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Paleocene Stratigraphy in Aqra and Bekhme Areas, Northern Iraq

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1. Introduction

The Paleocene Kolosh Formation of Iraq is comprised of flysch deposit of sandstones, marls, shales, intraformational conglomerates and thin beds of arenaceous limestone, deposited in subduction trench, parallel to the suture zone formed by closing of the southern Neotethyan ocean and finally collision between the Arabian, Anatolian and Iranian plates, extended North West-South East, from Mushorah (NW) to Kashti (SW) (van Bellen *et al.*, 1950 and Jassim and Buday, 2006) (Figure 1). Kolosh Formation is coeval with several other formations in other parts of Iraq. These formations are diachronous and define according to lithology. In north Iraq, it is pass to or inter-tongue with algal reef limestone (Sinjar Formation) and reef - back reef deposit (Khurmala Formation) (van Bellen *et al.*, 1959), moreover, a different set of paleocene formations are used in central, western and southern Iraq: Aaliji, Akashat and Umm Er Radhumma formations. The complex lithostratigraphy relationships between these units are not suitable for correlation and best resolved by biostratigraphy and sequence stratigraphy.

The Kolosh Formation was firstly described by Dunnington (1952; in van Bellen *et al.*, 1959) in Kolosh area northern Koi Sanjaq City, northern Iraq. It consists of shales and fine sandstones, composed of fragments of various grain size of green rock, chert and radiolarite, their age extended Paleocene - lower Eocene, while Al-Omari *et al*. (1993) and Al-Mutwali (2001) reported early Paleocene – early Eocene age to Kolosh Formation in Shaqlawa City north Iraq, Al-Mutwali and Al-Wazan (2010) recorded early – late Paleocene age to Kolosh succession in Duhok area (Figure 1).

The present study based on a (172) m-thick Kolosh and Sinjar formations surface section in the south limb of the Barat Anticline, Bekhme area, the mid point of the section at 36^{o} 39′ 48″ N, 44^{o} 14′ 42″ E and a (42) m-thick surface section in the north limb of Aqra anticline, the mid point of the section at 36^{o} 46′ 39″ N, 43^{o} 58′ 10″ E (Figure 1) (Figure 2 and 3). Sixty five samples are collected from both surface sections. The study involved a detailed field lithological description and identification of foraminifera assemblages from Bekhme surface section are interpreted as early Paleocene.

Based on paleontological and sedimentological attributes facies are recognized and used to interpret the sequence stratigraphy of Kolosh and Sinjar formations.

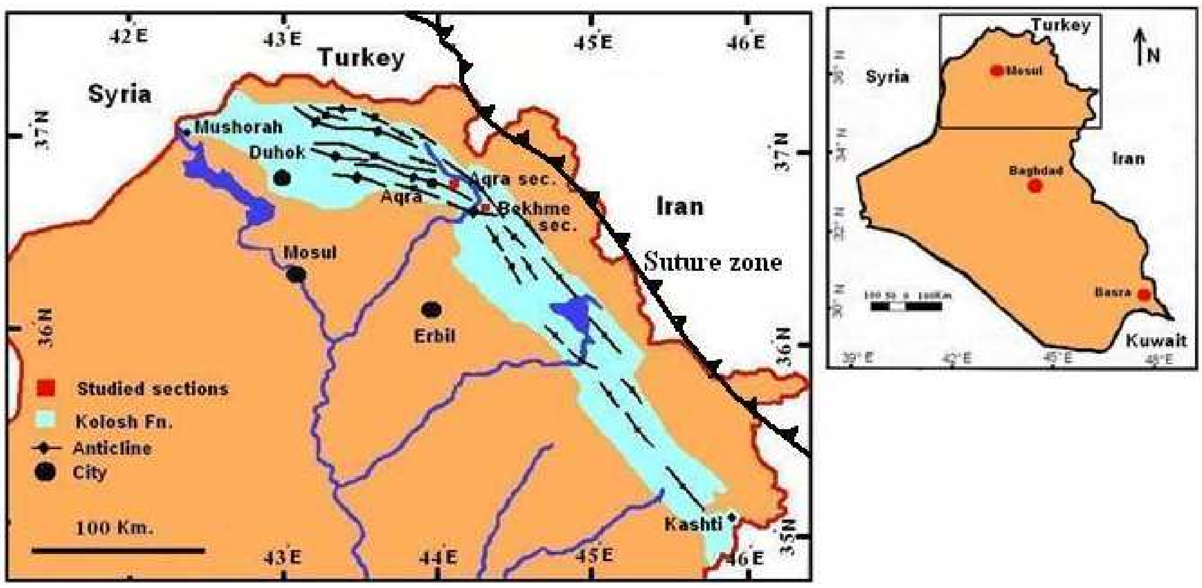


Fig. 1. Paleogeographic distribution of the Kolosh Formation and locations of the studied sections in the northern Iraq.

2. Petrography

Modal analysis was carried out for the sandstones of Kolosh Formation by point counting of an average of 300 point per thin section using the Gazzi-Dickinson method (Ingersoll *et al.*, 1984). The composition of sandstone (Table 1) indicated that they are lithic arenite – lithic graywacke (Figures 4). The mineralogical constituent are:

2.1 Quartz

Monocrystalline (Qm) and Polycrystalline (Qp) quartz occur through out the sandstones of the Kolosh Formation, in which monocrystaline has higher percentage than polycrystalline. Qm is commonly angular to subangular and parallel extinction with inclusion of zircon (Plate 1-1) and rutile suggesting a plutonic origin (Folk, 1974). Most Qp grain consist of >3 crystals (Plate 1-2), the contact between the subgrains are straight to suture and their grain size reach to 0.5mm, with subangular shape and wavy extinction suggesting metamorphic origin (Folk, 1974; Yan *et al.*, 2006).

2.2 Feldspar

K-feldspar (K) and plagioclase (P) representing the second rank of the total content of the studied sandstone. Orthoclase grains are subrounded with wavy extinction and perthitic texture (Plate 1-3), while microcline grains represented by cross twining texture (Plate 1-4). The plagioclase grains are less common, their grain size reach to 0.8 mm, with subrounded and contain poly twining. The provenance rock of feldspar are metamorphic and plutonic (Pettijohn *et al.*, 1973).

2.3 Rock fragments

The most abundant constituents are the carbonate rock fragments (Plate 1-5), generally, they are subangular with grain size reach to 0.5mm, represented micritic grains and bioclasts of

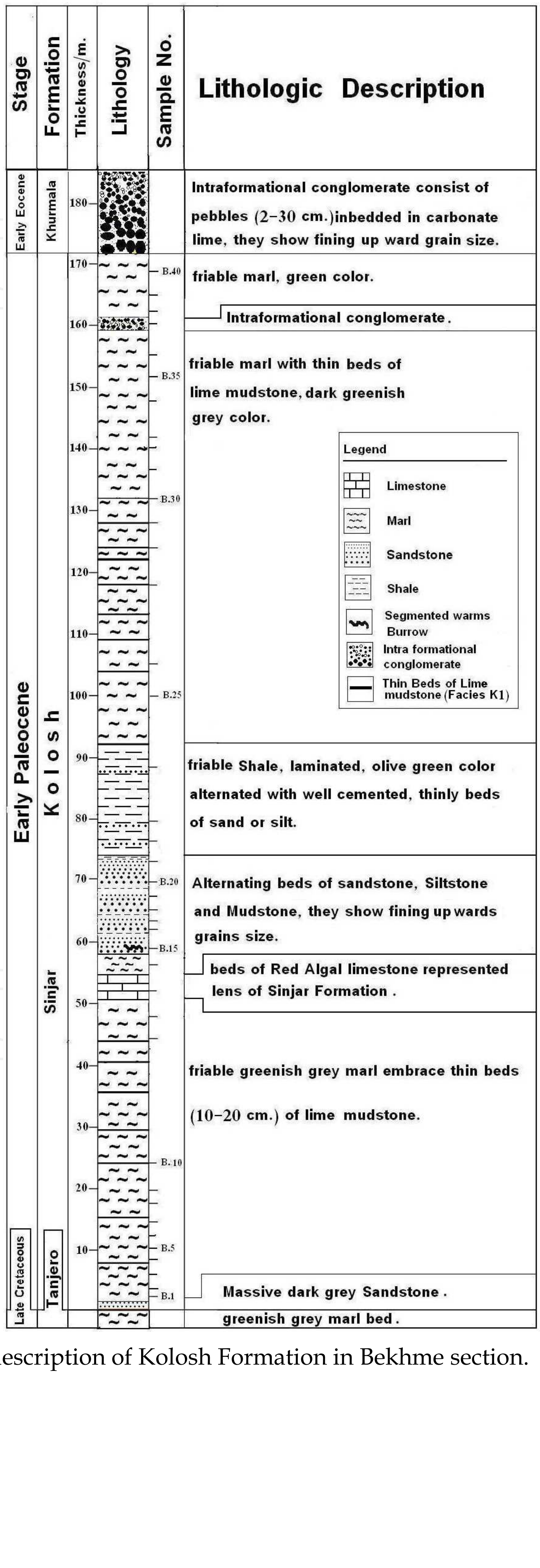


Fig. 2. Lithological description of Kolosh Formation in Bekhme section.

Sample No.	Monocrys. Quartz	Polycrys. Quartz	Plagioclase	K.Feldspar	Chert R. F.	Carbonate R. F.	Ign., Meta. & Other R.F.	Cement	Heavy Minerals	Matrix
B.15	7.56	1.20	0.48	1.20	4.20	24.00	3.36	15.00	3.00	40.00
B.16	11.30	2.06	0.35	3.22	8.34	17.10	16.94	24.75	5.64	10.30
B.18	7.68	0.80	1.04	1.04	2.08	44.24	5.84	12.80	4.48	20.00
B.19	10.26	3.42	1.36	5.64	15.93	25.65	4.27	15.04	3.93	14.50
B.20	9.54	5.04	0.45	3.24	15.30	27.54	11.07	16.47	1.35	10.00
B.21	3.82	1.16	0.34	0.92	1.74	31.90	0.920	16.04	1.16	42.00

Table 1. Modal analysis of the various petrographic constituents of Bekhme section.

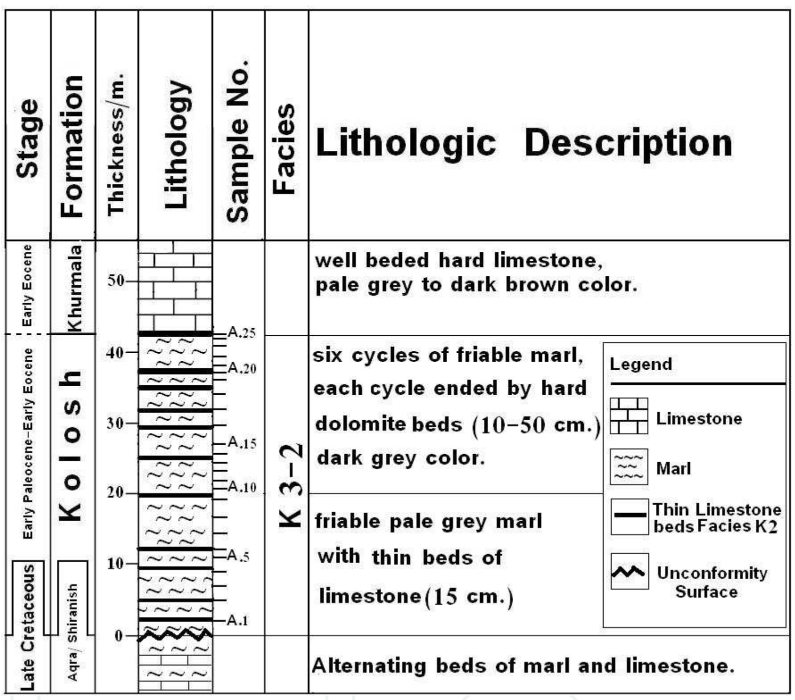


Fig. 3. Lithological description of Kolosh Formation in Aqra section.

pelecypod and gastropod. The source of the carbonate rock fragments is believe to be from the underlaying Mesozoic carbonate rock of the Arabian shelf, which are less resistant, accordingly they can not sustain long distances of transportation. The large content of carbonate rock fragments requires high relief and rapid erosion (Pettijohn, 1975).

Chert rock fragments are microcrystalline and cryptocrystalline (Plate 1-6), the grains are mostly angular with sharp to subsharp edges indicated to nearby source, the source rocks should be the radiolarian cherts of the Cretaceous Qulqula series and the carbonate formations include chert nodules.

The metamorphic (Plate 1-7) and igneous rock fragments show low content, indicating to the paucity of these rocks in the source areas, accordingly heavy minerals found with less amount.

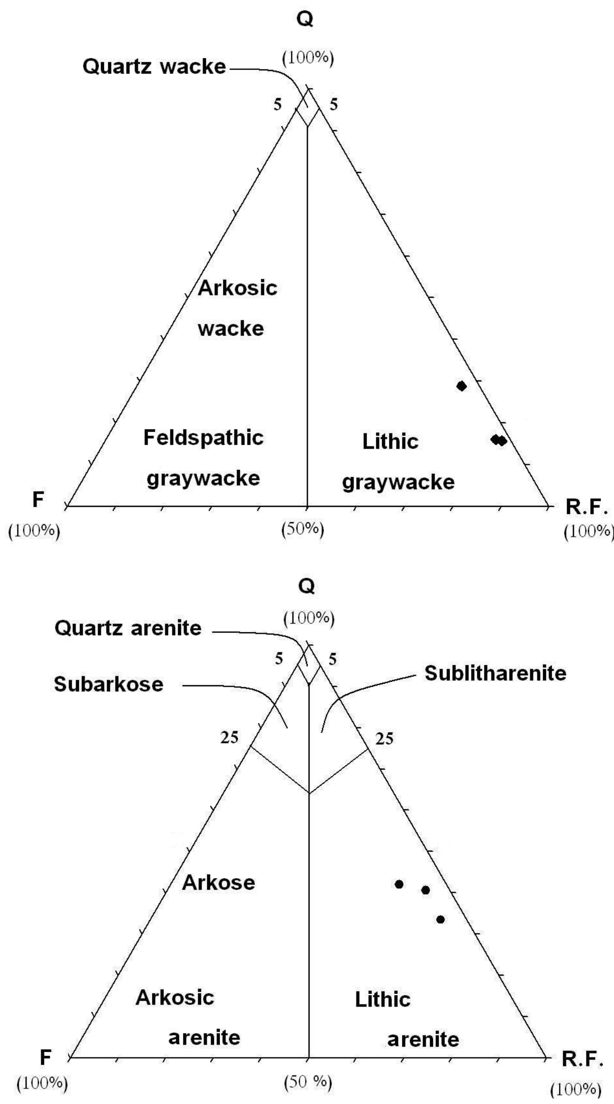


Fig. 4. Position of Kolosh Formation sandstones on the classification of Dott (1964).

2.4 Matrix and cement

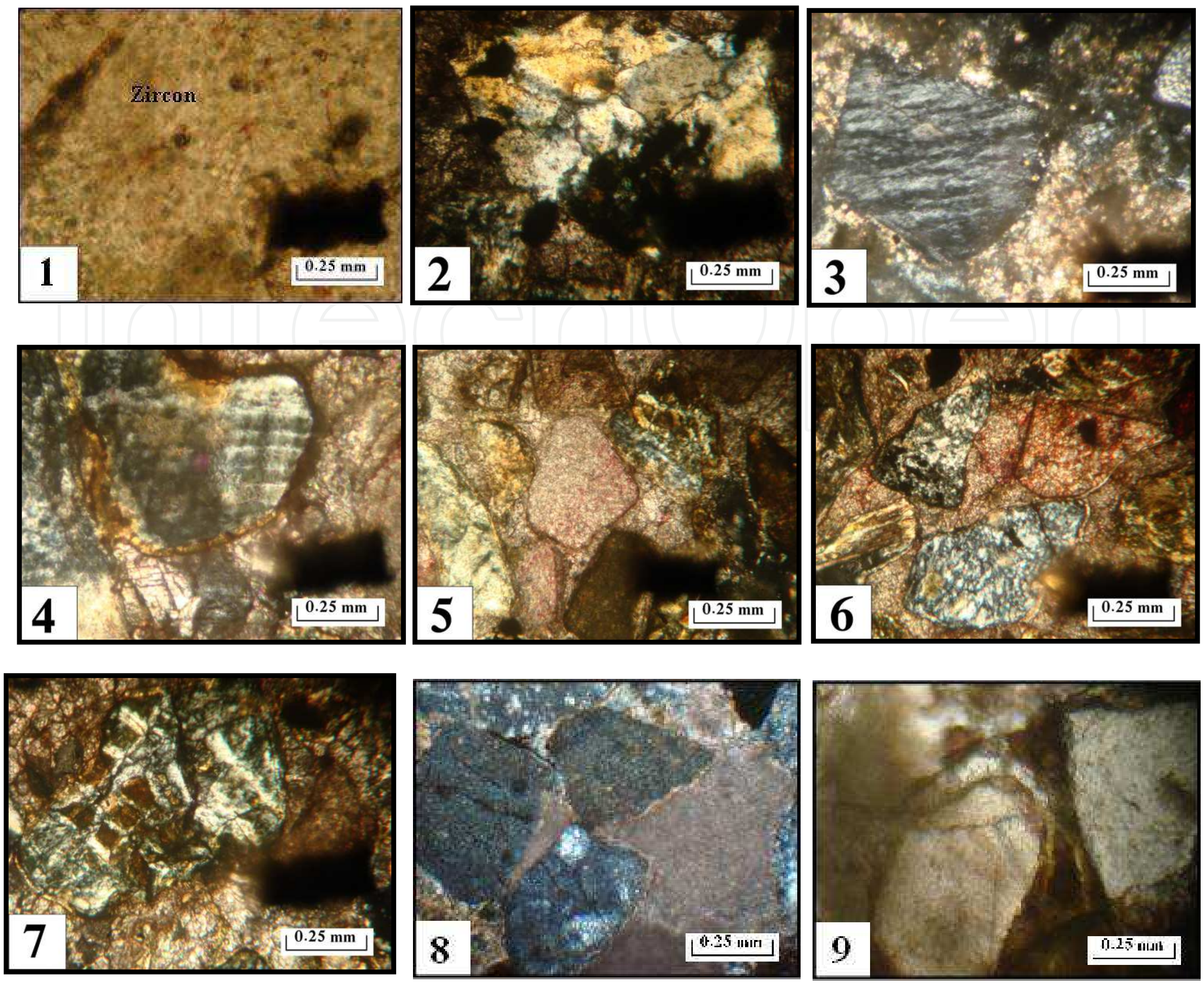
The carbonate cement form the abundant type of cement in all sandstones of Kolosh Formation, it occurs as microspar and sparry mosaic cement (Plate 1-8). The matrix consist of clayey – silty grains that filled the interpartical vugs (Plate 1-9), it embrace clay minerals in addition to quartz, feldspar and mica minerals.

3. Sedimentary facies

The studied Paleocene succession in Bekhme section consist of Kolosh and lens of Sinjar formations, while in Aqra section only Kolosh Formation was recognized.

3.1 Facies and depositional setting of Kolosh Formation

The Kolosh Formation contains six facies, donated K1 to K6, for which sedimentological and biological evidences are used to determine their depositional environment and bathymetry.



1- Inclusion of Zircon in Monocrystalline Quartz.
2- Polycrystalline Quartz.
3- Perthitic Texture of Orthoclase.
4- Cross Twinning of Microcline.
5- Carbonate Rock Fragment in Sandstone.
6- Angular to Subangular Chert in Sandstone.
7- metamorphic rock fragments in Sandstone.
8- Calcite Cement in Sandstone.
9- Clay Matrix in Sandstone.

Plate 1.

3.1.1 Lime mudstone facies K1

The facies represent thin bedded limestone with thickness ranging between 5 – 10 cm, dark grey color. The facies has a mud supported texture and allochems make up to 10% of the total contain (Plate 2-1). The predominant allochems are planktonic foraminifera represented by *Parasubbotina pseudobulloides, Praemurica pseudoinconstans* and *Subbotina triloculinoides*. The few miliolid, pelecypod and gastropod are recorded. Extraclasts of quartz and chert are record. The matrix consist of micrite and microspar. Carbonate cement fill the chambers of fossils. The sedimentological and paleontological evidences indicated to deep shelf margin environment of the facies (Wilson, 1975; Flugel, 2004).

3.1.2 Pelloidal lime wackestone facies K2

The facies is characteristically as grey dolomitic limestone with abundance of pelloids amount to 40 % of the total contain. The pelloids are rounded to subrounded shape consist of micrite, it have good preservation (Plate 2-2). The few generally affected by selective dolomitization that forming pelloidal fabric, according to Randazzo and Zachos, (1984), the origin of this type fabric is pelloidal lime wackestone. All the attributes indications subtidal – intertidal of restricted marine shelf (Wilson, 1975; Flugel, 2004).

3.1.3 Marl facies K3

This facies consists of green to dark grey marl, soft beds with thickness ranging between 3 – 15 m, embracing thin beds of hard limestone (Plate 2-3). The insoluble residue analysis indicates to carbonate contain of the facies that ranging between (35 – 60%). The allochems percentage ranging between (1 – 45%). These wide range of allochems content lead to subdivision the facies in to two subfacies:

3.1.3.1 Highly fossiliferous marl subfacies K3-1

The hard part of the subfacies included to the presence of allochems ranging between 25 – 45% of total subfacies content, represent by Paleocene planktonic foraminifera, the washing of 10 gm of soft marl samples indicated to the present of 400 – 600 specimen of planktonic foraminifera, the paleontological evidence point to outer shelf – upper bathyal environments of the subfacies, with depth ranging between 150 – 225 m (Gibson, 1989). The inter-tongue of thin beds of hard planktonic foraminiferal limestone with soft marls indicated to the base absent Bouma sequence which is dominated in deep marine basin (van Vliet, 1978).

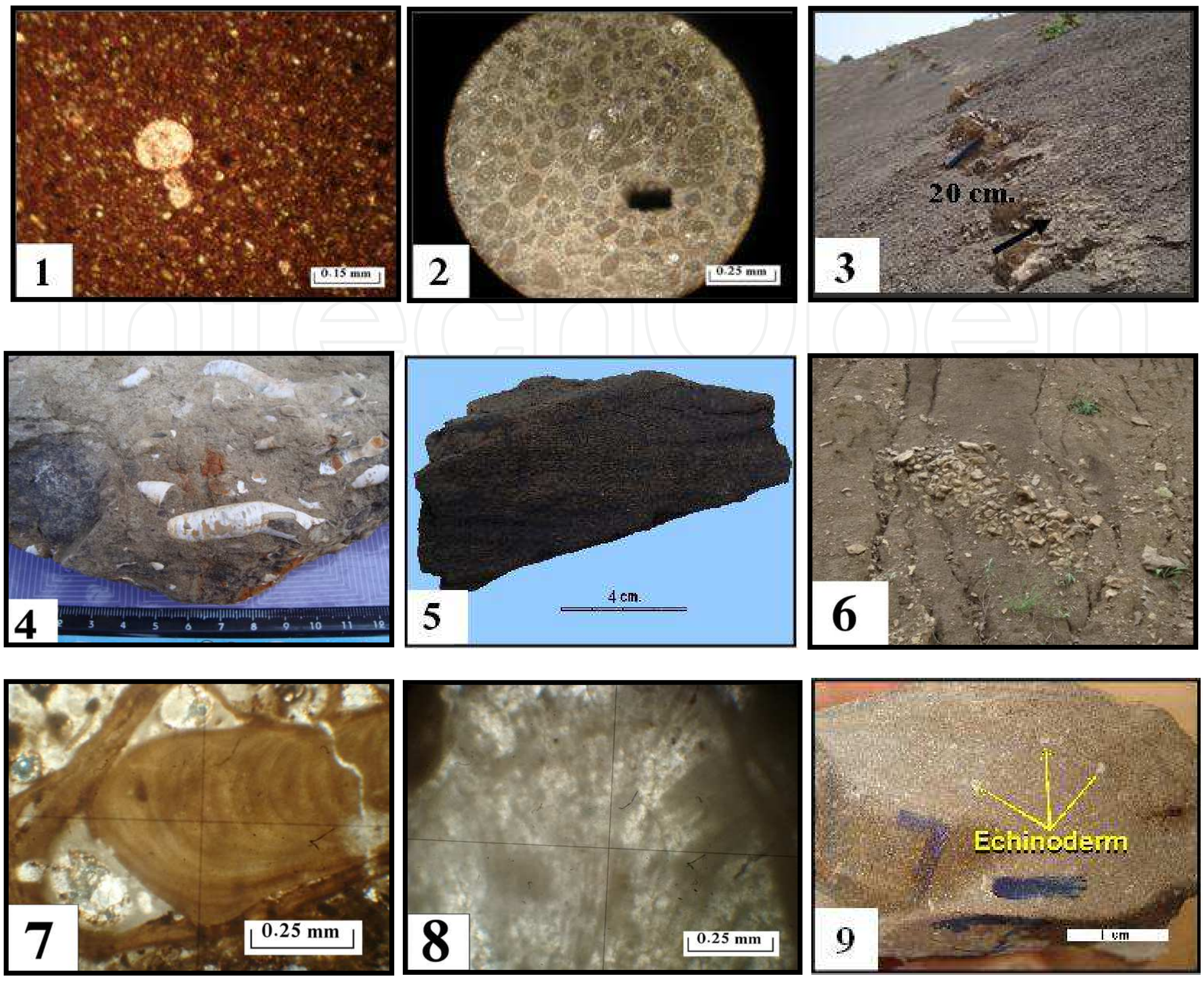
3.1.3.2 Poorly fossiliferous marl subfacies K3-2

The allochems of this subfacies represent less than 10% of the subfacies content. Also the washing samples show less than 100 specimens of Paleocene planktonic foraminifera. The subfacies of soft marl embracing thin beds of limestone and dolomitic limestone. The paleontological and sedimentological evidences indicate shallow marine environment extended from inner to middle shelf with water depth ranging between 40 – 100 m. (Gibsom, 1989).

3.1.4 Sandstone facies K4

The facies is typically soft greenish grey sandstones, it consist of fine – medium sandstone with thickness ranging between 2 - 5m. The grain size decreased upward, it started with structureless massive sandstone contain low percentage gravel grains (2 – 3mm in diameter) ranging between 1.00 - 2.26% of the total facies contain, these layer followed by laminated silty sandstone and the succession ended by thin bed of mudstone. Vertical burrows were recognized in some bedding planes and segmental warms burrows were recorded at level 60 m (Plate 2-4). Skeletal allochems are dominated by planktonic foraminifera and few benthonic foraminifera of shallow marine environment were recorded in the facies.

The sedimentological and paleontological evidences indicated to the lower part of the submarine fans environment of the facies (Emery and Myers, 2006) or lower part of Bouma sequence (Bouma, 2000; Stelting *et al.*, 2000 and Nichols, 2004).



1- Lime Mudstone Facies (K1) in Kolosh Formation.
2- Pelloidal Lime Wackestone Facies (K2) in Kolosh Formation.
3- Hard Thin Limestone Bed Within Marl Facies (K3).
4- Segmented Warms Burrow in Sandstone Facies (K4).
5- Lamination Structure in Shale Facies (K5).
6- Intraformational Conglomerate Facies (K6) in Kolosh Formation.
7- Lithophyllum operculatum Red Algae in Boundstone Facies (S1) of Sinjar Formation.
8- Parachaetetes sp. Red Algae in Boundstone Facies (S1) of Sinjar Formation.
9- Bioclastic and Lime intraclasts in Rudstone Facies (S2) of Sinjar Formation.

Plate 2.

3.1.5 Shale facies K5

The facies is characterized by soft greenish grey shale located at the middle part of the succession of Bekhme section with 17m thick (Plate 2-5), in which allochems dominated by planktonic foraminifera. The facies included low percentage of silt grains, thin beds (>15cm) of hard shale contain high percentage of carbonate cement and lamination structure of alternated silt and clay laminas, which is produced by the oscillated velocity of transportation medium was recognized in the facies.

All the attributes point to levee deposit of submarine fan channels which dominated in the middle part of the submarine fan (Bouma, 2000; Stelting *et al*., 2000 and Nichols, 2004).

3.1.6 Intraformational conglomerate facies K6

The facies has a total thickness of about 2 m at the top of Kolosh Formation in Bekhme section (Plate 2-6), it consist of random distribution intraclasts in calcareous clay matrix. The intraclasts diameter up to 25cm. the sedimentological evidence point to submarine channels depositional environment, in which they transported the sand and pebble grains to the deep marine (Al-Qayim and Salman, 1986; Boggs, 2006), generally these channels found at the upper part of the submarine fans(Nichols, 2004).

3.2 Facies and depositional setting of Sinjar Formation

The Sinjar Formation crop out at Bekhme section as a lens of carbonate facies with thickness ranging between (0.2m – 11m.) (Figure 2). Their facies donated S1 and S2, the sedimentological and biological evidences are used to determine their depositional environment and bathymetry.

3.2.1 Boundstone facies (S1)

The facies consist of two layer of white hard limestone of 0.6m. thick, it is grain – supported texture and allochems reach to 90% of the total content. The predominant allochems are red algae represented by *Lithothamnium ramosissimum*, *Lithophyllum sp*., *Lithothamnium androsovi, Lithothamnium operculatum* (Plate 2-7), *Parachaetetes sp*. (Plate 2-8), other allochems are miliolid, rotalid, echinoderm, pelecypod, and gastropod. Micrite fill the intraparticls vugs of the red algae . All the attributes indicated to organic buildup environments (Wilson, 1975 and Flugel, 2004).

3.2.2 Rudstone facies (S2)

The facies is typically hard grey to light brown limestone. Their thickness ranging between 0.3m. to 2.5m . The facies consist of bioclasts represented by lime intraclasts, echinoderm, red algae and coral up to 0.5cm in diameter (Plate 2-9), in addition to planktonic foraminifera and ostracoda. The allochems content ranging between 10 – 25% of the total facies content. The matrix embraces microspar produced by neomorphism. The facies affected by chemical and physical compaction, which indicated by fracturing of fossil and stylolite. Carbonate cement was recorded as granular, drusy and syntaxial cement. The sedimentological and biological evidences indicate to fore reef deposit within marine slope (Wilson, 1975 and Flugel).

4. Biostratigraphy

The studied rocks of Kolosh Formation exposed in Bekhme area are characterized by abundant well preserved planktonic foraminiferal assemblages, washed residues of Bekhme section were investigated from common diverse planktonic foraminifera to be used as biostratigraphic tools for investigating the marine setting of the formation. Twenty species belonging to six genera were identified in Kolosh Formation, the stratigraphic distribution of these species indicated two biozones and four subzone of the early Paleocene age (Danian) (Figure 5), these zones and subzones are correlated with similar ones established by other authors as shown in Table 2 and Table 3. The zonal scheme (P zones) followed in this study is that of Blow (1979). The zones and subzones are described in ascending orders as follows:

EPOCH	AGE	Bolli 1966	Toumarkine & Luterbacher 1985	Berggren et al. 1995	Olsson et al., 1999	Keller et al., 1995; Li & Keller 1998; Keller et al., 2007	Arenillas et al., 2004 ; 2006 & Molina et al., 2005	Berggren&Pearson 2005	Present Study
PALEOCENE EARLY	DANIAN	*Grt.uncinata*	*Morozovella uncinata*	P2 *Pr.uncinata–M.angulata*	P2 *Pr.uncinata–M.angulata*		*Gl. compressa*	P 2 *Pr. uncinata*	*Praemurica uncinata* (P2)
		Grt.trinidadensis	*Morozovella trinidadensis*	P1 *Parv.eugubina–Pr.uncinata*: P1c *Gl.compressa–Pr.inconstans*	P1 *Prav.eugubina – Pr.uncinata*: P1c *Gl.compressa/Pr.inconstans–Pr.uncinata*	P1d *Pr.trinidadensis*		P1c *Gl. compressa / Pr. inconstans*	*Parasubbotina pseudobulloides* (P1): *Pr.trinidadensis* (P1d)
						P1c(2) *Pr.inconstans*			*Gl.compressa/ Pr.inconstans* (P1c)
		Grt. pseudobulloides	*Morozovella pseudobulloides*	P1b *S.triloculinoides–Gl.compressa*	P1b *S.triloculinoides–Gl.compressa/Pr.inconstans*	P1c(1) *P.varianta*	*P. pseudobulloides*: *Subbotina triloculinoides*	P1b *S.triloculinoides*	*Subbotina triloculinoides* (P1b)
				P1a *Parv.eugubina–S.triloculinoides*	P1a *Parv.eugubina–S.triloculinoides*	P1b P1b	*Eoglobigerina trivialis*	P1a *P. pseudobulloides*	*Subbotina trivialis* (P1a)
		Grt.eugubina	*Globigerina eugubina*	Pα & P0 *Parv.eugubina & G.cretacea*	Pα *Parv.eugubina*	P1a(2) *Parv.eugubina*	*Parv.eugubina*	Pα & P0 *Parv. eugubina & G.cretacea*	Not studied
						P1a(1) *Parv.eugubina*			
					P0 *G.cretacea*	P0 P0	*G.cretacea*		
CRETACEOUS	MAASTR.	*Abathomphalus mayaroensis*			Not Studied	*Plummerita hantkeninoides*	*Abathomphalus mayaroensis*		

Table 2. Correlation of planktonic foraminiferal biozones with the outside Iraq biozones.

EPOCH	PALEOCENE EARLY					CRETACEOUS
AGE	DANIAN					MAAST.
Munim 1976	Grt.p. uncinata; Grt.p.praecursoria Radiolaria; Grt.p. uncinata	Grt. triloculinoides; Grt. inconstans	Grt. triloculinoides; Planorotalia compressa	Hiatus	Hiatus	
Abdel-Kareem 1986	Grt. uncinata	Grt. trinidadensis	Grt. trinidadensis	Grt. pseudobulloides	Hiatus	
Al-Omari et al. 1993	Grt. uncinata	Grt. trinidadensis; Grt. inconstans	Grt. trinidadensis; Grt. compressa	Grt. trinidadensis; Grt. pseudobulloides	Hiatus	
Sharbazheri et al. 2009			S. triloculinoides – Pr. inconstans (P1b)	Pav. euguabina– S. triloculinoides P1a	P. eugubina– G. cretacea Pα & P0	
Al-Mutwali & Al-Wazan 2010	Praemurica uncinata (P2)	P. pseudobulloides (P1); G. compressa (P1c)	P. pseudobulloides (P1); Subbotina triloculinoides (P1b)	Hiatus	Hiatus	
Present Study	Praemurica uncinata (P2)	Parasubbotina pseudobulloides (P1); P trinidadensis (P1d); G.compressa/P.inconstans (P1c)	Parasubbotina pseudobulloides (P1); Subbotina triloculinoides (P1b)	Parasubbotina pseudobulloides (P1); Subbotina trivialis (P1a)	Not studied	

Table 3. Correlation of planktonic foraminiferal biozones with the inside Iraq biozones.

4.1 *Parasubbotina pseudobulloides* interval zone (P1)

Definition: Interval Zone of the nominate taxon (Plate 3, figs. 5-6).

Boundaries: the zone bounded at the base by the disappearance of the Late Cretaceous planktonic foraminifera and the disconformity with the underlying Tanjero Formation. The top of the zone is placed at the first appearance of the *Praemurica uncinata* (Bolli).

Age: early Paleocene (Danian)

Thickness: The zone is 100 m. thick.

Characteristics: The zone is characterized by the presence of cancel planktonic foraminiferal species in the lower part. The easy distinguished and dominated of (*Parasubbotina pseudobulloides)* make it favor in the biostratigraphic studies (Bolli, 1966, Toumarkine & Luterbacher, 1985, Molina *et al*., 2005, Arenillas *et al*. 2004; 2006). Accordingly the biozone was subdivided into four subzones, these subzones are from base to top:

4.1.1 *Subbotina trivialis* Partial range subzone (P1a)

Definition: Partial range subzone of the nominate taxon (Plate 3, figs.14-15).

Boundaries: The subzone bounded at the base by the first appearance of the *Parasubbotina pseudobulloides* (Plummer). The top of the subzone is placed at the first appearance of the *Subbotina triloculinoides* (Plummer).

Age: early Paleocene (early Danian).

Thickness: The subzone is 5 m. thick.

Characteristics: In addition to the dominated of the nominate taxon, the following species have been recognized *Globanomalina archeocompressa, Eoglobigerina eobulloides, Subbotina trivialis, Parasubbotina pseudobulloides, Praemurica pseudoinconstans* (Plate 3, figs. 16-17; 1-2; 14-15; 5-6; 26)*, Eoglobigerina edita.*

This subzone is equivalent to the *Parvularugoglobigerina eugubina – Subbotina triloculinoides* subzone (P1a) of Berggren *et al*., (1995) and Olsson *et al*. (1999). It also equivalent to early Paleocene (Early Danian) *Parasubbotina pseudobulloides* subzone (P1a) of Berggren and Pearson (2005) and *Eoglobigerina trivialis* subzone of Arenillas *et al*. (2004); Molina *et al*. (2005) and Arenillas *et al*. (2006) (Table 2). In Iraq the subzone equivalent to the *Grt. Pseudobulloides* subzone of Al-Omari *et al*. (1993) (Table 3) , Therefore, we considered the *Subbotina trivialis* subzone to represent the early Paleocene (early Danian).

4.1.2 *Subbotina triloculinoides* interval subzone (P1b)

Definition: interval subzone of the nominate taxon (Plate 3,figs. 12-13).

Boundaries: The subzone bounded by the first appearance of the nominated taxon and ended by the first appearance of the *Praemurica inconstans* (Subbotina) and *Globanomalina compressa* (Plummer).

Age: early Paleocene (early to middle Danian).

Thickness : The subzone is 12m. thick.

Characteristics: The subzone is characterized by the nominate taxon in addition to the first appearance of *Woodringina hornerstowensis* (Olsson) and *Woodringina claytonensis* (Loeblich and Tappan) in the lower part of the subzone. The following species have been recognized *Globanomalina archeocompressa* (Plate 3, figs. 16-17), *Eoglobigerina eobulloides* (Plate 3, figs.1-2), *Eoglobigerina trivialis, Parasubbotina pseudobulloides, Eoglobigerina edita, Praemurica pseudoinconstans*.

This subzone is identical to the *Subbotina triloculinoids* subzone (P1b) of Berggren and Pearson (2005); Molina *et al*. (2005); Arenillas *et al*. (2004); Arenillas *et al*. (2006); Sharbazheri *et al*. (2009) and Al-Mutwali and Al-Wazan (2010). All the previous studies point to the early – middle Danian age of the subzone.

4.1.3 *Globanomalina compressa / Praemurica inconstans* interval subzone (P1c)

Definition: interval subzone of the two nominated taxa (Plate 3, figs. 18-19; fig. 23).

Boundaries: The subzone bounded by the first occurrence of the nominated taxa and the initial appearance of the *Praemurica trinidadensis* (Bolli).

Age: early Paleocene (middle to late Danian).

Thickness: The subzone is 31m. thick.

Characteristics: The subzone characterized by well – preserved planktonic foraminifera, it is distinctive by presence of *Subbotina cancellata* (Blow)(Plate 3, figs. 8-9) and *Parasubbotina varianta* (subbotina) (Plate 3, fig. 7), In addition to the following species: *Eoglobigerina eobulloides, Eoglobigerina trivialis, Parasubbotina pseudobulloides, Eoglobigerina edita , Praemurica pseudoinconstans, Subbotina triloculinoides*.

The subzone is equivalent to *Globanomalina compressa* / *Praemurica inconstans* subzone (P1c) of Berggren *et al*. , (1995) and Berggren and Pearson (2005), also it is identical to *P. inconstans* subzone of Keller *et al*. (2007), *Grt. inconstans* subzone of Munim (1976), Al-Omari *et al*. (1993) and Al-Mutwali and Al-Wazan (2010), which are assigned to early Paleocene (middle – late Danian) age of the subzone.

4.1.4 *Praemurica trinidadensis* interval subzone (P1d)

Definition: interval subzone of the nominate taxon (Plate 3, figs. 27-28).

Boundaries: The lower boundary is defined by the first occurrence of the nominate taxon. The upper of this subzone is placed at the first appearance of *Praemurica uncinata* (Bolli).

Age: early Paleocene (late Danian).

Thickness: The subzone is 52m. thick.

Characteristics: the predominant planktonic foraminifera in this subzone are *Praemurica trinidadensis* (Bolli) and *Praemurica praecursoria* (Morozova)(Plate 3, figs. 24-25), this subzone characterized by the occurrence of *Globanomalina imitata* (Subbotina) (Plate 3, fig. 22), *Eoglobigerina spiralis* (Bolli) (Plate 3, figs. 3-4), *Globanomalina ehrenbergi* (Bolli) (Plate 3, figs. 20-21), *Subbotina triangularis* (White)(Plate, 3, figs. 10-11) in addition to *Eoglobigerina trivialis, Parasubbotina pseudobulloides, Eoglobigerina edita, Praemurica pseudoinconstans, Subbotina triloculinoides, Praemurica inconstants, Globanomalina compressa, Parasubbotina varianta, Subbotina cancellata* .

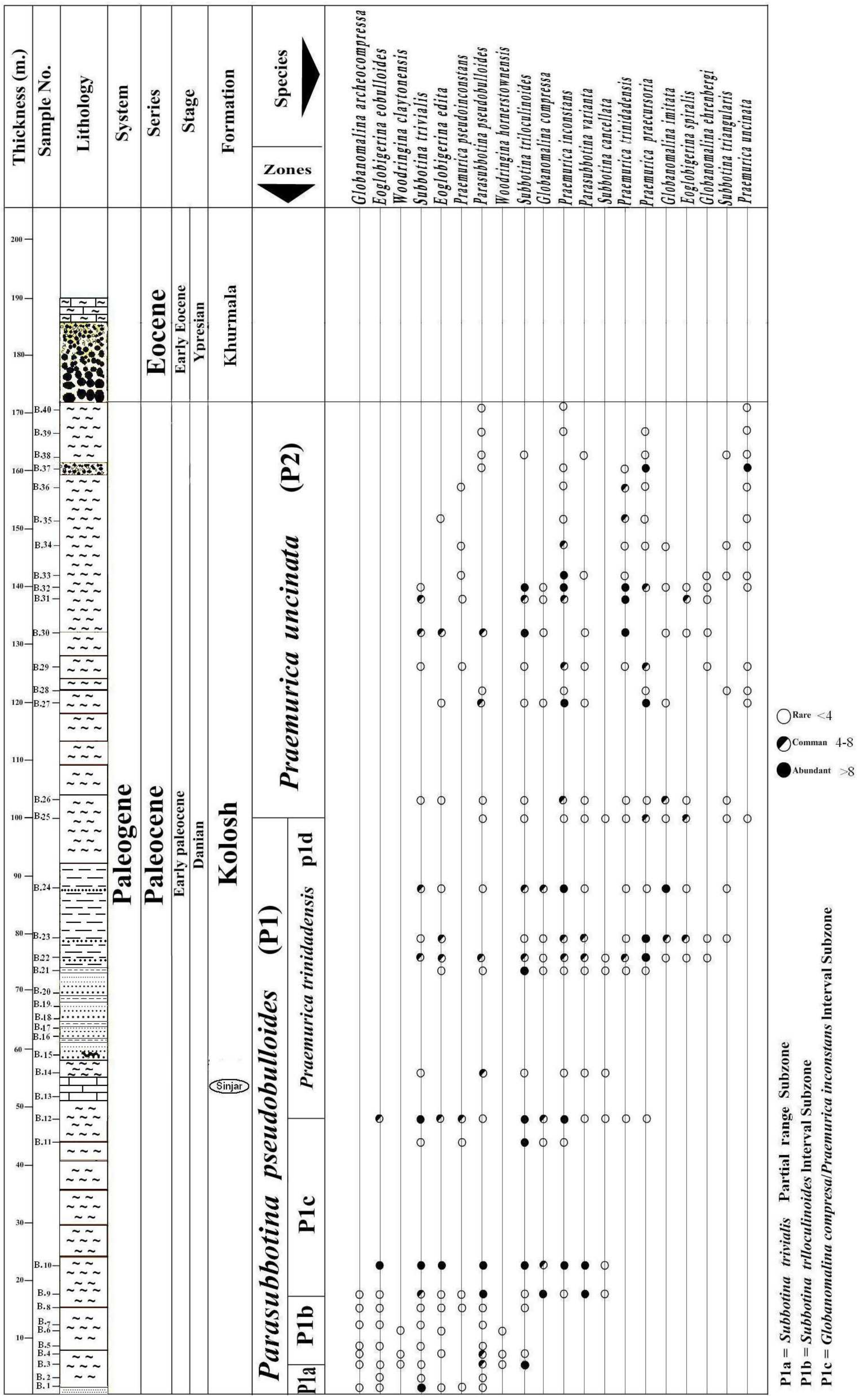


Fig. 5. Distribution of planktonic foraminifera In Kolosh Formation at Bekhme section.

The subzone is equivalent to *Praemurica trinidadensis* subzone (P1d) of Li and Keller (1998), Keller *et al*. (1995) and Keller *et al*. (2009), all of late Danian.

4.2 *Praemurica uncinata* interval zone (Part) (P2)

Definition: interval Zone (part) of the nominated taxon (Plate 3, figs. 29-30).

Boundaries: The base of the zone is defined by the first occurrence of the nominate taxon. The top of the zone is identified by the disappearance of the early Paleocene planktonic foraminifera at the disconformity with the overlying shallow marine carbonate rock of Khurmala Formation.

Age: late early Paleocene (late Danian).

Thickness : The zone is 72m. thick.

Characteristics: In addition to the nominate taxon this zone is characterized by the predominate of the following species: *Subbotina triloculinoides, Eoglobigerina trivialis, Globanomalina imitate* and *Praemurica trinidadensis,* and continuous occurrence of the following species: *Parasubbotina pseudobulloides, Eoglobigerina edita, Praemurica pseudoinconstans, Praemurica inconstant, Globanomalina compressa, Parasubbotina varianta, Subbotina cancellata, Eoglobigerina spiralis, Globanomalina ehrenbergi, Subbotina Triangularis and Praemurica praecursoria.*

This zone is equivalent to the *Praemurica uncinata* Zone (P2) of Kassab *et al*. (1986), Berggren *et al*. (1995), Olsson *et al*. (1999), Berggren and Pearson (2005), Chacon and Martin - Chivelet (2005), Bilotte *et al*. (2007) and Al-Mutwali and Al-Wazan (2010). The zone is also identical with *Grt. uncinata* Zone of Al-Omari (1995) and *Morozovella uncinata* of Abawi and Abdo (2001). All of late early Paleocene.

5. Sequence stratigraphy

The sequence stratigraphic analysis of Paleocene deposits (Kolosh and Sinjar formations) in Bekhme section interpreted four depositional sequence, designated Kolosh sequence 1 to 4 (Figure 6), The sequence, which vary in thickness from (13 – 66 m.) are described in terms of sequence boundaries (SB), lowstand system tract (TS), lowstand fan (LSF), transgressive system tract (TST), maximum flooding surfaces (MFS) and highstand system tracts (HST). As discussed in the final sections of this paper, correlations of depositional sequences and isochronous surface must be based on correlative biozones and follow the most recent conventions of the International commission on stratigraphy (ICS) as documented in Gradstein *et al*. (2004).

5.1 Kolosh sequence 1

The sequence 58 m. thick, begins with the deposition of (2 m.) of facies (K4), their content point to lowstand fans by turbidity currents. It is overlying the deep marine deposit of the Tanjero Formation (late Cretaceos age).

This is followed by marls (subfacies K3-2 and Lower part of K3-1) accompanied by an increased abundance and greater diversity of planktonic foraminifera that represent the TST. The MFS is positioned in the middle of subfacies K3-1, where the maximum number of species is recorded.

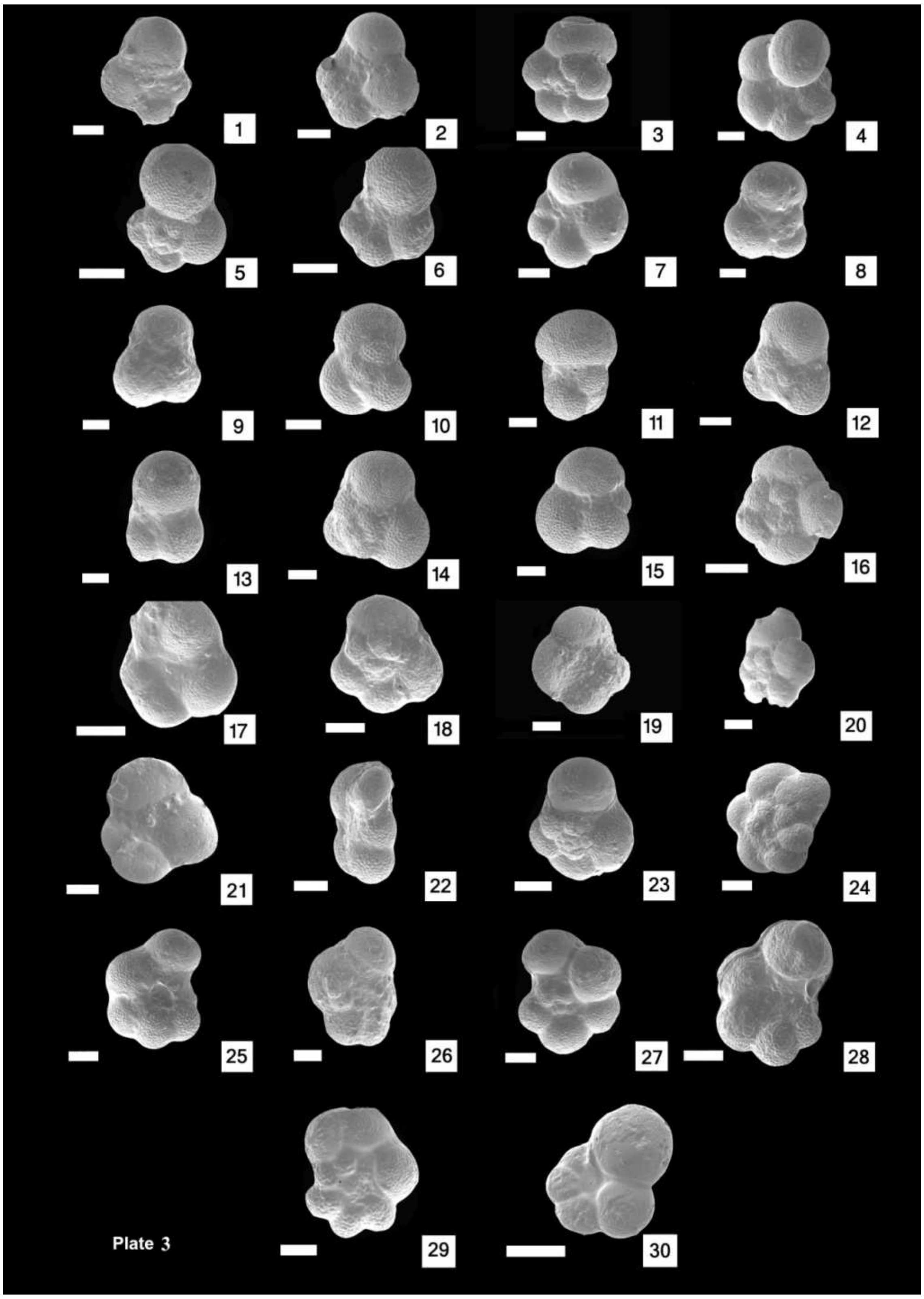


Plate 3. Scale bars 100 Micron

FIGURE 1 *Eoglobigerina eobulloides,* (Morozova), spiral side, Sample no. 1.
FIGURE 2 *Eoglobigerina eobulloides*, (Morozova), umbilical side, Sample no. 1.
FIGURE 3 *Eoglobigerina spiralis* (Bolli), spiral side, Sample no. 23.
FIGURE 4 *Eoglobigerina spiralis* (Bolli), umbilical side, Sample no. 23.
FIGURE 5 *Parasubbotina pseudobulloides* (Plummer), spiral side, Sample no. 1.
FIGURE 6 *Parasubbotina pseudobulloides* (Plummer), umbilical side, Sample no. 1.
FIGURE 7 *Parasubbotina varianta* (Subbotina), umbilical side, Sample no. 9.
FIGURE 8 *Subbotina cancellata* (Blow), spiral side, Sample no. 12.
FIGURE 9 *Subbotina cancellata* (Blow), umbilical side, Sample no. 12.
FIGURE 10 *Subbotina triangularis* (White), spiral side, Sample no. 26.
FIGURE 11 *Subbotina triangularis* (White), side view, Sample no. 26.
FIGURE 12 *Subbotina triloculinoides* (Plummer), spiral side, Sample no. 30.
FIGURE 13 *Subbotina triloculinoides* (Plummer), umbilical side, Sample no. 30.
FIGURE 14 *Subbotina trivialis* (Subbotina), spiral side, Sample no. 10.
FIGURE 15 *Subbotina trivialis* (Subbotina), umbilical side, Sample no. 10.
FIGURE 16 *Globanomalina archeocompressa* (Blow), spiral side, Sample no. 1.
FIGURE 17 *Globanomalina archeocompressa* (Blow), umbilical side, Sample no. 1.
FIGURE 18 *Globanomalina compressa* (Plummer), spiral side, Sample no. 9.
FIGURE 19 *Globanomalina compressa* (Plummer), umbilical side Sample no. 9.
FIGURE 20 *Globanomalina ehrenbergi* (Bolli), spiral side, , Sample no. 31.
FIGURE 21 *Globanomalina ehrenbergi* (Bolli), umbilical side, section, Sample no. 31.
FIGURE 22 *Globanomalina imitata* ((Subbotina),side view, Sample no. 24.
FIGURE 23 *Praemurica inconstans* (Subbotina), spiral side, Sample no.10.
FIGURE 24 *Praemurica praecursoria* (Morozova), spiral side, S.no.27.
FIGURE 25 *Praemurica praecursoria* (Morozova) umbilical side, S.no.27.
FIGURE 26 *Praemurica pseudoinconstans* (Blow), spiral side, Sample no. 9.
FIGURE 27 *Praemurica trinidadensis* (Bolli), spiral side, Sample no. 31.
FIGURE 28 *Praemurica trinidadensis* (Bolli), umbilical side, Sample no. 31.
FIGURE 29 *Praemurica uncinata* (Bolli), spiral side, Sample no. 33.
FIGURE 30 *Praemurica uncinata* (Bolli), umbilical side Sample no. 33.
All figures for Kolosh Fn. Bekhme section.

Plate 3. Figure listing

The HST is characterized by the upper part of subfacies K3-1 followed by subfacies K3-2 and capping limestone beds (Facies S1 and S2), both the lower and the upper contacts are interpreted as SB Type-1. The sequence spars about 2.8 my. The age of the MFS as calculated from biozone is (63.6 Ma) at interval (24 m.), according to Gradstein *et al*. (2004) (Figure 6).

5.2 Kolosh sequence 2

Sequence 2, 66m. thick, commence with the deposition of facies (K4) that deposited by gravity flow of the shallow marine sediment to accumulate in the deep marine as LSF. It is followed by facies (K5), their lower part showing increasing water depth upward indicated by the increasing of planktonic foraminifera percentage, it is represented the TST of the sequence. The middle of facies (K5) (at 80 m.) is picked as the MFS, where the planktonic foraminifera percentage reach maximum (35%) in the facies.

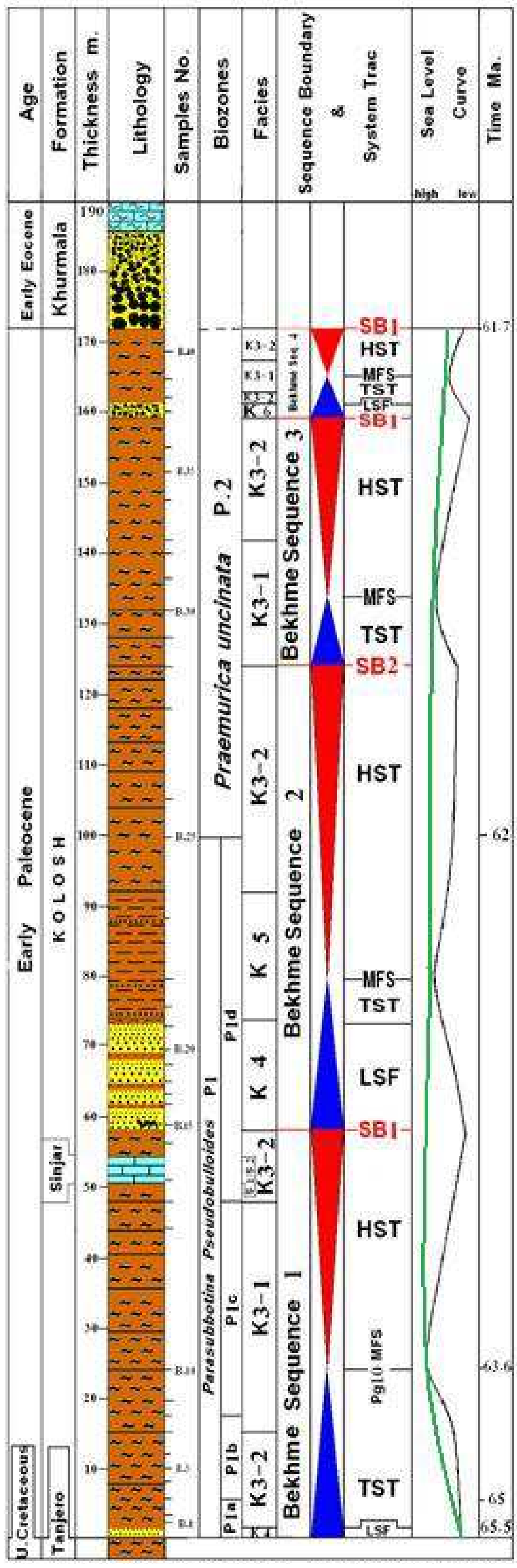


Fig. 6. Lithostratigraphy, biostratigraphy and sequence stratigraphy of the Bekhme section

The upper part of (K5) followed by subfacies (K3-2), both display a shallow environment upward, suggesting the HST of the sequence. The sequence spans less than (1 my), the upper SB is Type 2 (Figure 6).

5.3 Kolosh sequence 3

This sequence begins with the deposition of the facies (K 3-1), It is lower part show increasing of diversity and percentage of the planktonic foraminifera assigned to the TST.

The MFS is represented at the middle of subfacies (K3-1) where the planktonic foraminifera percentage decreasing and followed by subfacies (K3-2) as the HST, the upper SB is Type-1.

5.4 Kolosh sequence 4

Facies (K6) represents the LSF of this (13m.) thick sequence, (Figure 6). It is followed by subfacies (K3-2) and part of subfacies (K3-1) showing increasing water depth and the TST with a retrogradational stacking pattern. The MFS occurs at interval (163m.) within subfacies (K3-1), the upper part of the (K3-1) and the overlying subfacies (K3-2) reflect decreasing water depth and the HST with a progradational stacking pattern. The upper boundary is SB Type-1 below the shallow marine deposit of Khurmala Formation.

The four sequence of Paleocene form a third – order sequence with a total thickness of about, duration of approximately (3.8 my.) and MFS at interval (24m.), and (63.6 Ma).

6. Correlation to Aruma sequence

In central Arabia, Aruma Formation subdivided into three informal members Khanasir limestone, the Hajajah limestone and the Lina shale members (Phillip *et al*., 2002), They interpretated the khanasir member as Aruma sequence 1, hajajah member as Aruma sequence 2 and 3 and Lina member as Paleocene age Aruma sequence 4. the maximum flooding surface of Aruma sequence 4 may correlate with Kolosh third orders MFS.

7. Correlation to Arabian plate maximum flooding surface

Sharland *et al*. (2001) consider MFS Pg10 as late paleocene and positioned it in the base of Kolosh Formation; But in the global planktonic foraminiferal Biozone (P4), which is younger than the studied section in the time scale of Gradstein *et al*. (2004) MFS Pg10 has an age of 58 Ma, this age appear too younger to correlate with the third order MFS of Kolosh in Danian.

8. Correlation to global maximum flooding surface

The 3rd order Kolosh sequence can be correlated with European Danian transgressive surface of Gradstein *et al*. (2004), which lies within the planktonic foraminifera biozone (P1b), also it can tentatively correlated with Danian 3rd order sequence (TP1) of Blake Plateau, of the eastern united state (Schlager, 1992).

9. Depositional environment and sedimentary model

The sedimentary evidences of Kolosh Formation clastic deposit indicated to submarine fan environment that spilled over in the narrow Ne-Tethys onto the passive continental margin of the Arabian plate from the active margins of the Iranian and Anatolian plates (Numan, 1997).

The Kolosh Formation is widely distributed in the subsurface and at outcrop in parts of northern Iraq, and is coeval with several other formations in other part. These formations are diachronous and defined according to lithology; for examples: marine marl and marly limestone (Aaliji Formation), reef and back reef (Sinjar and Khumala formation) and clastics (Kolosh Formation) (Dunnington, 1958; van Bellen et al., 1959 and Jassim and Goff, 2006). These formations can pass below, above and inter-tongue with one another.

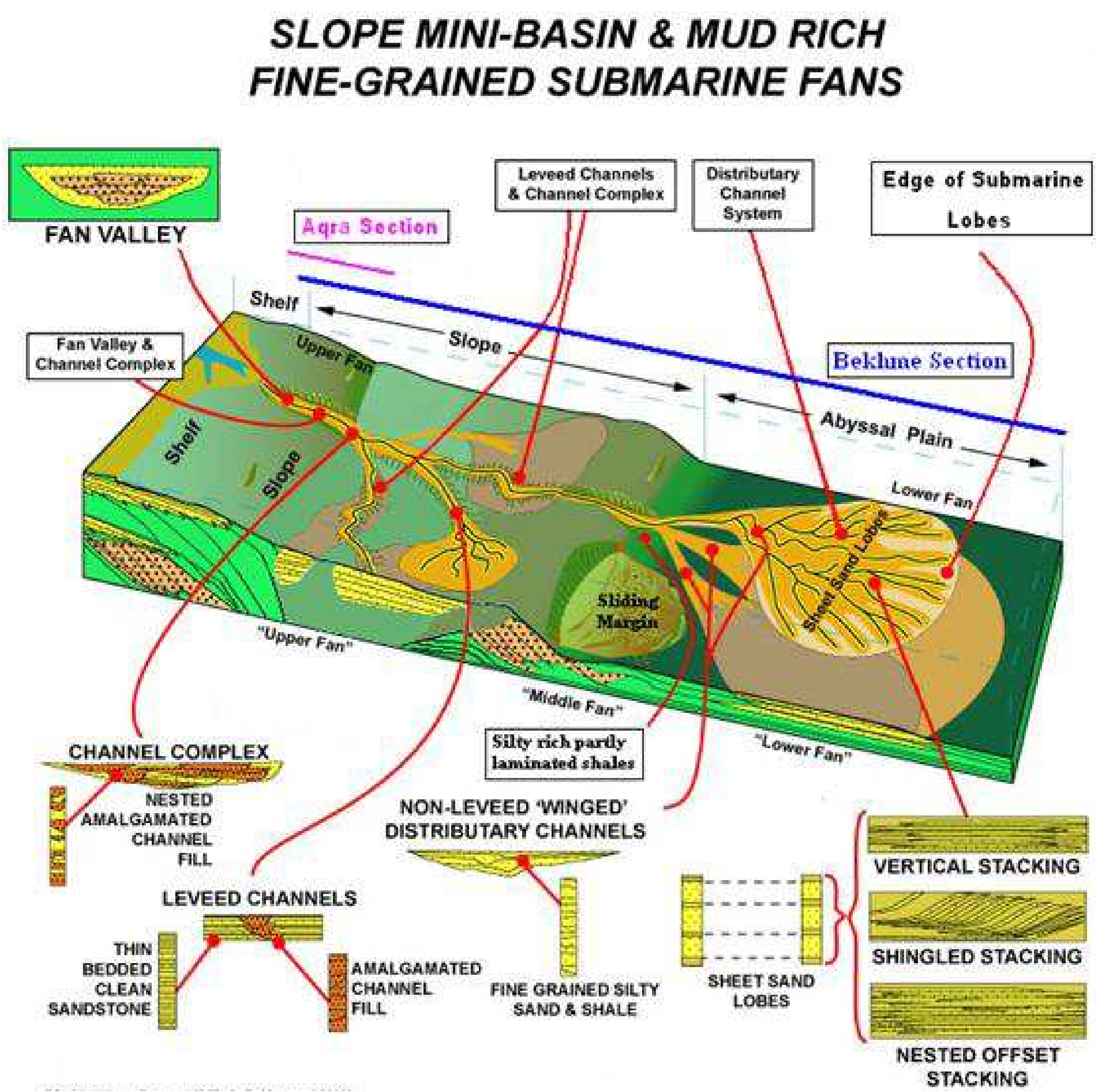


Fig. 7. Mud-rich, submarine fan model (modified from Bouma, 1997 and DeVay et al., 2000)

The lower boundary of Kolosh Formation in Bekhme section was mentioned as a disconformity K/T boundary with the underlying Tanjero Formation. It is followed by 2m thick of sandstones facies (K4) contains gravel grains of shallow marine deposit bypasses the middle and outer shelf and ended up in the outer fan imprinting the usual turbidite sole marks. (Al-Qayim and Salman, 1985 and Bouma, 2000).

Grey to olive green thick marl beds facies (K3) bearing fine silt and planktonic foraminifera deposited in continental slope at the edge of submarine fan lobes, where the turbidite current speed diminished and the foraminifera rainfall dominated, these unit continue until another influx of turbidite sandstone (Facies K4) is introduce or carbonate thin bed (Facies K1) where deposited as a result of short- lived phase of pelagic sedimentation dominated, when the sea level relatively stagnate and the turbidity current laterally switching to built a new lobs leaving the previous lobes area with carbonate production conditions. The cycles of marl and carbonate beds represent the lowest part of the outer fan (Figure 7).

Interfingering lens of Sinjar Formation was identify in the top of marl – limestone cycles, ranging in thickness between (0.2m – 11m), it consist of boundstone facies (S1) and rudstone facies (S2) their depositional environment point to organic build up - fore reef deposit within marine slope.

Four cycles of Bouma sequence are overlying the lowest part, these cycles deposited by turbidity current that bypasses the mid fan and deposited their bedload as a sheet sands or depositional lobes (Bouma, 2000). Each cycle commence with deposition of sandstones (facies K4), which consist of massive badly sorted sandstone were representing *Ta* interval of Bouma sequence (Bouma *et al*., 1985). *Td* and *Te* interval can be found overlaying *Ta* interval directly, *Tb* and *Tc* interval are difficult to identify or may be eroded by the next gravity flow coming from the same distributary, eroded parts of the underlying deposit (Bouma *et al*. 1985 and Bouma, 2000). A number of layers are stack on top of one another as a sheet sand layers this part of the section representing the lowest part of the mid fan and the upper part of the outer fan (Figure 7). (Reading, 1986; Bouma, 2000; Kirschner and Bouma, 2000 and Nichols, 2009).

Seventeen meter of shale beds overlying the package of sandstones layers, it is silty rich partly laminated shale beds (Facies K5) embrace thin siltstones - fine sandstones characterized by parallel lamination and highest porosity, which is generally well cemented, the sand to shale ratio of the shale beds is low, and the carbonate material of the sandstone beds were ranging between 32 - 44% of the total content, it make the thin siltstones-fine sandstones hard and easy recognized in the field. A block of coral bearing limestone bed of 0.8m. thick and 4m. width (Figure 8) is embedded within the shale facies. It is sliding from the upper part of the shelf as a result of active turbidity current and storms originate from the tectonic earthquake. The shales – sandstones layers deposited in the mid fan as levee and over bank deposit (Figure 7). (Darling and Sneider, 1992; Basu and Bouma, 2000; Bouma, 2000; Steling *et al*., 2000 and Nichols, 2009).

The upper succession of Kolosh Formation in Bekhme section embraces poorly fossiliferous marl facies (K3-2) characterized by low P/ B ratio, benthonic forams represented *Lokhartia spp., Rotalia spp., eponids spp. and Quinqueloculina spp.* These genera were indicated to shallow marine environment (inner – middle shelf) (Berggren, 1974; Petters,1978 and Leckie and Olson, 2003), The present of *lokharitia* point to regional regression during late Paleocene

Fig. 8. Sliding coral bearing limestone bed in the upper part of shale facies.

(Berggren, 1974). Marl facies embedded a layer of conglomerate facies (K6) contains intrabasional (preigenetic) clasts. It is interpreted to represent the distal toe deposit of flows debouching from a main feeder canyon at the foot of the slope (Browne *et al.*, 2000). The sedimentological evidences of the upper succession indicated to the upper fan sediment (Figure 7).

The Kolosh formation in Aqra section is 40m thick, The variable thicknesses of the two sections are due to the bathymetry of the Kolosh basin which is a result of the inherited anticlines of Cretaceous age. Aqra section consists of alternated thick marl facies (K3-2), it is very poorly fossils, representing by few bad preserved benthonic forams only, and pelloidal lime packstone facies (K2)), the succession is pale grey color. The sedimentological and biological attributes indicated to semirestricted platform (Flugel, 2004) and represented upper fan deposit.

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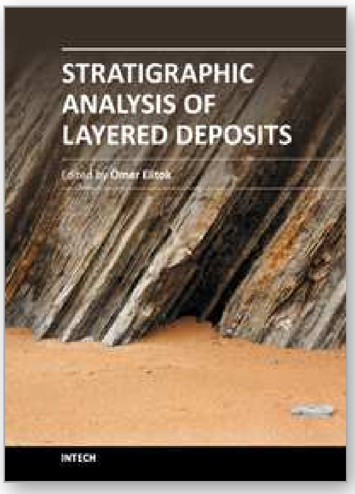

Stratigraphic Analysis of Layered Deposits
Edited by Dr. Ömer Elitok

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Stratigraphy, a branch of geology, is the science of describing the vertical and lateral relationships of different rock formations formed through time to understand the earth history. These relationships may be based on lithologic properties (named lithostratigraphy), fossil content (labeled biostratigraphy), magnetic properties (called magnetostratigraphy), chemical features (named chemostratigraphy), reflection seismology (named seismic stratigraphy), age relations (called chronostratigraphy). Also, it refers to archaeological deposits called archaeological stratigraphy. Stratigraphy is built on the concept "the present is the key to the past" which was first outlined by James Hutton in the late 1700s and developed by Charles Lyell in the early 1800s. This book focuses particularly on application of geophysical methods in stratigraphic investigations and stratigraphic analysis of layered basin deposits from different geologic settings and present continental areas extending from Mexico region (north America) through Alpine belt including Italy, Greece, Iraq to Russia (northern Asia).

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