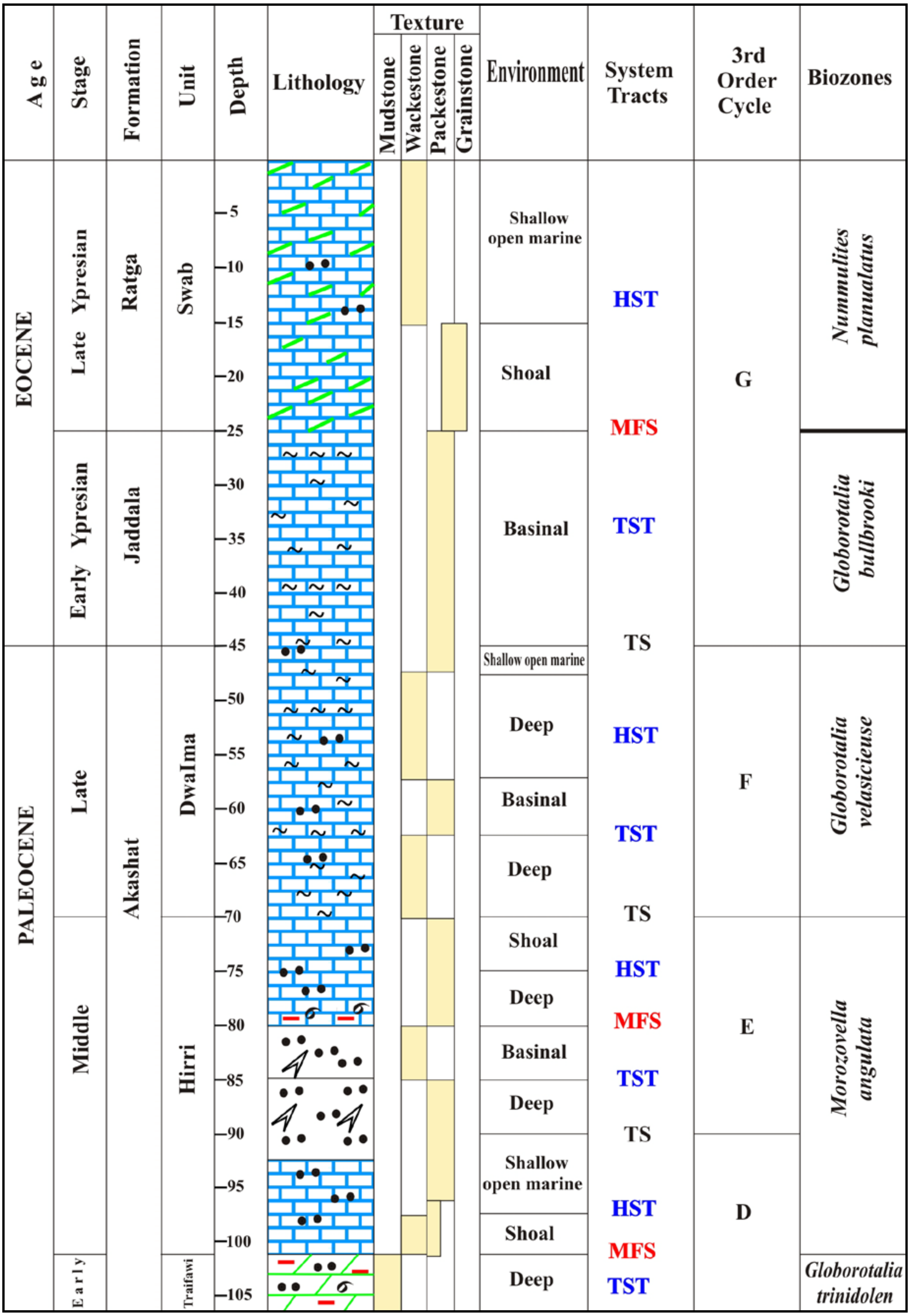


Fig.8: Facies stacking pattern and sequence stratigraphic subdivision of BH5/8

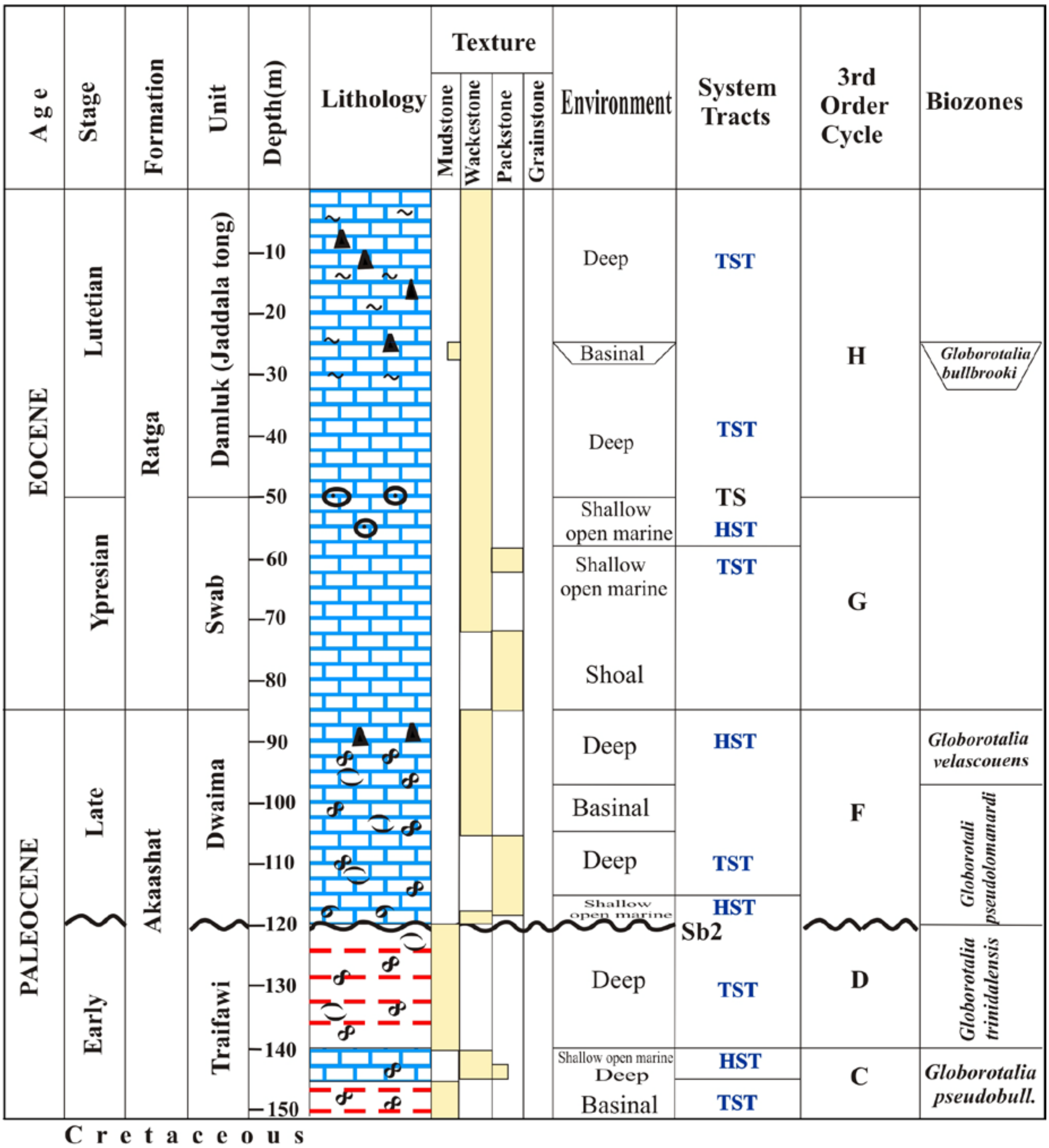


Fig.9: Facies stacking pattern and sequence stratigraphic subdivision of BH5/6

## CONCLUSIONS

- The K/T boundary represents a transgressive boundary (TS) that can be correlated with the global Paleocene Transgression.
- The Paleocene sequence was developed through six 3rd order cycles; they represent successive episodes of sea level rise, and stillstands. Local tectonism and paleogeography caused subdivision of these cycles, reflecting minor relative sea level changes.
- The Early Paleocene is represented by four 3rd order cycles; each cycle consists of a relalively thick basinal facies of the TST and thin deep facies of the HST.
- A maximum flooding surface (MFS) separates the Danian from Selandian. when the transgressive basinal facies changes into a deep and shallow open marine facies of the HST.
- The Middle Paleocene is represented by the upper part of cycles D and E. It is divided into three 4th order cycles $E_1$, $E_2$ and $E_3$, in the west of the studied area. Cycle E represents generally a shallowing upward. whereas the fluctuation from basinal-deep-shallow open facies ($E_1$) or basinal-shallow open facies ($E_2$) and shallow open marine-shoal facies ($E_3$), reflect minor relative sea level fluctuation.
- The Late Paleocene is represented by one 3rd order cycle (F). This cycle consists of a retrogradational pattern of deep or basinal facies of the TST; bounded by a maximum flooding surface (MFS).
- The Paleocene/ Eocene boundary throughout the area in western Iraq is clearly conformable and represents a (TS) boundary.

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