

## New geologic setting of Bekhme Formation



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Abstract:

Since the first description of Bekhme Formation (Late Campanian- Early Maastrichtian) by Wetzel in 1950 (in Bellen *et al.*, 1959), no updating is published by later studies except confirmation of the first description. However, few published studies are deviated from the majorities and give serious suspicions about many parts of the previous description. The present study tries, on bases of stratigraphy, Correlation with Iran, fieldwork and paleontology, to evaluate these doubts and try to give evidence for abandoning this formation and changing it's name to new formation (Perat Formation). Accordingly, it was proved that the top of Bekhme Formation is older than Late Campanian and it's actual age is Turonian-Campanian. Additionally, it is concluded that the related basal conglomerate is chaotic fault breccia. The changing of the name is based on the analysis of evidence of the previous studies, and introduction of new ones in which new stratigraphic column, stratigraphic positions and new depositional basin, tectonic and paleogeographic setting are proposed or established.

**Keywords:** Bekhme Formation, Kometan Formation, Aqra Formation, Aqra-Bekhme Formation, Shiranish Formation

### Introduction

According to Bellen *et al.* (1959), the type section of Bekhme Formation is located in the Bekhme Gorge in the High Folded Zone (Fig.1) and divided into three parts, the Upper division consists of 211 m of bituminous secondary dolomites with dispersed glauconite, replacing glauconitic, organic, detrital limestones, with some globigerinal limestone intercalations with macrofossil detritus, etc. Middle division, is recognized normally as the "Cosinela zone", 94m thick, comprising reef-detrital limestones with rudist debris, alternating with fore reef shoal limestones with rich foraminiferal faunas. The lower part is called Basal conglomeratic Division, 10 m thick, by the aforementioned author and comprising globigerinal and foraminiferal limestones and Polygenetic breccia conglomerates, with ferruginous globigerinal marls locally.

Buday (1980) combined Bekhme and Aqra Formations under the name of the Aqra- Bekhme Limestone Formations and stated that it wedges out relatively rapidly and (mainly towards the southeast) it forms tongues of relatively small thicknesses within the Shiranish and Tanjero Formations only. Recently, Lawa *et al.* (2013, p.78) and A-Qayim, (2010, p.389) put Aqra-Bekhme in the middle part of Shiranish and Tanjero Formations and surrounded by latter two formations from all sides. This position not agrees with field evidence as the formation in most places underlain by Qamchuqa Formation not by Shiranish or Tanjero Formation such as Bekhme gorge, Gali Zanta and near Aqra town. The age of the formation (Aqra-Bekhme) is Late Campanian - Early Maastrichtian (Bellen *et al.*, 1959, Buday, 1980, Al-Qayim, 1989).

According to the all previous studies, the Qamchuqa Formation is overlain by Bekhme Formation unconformably. Bellen et al (1959) mentioned the occurrence of polygenetic and basal conglomerate and breccias (about 10m thick) between the two formations. They mentioned that the conglomerate represents a gap, which extends from Late

Albian to Early Campanian. Buday (1980) mentioned that the contact is as a rule unconformable due to occurrence of conglomerate at base of Aqra-Bekhme Formation. More recently, Al-Qayim (1989), Al-Qaradaghy (1989), Al-Qayim and Shaibani (1995), Omar (2006), and Jassim and Golf (2006) have mentioned unconformable contact too.

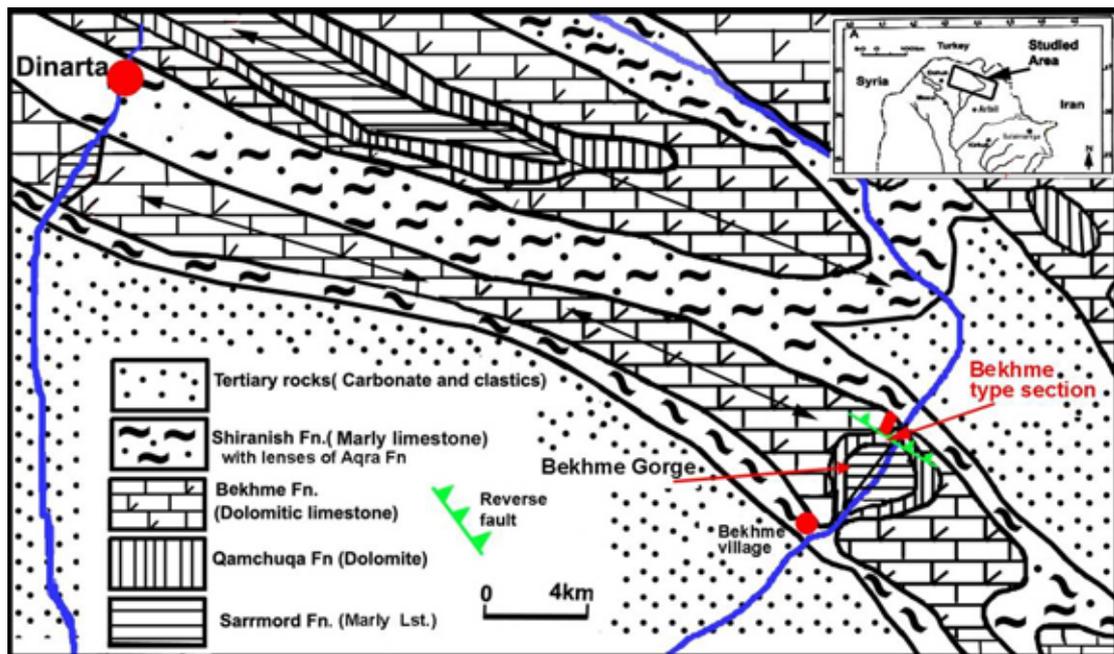


Fig.(1) Location map and simplified geological map of the area around Bekhme Gorge (Modified from Sissakian, 2000 by Ameen and Karim, 2008).

## Discussion

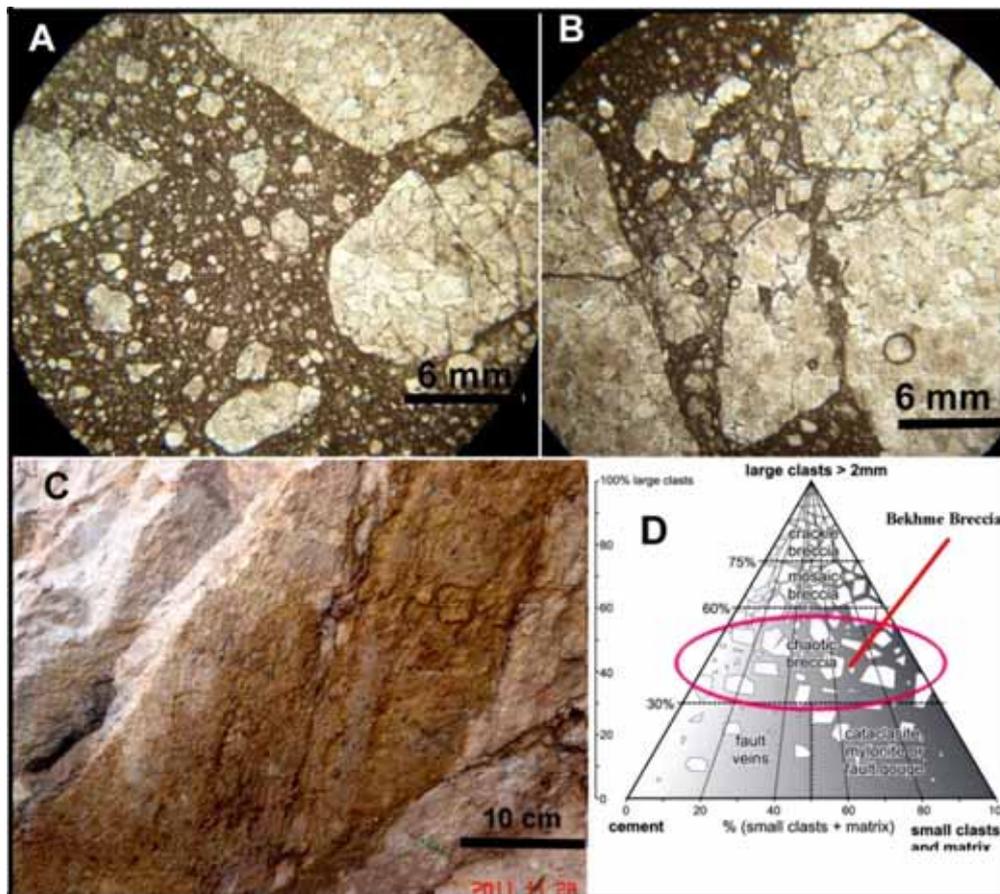
### Age equivalency and basin sharing of Bekhme and Kometan Formations

There are many reasons why Bekhme Formation is age equivalent and shared same basin with Kometan Formation. The first reason is the study of Ameen and Karim (2008) which refused the existence of conglomerate at the contact between Qamchuqa and Bekhme formations and correlated the lower part of the latter formation with Kometan Formation. They concluded the conglomerate is fault breccias that are derived from beds that located about 20meters above the contact (above the conglomerate).

In this study, the above conclusion is further ascertained by finding of striated and planer fault surface with fault breccias along the stratigraphic position of the claimed unconformable contact. In some case the fault breccias transformed to more or less mylonite-like rocks (Fig.2). The clasts of the breccias consist of monogenic angular clasts of the secondary coarse dolomite which shows that the brecciation is occurred during burial not during deposition. In many case the detached clasts can be combined like puzzle game. This type of breccia is called "Choatic breccia" by Mort and Woodcock (2008) (Fig.2B).

The breccia origin is clear from the observation of Bellen et al (1959) whom mentioned three constituents of the conglomerate at the base of Bekhme Formation. The first one is that it contains limestones of Late Cretaceous and the second is that conglomerate contains *Pseudosiderolites Cf. heracleae* (Arnil) and the third is that it contains Qamchuqa dolomites. The objection of the present author is that these constituents prove fault origins of conglomerate as it must contain Middle Campanian and older limestone and the *Pseudosiderolites Cf. heracleae* (Arnil) is belong to middle part of the Bekhme formation (Bellen et al.,

1959). Therefore, the question is how middle part clasts (with latter fossil) can be present at the base of the formation inside the conglomerate? This proves that the clasts are derived by fault not by depositions as deposits are always derived from underlying (older) beds not from the overlying ones (younger beds). About the last constituent both Qamchuqa and Bekhme Formations contain same types of dolomite and their dolomites cannot be differentiated especially when they exist as clasts. Therefore the presence of the Qamchuqa dolomite is not accurate and it possibly belongs to Bekhme Formation.



**Fig.(2)** Characteristics of the fault breccias (previous conglomerate) between Bekhme and Qamchuqa Formations in Bekhme Gorge. A) Several angular and intensely fractured clasts of same lithology (coarsely crystalline dolomite). The matrix (dark colour) is pulverized rock material (dolomite) which transformed to mylonite like rocks. B) Same breccia as previous one show crushed and fractured clasts, it is clear that these unstable clasts are in situ and not transported. C) Planner and polished surface that located at the contact between the aforementioned formations which assumed as fault plane in this study. D) Triangle shows the types of fault breccias (Mort and Woodcock, 2008) on which breccia of the present study (red oval circle) are indicated.

The second reason the study of Karim *et al.* (2012, in press), in which they refused, on the basis of available paleontology, the previous age (Late Campanian-Early Maastrichian) of the Bekhme Formation and showed that the age the formation is Turonian-Campanian. They constructed a model that connects Cretaceous deep facies, from the east, with the shallow facies from the west. In the model they assumed that the Kometan is age equivalent of Bekhme Formation and deposited in the laterally shared basin (Fig.3B). They found *Globotruncanita (Radotruncana) calcarata* at the base of Shiranish Formation and proved that the top of Bekhme Formation is older than Middle Campanian (when the underlying glauconite bed is encountered) (Fig.3B).

The third reason is the conclusions of the detailed studies (as M. Sc. theses) of Al-Qaradaghy (1989) and Ali (2010) in which they divided the Bekhme Formation in Bekhme Gorge into four units: Basal Conglomerate Unit (B<sub>1</sub>), Dolomitic Calcarenite, Unit (B<sub>2</sub>), Bedded Dolomitic Limestone Unit (B<sub>3</sub>) and Massive Dolomitic Limestone (B<sub>4</sub>). In these units they neither found index fossils for age determination nor large forms (such as *Luftusia* and *Omphalocyclus*) and endemic rudists (such as *Dictyoptiychus*). These fossils are abundant in the Early Campanian-Maastrichtian carbonate of Middle East (in Iraq, Iran, Turkey and Oman) (see Sadiq, 2009, Abdelghany, 2003 and Ozcan, 2007) but these fossils are not found in Bekhme Formation. The presence of globigerinal marls (Bellen *et al.* (1959) in Bekhme Formation is neither seen by Al-Qaradaghy (1989) and Ali (2010) nor by present author. Therefore, the present author thinks that mentioned the globigerinal marl is taken from the lower part of Shiranish Formation not from the Bekhme Formation.

The fourth reason is the study of Al-Mutawali *et al.* (2008) and Al-Shireedah, (2009) whom indicated paleontologically, the age of the Bekhme Formation as Late Campanian in northeast of Dohuk City at southern limb of Bekher anticline. They found *Globotruncanita (Radotruncana) calcarata* and indicated that the formation mainly composed of marly limestone with relatively rich planktonic forams. The above two studies are the main and serious disagreement to the present study and to that of Ameen and Karim (2008) and Karim *et al.* (2012) too. The present study justifies this disagreement by emendation of the claimed Bekhme Formation of Bekher anticline and changing it to Shiranish Formation. This is because it consists mainly of marly limestone (without dolomite) and rich in Planktonic forams (Fig.4F) while the type section of the Bekhme formation mainly consists of massive secondary dolomite. The conglomeratic limestone (the flat pebble conglomerate) that is mentioned by Al-Mutawali *et al.* (2008) is representing interfinger of Aqra Formation inside Shiranish Formation. The section of the Bekher anticline is similar to the section of Bekhme gorge in which Shiranish Formation (overlying Bekhme Formation) contain two interfinger of Aqra Formation (Fig.4 G).

Karim *et al.* (2012), at the base of Shiranish Formation, found *Globotruncanita (Radotruncana) calcarata* which is index fossil of base of upper Campanian, the same fossil is found too in the base of Bekhme Formation by Al-Mutawali *et al.* (2008). Therefore, both paleontology and lithology support that the section of Bekher is Shiranish Formation not Bekhme.

The fifth reason is that the glauconite bed between Bekhme and Shiranish Formations at Bekhme gorge (Karim *et al.*, 2012) is exist too in Dokan area

between Kometan and Shiranish Formations (Karim et al., 2001, Taha (2008) and Karim et al., 2008) (Fig. 6B and C). The two glauconitic beds are nearly similar in lithology and stratigraphic position (age of Middle Campanian). The glauconite bed has regional distribution which can be used as

regional datum (Loutit, et al., 1988, Van Wagoner, et al., 1988, Gallaway, 1989, Haq, 1991 and Emery and Myers, 1996). Therefore the two beds are synchronous and since Bekhme Formation is located below the bed at Bekhme gorge, therefore, it has the age of Middle Campanian and older.

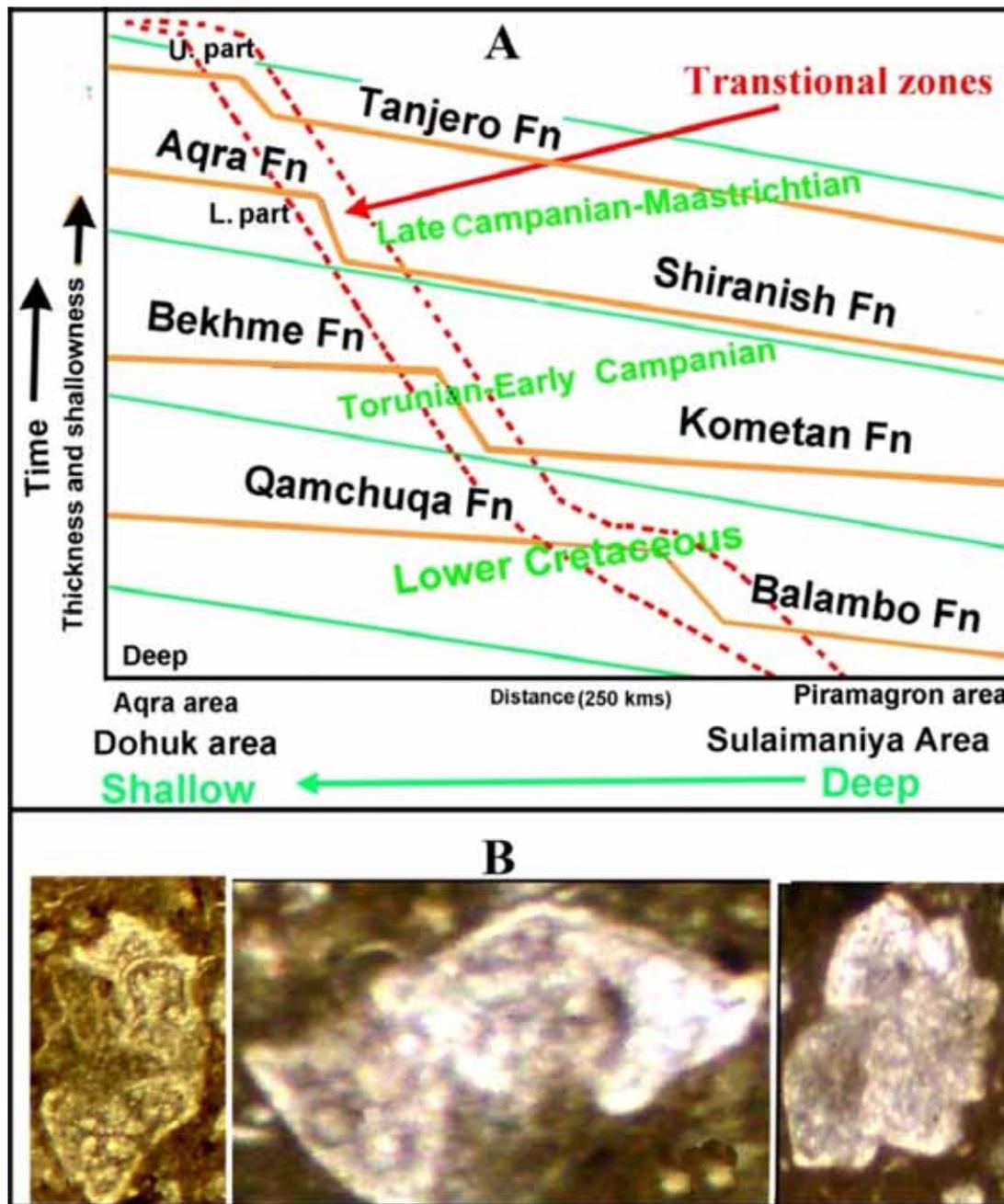


Fig. (3) A) a simplified model shows generalized spatial and temporal relations between deep and shallow Cretaceous formation (Karim et al., 2012). B) Different section of *Globotruncan calcarata* index fossil of the base of Late Campanian at Bekhme Gorge (PPL, 40X)

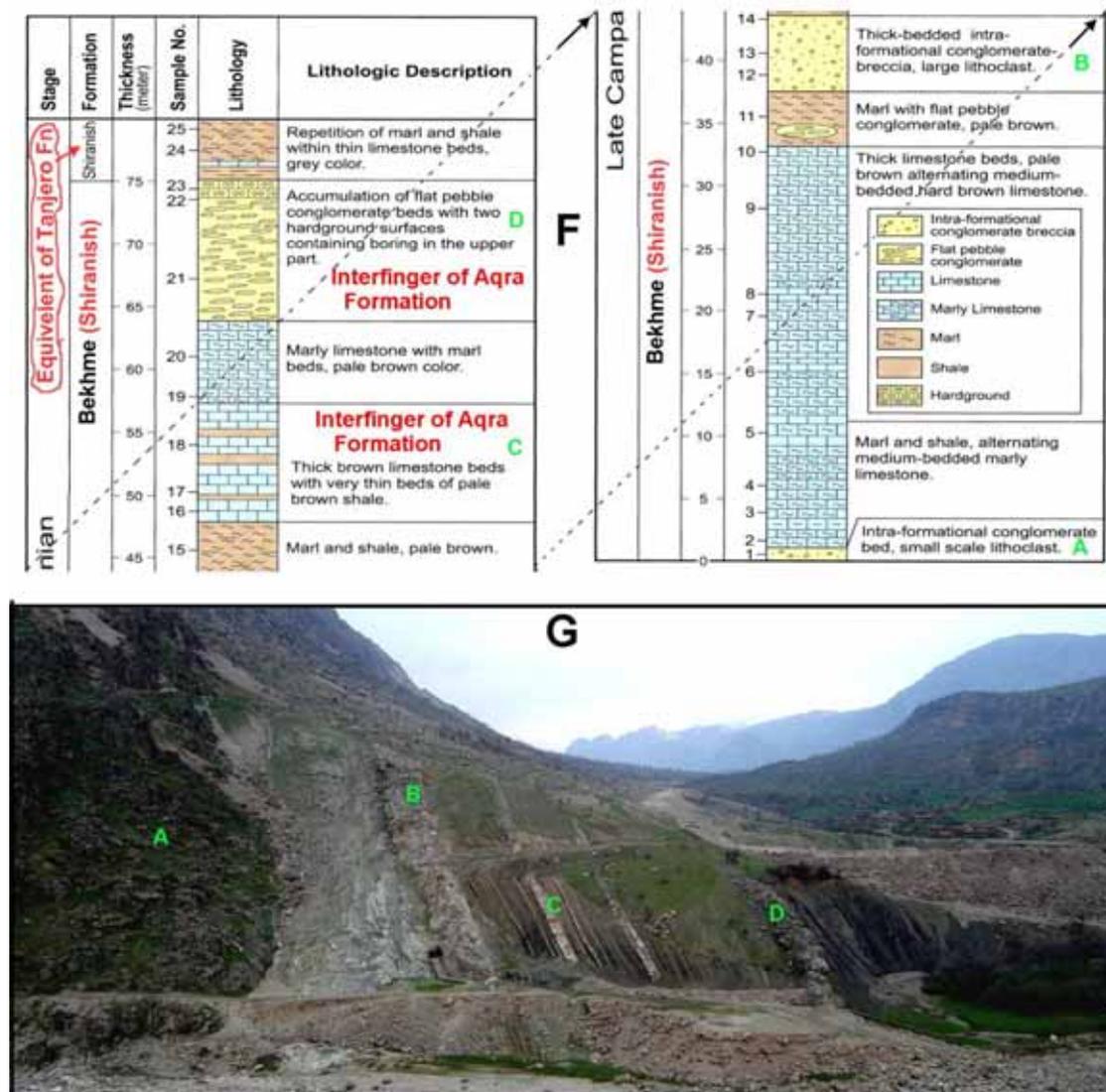


Fig.(4) F) Stratigraphic column of the claimed Bekhme Formation at Dohuk area by Al-Mutawali et al. (2008). In the present study it is emended (modified) in red fonts and changed to Shiranish Formation as it contain marl and planktonic foram without dolomite. G) Section of right side of northeastern inlet of Bekhme Gorge which is correlated with the upper section by green letters.

The seventh reason is that in Iran equivalent of Kometan Formation is Ilam Formation which is deposited in shallow and deep environments on a carbonate ramp with four microfacies: tidal flat, lagoon, shoal and open marine (Adabi and Mehmandosti, 2008). The stratigraphic column and depositional model that are constructed by the two authors show that Ilam Formation, in Iran (Izeh, Ahvaz section) is deposited in an environment

equivalent to transitional zone of Karim et al. (2012)(fig.3) which show interfingers of shallow fossiliferous and oolitic limestone in side deep fine grain limestone (Fig.5). The description given by Mogaddam, (2002) shows that Ilam formation, in its type locality is similar to Kometan Formation in Dokan area and in it's type section. This author cited that the former formation consists of 190 meters of well bedded pelagic argillaceous

limestone which is deposited in deep marine environment.

Another study that needs emendation is that of Al-Azzawi and Al-Khatony, (2010) in which they studied structural analyses and tectonic interpretations of Shaikhan

Anticline and showed Bekhme Formation that is located under Kolosh Formation. But, according to result of the present study, it is more possibly Aqra Formation than Bekhme.

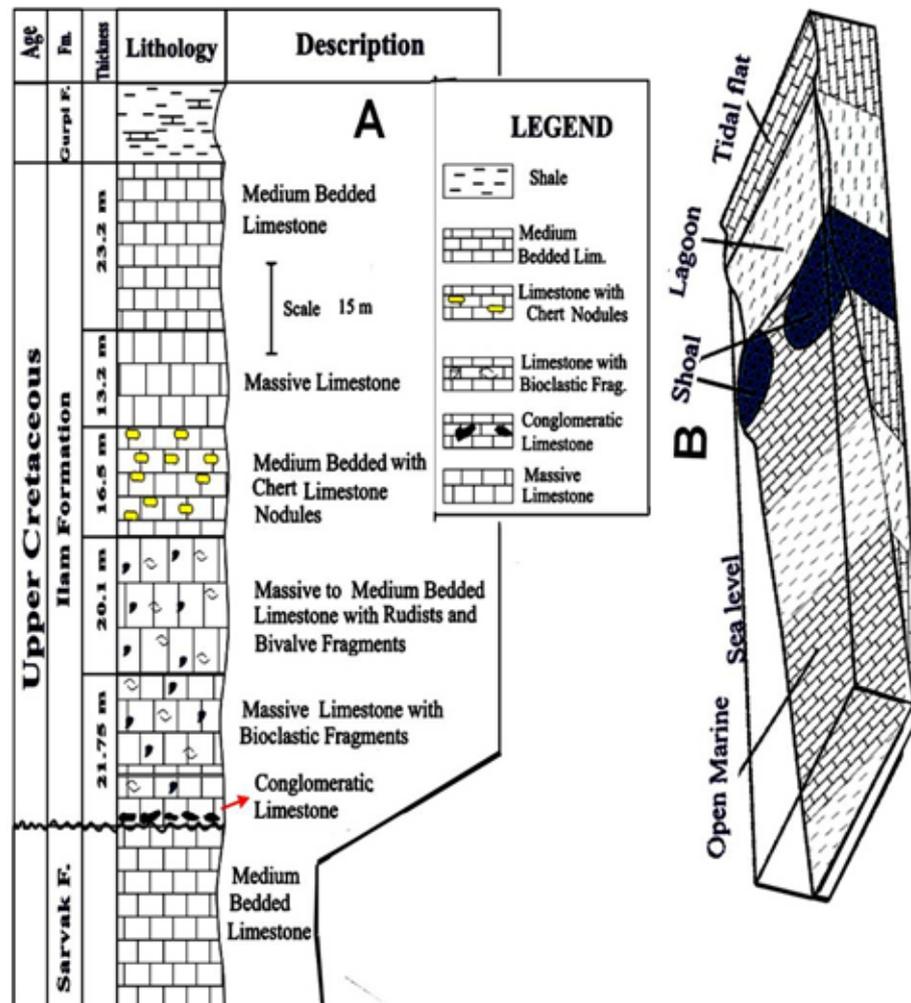


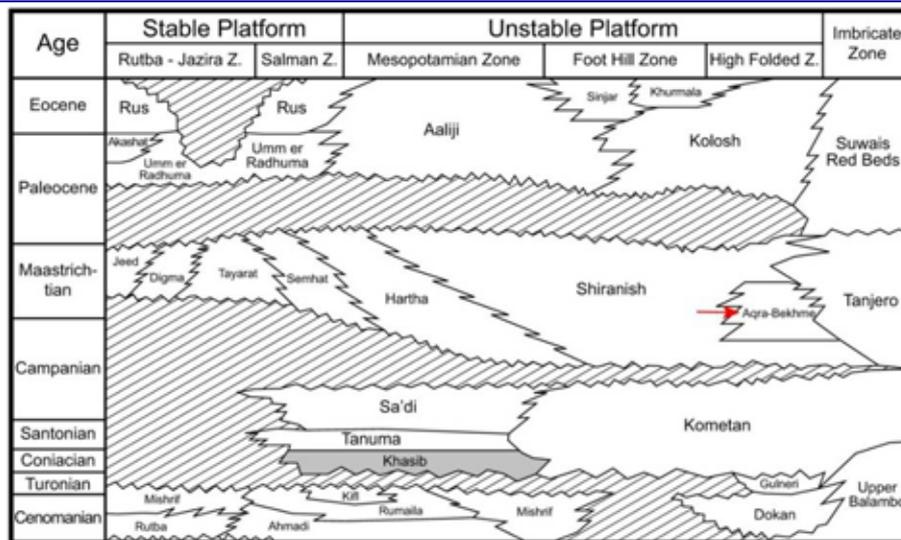
Fig.(5) Stratigraphic column and environmental model of Ilam Formation in Iran show that formation contains shallow and deep facies which is agree with the result of this study that Kometan and Bekhme Formation are age equivalent and shared same basin. B) Adabi and Mehmandosti (2008).

### Reasons for abandoning Bekhme Formation

- 1-The age of Bekhme Formation is not Late Campanian-Early Maastrichtian but it is Turonian-Middle Campanian.
- 2-The Bekhme Formation is combined with Aqra Formation as Aqra-Bekhme Formation by Buday (1980) and this

term is recently used by Al-Qayim (1989, 1995 and 2012) and Lawa et al. (2013, p.78) which is not applicable according to the result of this study, since the Aqra Formation is highly fossiliferous (contains large forams and rudists) and mostly consist of limestone while the former is relatively barren

- from fossil and mostly consists (according to Bellen et al., 1959) of dolomite.
- 3-The stratigraphic position of the formation is changed from being equivalent to Shiranish and Tanjero formations (Jassim and Goff, 2006; Al-Qayim, 2010, p.389) (fig, 6) to equivalent of Kometan Formation. This study suggests that if the formation would be combined, it is better to be combined with Qamchuqa Formation since Bekhme Formation is lithologically, tectonically and paleontologically more closely related to Qamchuqa Formation than Aqra Formation. Moreover than that, the contact between these two later formations is conformable as proved by (Ameen and Karim, 2008).
- 4-The tectonic of the formation are changed from foreland basin (when its age being Late Campanian- Early Maastrichtian) to oceanic continental margin when the new age of the present study is concerned.
- 5- Al-Qayim et al. (2005, p.113 and 114) and Ma'ala (2008) used the term Bekhme–Aqra Formation for that lens of the Aqra Formation that located inside Tanjero Formation in Chawrta-Mawat area. This means that two completely different formations in lithologies and ages are combined together by above authers. In Chawrta-Mawat area, the lithology and age of Aqra formation are limestone and middle Maastrichtian respectively while that of Bekhme (in type area) is dolomite and Turonian-Campanian. This usage is even opposite to the suggestion of Bellen et al (1959) who stated that where the Aqra limestone is superimposed directly upon the Bekhme limestone, without intervention of Shiranish or Tanjero formations, the composite name Aqra-Bekhme limestone may be used. It is known that the Bekhme formation does not exist in the Mawat-Chwarta area to use this composite name. Therefore, it better to change the name of the Bekhme Formation to avoid the usage of Bekhme-Aqra Formation in Chwarta–Mawat Area.
- 6-Recently the main lithology of the formation is changed to marl, marly limestone and limestone without dolomite by Al-Mutawali *et al.* (2008) and Al-Shireedah (2009). As the main lithology of the formation is originally dolomite, the change of the name is urgent to remove confusion.
- 7- Another confusion, in the previous studies of Bekhme Formation is the study of Al-Mutwali and Al-Doori (2012) and Al-Mutwali and Al-Haidary (2012). Each of the two studies had sampled a section near the Dohuk Dam and the distance between them is about 6 kms. In these two studies there are overlapping (repetition) of two biozones between the former study (about Bekhme formation) and the later one (about Shiranish Formation). The overlapping biozones are *Globotrancana aegyptica* and *Gasserina gansseri* which are representing more than the half of the thickness of the two formations. This repetition of the two biozones in two different formations of the same area (between sections of 6 kms distance) is great confusion in the definition of the two formations. The present study tries to remove this confusion by assuming that both sections of the two studies represent Shiranish Formation (with possible equivalent of Tanjero Formation) and the change of the name remove this confusion about the geologic column of the area.



**Fig. (6)** Stratigraphic column of Late Cretaceous and Early Tertiary (compiled by A-Qayim, 2010) from different authors) shows the stratigraphic position of the Aqra-Bekhme Formation (Red arrow)

8-The change of the previous paleogeography and tectonics of the area is urgent since the removal of Albian-Middle Campanian unconformity and deposition of neritic limestones instead, cannot be understood without removing the old name “Bekhme Formation”. The paleogeography of the area around Mosul, Arbil and Dohuk town is changed from uplifted high topography terrestrial land, during Albian-Middle Campanian, to a low-gradient basin margin topography that was covered by normal marine neritic sea (Fig.7).

9-The Cosinela Zone of Bellen *et al.* (1959) which is 94m thick is not recorded by the recent detail study of Ali (2010) and Al-Qaradaghy (1989), even the definition and photos of the “Cosinela” cannot be found in internet.

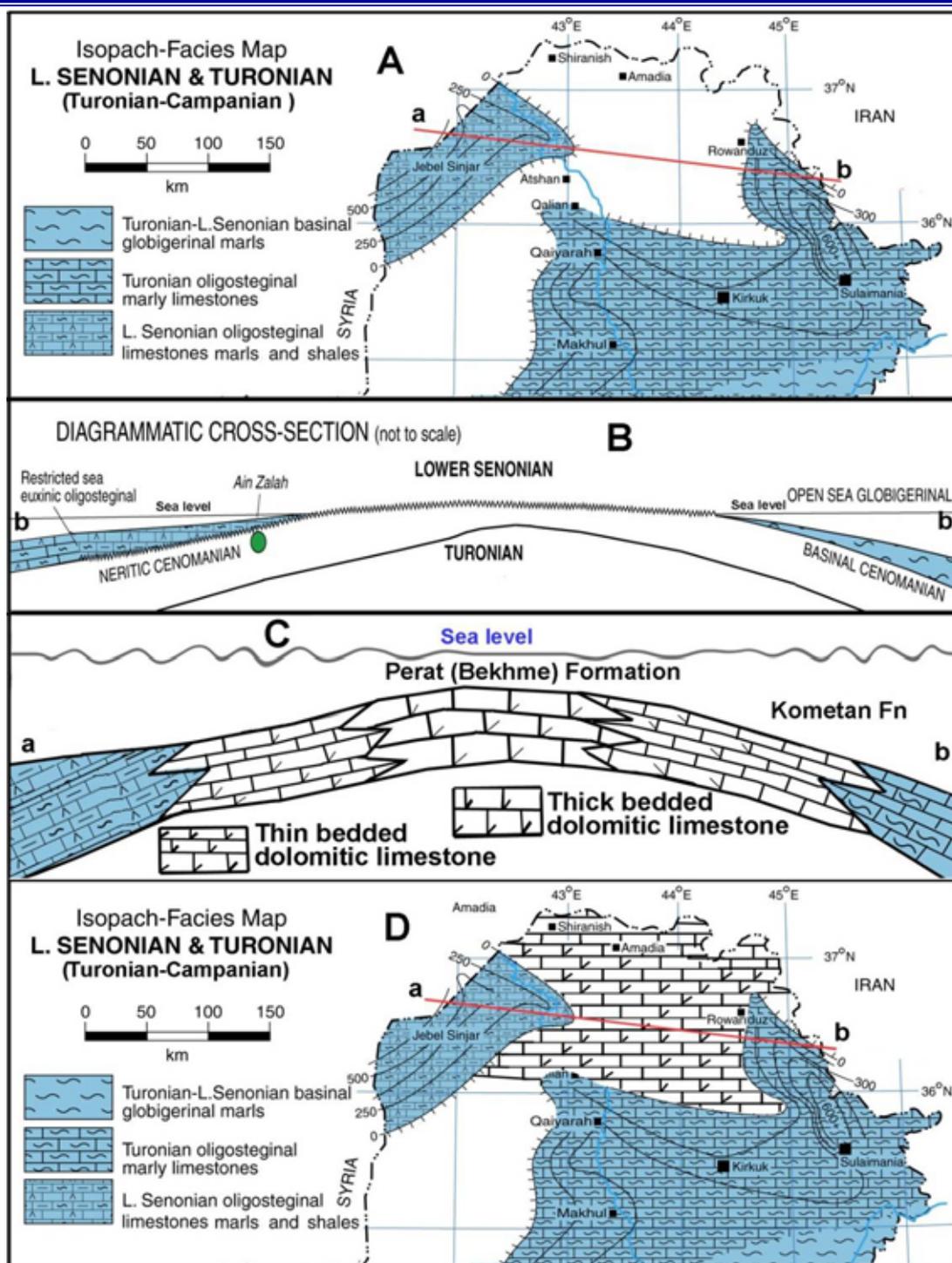
10- The equivalent of the unconformity between Qamchuqa and Bekhme Formations is not found in Iran as seen from (Fig. 8).

11-In the world, the reefal limestones of the Campanian-Maastrichtian age are rich in fossils such as large forams (Luftusia and Omphalocyclus) and rudist

but Bekhme Formation doesn't contain any of them except rare rudists. Therefore, its age is suspicious.

### Changing of terrestrial land to sea

According to Dunnington (1958 in Jassim and Goff, 2006), in the Late Campanian time ophiolites are obducted across the NE margin of the Arabian Plate. The compression that was associated with this obduction initially uplifted the Balambo-Tanjero Zone and the adjacent parts of the Unstable Shelf. He added that during this uplift considerable thickness of Upper Turonian-Lower Campanian sediments were eroded and locally these sediments were completely removed on the Mosul High (it called Khleisia-Mosul High by Horbury, 2007). In the present study, this eroded and uplifted area is shown in the figure (7A) which is modified and change to shallow basin, to agree with the result of the present study in the figure (7B). The times expanded stratigraphic column of the area is change to agree with the result of the present study (Fig.9 and 10).



**Fig. (7)** A and B) Facies maps of Cretaceous and related geologic cross section along the red line (ab) (Dunnington, 1958 and Aqraw, *et al.* 2010 ) which shows studied area (white area). C and D) modification of the section and facies map to agree with the result of the present study.

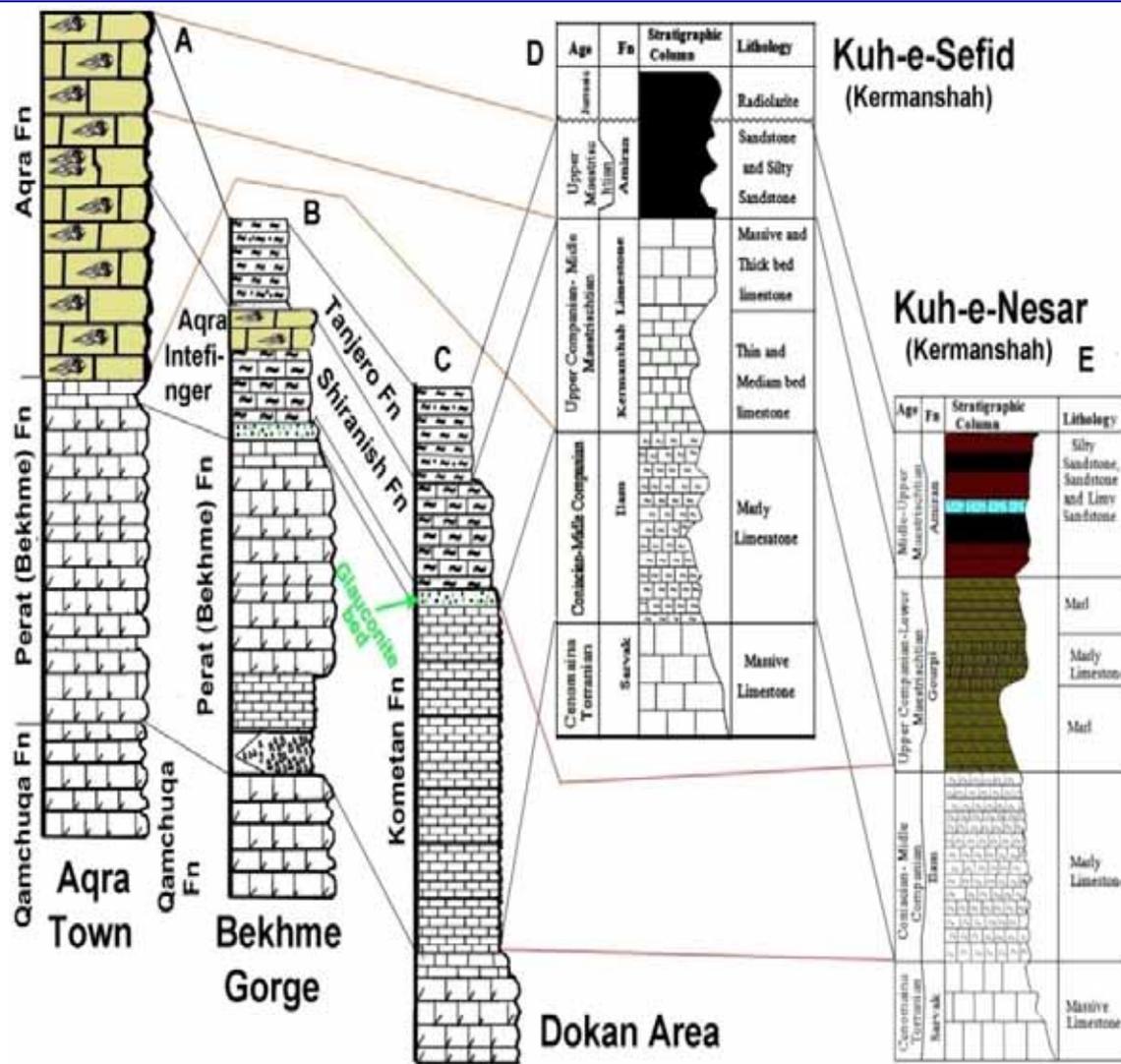


Fig. (8) Correlation of stratigraphic units of the Cenomanian-Maastrichtian in Iraq (A, B and C) and Iran (E and D, Rad, 2011.).The red lines represent direct correlation.

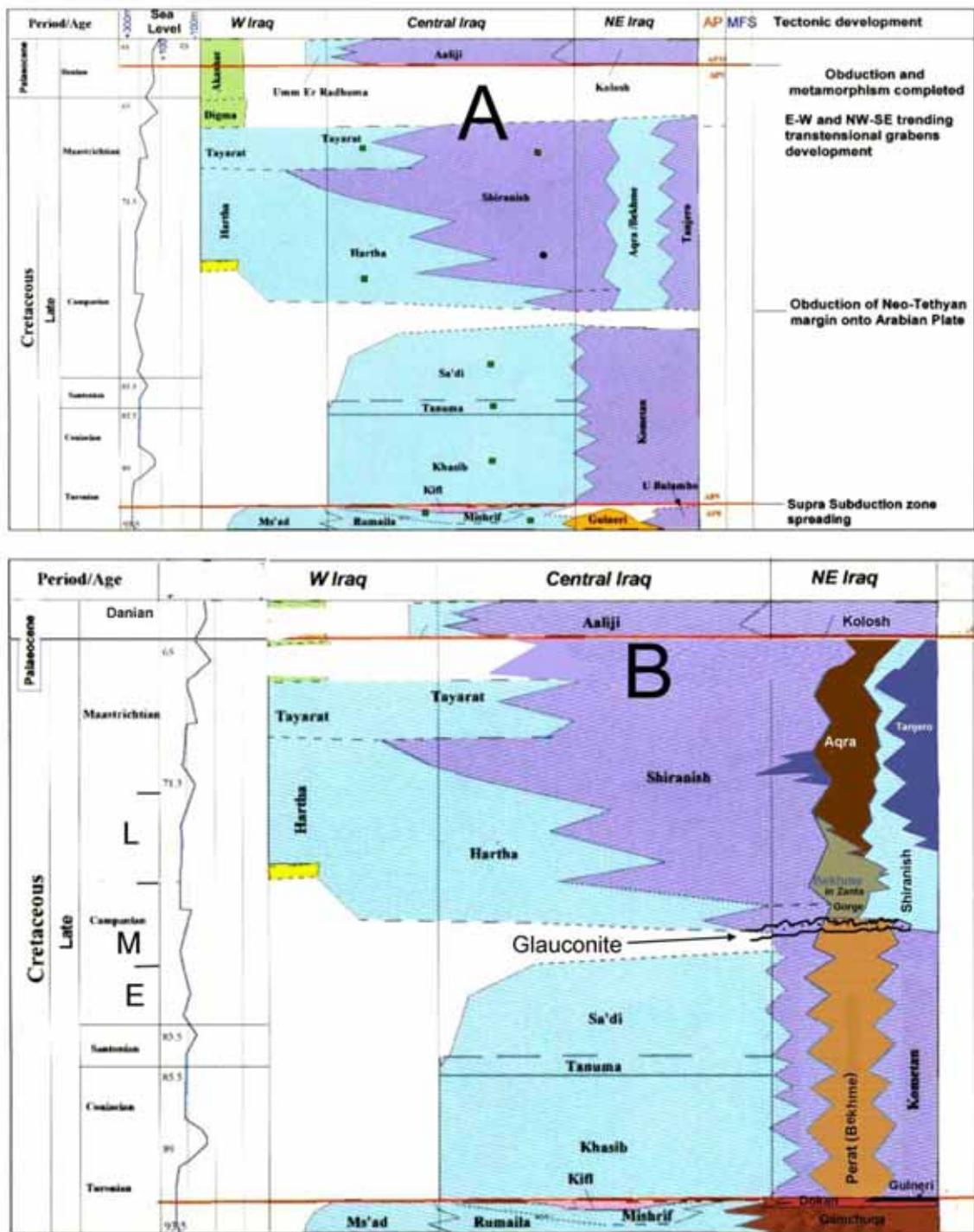


Fig. (9) A) Stratigraphic column of Late Cretaceous (Jassim and Goff, 2006). B) Same column modified to agree with the present study.

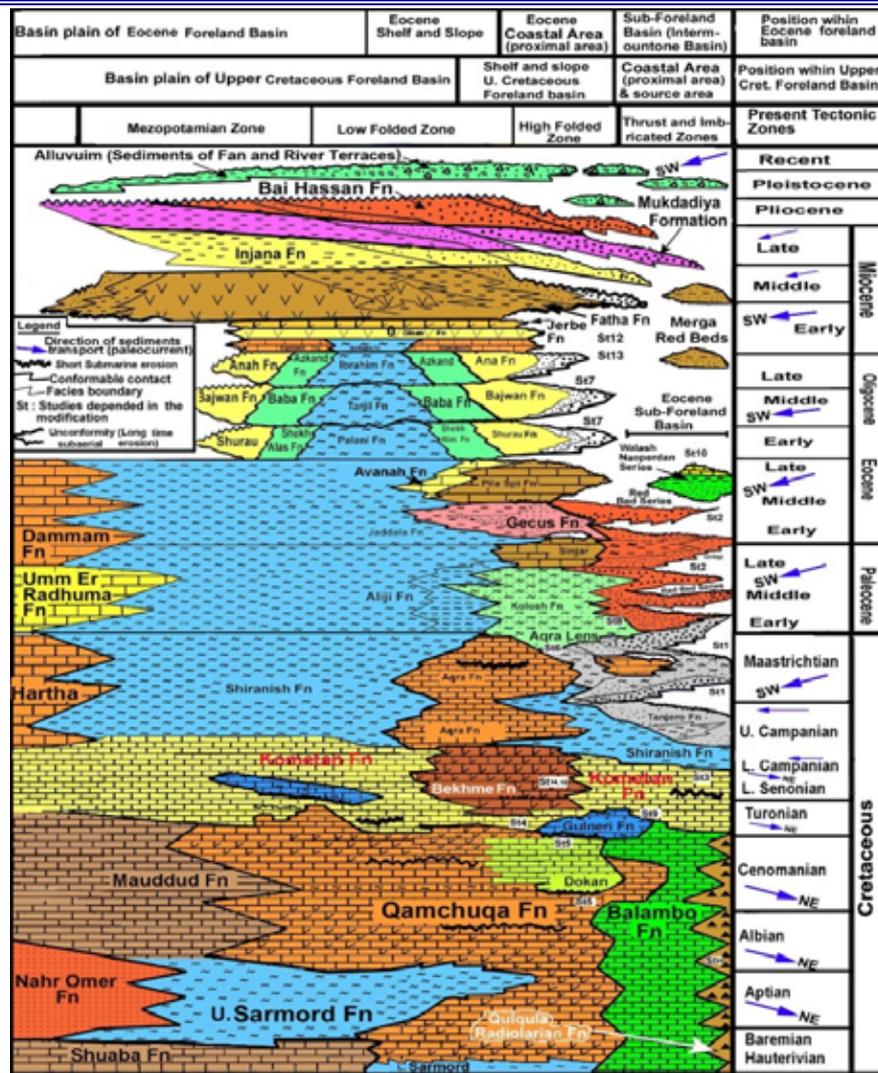


Fig. (10) Stratigraphic column of Cretaceous and Tertiary (modified from Karim, 2010) show position of the Kometan, Shiranish and Bekhme Formations.

**CONCLUSION**

This study has the following conclusions

- 1-The previous basal conglomerate of Bekhme Formation is proved to be chaotic breccia.
- 2-The Agra and Bekhme formations are very different lithologically, environmentally, tectonically and paleontologically. So they must be separated
- 3-The previous stratigraphic column and tectonic setting and facies map of the area is changed from terrestrial land to shallow sea of Neo-tethys.

- 4-The new name (Perat Formation) is suggested for the bekhme Formation to avoid previous confusion that associated with it's name, age, boundaries, environment, lithology, fossil and tectonics.
- 5-The definition of the Bekhme Formation is more accurately acceptable for Zanta Gorge where the reefal carbonate of late Campanian occur.
- 6-The result of the present study agrees with geology of Iran which is shown by correlation of the rock columns of the studied area with of the Iran.

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