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BIOSTRATIGRAPHY AND ENVIRONMENTAL RECONSTRUCTION OF THE AKASHAT FORMATION (PALEOCENE PHOSPHATIC SEQUENCE), WESTERN DESERT, IRAQ

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ABSTRACT

The exposure of the Paleocene sequence (Akashat Formation) in the Rutbah area is distributed in a relatively thin N – S strip extending from north of the Ga'ara depression down to the Iraqi – Saudi Arabian international border, and it is roughly 40 – 50 m thick, truncated east of the Ga'ara depression. The Paleocene sequence, in its exposures north and west of Rutbah area, is phosphatic. The biostratigraphy and depositional environment of the surface exposure of the sequence and that of borehole sections to the west of the exposure areas is studied in some detail in this work. The Paleocene sequence is conformably overlain by the Eocene sequence throughout the exposed and subsurface sections (except in the eastern side of the Ga'ara depression). The underlying sequence belongs to the Late Cretaceous with a hiatus of variable durations. South of Rutbah – Amman highway the break is relatively shorter than that in the Akashat area, especially along the western and northern rims of the Ga'ara depression. In boreholes to the west, the Paleocene sequence increases in thickness, the break with the underlying Late Cretaceous sequence may be negligible or missing. The following planktonic zones are recorded from subsurface and surface sections:

1- *Marozovella valasconsis* Zone, Late Paleocene (Thanatain)
2- *Marozovella angulata* Zone, Middle Paleocene (Selandian)
3- *Globoconusa daubgergensis* Zone, Early Paleocene (Danian)

الطباقية الحياتية والبيئة الترسيبية لتكوين عكاشات (تتابع الباليوسين الفوسفاتي)، الصحراء الغربية، العراق

ساهرة عبد الكريم محمد و كفاح نوري الكبيسي

المستخلص

يهدف البحث الى دراسة تكوين عكاشات (عمر الباليوسين) المتكشف في منطقة الرطبة كحزام يمتد باتجاه شرق – غرب وشمال منخفض الگعرة حتى الحدود العراقية السعودية جنوبا، كما شملت الدراسة مقاطع لعدة آبار شمال وجنوب منطقة الرطبة باتجاه الحدود الغربية ويختفي التكوين تماما شرق منخفض الكعرة. يتميز تكوين عكاشات بوجود الفوسفات. تمت دراسة الطباقية الحياتية والبيئة الترسيبية للمقاطع السطحية وتحت السطحية وتعيين الحدود العليا للتكوين التي أشرت وجود سطح توافقي في كل المواقع مع تتابع الإيوسين الأسفل. كما أظهرت الدراسة ان الحدود السفلى للتكوين تكون بتماس

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كأنه توافقي في كثير من المواقع تحت السطحية وفي بعض المواقع كأنها تسجل انقطاع لفترة محدودة. تم تسجيل الأنطقة الحياتية المعتمدة على المتحجرات الطافية لعمر الباليوسين وهي من الأحدث الى الأقدم:

1- *Marozovella valasconsis* Zone, Late Paleocene (Thanatain)
2- *Marozovella angulata* Zone, Middle Paleocene (Selandian)
3- *Globoconusa daubgergensis* Zone, Early Paleocene (Danian)

INTRODUCTION

The Paleocene sequence (Akashat Formation) of the Stable Shelf area of Iraq (i.e. Western and Southern deserts of Iraq) is exposed in a narrow strip along the Iraqi – Saudi Arabian border line towards the Southern Desert and, in a N – S oriented narrow strip west of the Rutbah uplift, extending from the Akashat area southwards and passes into Saudi Arabia (Fig.1). Some outcrops around the Nukhaib area are also documented by Al-Mubarak and Amin (1983).

In the Southern Desert of Iraq, the Paleocene sequence is represented by the Umm Er Radhuma Formation which was first described in 1952, by Bramcamp from Saudi Arabia (Bellen *et al*., 1959). A supplementary type section from Zubair 3 borehole was described by Owen and Nasr (1958) as 458 m thick of dull white or buff microcrystalline and porous dolomitic limestone with anhydrite and occasional chert in the upper part. The environment of deposition of the formation is suggested to be lagoonal by Basi, (1983); Tamer Agha, (1984); and Jassim *et al*. (1984).

This lithology, described from the Southern Desert, changes quickly in the direction of the Nukhaib area and especially in the direction of the Rutbah town. The Paleocene in the latter area is strongly phosphatic and completely different from the known lithology of the Umm Er Radhuma Formation. This finding led Buday (1980), to assume that nomenclature change is necessary. Al-Sheikhly (1980) also recognized such differences in his study of Ostracoda in the Paleocene sequence from Iraq and neighboring countries. Jassim *et al*. (1984) suggested the name Akashat Formation and they suggested the type section to be in Semhat hill on the western rim of the Ga′ara depression (Sheet No. NI-37-11-45, scale 1: 250 000). They (op.cit) gave 30 m thickness for the formation. Later studies by the authors found that the lower 18 m is of Cretaceous age and were assigned to a formation, called the “Jeed Formation”, which was abandoned later and the relevant Cretaceous sequence is part of the Digma Formation now.

The study of Jassim *et al*. (1984) revealed evidence of the Danian age to be present in the area. Qassim (1985) studied the petrology and sedimentary facies of the Upper Cretaceous – Paleocene phosphatic sequence in the Rutbah – H_3 area, Western Desert. Aba-Hussain (1987) studied the petrography and facies analysis of the Paleocene phosphatic units in the Ga'ara – Akashat area. During the period 1986 – 1990 detailed mapping (scale 1: 25000) of the Late Cretaceous and Early Tertiary phosphorite-bearing sequences in the Western Desert resulted in dividing the Akashat Formation into three members; from older to younger: Traifawi (Lower Paleocene), Hirri (Middle Paleocene) and Dwaima (Upper Paleocene). The Depositional history and paleogeography of the Upper Cretaceous-Paleogene phosphorite-bearing sequence was previously studied in the Western Desert (Al-Bassam *et al*., 1990 and Al-Bassam and Karim, 1992). The name “Akashat Formation” was formally recognized as a new formation in Iraq with three members by the National Geological Correlation Committee (Al-Bassam and Karim, 1997). In a more recent study, Al-Ganabi (2004) studied the Danian Ostracoda in the Western part of Iraq.

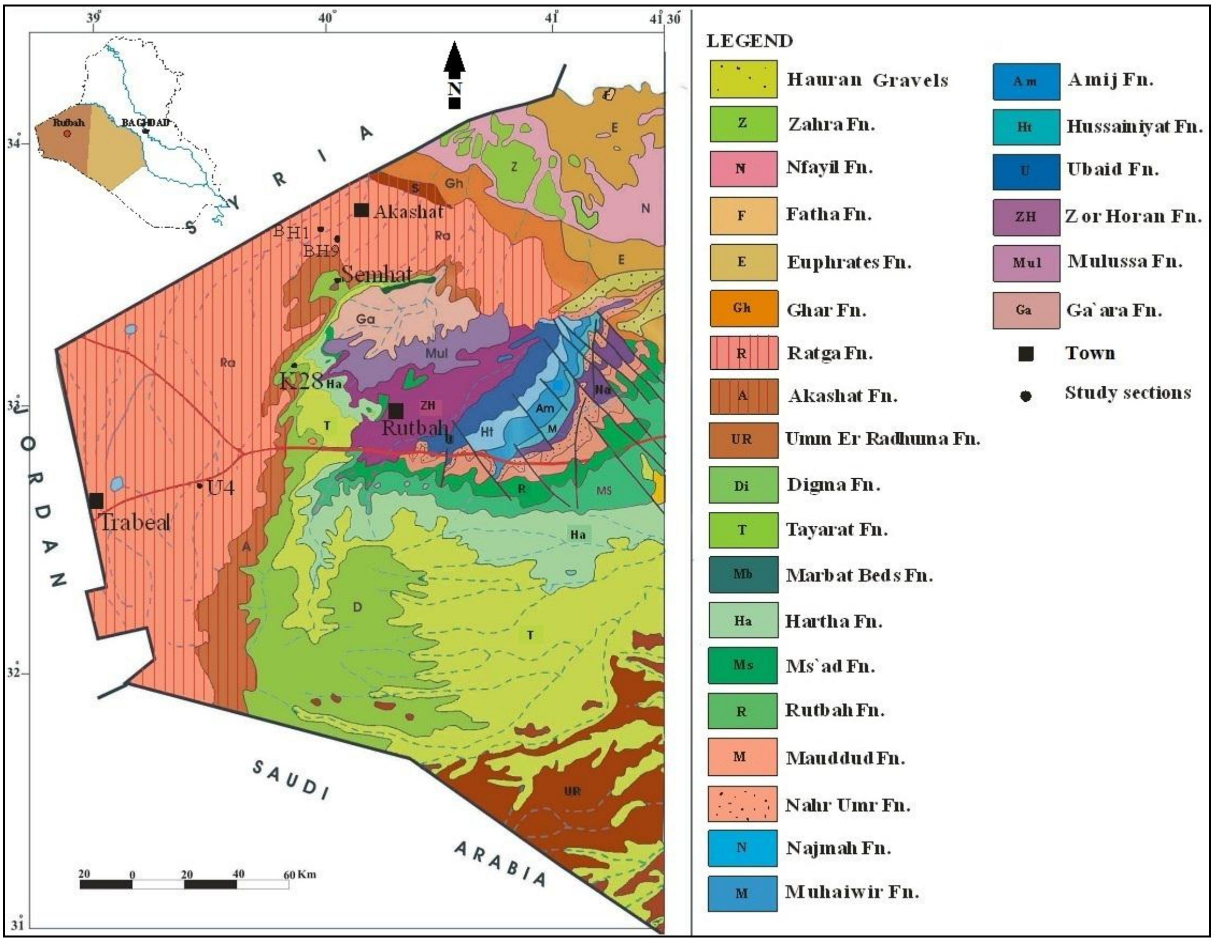

Fig.1: Geological map of Iraqi Western Desert, scale 1: 2 000 000
(after Sissakian and Mohammed, 2007)

THICKNESS VARIATION

The thickness of the Paleocene sequence in the Western Desert, west of the Hauran Uplift varies from 12 m (Semhat), 22 m (K28, 50 Km south of Akashat mine) and 44 m (H_3 area). The Paleocene sequences drastically increases in thickness towards the Jordanian and Syrian borders and in the direction of the Euphrates River. Near Wadi Swab area, the thickness of the Paleocene sequence exceeds 190 m (BH1). Towards the eastern rim of the Ga′ara depression, the Paleocene becomes is gradually truncated by the Eocene sequence and it is missing along Wadi Hauran.

STRATIGRAPHY AND LITHOLOGY

The lithology of the Akashat Formation is variable from place to place and unless a proper stratigraphic evaluation using microfauna, it is very easy to miscorrelate the various units. For this purpose we will describe the lithology in a stratigraphic prospective.

- **Danian**

According to the present study the Danian seems to be present throughout the exposure area and boreholes though the thickness and facies changes drastically (Figs.2, 3 and 4):

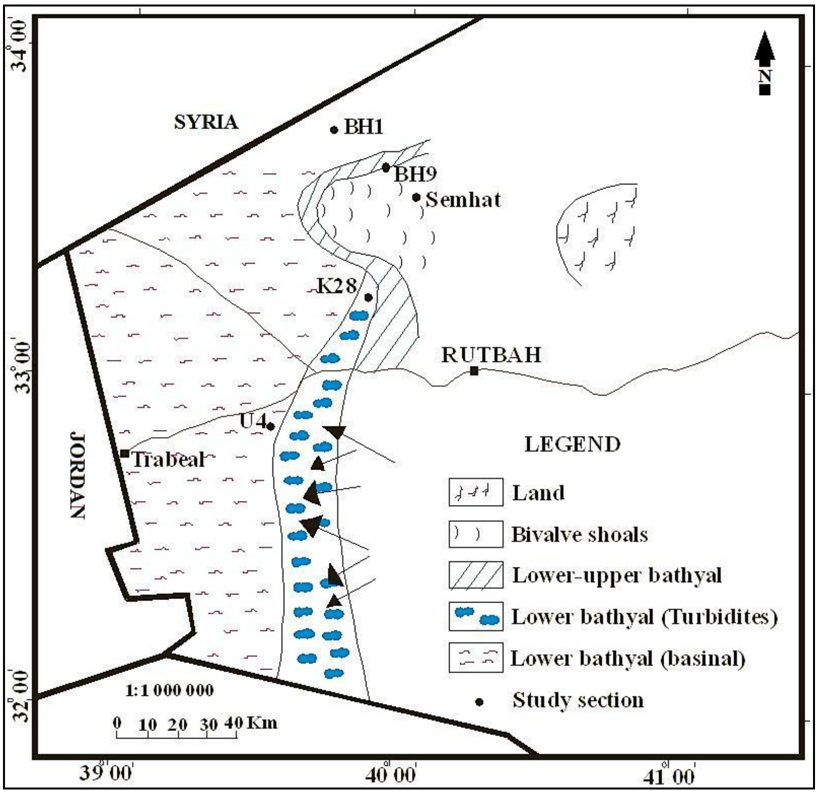

Fig.2: Paleogeographic configuration of the Early Danian in the Western Desert of Iraq (after Jassim and Karim, 1984)

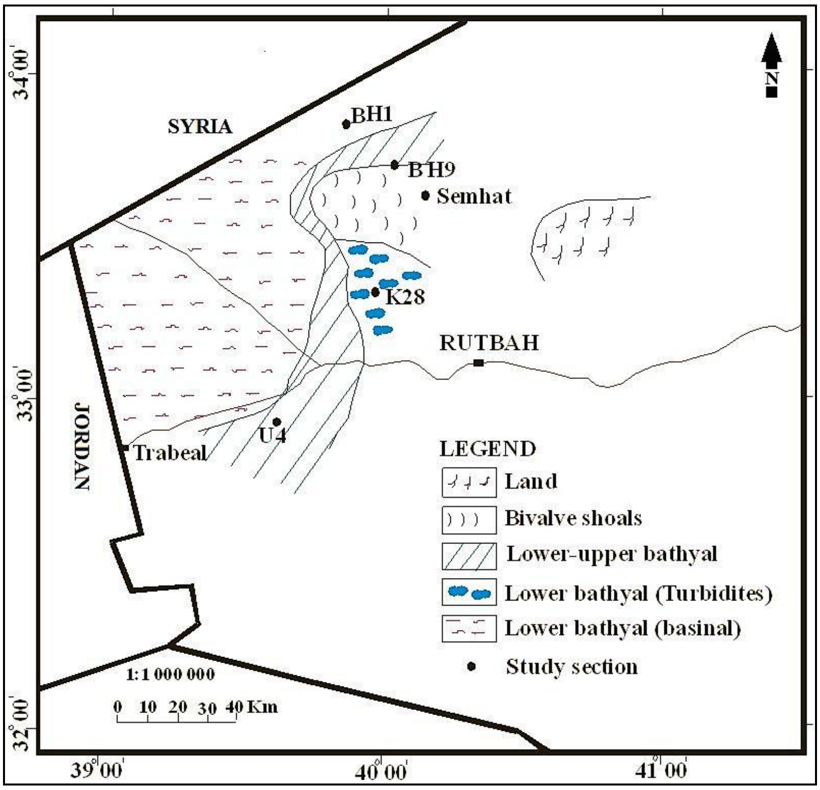

Fig.3: Paleogeographic configuration of the Late Danian in the Western Desert of Iraq (after Jassim and Karim, 1984)

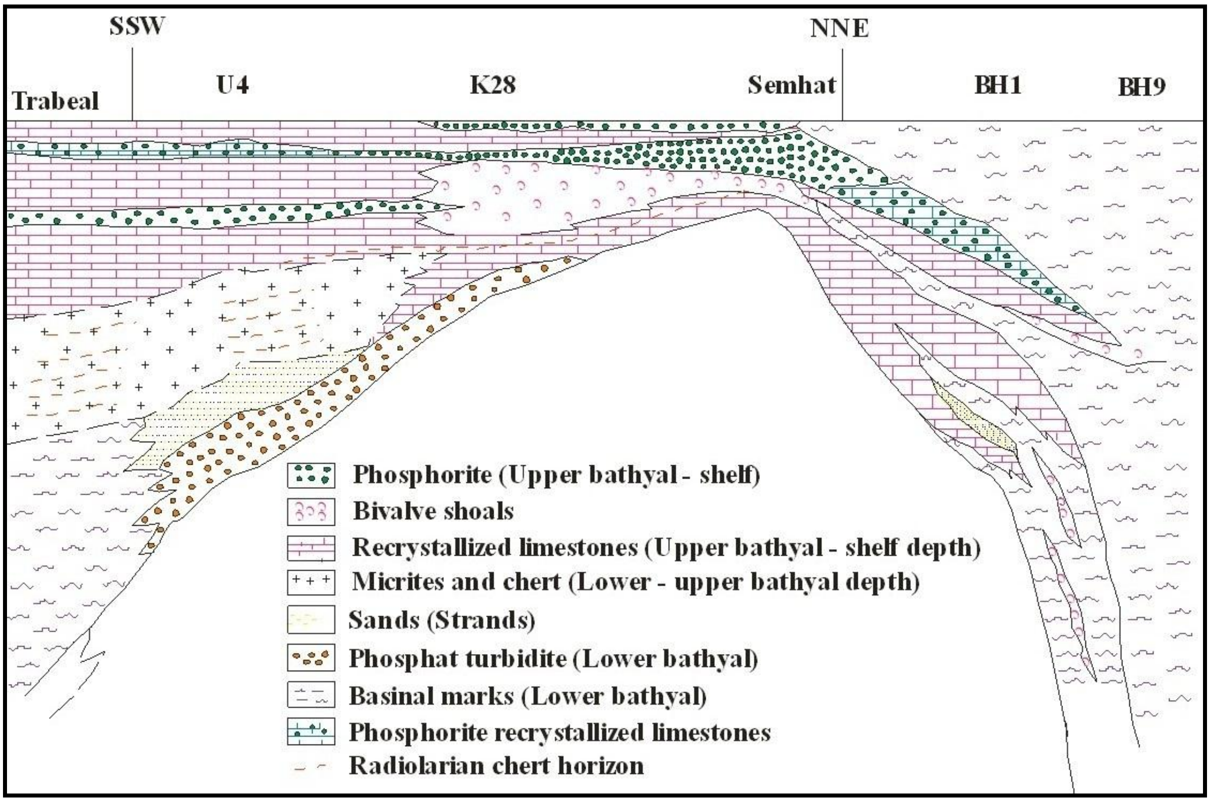

Fig.4: Facies model of the Paleocene sediments of the Western Desert of Iraq (after Jassim and Karim, 1984)

– **H_3 Area** (South of Baghdad – Amman highway, 50 Km West of Rutbah town)**:** The Danian section from H_3 area is largely described from trenches undertaken by Iraq Geological Survey (GEOSURV), the samples were kindly made available by Mr. Dikran Hagopian (Retired Senior Geologist at GEOSURV). The sequence may be seen exactly at the junction 45 Km west of Rutbah. Further samples were taken from borehole U4 (GEOSURV) which partly penetrates the Danian sequence. It is noteworthy that the Danian sequence of this area has been lumped under the newly suggested-"Jeed Formation" (abandoned now) within the (Late Cretaceous sequence) due to similarity in lithology and facies (Jassim *et al*., 1984). The Danian age was not determined at the time in this area, but later, samples from the H_3 area reported by Jassim and Karim (1984), confirmed the Danian age. The Danian sequence in the H_3 area is 25 m thick and is divided into three main units, from base to top these are:

- **The Shale-Chalk-Phosphate (Turbidite?) Unit (7 m):** This unit is composed of alternation of flaky buff to grey shale and white chalk. The flaky shale contains ribbons of intraclastic and bone phosphate, sometimes repeatedly with the shale forming laminae but often not in regular alternation. The flaky shale usually starts very sharply by white chalk, the contact is marked by load casts. Qassim (1985) and Al-Bassam and Al-Saadi (1985) studied the clay mineralogy of the shale unit and revealed the abundance of montmorillonite and palygorskite. The chalk interlayers are usually very light and are rich in planktonic fauna (often silicified) and spicule like silica needles. Al-Bassam and Al-Saadi (1985) revealed, by X ray diffraction analysis, a tridymite structure for the silica. The fauna identified by Karim (1977) are: *Globoconusa daubjergensis* BRONNIMANN; *Chiloguembelina* sp.; *Euglobigerina* cf. *danica* BANG; *Guembelitria* spp.; *Parasubbotina pseudobuloides* (PLUMMER); *Globanomalina compressa*

EHRANBRG; *Globobulimina* sp.; *Bulimina* sp.; *Siphogerinoides elegantus* PLUMMER; *Cibicides* sp.; *Valvulinaria ravnia* BROTZEN and *Ganrdryna* sp. The chalk interlayers reveal *Globoconusa daubjergensis* BRONNIMANN and *Guembelitria* spp. The character of this unit and the presence of the phosphate intraclasts in repeated event with the shale; possibly indicate turbidity pulses in deep sea (bathyal – basinal) usually depositing biogenic oozes (chalk).

- **Sandstone Unit (7 m):** This unit changes in lithology northwards near the Baghdad – Amman highway into clayey phosphatic limestone. The sandstone is yellow quartizitic sand, often Phosphatic, it usually contains interlayers of silicified shelly limestone. Fauna: benthonic marine fauna only *Cibicides* sp. In our opinion, more undisturbed exposures should be found to study the internal structure of the sand. However, the presences of the sand unit between deep water sediments without obvious shallowing may indicate that the sandstone is of sand strand type, occasionally developing into bivalves shoals.

- **Biomicrite – Chert Unit (11 m):** This is a foraminiferal biomicrite or micrite with recrystallized planktonic tests, often alternating with micrite or sparite with small pieces of bivalve shell fragments, sometimes of large *Lenticulina* sp. Black, white and grey chert is found at different levels. It is assumed that the unit was deposited in a bathyal to shelf edge depth, due to the alternation of planktonic and planktonic – benthonic and broken shells. This particular unit, due to its several chert intercalations is well recognized in satellite imageries as a black strip which rapidly diminishes north of the highway, but extends southwards to Saudi Arabia. It is interesting to note that in a Water Development borehole at Traibeal border station, the lower part of the Danian develops as black shale at least 30 m thick. At depth of 278 m, one sample of black shale revealed Danian fauna like: *Globoconusa danbjergensis* BRONNIMANN and *Euglobigerina* cf. *danica* BANG.

– **Section K28** (28 Km from Rutbah – Akashat junction)**:** The Danian part of this section is 7 m thick out of 22 m of the total Paleocene sequence:

- **Shale-Chalk-Phosphate Unit (3 m):** This unit is similar in every respect to that of H_3 area. However, no fossils are recorded.

- **Recrystallized Limestone Unit (3 m):** Very coarse – crystalline patchy limestone of nearly 1m thick usually associated with thick silicified limestone at top and is devoid of fossils.

- **Phosphatic Limestone Unit (1 m):** Bone phosphatic limestone, coarse at base and rich with bone fragments. The bones and phosphate intraclastic are embedded in coarse – crystalline calcareous matrix. The top layer is recrystallized shelly limestone. The fragmentary nature of the rock indicates shallow marine environment at depth above wave base.

– **Semhat Section** (15 Km Southeast of Akashat mine)**:** The Danian in the Akashat section is 3 m thick out of 12.5 m of the Paleocene sequence. It is characterized from base to top, by the following lithological units:

- **Purple Flaky Shale Unit (0.8 m):** Pink, dolomitized flaky shale with abundant planktonic and benthonic foraminifera of similar assemblage to that of H_3 area. The shale is dolomitic as isolated dolomite rhombs are present.

- **Bone Phosphatic Limestone Unit (2.0 m):** Course bone and phosphatic intraclasts in recrystallized calcareous matrix containing isolated dolomite rhombs. Recrystallized fragments of *Cardium* sp. and other shell fragment are common.

- **Dolomitic Limestone Unit (0.7 m):** Dolomitic recrystallized limestone and shale grading upwards into dolostone with few phosphatic intraclasts. The later section of Semhat was possibly deposited in bathyal to shoal conditions as represented by the planktonic assemblage at the base and the *Cardium* spp. Fragments at top.

– **BH9** (28 Km Northwest of Akashat mine)**:** The Danian sequence of BH9 is 20 m thick and is dominated by marl and biomicrite of bathyal to basinal depth. The sequence from base to top is as follows:

- **Marl and Biomicrite Unit (6 m):** Marl and biomicrite with planktonic fauna, such as: *Globoconusa danbjergensis* BRONNIMANN. The unit is unmistakably of bathyal depth due to the presence of planktonic fauna in association with deep water benthonic fauna (as quoted for H_3 section). The unit contains phosphatic limestone at its top which indicates shallowing.

- **Sandstone Unit (2 m):** This is quartz sand with phosphatic grains and contains few benthonic foraminifera like *Cibicides* sp., and is therefore of marine origin and is comparable to the sandstone unit of the H_3 area.

- **Marl Unit (13 m):** This marl sequence occasionally contains limestone intercalatic rich with bathyal benthonic foraminifera such as: *Siphogerinoides elegantus* PLUMMER, *Lenticulina* sp., *Bulimina* sp. and *Ganrdryna* sp.

– **BH1** (32 Km Northwest of Akashat mine)**:** The thickness of the Danian sequence in this borehole is over 110 m and is composed of marl with occasional alternation of shelly limestone. The marl contains planktonic and benthonic foraminifera and represents oscillation of the sedimentation from bathyal to shelf edge or shoal as indicated by the presence of repeated bivalve-rich limestone and deep water marls.

▪ **Middle and Late Paleocene**

The Middle and Late Paleocene rocks are lumped in one sequence since it is not easy to separate the two in most of the sections (Fig.4):

– **H_3 Area** (South of Baghdad – Amman highway, 50 Km West of Rutbah)**:** The Middle and Late Paleocene of H_3 area is described from BHU4 (of Iraq Geological Survey). From bottom to top, it is composed of the following:

- **Shelly Phosphatic Limestone Unit (4 m):** This unit is a shelly limestone with phosphatic intraclastic changing to micritic limestone in the upper 2 m. The planktonic foraminifera are: *Morozovella angulata* WHITE, *M. uncinata* BOLLI, and benthonic foraminifera *Valvulinaria ravnia* BROTZEN.

- **Oolitic Phosphatic Limestone Unit (2 m):** Oolitic and intraclastic phosphates, embedded in fine calcareous matrix with, planktonic foraminifera often forms the nucleus of the oolites.

- **Claystone Unit (0.3 m):** Brown calcareous claystone with dolomite rhombs, rich in dwarfed planktonic foraminifera and ostracods. An event of environmental stress may be assumed for this unit.

- **Bone Intraclastic Phosphorite Unit (0.3 m):** Bone, phosphatic intraclasts and pellets comprise more than 50% of the rock constituents; embedded in fine micritic groundmass with abundant heavily spinose planktonic fauna, and overlain by radiolarian chert. This assemblage and lithology indicate marine water of basinal – bathyal depth and shelf edge. This unit belongs to the Middle Paleocene age (Selandian) based on the finding of planktonic foraminifera *Morozovella angulata* WHITE.

- **Intraclastic Micrte and Calcareous Claystone Unit (6 m):** The unit is formed of alternations of intraclastic micrite with calcareous claystone indicating fluctuation from bathyal to shelf edge. The associated fauna are: *Morozovella valascoensis* (CUSHMAN); *M. aequa* CUSHMAN and RENZ; *M. acuta* TOULMIN; *Globorotalia esnaensis* (LEROY); *Subbotina triloculinoides* PLUMMER and bentonic fauna such as: *Astacolus gladias* (PHILIPS); *Nodosaria macneili* CUSHMAN; *Lenticilina wilcoxensis* CUSHMA and PONTON; *Dentalina* sp. and *Bulimina* sp.

- **Phosphorite and Phosphatic Limestone Unit (2.5 m):** Coarse peloidal and intraclastic phosphorite grading upwards into phosphatic limestone.

- **Intraclastic Limestone with Bone Fragments Unit (2 m):** This unit belongs to the Late Paleocene (Thanetian) based on the presence of *Morozovella valascoensis* CUSHMAN and was deposited in marine conditions of bathyal to shelf edge depth. In surface sections, south of H_3 area, oolitic phosphorite are seen in the Late Paleocene sequence.

– **K28 Section** (28 Km from Rutbah **–** Akashat junction)**:** From base to top:

- **Phosphorite – Shelly Limestone Unit (12 m):** This unit is composed of phosphorite at the base, grading into phosphatic limestone and shelly limestone with chert nodules, followed by oolitic phosphorite and recrystallized phosphatic limestone with abundant chert nodules and bands. Siliceous matrix around oolites is common in some part. The unit is characterized by shelly limestone with *Cardium* spp., repeated at least four times. It is likely to be deposited in shallow shelf conditions above wave base.

- **Micritic Limestone Unit (4.2 m):** Patchy recrystallized micritic limestone with chert nodules and a flakey shale horizon. Similar shale from the Akashat area contains benthonic foraminifera: *Frondicularia phosphatica* REUSS and planktonic foraminifera such as: *Morozovella valascoensis* (CUSHMAN) and therefore bathyal marine origin is assumed for this unit (Karim, 1977).

- **Coprolitic Phosphorite Unit (0.5 m):** Bone fragments and coprolites in calcareous matrix, in places rich in shell fragment, most probably deposited in a semi restricted basin.

– **Semhat Section** (15 Km Southeast of Akashat mine)**:** The section is devoid of planktonic and benthonic foraminifera and is composed of (from bottom to top):

- **Shelly Limestone Unit (2.5 m):** Shelly limestone with silicified gastropods (*Turretella* sp.) and pelecypods (*Cardiua* sp.).

- **Oolitic Phosphorite Unit (6 m):** Oolitic phosphorite in recrystallized calcareous matrix, the oolites become coarser in the upper meter. Shallow marine water above wave base is assumed to the oolite accumulation. A phosphatic sand strand cannot be excludes.

- **Flaky Shale Unit (0.2 m):** Possibly equivalent to the Akashat shale unit with *Frondicularia phosphatica* REUSS (Fig.5).

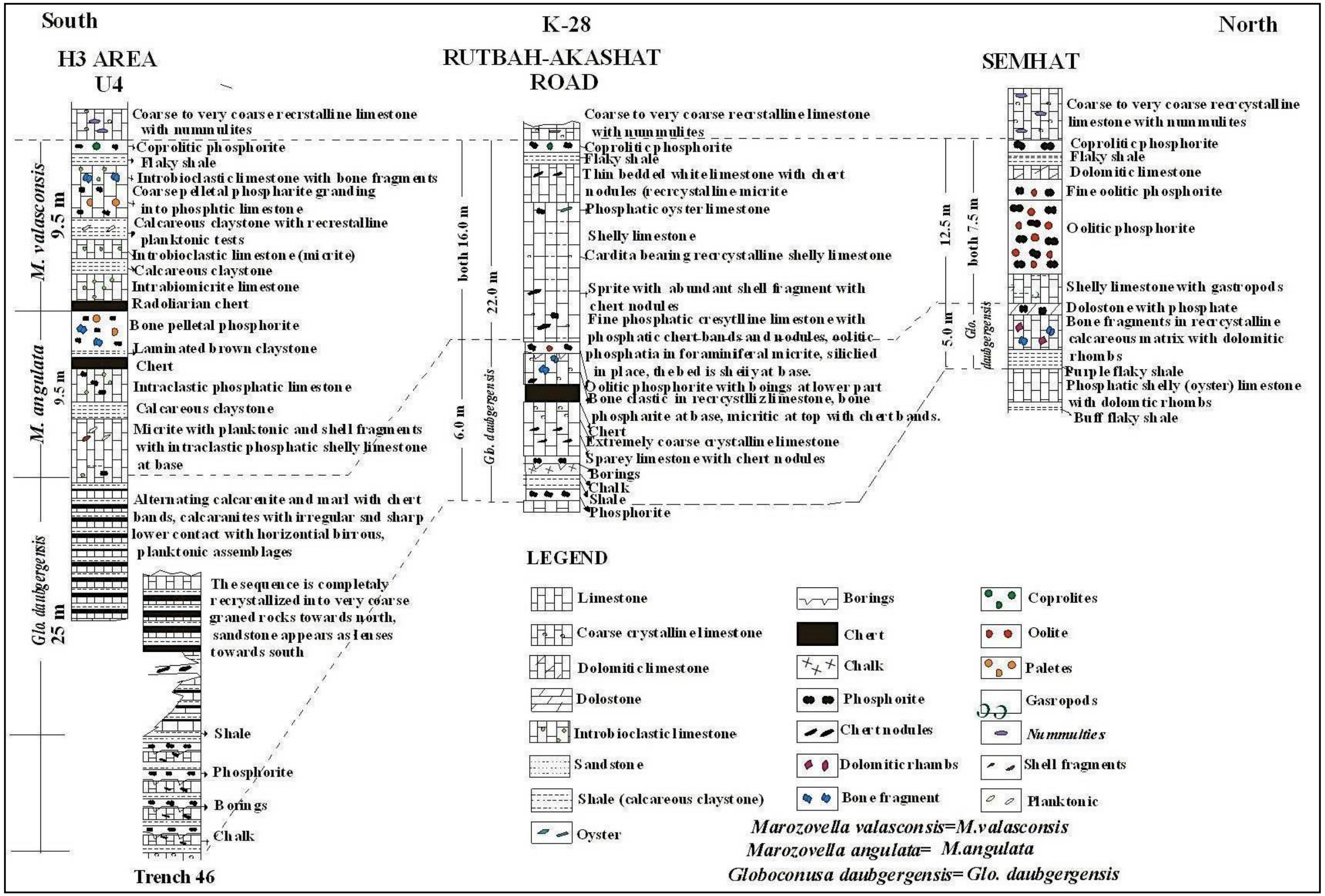

Fig.5: Correlation chart of Paleocene in the Western Desert

assemblage in this zone is characterized by: *Bulimina* sp.; *Globobulimina* sp.; *Siphogerinoides* sp.; *Valvulinaria* sp.; *Cibicides* sp.; *Gabonella* spp. and *Gaudryna* sp.

– **BH9** (28 Km Northwest of the Akashat mine)**:** The section is comprised from bottom to top of:

- **Marl and Biomicrite Unit (8 m):** Marl at base changing to biomicrite with planktonic foraminifera of *Morozovella angulata* WHITE, Middle Paleocene (Selandian), occasionally with recrystallized macroforams. The environment is of bathyal marine depth occasionally approaching shelf edge.

- **Phosphatic Biomicrite Unit (6 m):** Phosphatic foraminiferal biomicrite with planktonic foraminifera of *Morozovella valascoensis* (CUSHMAN). It is deposited in a marine condition of bathyal depth with occasional shelf edge approach resulting in the income of phosphatic intraclasts.

- **Marl Unit (13 m):** Green marl rich in planktonic foraminifera of *Morozovella valascoensis* (CUSHMAN), and benthonic foraminifera of bathyal depth. This unit belongs to the Late Paleocene (Thanetian).

– **BH1** (32 Km Northwest of Akashat mine)**:** The section from bottom to top:

- **Marl and Marly Limestone Unit (53 m):** Sometimes sandy with shelly limestone at top. It contains planktonic foraminifera *Morozovella angulata* WHITE (Selandian). The unit is of bathyal depth, shallowing near top to shoal depth.

- **Marl, Limestone and Shelly Limestone Unit (29 m):** This unit is formed of cycles of marl, limestone and shelly limestone indicating oscillation from bathyal to shoal depth. The unit contains abundant planktonic fauna such as *Morozovella valascoensis* (CUSHMAN) (Thanetian) associated with bathyal benthonic fauna similer to U4 subsurface section.

BIOSTRATIGRAPHY AND PLANKTONIC FORAMINIFERA ZONATION

Planktonic foraminifera zonation for the Paleogene from areas around the world, such 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 (1969a and b, 1970, 1971, 1972a and b); Postuma (1971); Krasheninikov and Hoskins (1973); Bolli and Krasheninikov (1977); Kureshy (1979); Bang (1977, 1979 and 1982); Berggren *et al.* (2000); Hanif *et al*. (2012) and Guithern *et al*. (2017).

The Bio-Zones of the study area are indicatives of Early – Late Paleocene age. The Late Maastrichtian – Early Paleocene boundary is placed at the first occurrence of the Danian Datum *Globoconusa daubjergensis* BRONNIMANN. The Late Paleocene – Early Eocene boundary is placed at the *Nummulites fraasi – Nummulites deserti* Zone of Early Ypresian.

- **Paleocene Zonation**

Three planktonic zones are recognized in the present study:

– ***Globoconusa danbjergensis* Zone of Danian Age** (in U4 between depth intervals of 52 – 42 m and in BH9 76 m). This zone is characterized by the most important event of the appearance of the *Globoconusa daubjergensis* BRONNIMANN (Fig.6a, b and c), also it marks the first occurrence of *Subbotinas*, *Globanomalinas*, and *Chiloguembelinas* and the extinction of all *Globotruncanas*; *Heterohelix* and others. Present with the index species are *Chiloguembelina* sp.; *Guembelitria* spp.; *Globanomalina compresse* (PLUMMER); *Parasubbotina pseudbulloides* (PLUMMER); *Euglobigerina* cf. *danica* BANG (Fig.6d, e and f), (is present in the basal Danian in Traibeal borehole at depth 278 m) and *Chiloguembelina* spp. This zone is established by the authors for the first time in Iraq, with the index species of *Euglobigerina* cf. *danica* BANG; *Globoconusa daubjergensis* BRONNIMANN and *Guembelritia* spp.

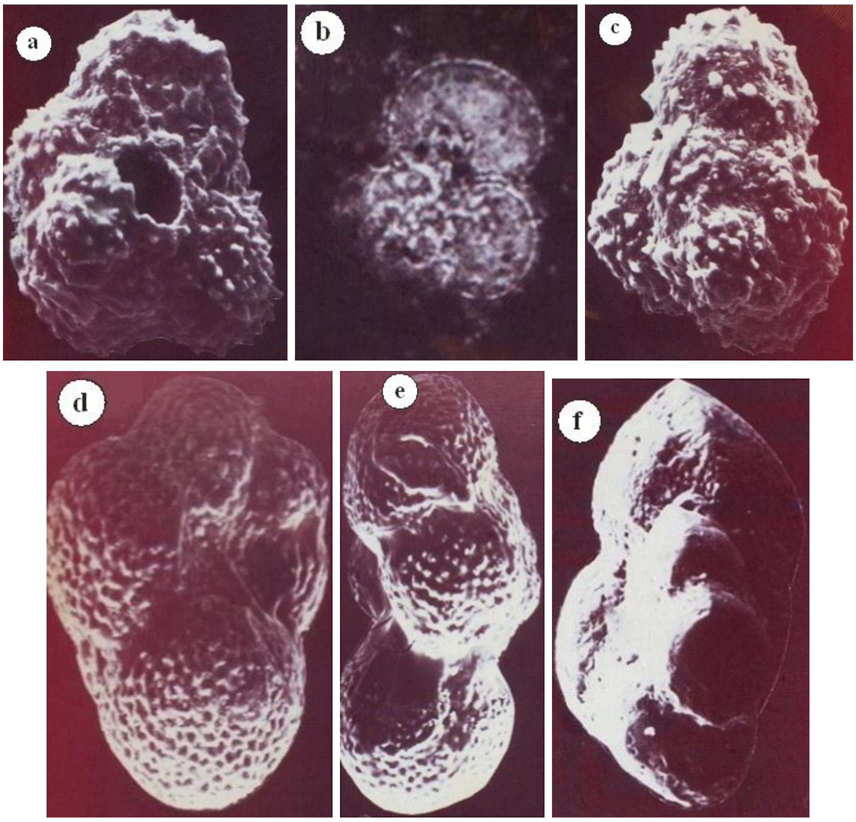

Fig.6:

a) *Globoconusa daubgergensis* BBONNIMANN, Dorsal side, Traibeal borehole, depth 248 m, W.D., X800;
b) *Globoconusa daubgergensis* BBONNIMANN, Dorsal side (thin section), Traibeal borehole, depth 248 m, W.D., X300;
c) *Globoconusa daubgergensis* BBONNIMANN, Dorsal side, Traibeal borehole, depth 248 m, W.D., X800;
d) *Eoglobigerina* cf. *danica* BANG, Traibeal borehole, depth 248 m, W.D., X270;
e) *Eoglobigerina* cf. *danica* BANG, Traibeal borehole, depth 248 m, W.D., X270;
f) *Eoglobigerina* cf. *danica* BANG, Traibeal borehole, depth 248 m, W.D., X270

– ***Morozovella angulata* Zone of Middle Paleocene (Selandian) Age:** This zone is characterized by the first occurrence of *Morozovella angulata* (WHITE); *Praemurea uncinata* BOLLI (Fig.7f); *Parasubbotina pseudobulloides* (PLUMMER); *Subbotina triloculinoides* PLUMMER; *Globigerina haynesi* EL-NAGEER and others. Associated benthonic foraminifera within this zone are: *Anomalina* sp.; *Lenticulina* sp.; *Valvulinaria ravni* BROTZEN; *Bulimina* sp.; *Dentalina* sp.; *Gyroidina* sp. and *Cibicides* sp.

– ***Morozovella valascoensis* Zone of Late Paleocene (Thanetian) Age:** This zone is characterized by the first findings of *Morozovella valascoensis* (CUSHMAN) (Fig.7a and b), and abundant occurrence of heavily keeled planktonic foraminifera i.e. *Morozovella acuta*

TOULMIN (Fig.7c); *M. aequa* CUSHMAN and RENZ (Fig.7d); *M. esnaensis* (LEROY); *M. woodi* EL-NAGGAR; *M. irrorata* LOEBLICH and TAPPAN and *Subbotina triloculinoides* PLUMMER. Benthonic foraminifera present within this zone are: *Frondicularia phosphatica* REUSS (Fig.7e); *Vaginulepsis midwayensis* (FOX and ROSS); *Astacolus gladias* (PHILIPS); *Nodosaria macneili* CUSHMAN; *Lenticilina wilcoxensis* CUSHMAN and PONTON; *Valvulinaria ravni* BROTZEN; *Bulimina* sp.; *Dentalina* sp. and *Anomalina* sp.

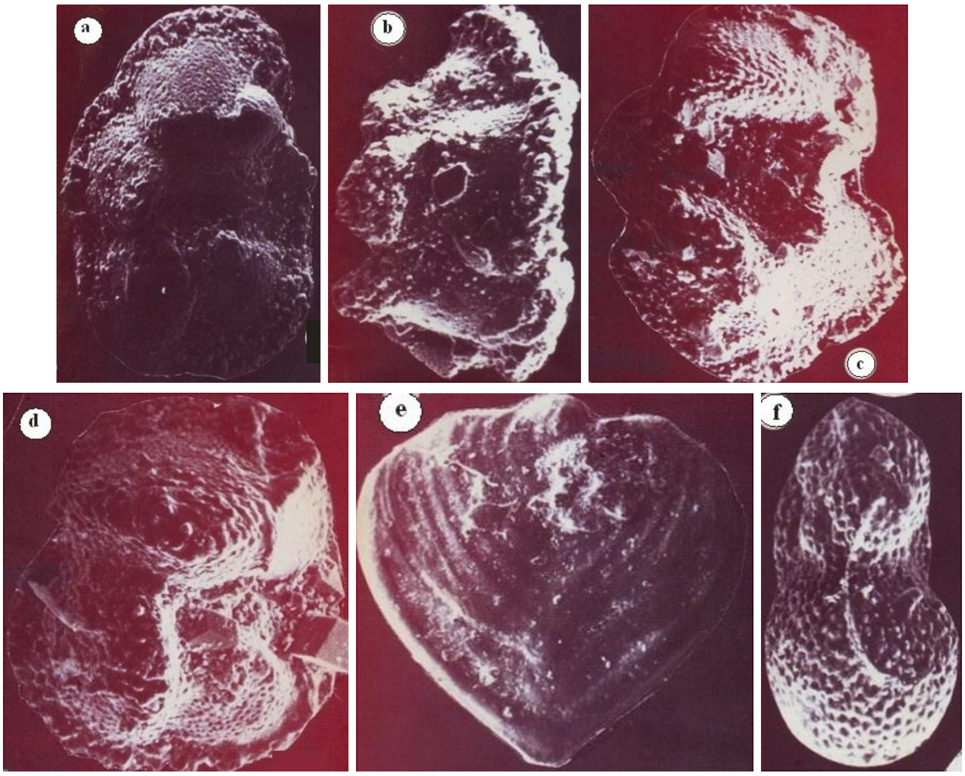

Fig.7:
a) *Morozovella valascoensis* CUSHMAN, Ventral view, BH 9, S. No.9, W.D., X160;
b) *Morozovella valascoensis* CUSHMAN, Side view, BH 9, S. No.9, W.D., X160;
c) *Morozollea acuta* TOULMIN, BH 9, S. No.9, W.D., X160;
d) *Morozollea aequa* CUSHMAN and RENZ, BH 9, S. No.9, W.D., X200;
e) *Frondicularia phosphatic* REUSS, BH 9, S. No.8, W.D., X25, and
f) *Praemurea uncinata* BOLLI, BH 9, S. No.10, W.D., X360

- **Paleoecology**

The Paleocene planktonic and benthonic foraminifera in exposed and subsurface sections north and west of the Rutbah area (Fig.1) are studied in detail, planktonic/ benthonic ratio, presence and/ or absence of shells (complete and/ or fragments), bone fragments, algae and abundancy of lime mud are utilized in determining and reconstructing the environmental history of the Tethyan Paleocene phosphorite bearing sequence in Western Iraq.

− **Planktonic Foraminifera:** Planktonic foraminifera are important constituents of the oceanic planktonic fauna, and are the major contributors to extensive calcareous deposits covering the ocean floor. Their distribution and ecology in modern seas have been intensively studied by: Bradshaw (1959); Be (1959, 1960 and 1964); Be and Tolderlund (1971a and b);

Kafeciogla (1975); Cifelli and Benior (1976) and Berggren *et al.* (2000), to name only few. These authors have established three major faunal groups among the planktonic foraminifera:

a. Cold water fauna, characterized by various *Globigerina* species.
b. Transitional water fauna, which represent a mixture of *Globigerina* and *Globorotalia* species.
c. Warm water fauna (tropical – subtropical) composed mainly of *Globigerinoides*, keeled *Globorotalia* and spinose *Globigerina* species.

Legett (1985) concluded that when seas were cooler, when Carbon Compensation Depth (CCD) was lower and when the biosphere extinction rate of the nekton planktonic organism was relatively high, global diversity is low and communities are reduced in complexity. The Paleocene planktonic distribution patterns and population can be summarized as follows:

- In the interval of *Globoconusa danbjergensis* Zone (Danian) planktonic foraminifera ranges between 80 – 90 % of the total population and are dominated by *Globoconusa danbjergensis* BRONNIMANN and *Guembelitria* spp., which indicate cool – temprate open marine environment (basinal).

- The Middle Paleocene *Morozovella angulata* Zone, planktonic foraminifera ranges between 50 – 40% and are mainly of *Morozovella angulata* (WHITE); *Praemurea uncinata* BOLLI and *Parasubbotina pseudobulloides* (PLUMMER) which indicate warmer open marine environment.

- In the *Morozovella valascoensis* Zone of Late Paleocene age, the planktonic foraminifera ranges between 50 – 60 % and are mainly of heavily spinosed, thickly keeled Globorotalias and Globigerinas species, and are typical tropical to subtropical open marine environment.

− **Benthonic Foraminifera:** The distribution of recent benthonic foraminifera of the Atlantic Ocean was documented by: Phleger (1951); Sengupta (1971); Hamdan (1971); Berggren (1977); Lohmann (1978); Rodrigues and Hooper (1982) and Otto *et al*. (1985). In the Pacific Ocean, the distribution of benthonic foraminifera were established by: Bandy and Arnal (1957); Braoshaw (1959); Bandy (1961 and 1964); Phleger (1964); Ingle *et al.* (1980), within the Gulf of Mexico and Pelum and Frerichs (1976) studied the deep water foraminifera. The Mediterranean benthonic foraminifera have been studied by Blanc-Vernet (in Murray, 1973). In a relatively recent work, Al-Ganabi (2004) studied the environmental conditions of the Danian sequence in the western part of Iraq based on mollusks and ostracods.

In general all the above mentioned authors categorized the benthonic marine environment into the following depth zones:

1- Inner shelf zone, depth 50 m
2- Central and outer shelf zone, depth 50 – 150
3- Upper bathyal zone, depth 150 – 600
4- Middle bathyal zone, depth 600 – 2430
5- Lower bathyal zone, depth 2430 – 4000

These depth zones are similar to depth zones proposed by Murray (1973). The Paleocene benthonic foraminifera present in the study area are related to the last three depth zones, and they are similar to the benthonic foraminifera of the Atlantic – Tethyan regions of midway type fauna (Berggren and Aubert, 1975 and Tipton 1975; see the Paleogene of Wesrern USA).

- **Bivalves:** In general the most dominated of bivalves are the filter eaters i.e Oysters, Cardiums and Venericardias, which require fine substrata, clear water, rich food and slow rate of sedimentation. (Milliman, 1974 and Fursich, 1981). They also stated that oysters thrive best in subtidal (neritic) oceanic water of high latitudes.

- **Basic Phosphorite Facies**

What could be said for the Paleocene phosphate facies may be said for the other phosphorite of the area apart from abundance differences (Figs.4 and 8). Let us first describe the basic criteria for the phosphorite of the Paleocene. It is clear from the analysis of sediments from boreholes and exposures that few basic facies are characteristic; these are:

- **Facies I. Oolitic Phosphorite:** Phosphate Oolites are characteristic of the Middle Paleocene phosphatic sequence (the industrial bed at the Akashat mines), but are less abundant in the Upper Paleocene and are not present in the Early Paleocene (Danian). They usually produce thick phosphorite deposits; the oolites are embedded in recrystallized calcareous matrix, sometimes associated with bone fragments, shark teeth and peloids and may contain planktonic test as nucleus. Oolites are usually well sorted, indicating an agitated oscillatory environment and is therefore deposited in shallow marine water above wave base, in a basin connected the open sea.

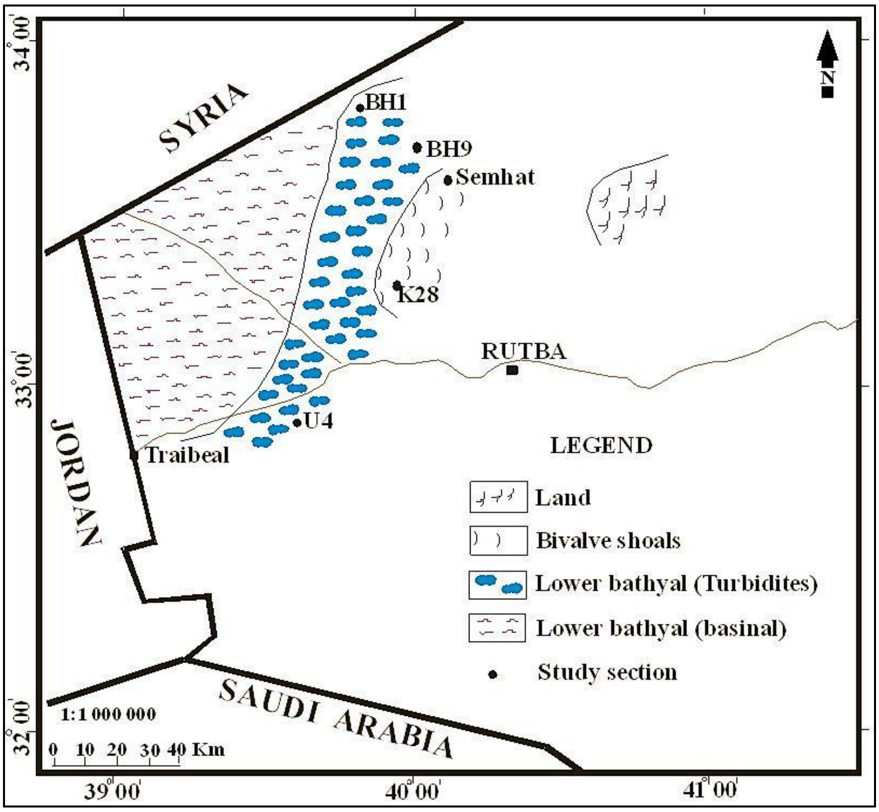

Fig.8: Paleogeographic configuration of the Middle Paleocene in the Western Desert of Iraq (after Jassim and Karim, 1984)

- **Facies II. Microsphorite:** Microsphorite has been described from Iraq, in the Upper Cretaceous phosphorites for the first time by Qassim (1985). He described it as lenticules in limestone or as matrix for phosphatic intraclasts. The authors have also noted the latter form in the Upper Cretaceous section of Semhat. The reason we include this facies in our model regardless of its rarity is logical. First of all, the authors have noted that cyclicity in sedimentation, especially deduced from borehole sections, indicate that deep water bathyal sediments grade upwards into intraclastic phosphorite (sometimes with hardground) then to chert or limestone of deeper water origin. If the hardground means emergence then it would seem that the phosphate should have deposited as microsphorite in non-agitated environment, possibly by replacement of the calcareous mud. On exposure, these phosphates are then broken by wave action and redeposited as intraclastic phosphorite on hardgrounds. This model also explains the rare occurrence of microsphorite in an oscillating sea level environment. The next deepening event brings about the deposition of biomicrite or chert.

- **Facies III. Coprolitic Phosphorite:** This type of phosphorite is characteristic of the Latest Paleocene and is usually seen to grade into the overlying nummulitic limestone of the Eocene. The coprolitic phosphorite is seen only in the area around the Akashat mines (i.e. Semhat, Akashat and K28), but are absent basin-ward (e.g. in H_3 section). Coprolites are often associated with bones and in places with oyster shells. We believe that the coprolites are deposited in semirestricted basin with abundant fish excrements. However, the coprolites must have been deposited below wave base; otherwise they would have been totally destroyed. Any reworking at later stage may alter their position.

- **Facies IV. Phosphate Intraclasts:** These phosphate deposits are usually characteristic of the Late Paleocene and especially the Middle Paleocene. They are often associated with bone fragments, broken oolites and pellets, limestone intraclasts and sand grains. All intraclasts are usually embedded in a spary matrix containing shell fragments and foraminiferal tests. These phosphorites are produced under high energy environment (above wave base) from earlier phosphorite mat and passes into calcareous sandstone or sandy limestone.

- **Facies V. Phosphoclasts:** Phosphate intraclasts and phosphatic bones, together with sand grains and rock fragments slump, as turbidities-like flow, into the deeper basin producing banded phosphorite ribbons and claystone, having sharp contact (associated with load casts and pseudonodules) with the underlying biogenic mudstone of deep sea origin. This facies is characteristic of the Danian and some Cretaceous phosphorite.

- **Paleogeography**

The paleogeography of the Paleocene in the area west of the Rutbah Uplift is depicted in four maps (Figs.2, 3, 8 and 9). For the purpose of the reconstruction of paleogeographic maps,some basic facial groups are recognized in this study (Fig.10), which are:

1- Basinal: This includes the two basic units laid down in lower bathyal depth :
   a. Marls and shales with planktonic foraminifera assemblage.
   b. Claystone and phosphate of possible turbidity-currents origin in alternation with deep sea oozes.
2- Lower – Upper Bathyal depth and is represented by biomicrite with abundant planktonic fauna in alternation with micrite or sparite with shell fragments.
3- Upper Bathyal – Shelf: This subdivision contains most of the oscillatory association of intraclastic phosphorite, oolitic phosphorite and recrystallized partly shelly limestone, with thin subdivision of small bathyal incursions may be lumped too.
4- Shoals: This subdivision covers the units of oyster and cardiumbearing limestone with very small deeper water incursions.

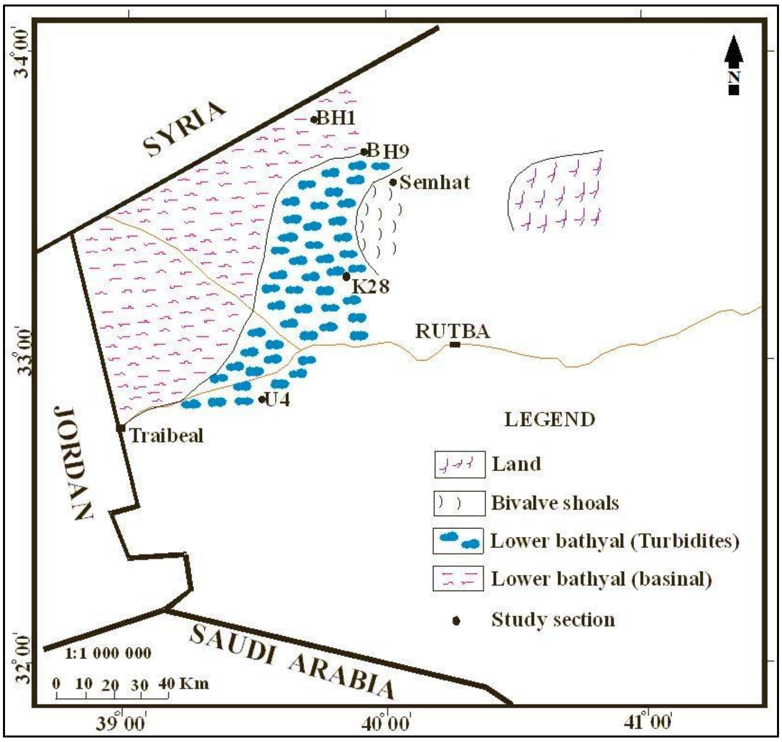

Fig.9: Paleogeographic configuration of Late Paleocene in the Western Desert of Iraq (after Jassim and Karim, 1984)

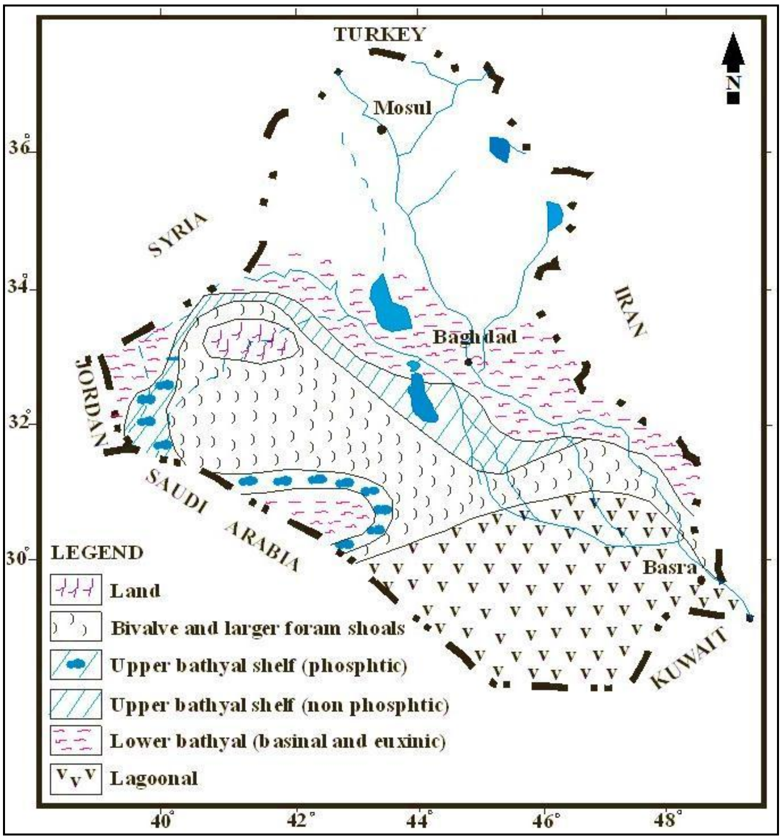

Fig.10: Paleogeographic configuration of the Paleocene in the Western and Southern deserts of Iraq (Scale 1: 5 000 000) (after Jassim and Karim, 1984)

Jassim and Karim (1984) indicated for the first time that a deep basin existed west of the Rutbah Uplift and have generally localized the phosphate sedimentation at the shelf edge of that deep basin. In the paleogeographic maps we have presented in this paper, it is evident that the phosphate bearing sequences are either the shelf edge sequence or the turbidities sequences and that both are basinal sequences devoid of proper oyster shoals. It is clear from Fig.1 that the Danian shore line configuration is roughly N – S and that this picture is quite different for the Middle and Late Paleocene. First of all shoals were developed in the area of K28 and Semhat sections which are located at the western plung of the NE – SW oriented Hauran Uplift indicated by Radosevic and Lesevic (1980). The swing of the basinal sequences towards southwest could be explained by the E – W trending structure that depressed the northern part of the area and elevated the southern side. The map (Figs.10), is drawn after the detail geological study by Jassim and Karim (1984) and this was proven by the detail study of the subsurface sections from the Southern Desert by Karim and Al-Kubaysi (2015). Similar configuration explaines the presence of the Eocene basinal Jaddala Formation globigerinal marls north of the Rutbah – Amman highway and the Eocene Ratga shoal *Nummulies gizehensis* limestone south of the highway (Hagopian, 1980). The Early Paleocene sequences is generally speaking of deeper water origin than the Middle and Late Paleocene sequences and shows less features of oscillation in sea level. It is rich in planktonic foraminifera such as: *Globoconusa daubjergensis* BRONNIMANN; *Guembelitria* spp.; few *Chiloguembelina* spp. and *Globorotalia pseudobuloides* (PLUMMER), and benthonic foraminifera like: *Gabonella* sp.; *Bulimina* sp. and *Siphogerinoides* sp.

The Early Paleocene sequence was deposited in cooler deep water environment. The Middle and Late Paleocene are predominated by shoaling on the continuation of the NE – SW trending Hauran Uplift.

CONCLUSIONS

- The Paleocene phosphatic sequence of the Akashat Formation is confirmed to be of Early Paleocene (Danian) – Middle (Thanetian) – Late Paleocene (Selandian) age, with several newly recorded genera and species.
- Five basic phosphorite facies are established in the phosphate-bearing sequences which are of shelf edge sequence and turbidities-like sequence.
- The Early Paleocene is generally of cooler and deeper marine water environment, whereas, the Middle – Late Paleocene is predominated by warm shoaling conditions.
- The whole Paleocene phosphatic sequence is composed of shoaling upward cycles; each begins with basinal marine condition grading into bathyal – upper bathyal conditions and ending with shoaling condition.

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