Stratigraphy and Facies analysis of the Govanda Formation from western Zagros, Kurdistan Region, Northeastern Iraq

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Abstract

A part of the Govanda Formation is studied in six outcrops sections in the northeastern Iraq near the Iraq-Iran border. It consists of biogenic and detrital limestones (conglomeratic limestones), and highly fossiliferous limestones of reef-fore reef facies with occasional inter beds of terrigenous sediments. The formation is very important tectonically for its location in the very active Sinandij-Serjan (Suture) Zone and for its deposition in Late Middle Miocene which assigned previously as age of continental-continental colliding of Zagros Fold-Thrust belt. Additionally, it overlays different rocks of pre-Miocene age and the most important one is its resting on Qulqula Radiolarian Formation (Kermanshan Radiolarites in Iran) in an angular unconformity relationship. The high energy and tectonically active shallow normal marine environment is inferred from many facies such as coral framestone, pelecypod floatstone, coral and lithoclast rudstone, coral bufflestone, stromatolite bindstone, Foraminifera and red algae bioclasts, packstone–wackstone, reworked Foraminetral-lithoclast grainstone-packstone, lithoclast grainstone and terrigenous lime sandstone. The depositional environment of the formation was high energy shallow and normal marine sea which was consisted of fore-reef, reef and back-reef. The tectonic and paleogeographic relations of the formation are discussed in term of facies and boundary condition. It is confirmed that the Sanandij-Sirjan Zone was subjected to extension not compression (continental-continental colliding) as cited in some studies. The richness of the basin with fauna indicates that it was connected to both Indian Ocean and Mediterranean Sea.

Key words: Govanda Formation, angular unconformity, Sanandij-Serjan Zone, Miocene facies analysis, Iraqi Thrust Zone

1-Introduction

The Govanda Formation represents the deposits of the early Middle Miocene and has the thickness up to 150 m thick (Jassim and Goff, 2006). It was first described, according to Bellen et al.

(1959) by Dunnington, Al-Naqib and Morton in 1957. In Iran, it is equivalent to Asmari Formation and its type locality , in Iraq, lies on the northwestern slopes of the Govanda Plateau in the Imbricated Zone of northeastern Iraq at latitude 37° 07' 58" N and longitude 44°12' 53" E in the Arbil Governorate. According to Bellen et al., (1959), the lithology of type section, from top to bottom is as follows: The lowermost 6 m, is composed of a polygenic basal conglomerate and passing upwards into conglomerates with pebbly sandstones and siltstones. These terrigenous clastics are overlain by roughly 20 m of silty and sandy, detrital limestones with abundant derived Cretaceous fossils. The overlying 80-90 m, i.e. the bulk of the formation, is made up of limestones of reef-fore reef facies.

The previous studies of Govanda Formation indicates to shallow marine reef-fore-reef environment, strongly affected by the supply from the nearby rising land, as testified by the presence of clastics not only at the bottom, as in the type locality, but sometimes intercalating with the limestones too (Buday, 1980). The latter author added that its lower contact is unconformable and the formation had transgressed on Red Bed Series and its upper contact is not visible. In Shalair valley, the thickness of the formation is about 100m and composed of a basal conglomerate (contains chert pebbles derived from Qulqula Radiolarian Formation) which passes upwards and laterally into fossil rich sandy limestone capped by thick oyster-bearing limestone (Jassim and Goff (2006). The latter authors added that the formation is underlain unconformably by the Swais Group, Tanjero Formation and locally by the Qulqula Group.

. 1.1. Location

The studied area belongs to Kurdistan Region, Northeast Iraq in the Sulaimani Governorate near the Iraq-Iran border (Fig.1). The sections of the formation are distributed in six different areas. The first section is located in the southwestern boundary of Shalair valley at 25k to the northwest of Penjwin (Penjween) town (Fig.2 and 3). The center of this section is located at latitude and longitude of 35^{o} 45^{-} $58.82^{=}$ N and 45^{o} 49^{-} $29.20^{=}$ respectively. Its outcrop (Bahe outcrop) is largest and have length and width of 15km and 1km respectively and it elongates along Gole stream from Komari (from southeast) to Bahe villages at northwest (Fig.4 and 5). The second section is located at the latitude and longitude of 35^{o} 40^{-} $32.75^{=}$ N and 45^{o} 52^{-} $14.01^{=}$ E respectively and its outcrop (Qizlar outcrop) include the area at the north and northeast of the Qzlja village at 10 km southwest of Penjwin town. These latter two outcrops are mapped by Buday and Jassim (1987).

The third section is located between Rashan and Qizlja outcrops on the Mila Kawa peak, exactly on the western side of the paved road to Penjween Town. On this peak there is small outcrop (Mila Kawa outcrop) of the formation has about 10m thickness and has lateral continuity only for about 100m. The forth section is located in middle of the bottom of the Rashan (Taza De) valley especially along the southern side of the stream that flow in the valley. The center of the section is located at the intersection of latitude and longitude 35^{o} 31^{-} $14.91^{=}$ N and 45^{o} 59^{-} $54.84^{=}$ E respectively. It's out crop is has thickness, length and width of 10, 10000 and 200 meters respectively.

The fifth section (Rashan outcrop) is located in the head of Dola Chawt near the Barda Balaka village and their outcrop (Barda Balaka outcrop) is small less than one quarter of square kilometers. The outcrops are distributed on both sided of the unpaved road pass through the village (Fig.2 and 3) and rested on Qulqula Radiolarian Formation. The center of this section is located at the intersection of latitude and longitude 35^{o} 33^{-} $07.82^{=}$ N and 45^{o} 49^{-} $35.02^{=}$ E respectively.

There is another section (sixth section) in 3km to the west of Chuarta town and found by Al-Barzinjy (2005).This outcrop (Chwarta outcrop) is very small and has surface area 50 square meters and consists of coral colony limestone and this author included it in the unit six of Red Bed Series but it most possibly belongs to Govanda Formation. The center of its exposure is located at latitude and longitude of 35^{o} 43^{-} $26.94^{=}$ N and 45^{o} 51^{-} $32.76^{=}$ respectively (Fig.2 and 3).

1.2. Tectonic setting of the studied area

According to Buday (1980), the studied is tectonically located in the Thrust Zone and when the tectonic division of Jassim and Goff (2006) is considered, it located in of the Qulqula-Khuwakurk and Penjween-Walash Zones as a two neighboring Zones of Suture Zone. The area has the most complex geological condition in Iraq which manifested by brecciation, thrusting, transpression deformation, igneous intrusion and metamorphism.

In the studied area four main thrust sheets can be identified in the field, the largest is outer (lower) one which consists of Qulqula Radiolarian Formation sheets that were thrusted on different units in different areas, such as Tanjero, Shiranish, Kometan, Balambo Formations in addition to Jurassic rocks.

The Qulqula Radiolarian Formation is about 1000 meter thick and consists of bedded chert, siliceous shale, marl and limestones which are studied by Karim and Baziany (2007), Karim et al. (2009), Karim et al. (2011) and Baziany (2013). The second sheet consists of Avroman Formation which is thrusted on the Qulqula Radiolarian Formation. Avroman Formation is composed of detrital and biogenic limestone of reefal facies which studied by Karim (2007). The third sheet consists of many smaller sheets but the main third one is Penjween Ophiolite complex which is thrusted on the Merga Red Bed and Qulqula Radiolarian Formation. The Penjween Ophiolite complex consists of gabbro, peridotite, dunite and small bodies of acidic rocks. The forth sheet is the metamorphic rocks that are consisted of phyllite, hornfels and calcsilicate marble (Karim et al. 2016). Structurally, the main folds are so deformed that cannot be identified and only the small folds are observable.

The studied area is located in the Sanandij-Sirjan Zone it located between Main Zagros Thrust at southwest and Urmia-Dokhtar Magmatic Zone at the northwest (Moghadam and Stern, 2015; Jamshidi Badr et al., 2010). However, the definition of Stocklin (1968 in Yousefirad, 2011) and tectonic map of Ghazi and Moazzen (2015) are considered in this study.

Geomorphologically, the area is a part of high mountain series of Zagros belt and due to a aforementioned sheets, the main (large) valleys have northwest-southeast trend which are subsequent valleys such as Taza De and Nalparez, Ahmad Klwan, Qzlja, shalair, Gole valleys or streams. These valleys are surrounded from northeast and southwest by high mountains that are more than 2000 m high above mean sea level. The mountains are Surren, Spidara, Kani Shawkat, Taryar Qaya, Harzala, Nizara, Bahe. Many small obsequent and consequent valleys are descending from the high mountains. These valleys have emepheral streams and joining the large ones.

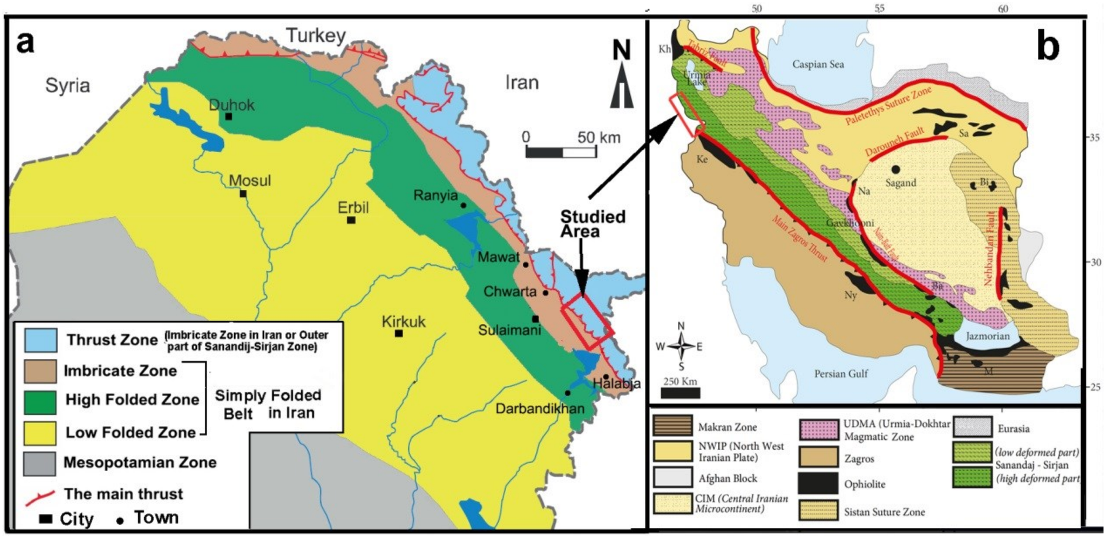

Fig. (1) a) Tectonic subdivision Northern Iraq (Jassim and Goff, 2006) shows the studied area ,b) Location of the sudied area in the Zagros fold-thrust belt (modied from Ghazi and Moazzen, 2015).

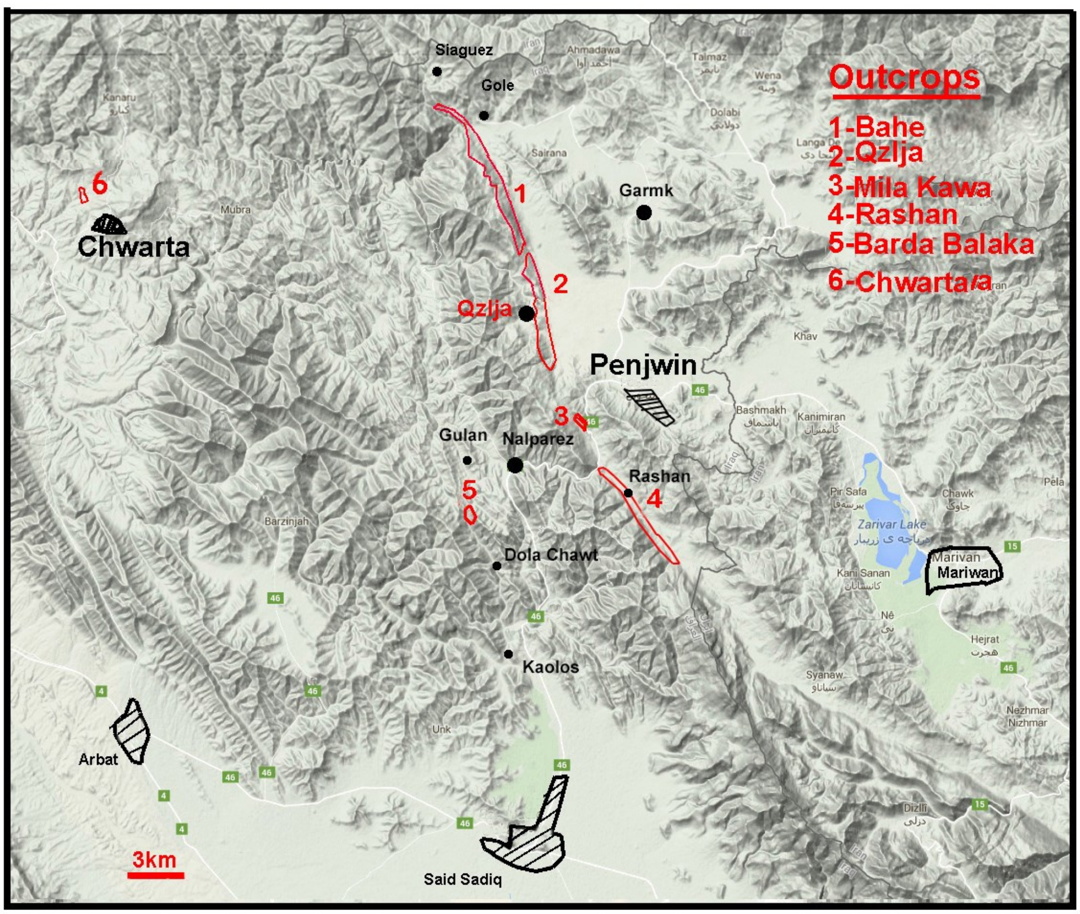

Fig. (2) The Location of the studied outcrops on Google

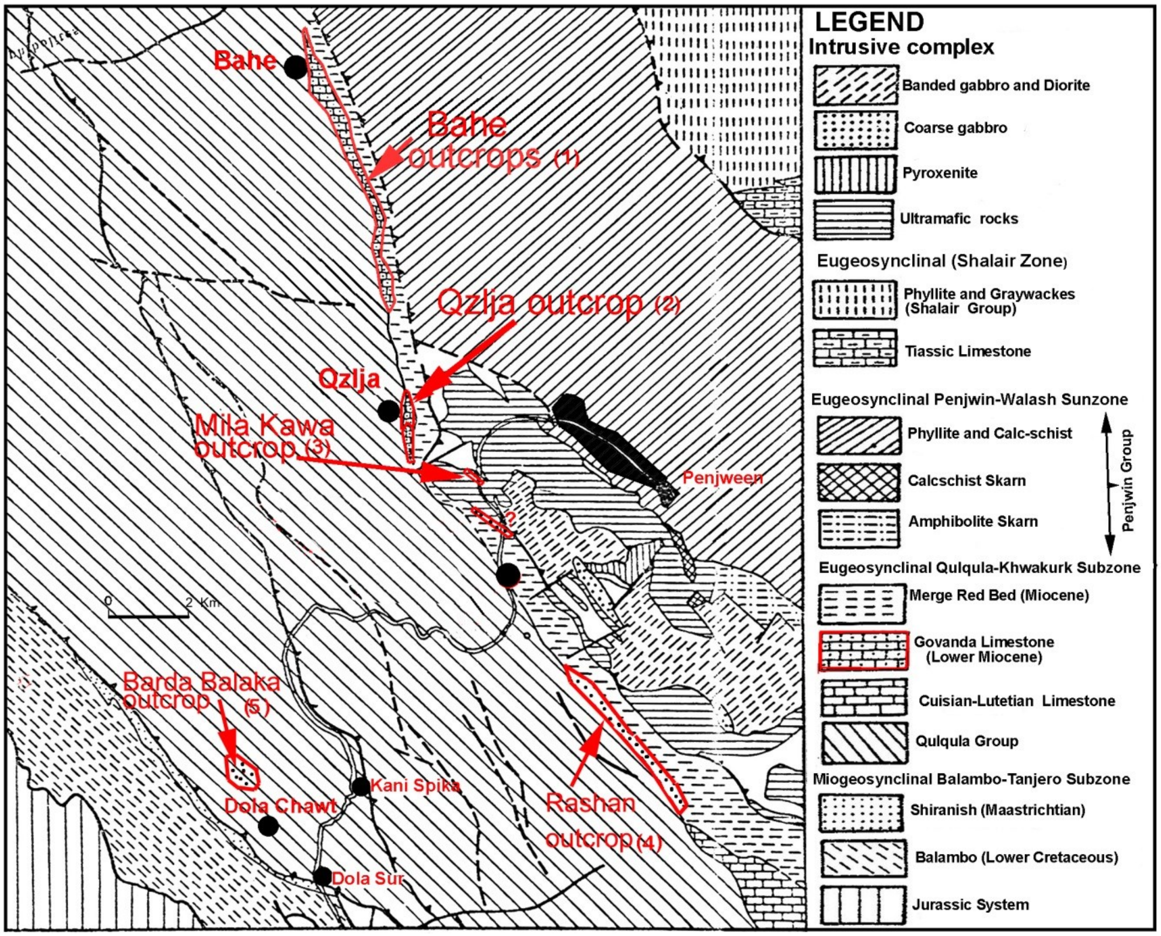

Fig. (3) Geological map of the studied area (modified from Buday and Jassim, 1987) on which the studied sections (outcrops) are indicated

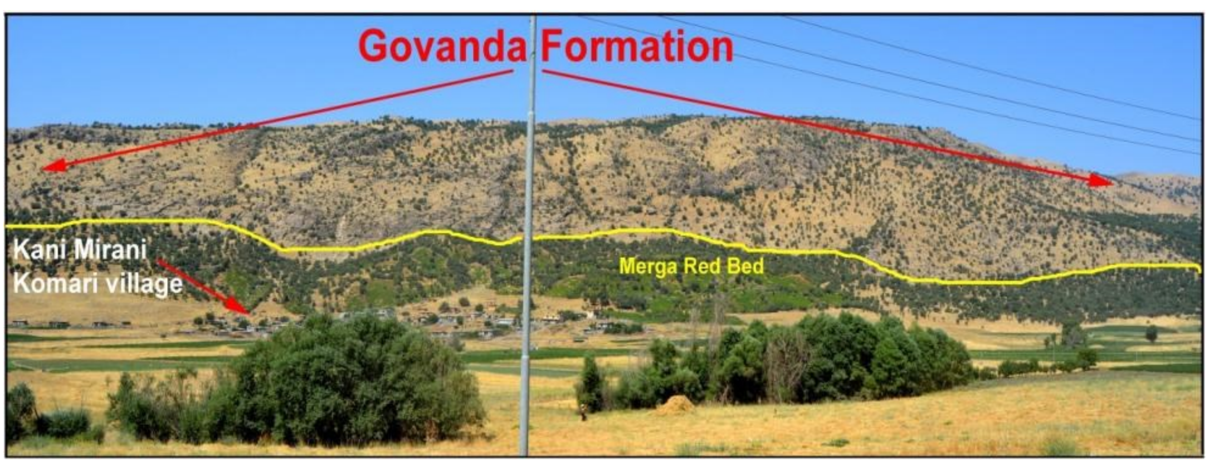

Fig. (4) An outcrop of Govanda Formation at south and southwest of Bahe and Kani Mirani Komari, southwestern boundary of Shalair valley, Penjwin area

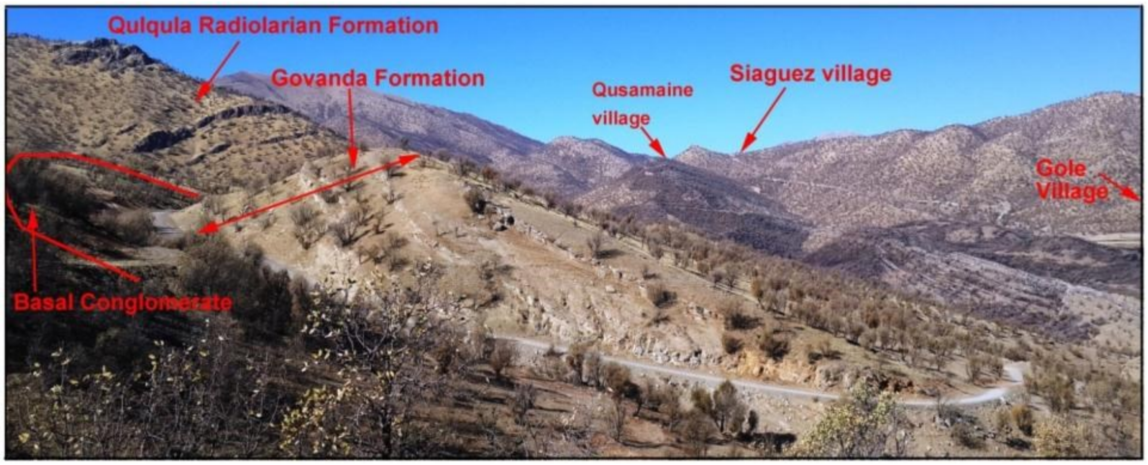

Fig. (5) An outcrop of Govanda Formation (section no.1) at 200m west of Bahe village, southwestern boundary of Shalair valley, Penjwin area

1.3. Method of the study

This study depends on the field study during which the upper and lower boundaries are examined. Geographical extends are plotted on the map and 23 samples are taken for lab study and they are inspected under stereoscopic microscopes for indication of allochems and orthochems. Selected samples are cut for thin section preparation for petrographic study under polarizer microscope. In the thin sections and on the hand specimens, the facies are indicated after the differentiation of the rocks constituent including fauna, lithoclasts, intraclasts, extraclsts and boiclasts. For this indication, the Dunham (1962) classification and its modification by Embry and Klovan (1971) are used.

2. Results

2.1. Geological boundaries of the formations

2.1.1. The lower boundary

The lower contact of the formation is exposed in many areas and rested on different lithologic units. In type area, in Arbil Governorate it rests on Kirkuk Group and Tanjero Formation unconformably (Bellen et al.1959 and Buday, 1980) and according to AL-Hietee (2012) it represent transgressive over previous units. In the northwestern part of the studied area in Bahe and Qzlja outcrops (Fig.2, 3, 4 and 5), it overlies Qulqula Radiolarian Formation unconformably in angular relationship near Gole, Bahe and Qzlja villages. The angular unconformity can be seen clearly from intense folding of the beds Qulqula Radiolarian Formation below the Govanda Formation (Fig.6a). In this area there is about 1.5 of polygenetic basal conglomerate between the two formations and it consists of gravel conglomerate with red clayey sandstone matrix or cemented by calcite (Fig.6b). In some location show intense brecciation especially on the northern bank of the Gole stream. The same angular relation is true for Barda Balka outcrop near Razla village which rest on the Qulqula Radiolarian Formation and the contact shows highly shearing and brecciation which most possibly tectonic. The lower boundary in southeastern part of the studied area (Rashan outcrops) rests on the sandstone of Merga Red Bed which may be tectonic, because, according to Buday (1980), Merga Red Bed is most possibly late Miocene in age.

2.1.2. The Upper Boundary

According to Bellen et al. (1959) and Buday (1980) the upper boundary is erosional in most places while the formation is overlain by Merga Red bed in some places. In the studied area, as mentioned before, it seems that what called "Merga Red beds" in the Penjwin (Penjween) area is located below Govanda Formation.

There is small outcrop of the formation between Rashan and Qizlja outcrops, exactly on the Milakawa peak and on the western side of the paved road. This outcrop intensely brecciated and consists of mixture of detrital and nummulitic limestone with sandstone and calcareous shale (Fig.7). It is located between Ophiolite (Penjwin ophiolite of Jassim and Goff, 2006) at the top and Merga Red Bed at the base. In this locality both boundaries are tectonic. This outcrop is containing nummulite of Eocene age which are most possibly reworked. A small part of Bahe outcrop, at 800m to the southwest of Gole village, is overlain (covered) by lithified oncoidal massive limestone and travertine (Fig.8). The age of this limestone is not known but it may be belonged to Pleistocene or Sub-Recent as the dips of its strata are nearly coinciding with local slope of the area.

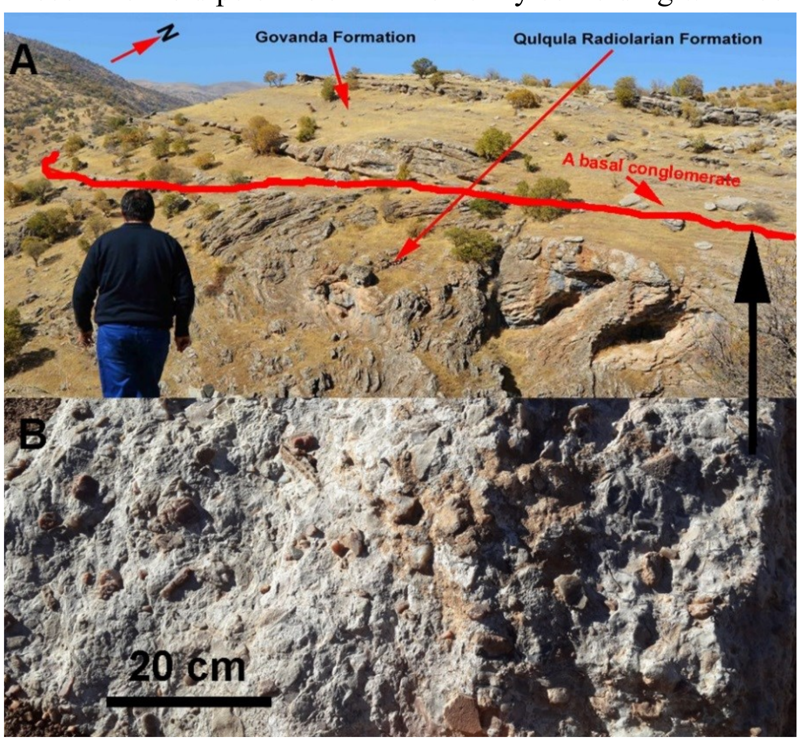

Fig. (6) a) Resting of Govanda Formation (Middle Miocene) on Qulqula Radiolarian Formation in angular relation (angular unconformity) at 5 km south Siaguez Village in Shalair valley directly to the north of Bahe Village. b) Basal conglomerate between Govanda and Qulqula Radiolarian Formations near Bahe Village.

Fig. (7) Possible Govanda Formation (brecciaed) between Penjwin Ophiolite and Merga Red Bed on the Mila Kawa peak near Kani Manga Village.

Fig. (8) Stromatolitic (oncoidal) limestone on the Govanda Formation at 200m to the north Bahe Village.

2.2. Facies Analysis

Litho and biofacies analysises of the Govanda Formation is difficult task due to many facts, the first is the presence of reworked fossil from Cretaceous (Bellen et al.1959) and from possible Eocene ages (as inferred from present study). The second is complexity of its boundaries condition which is highly variable geographically and chronologically which constrain the accurate definition of the facies. The third is the intense deformation and distortion of the allochem constituents of the facies due to its location in the Suture Zone or Sanandij-Serjan Zone, therefore the deformation limits the accuracy of the identification. The forth is presence of some degrees of recrystallization which limit the accuracy of documentation and the photos of the facies might not be so clear. The fifth is most facies contain more or less terrigenous clasts which restrict accurate naming. However, many facies are found in the Govanda Formation, which have environmental and paleogeographic importance. These facies can be recognized in both polished slabs and thin sections. In rare cases this facies contain whole echinoderms skeleton.

2.2.1. Pelecypod floatstone Facies (F1)

This facies is supported by carbonate matrix that contains more than %10 grains larger than 2mm. The matrix of floatstone does not necessarily correspond to be only micrite, but often consists of fine-grained textures that must be described separately (Flugel, 2004). This facies is very common in the lower part Bahe section and it occur rarely too in the Qizlja and Barda Balaka sections (Fig.9). This facies consist of skeletons or bioclasts of pelecypods (Fig.10) with or without coral and red algae fragments (that are larger than sand size) and floated or embedded in fine matrix of sand or silt sized bioclast or lithoclasts. The thicknesses of this facies are 10–80 cm and have sharp base with sandy marlstone. This facies show crude lamination and alternated with sandy marlstone. In one case and in the Barda Balaka section, there is a sample contain clasts of large gastropod and other unknown fossils (Fig.11). Generally, in this outcrop and its section, the clasts are very angular and the delicate sculptures are clear, which are denoting very short distance of transportation and relatively rapid deposition. This facies may be deposited in backreef setting.

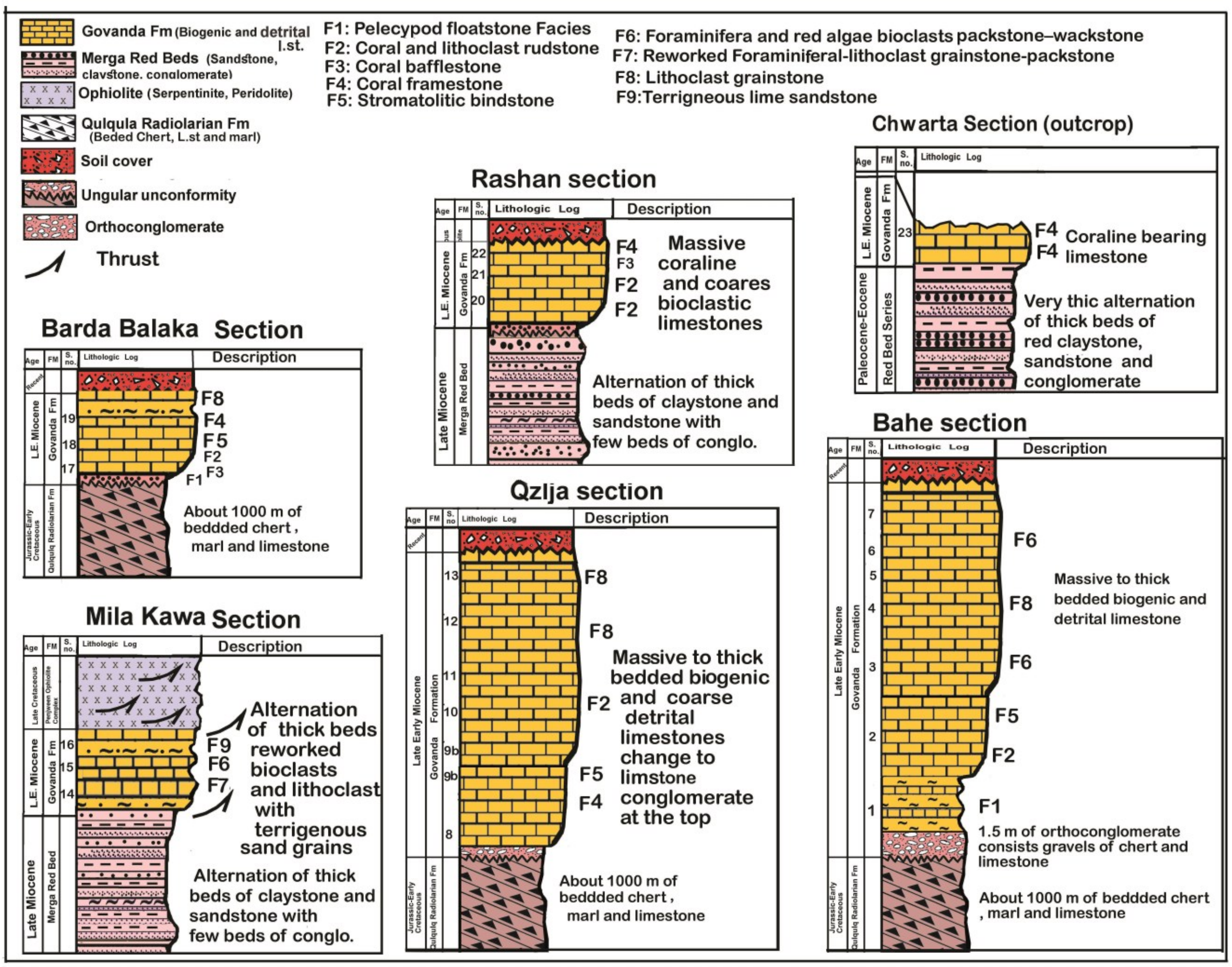

Fig.(9) Stratigraphic column of the studied sections

Fig. (10) Pelecypod (including oysters) floatstone in the lower part Govanda Formation in the Bahe outcrop

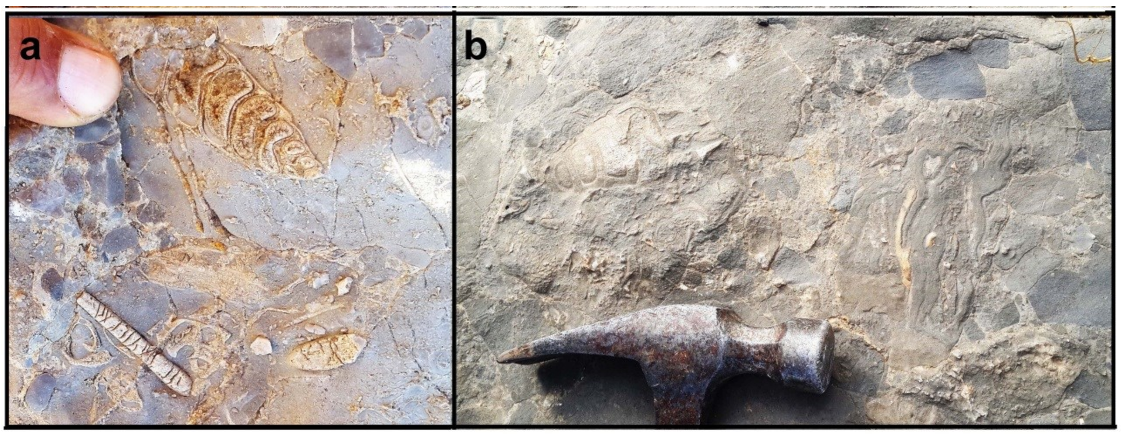

Fig. (11) a) Gastropod and lithoclast floatstone in Barda Balaka outcrop, b) Gastropod lithoclast floatstone with patches of stromatolite at the left.

2.2.2. Coral and lithoclast rudstone (F2)

This facies consist of pebble size limestone lithoclasts and bioclasts or skeletons of coral and it is very common in all section. Coral bioclast rudstone is common in Rashan and Bahe sections which consist of elongate, 2-3 cm long and 0.3-1 cm in diameter (Fig.12). The lithoclast rudstone is very common in Qzlja and Barda Balaka and make up more than 50% of the thickness of the section (Fig.13). The lithoclast rudstones are composed of angular to sub-angular pebbles of limestone clasts of different constituent including coral or algae or bioclasts or lithoclasts pebbles. The lithclasts can be called limestone conglomerates (extra or intraformational conglomerate) or breccia. The thickness of this facies is about 30m around Qzlja village and this high thickness cannot be formed by faulting but it is depositional formed by erosion of tectonically fractured limestone rocks in the basin or on surrounding terrestrial land or it may be a reef talus deposits.

This facies may be derived from reef tops and deposited in high energy setting (forereef) due to rockfall and various mass-flow processes.

According to Flugel (2004), rudstone is, an equivalent to packstone and grainstone, but its grains are self-supported carbonates rocks containing more than 50% grains larger than 2mm. This facies can be further characterized by compositional and textural criteria. Deposition of rudstone needs erosion and transportation. He farther added that erosion can be triggered by shallow water settings allowing destruction by storms.

The allochems are bound by fine grain matrix such as: sand and silt sized carbonate grains in addition to lime mud (matrix-supported fabric). This facies is introduced into Dunham (1962) classification by Emery and Klovan (1971), it consists of self-supporting allochems (more than 2 mm in diameters) bounded by micrite (mudstone). According to Wilson (1975), rudstones is deposited in fore-reef environment; where strong waves are prevalent. Praptisih and Kamton (2014) have found this facies in Klapanunggal formation (Late Miocene), western Java, Indonesia which is deposited in fore-reef environment. Melim and Scholle (1995) found this facies in fore reef of Capitan Reef which is associated with packstone and wackstone.

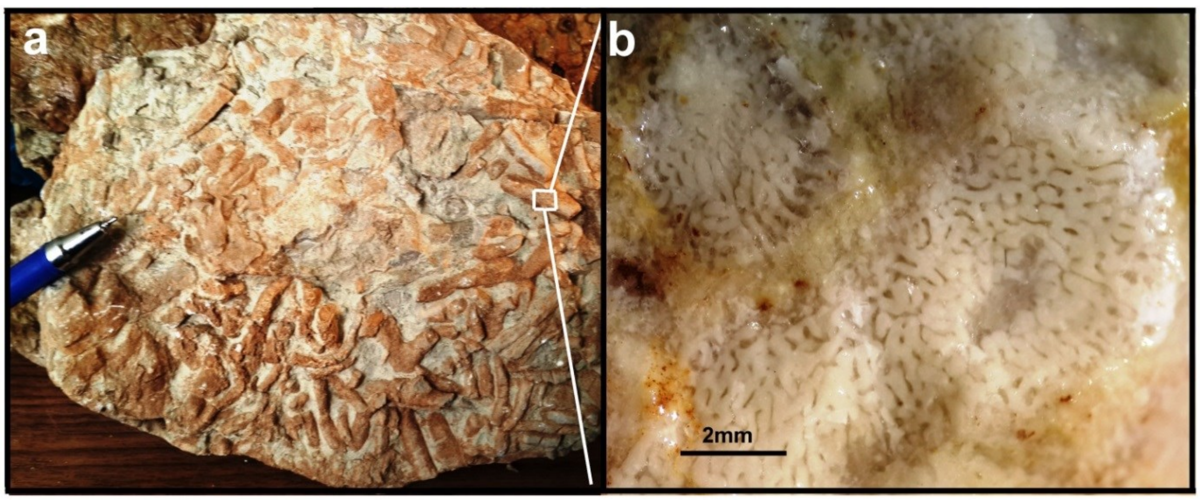

Fig.(12) a) Coral rudstone consist of broken fragment of scleractina coral colony near Taza De Village on the Rashan outcrop, b) Detail of the coral under stereoscope microscope.

Fig. (13) Limestone rudstone (limestone conglomerate) in the middle part of the formation at 100m to the north of Qzlja Village

2.2.3. Coral bafflestone (F3)

This facies is well expressed in the sections of Barda Balaka and Qzilja outcrops which is resemble a loose bundle of thin wood sticks that are about 0.2–4cm thick and more than 10cm long (Fig.14). It occurs in thick and massive beds of the middle part of the section of latter outcrops. The broken and re-deposited fragments of this facies are generating the coral floatstone or rudstone (Fig.12a).

In hand specimen, the red algae coated corals and other grains look like elongate oncoids (Fig.15b) but they are not oncoids due to fact that red algae excluded from algaes that form stromatolies and oncoids by Scholle and Ulmer-Scholle (2006). In many cases the corals steam and polyps are surrounded and covered by crustose red algae (Fig.15b and c) which may resulted from the competition between algae and corals on coral reefs as discussed by McCook et al. (2001).

The spaces between the coral branches are filled with white lime mud and sand size bioclasts. In literature, this facies is called bafflestone (Emery and Klovan, 1971), because it has dendritic shape and performs as sediment accumulator from the nutrient bearing current and waves by filtering; and trapping sediments. Walker and James (1992) have included this facies in the colonization stage of the reef structure. The presence of corals indicates normal marine salinity (Riding and Tomas, 2006). According to Flugel (2004) the criteria for identifying the bafflestone is the presence of large number of in situ stick-shaped fossils. This facies is mentioned by Pomar *et al.* (2005) in the rocks of Upper Cretaceous platform in the Pyrenees, Spain. The present study indicates that this facies is most possibly deposited in backreef environment.

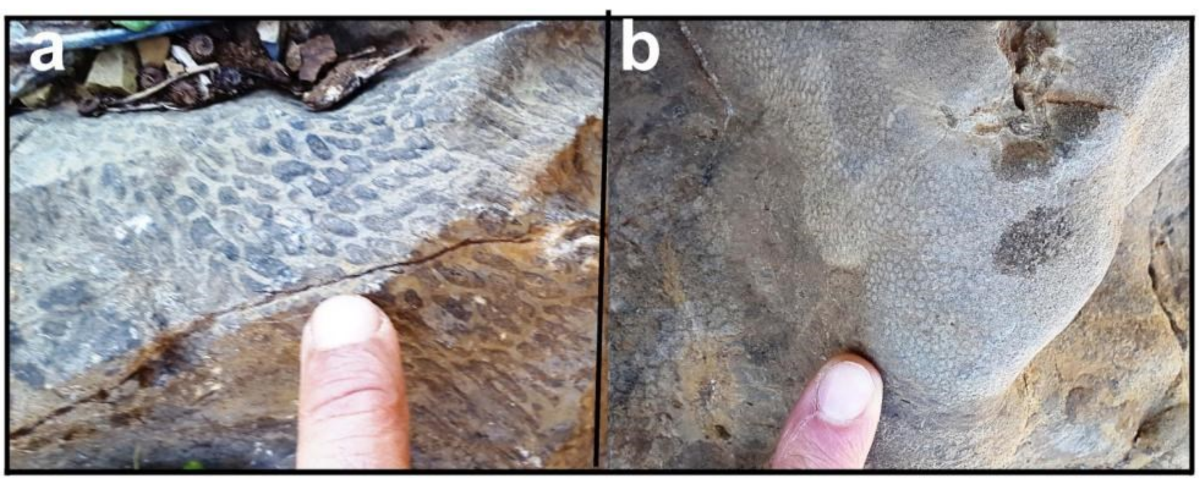

Fig.(14) a) A outcrop photos of the coral bafflestones of Barda Balaka outcrop, between the stems, fine lime mud and sand size allochems are deposited. b) Same facies of the Rashan outcrop shows vertical finger like corals streams some ones are branching.

2.2.4. Coral framestone (F4)

This facies is common in Barda Balaka and Chwarta sections while it is rare in Qzilja and Bahe sections; under hand lens and binocular microscope, it consists mainly, of irregular or global bodes (colonies) or patches of pentagonal coral and brain-like corals. The sizes of the colonies or patches are different but the common one are 5cm to 30cm (Fig.15a, b) the spaces between patches are filled with fine grained carbonate (lime mud and fine-grained allochems). Many specimens are found that contain single large corals (mushroom corals) with a diameter of 3-7 cm which consisted of framestone and is associated with red algae (Fig.15a). The present study indicates that this facies is most possibly deposited in backreef environment. According to Flugel (2004) and Wu et al. (2012) this facies is deposited on reef core (reef body) environment.

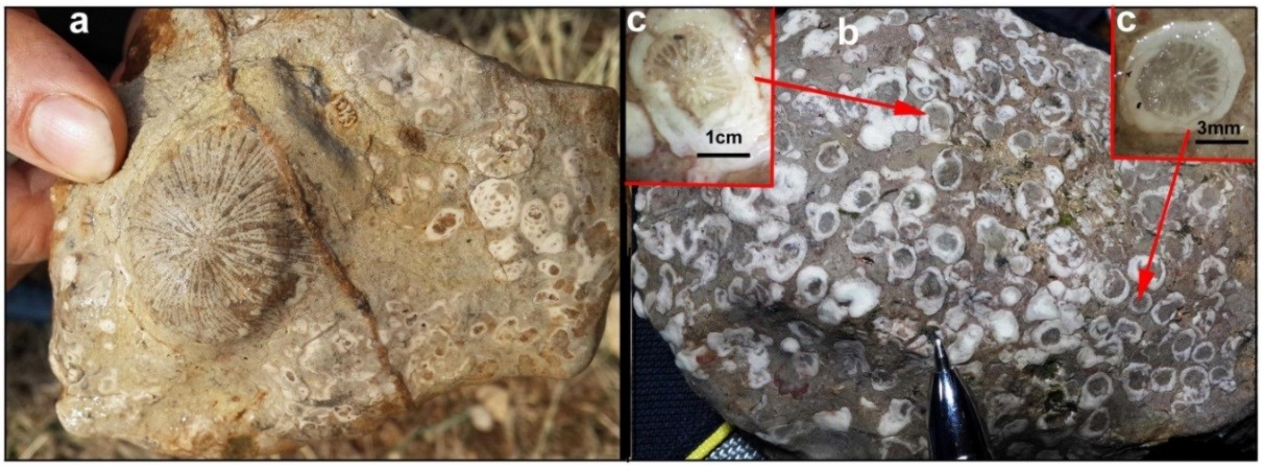

Fig.(15) a) Coral framestone consist of scleractinian coral colony at lower part of Qzlja section, s.no.9a b) Coral and other grains are coated by red algae, c) Close-up of the coral surrounded by red algae (white) under stereoscope microscope, s.no.9b

2.2.5. Stromatolitic bindstone (F5)

Flugel (2004) cited that this facies, as a type of limestone, consists of rigid framework (skeleton) build by framework of the organisms. Bindstone was introduced to the classification of carbonate by Embry and Klovan (1971) as a part of the boundstone of Dunham (1962). The distribution and morphology of the skeletons should fit into an imaginary three dimensional organic framework. Many organisms are contributing to deposition of framestones as corals, coralline sponges, stromatoporoids, rudist bivalves and calcareous red algae.

In the studied sections and outcrops, this facies is not common but exist in all sections especially in Qzlja and Barda Balaka sections. Under hand specimen can be seen as dense undulated and corrugated laminations that most possibly represent stromatolites (Fig.16a). On the Qzilja section, there is highly wavy limestone and under stereoscope microscope it shows dense reticulate texture and it is made of layers with tiny pillars forming brick like wall structures which are distinctive features of stromatolites (Fig.16b and 17). These limestone are stromatoporoids bindstone according to the comparison of the present sample with those published in web site (see http://www.earthsurfaceprocesses.com/3f-E-StromatolitesStromatoporoids.html). In the Bahe section stromatolitic limestone occurs too which consists of oncoids formed by microbes (microbalite) but the age of this bed is not known. In this context, McConnell (1975) consider this type of stromatolite as stratiform type and attributed its deposition to intertidal and possibly supratidal environment.

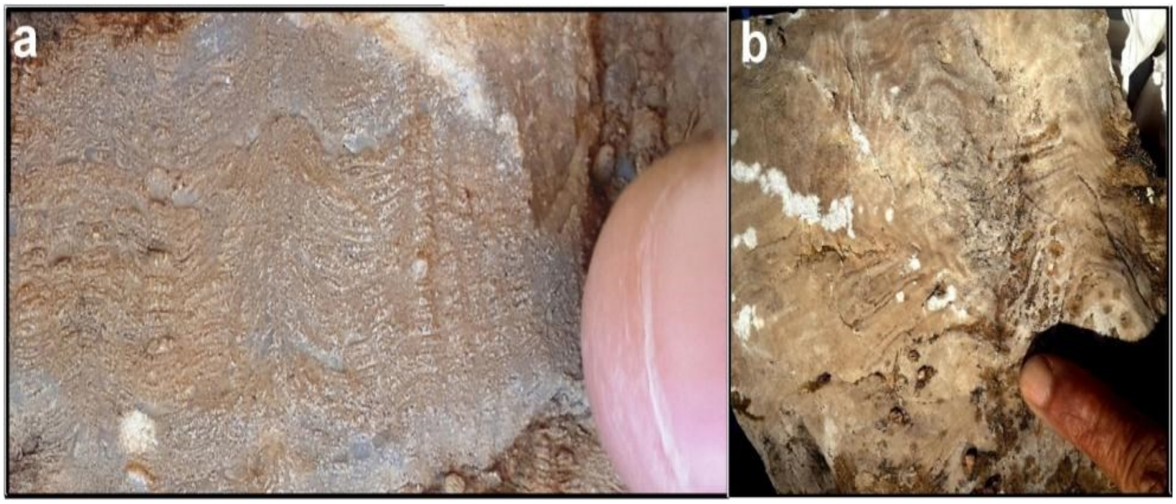

Fig. (16) a) Algal stromatolitic bindstone in the Barda Balaka outcrops, b) Stromatoporoid bindstone in the Qzlja outcrop, see figure 17 for enlarged views.

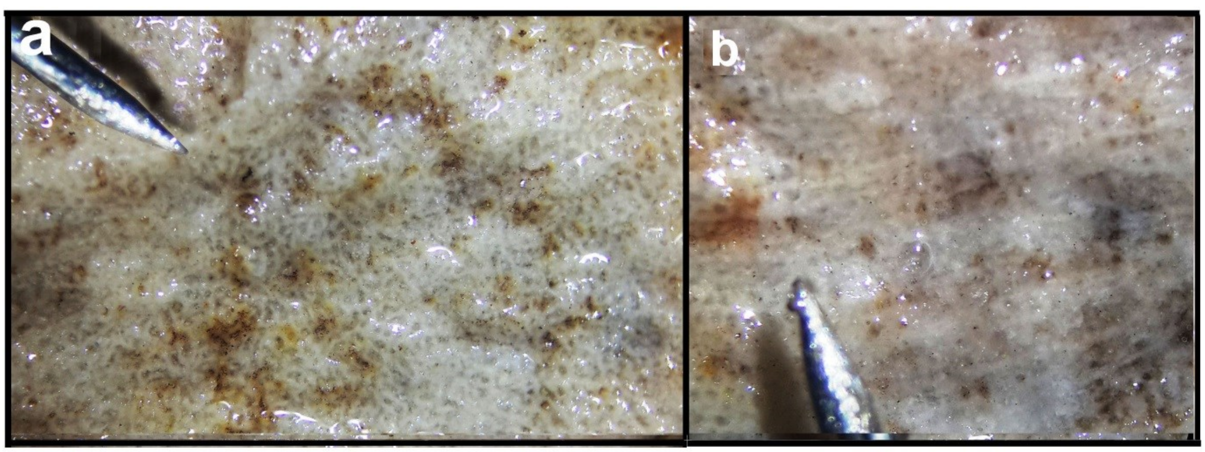

Fig.(17) Stromatoporoid (sponge) bindstone (or framestone) under normal light stereoscope microscope in the Qzlja outcrop, it was taken from the top of figure 16b, a) Cross section and b) Vertical (longitudinal) section, the scale: tip of paper pin (needle)

2.2.6. **Foraminifera and red algae bioclasts packstone–wackstone (F6)**

This facies is located in the middle of the formation, alternates with coral bafflestone facies, and consists, in outcrop, of dark grey massive to crudely laminated limestone. This limestone characterized by the occurrence of various foraminifera skeletons of in-situ species and in most cases; it is associated with bioclasts of red algae and pelecypods in addition to lithoclasts but without planktonic forams. There are many species of forams in the Bahe outcrop such as Borelis melo melo and Borelis melo Curdica and unknown miliolids (Fig.18a and b) while those of Mila Kawa outcrop include different reworked nummulites, lepidocyclina species and rotalids (Fig. 19).

The age of the in situ forams of the former section is Late Middle Miocene due to presence of Borelis melo curdica-Borelis melo melo with other miliolids forams while the age of latter outcrop is not known because the fossils are reworked.

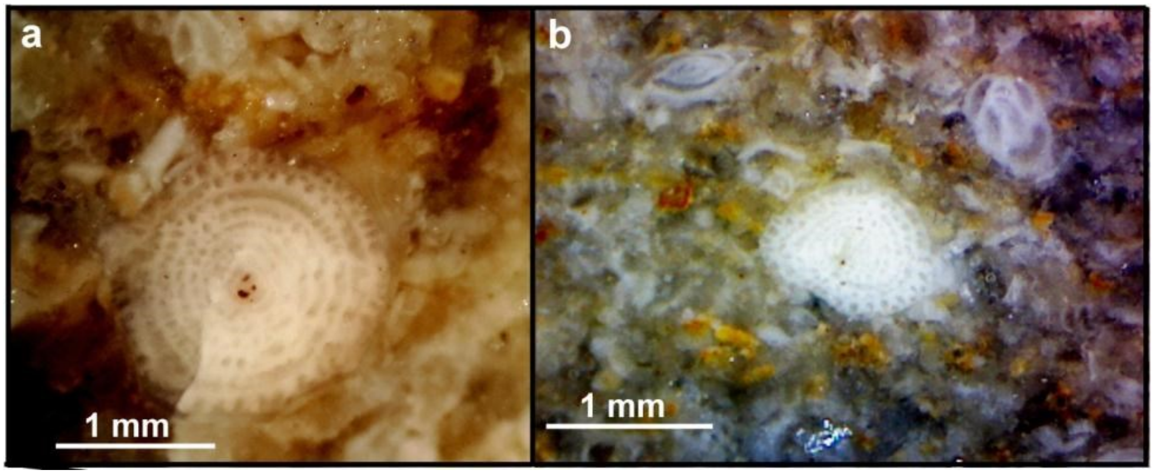

Fig. (18) a) Borelis melo curdica in the Qzilja-Bahe outcros., no.3. under stereoscopic microscope b) Foraminifera-lithoclast packstone with Borelis melo melo with other miliolids foram s.n.10. Both photo are taken under normal light by stereoscope microscope. s.no.4.

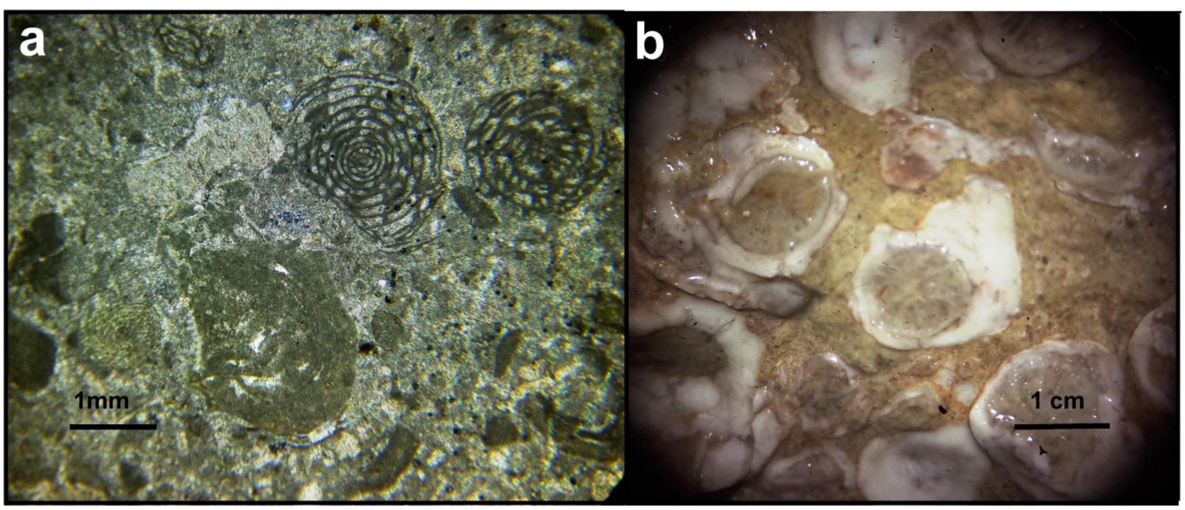

Fig. (19) a) Red algae (grey and black grains) and foramioneral (borelis melu curdica) wackstone of the Bahe outcrop, b) Crustose red algae covering coral which form massive rocks in Lower part of Qzja section, s.no.9

2.2.7. Reworked Foraminiferal-lithoclast grainstone-packstone (F7)

The reworked forams accompanied with terrigenous clasts of sedimentary, igneous and metamorphic works that are derived from nearby uplifted land. Additionally, they are intensely deformed both in brittle and ductile manner which can be seen as suture contact between the forams and relatively deep penetration of one foram into others (Fig.20a and b). This deformation is tectonic and not lithostatics due to their location under the ophiolite sheet (Penjween Ophiolite) and bounded below by Merga Red Beds.

2.2.8. Lithoclast grainstone (F8)

The major components of this facies are lithoclasts which consist of oval or spherical sand-sized grains of limestone. They consist of limestone clasts that are well sorted and well-rounded allochems bound together by spary calcite cement. They appear transparent under binocular microscope and in some intervals this facies contain bioclasts (Fig.21a). The facies was deposited in high energy agitating environment in which all the fine grain sediments (lime mud) is washed out. Due to this washing the space between the grains is remained empty and later during diagnesis filled with spary calcite cement. This facies is recorded in the Barda Balaka section only and alternates with lithoclast rudstone (limestone conglomerate) (Fig.21b) and coral bindstone. The age of this facies is not known and the present author are not sure if it is belong to Govanda Formations because the rocks of this outcrop are mixed and brecciated and layer boundaries are not distinguishable between facies (beds).

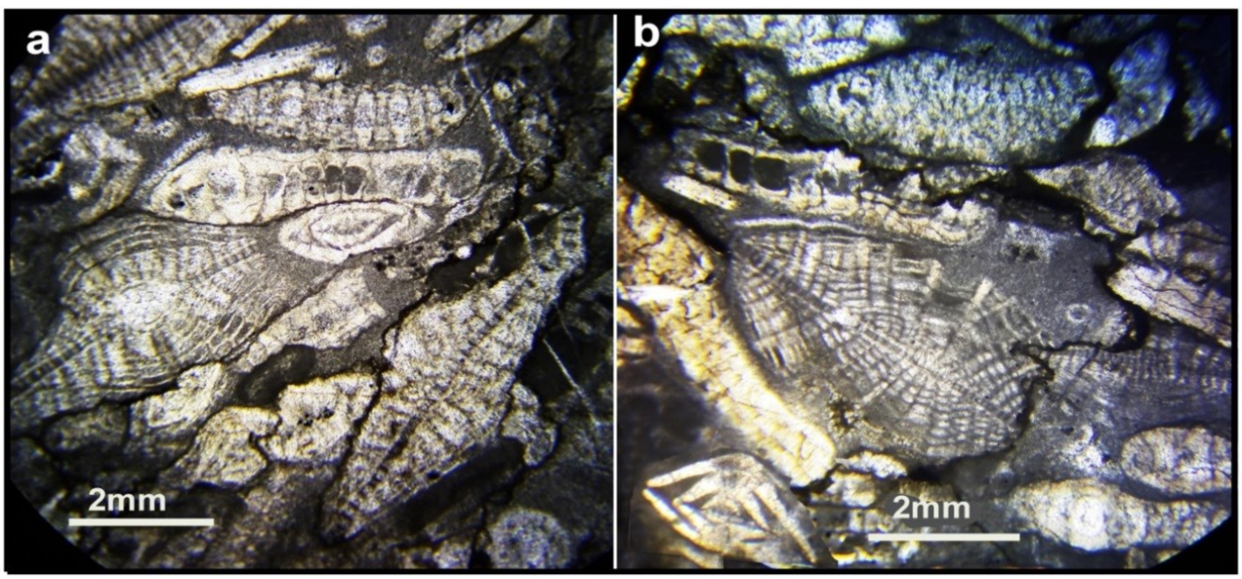

Fig. (20a and b) Reworked foraminiferal packstone from Mila Kawa outcrop, the forams are intensely deformed both in brittle and ductile manner which can be seen as suture contact between the forams and relatively deep penetration of one foram into others. s.no.14, ppl, X40

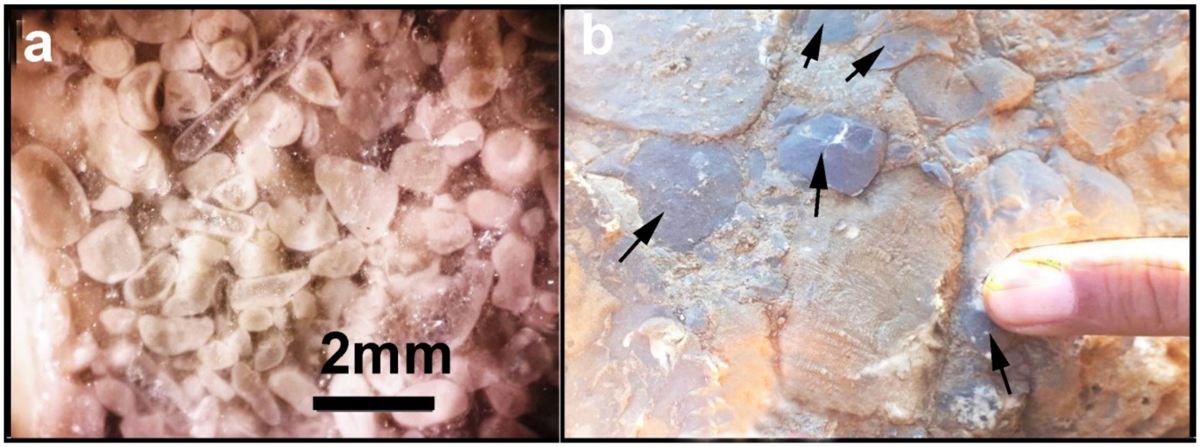

Fig.(21) a) lithoclast grainstone in the Badrda Balaka outcrop, s.no.19a , normal light, X20, b) Rudstone consists of lithoclast (black grains indicated by arrows) and coral bioclast (light grey), s.no.19b

2.2.9. Terrigneous lime sandstone (F9)

The name of this facies refers to its derivation from terrestrial (terrigeous) land by rivers and to its limestone clasts content. The major components of this facies are lithoclasts which have angular, elongate and badly sorted coarse sand-sized grains of different rocks (Fig.23a and b). They consist of deformed fossils Nummulite whole skeletons and fragments (nu), fossil fragment, black limestone, chert, jasper metamorphic, volcanic and igneous (Fig.22 and 23) clasts which are derived from terrestrial lands that were surrounded basin of deposition.

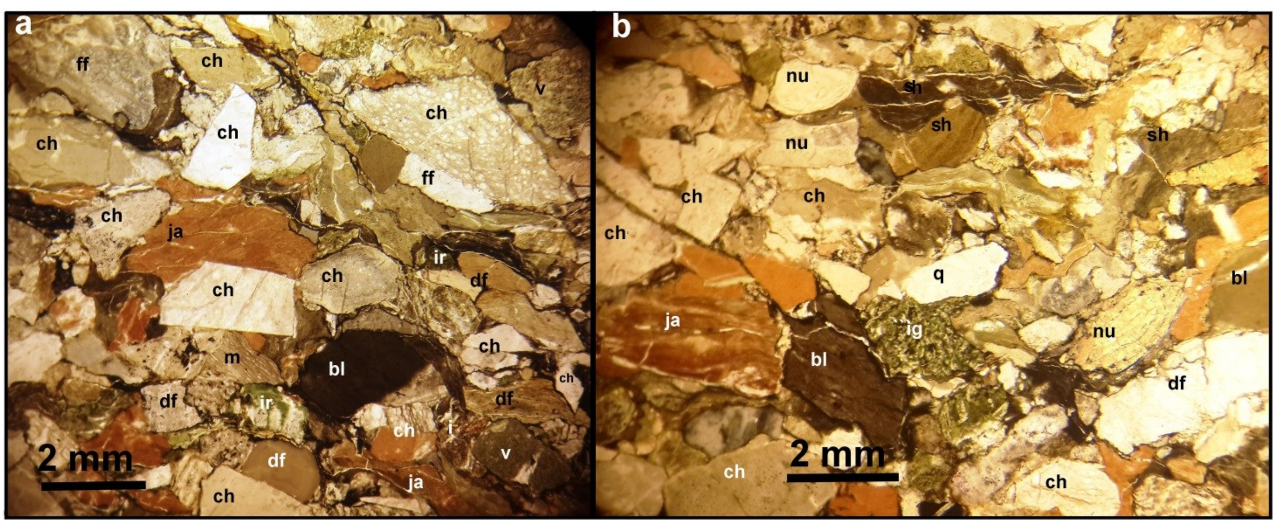

Fig.(22) The terrigneous sandstone contains lithoclasts, and deformed fossils (df), nummulite (nu), fossil fragment (ff), black limestone (bl), chert (ch), jasper (ja), limestone (l) metamorphic (m), shale (sh) volcanic (v) and igneous (ir), both photos are taken under plane polarized, s.no. 14. ppl.

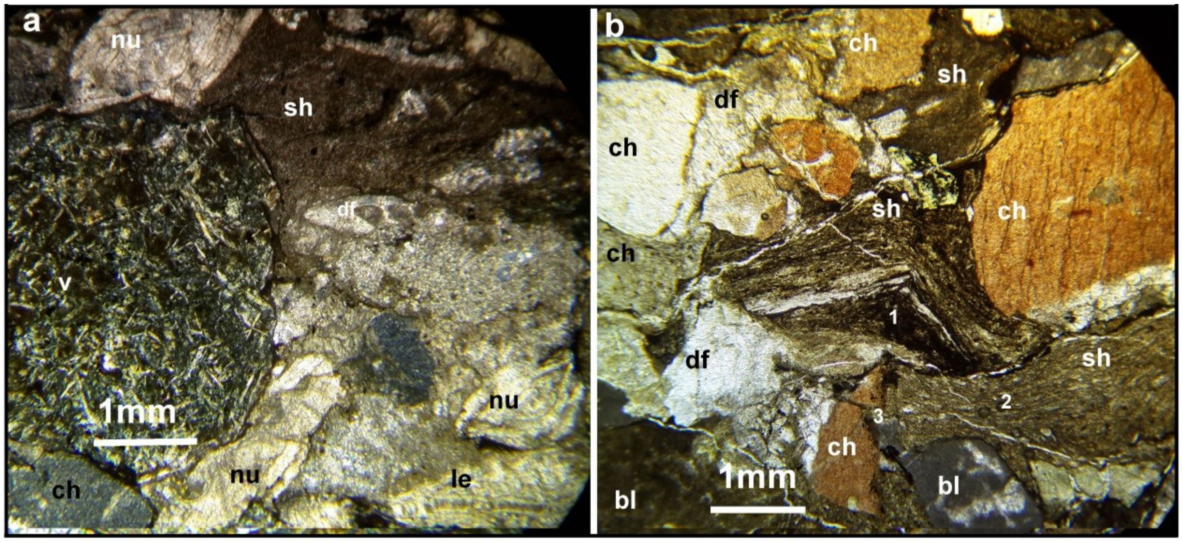

Fig.(23) a) Association of deformed Nummulite (df) and lepidocyclina (le) with volcanic (v) and chert fragments (ch), b) Clear flexure slip and flexure flow folding (1 and 2) and faulting (3), both photo belong to the Mila Kawa section (or outcrop), s.no.15, ppl, X40.

This facies is directly located below the reworked foraminiferal packstone in the Mela Kawa outcrop. In few bed, sedimentary, igneous and metamprphic rocks clasts can be seen together and the clasts shows clear syntectonic flexure slip and flexure flow folding (1 and 2) and faulting (3) (Fig. 23b). The different types of clasts indicate diversity of sources from which the sediments are derives which included different type of sedimentary, igneous and metamorphic rocks. There are gradational facies changes between this facies and the previous one (foraminifera and lithoclast packstone-wackstone). Figure (20a and b) shows this gradation which contains both nummulite (nu) and lepidicyclina (le) formas with clasts of different rocks (Fig.23a).

3. Interpretation and discussion

In the discussion of the Govanda, one does not know when and where to start writing because many factor and properties, the first is it's boundary condition, lithology, facies diversity, and its tectonic location in the are highly variable. The most important issue of the boundary condition is its resting on the tilted and folded Qulqula Radiolarian Formation in a stratigraphic relation of angular unconformity (Fig.6). In literature this unconformity is not the only angular one, in the Zagros Fold-Thrust belt, Karim et al. (2011); Karim and Baziany (2007, p.58) have conclude an angular unconformity between Qulqula Radiolarian Formation and Red bed Series in foothill of the Qandil and Gimo Mountain Ranges in Qaladiza and Mawat areas nearly on the southern boundary of the Sanandij-Sirjan Zone. They discussed that the age of tilting is pre-Paleocene in age. The angularity of present unconformity is better expressed in lateral continuity and tilt angle between the two units and represented by basal conglomerate (Fig.7).

Another issue is its location in the Suture (Sanandij-Sirjan) Zone which, according to Ghazi and Moazzen (2015) is the most active tectonic zone of Zagros since the Jurassic. Moreover than that Sadeghi and Yassaghi (2016) mentioned that this zone was area of collision of Zagros. The original location of the Govanda Formation was more northeastward in the Zone but it moved (with all other rocks) southwestward by thrusting of the Iranian (Eurasian) plate over Arabian one.

From the type of facies it is clear that normal marine and shallow carbonate rich fossils are deposited during Late Middle Miocene. The richness of the formation with fossils is most possibly attributed to rich nutrients that were arrived the basin from the surrounding sources areas. It is possible that each source was represents by a thrust sheet and the basin may be piggy back basin. The age, zone and angularity of deposition is very important for tectonic and paleogeographic evolution of the Zagros. Although, the carbonate deposition (with associated clastics) shows active tectonic but not to a degree to justify for continental-continental colliding of Arabian–Iranian plates as cited by Mouthereau et al. (2007), Allen and Armstrong (2008); Aral et al. (2010), McQuarrie and van Hinsbergen (2013) during Miocene. This colliding not agree with subsidence of the area and deposition of normal marine carbonate during Miocene as mentioned by Buday (1980); Jassim and Goff (2006) and inferred from present study. Conversely, the studied area must be subsided to a basin not uplifted to a terrestrial area.

Therefore, the colliding must occurred before Miocene due to intense deformations in pre-Miocene age as testified by angular unconformity with Qulqula Radiolarian Formation (Fig.6 and 9). It seems that the studied area was an intracontinental shallow basin more or less similar to present day Eastern Mediterranean sea or Arabian Gulf in which shallow water carbonates and clastics are depositing. The Paleogeographic map of Scotese (2001) during Middle Miocene shows that this basin was connected to open marine via Mediterranean, Arabian Sea and Arabian Gulf (Fig. 24). Other evidence for connection is the map published by Rögl and Steininger, 1983 in Çağatay et al. (2006) and shows the latter sea that extend to the near studied area during Middle Miocene. Additionally, when the map of the Bosworth et al. (2005) is considered, there is a connection to the Arabian Gulf and Indian Ocean. The richness of Govanda Formation with normal marine fauna aids strongly the connection of studied area to the above mentioned see and ocean.

Last issue of the Formation is its environment which was normal marine shallow water sea as indicated by its rich fossil content. This environment can be subdivided to several one according the specific depositional facies. The content of echinoderm and coral floastone and rudestone are indicating fore-reef. While the coral framestone and bufflestone with different algae representing reefal core environment. The foraminiferas and red algae bioclasts, packstone–wackstone with miliolid forams and stromatoiles are best evidence for backreef environment.

The existed lagoon was semi-restricted lagoon which called “leaky Lagoon” by Kjerfve (1994) who defined it as a lagoon connected through wide channels to the sea by which the water interchange is fast and unlimited. Lower, middle and upper parts of the formation are deposited in the fore-reef, reef and back-reef respectively.

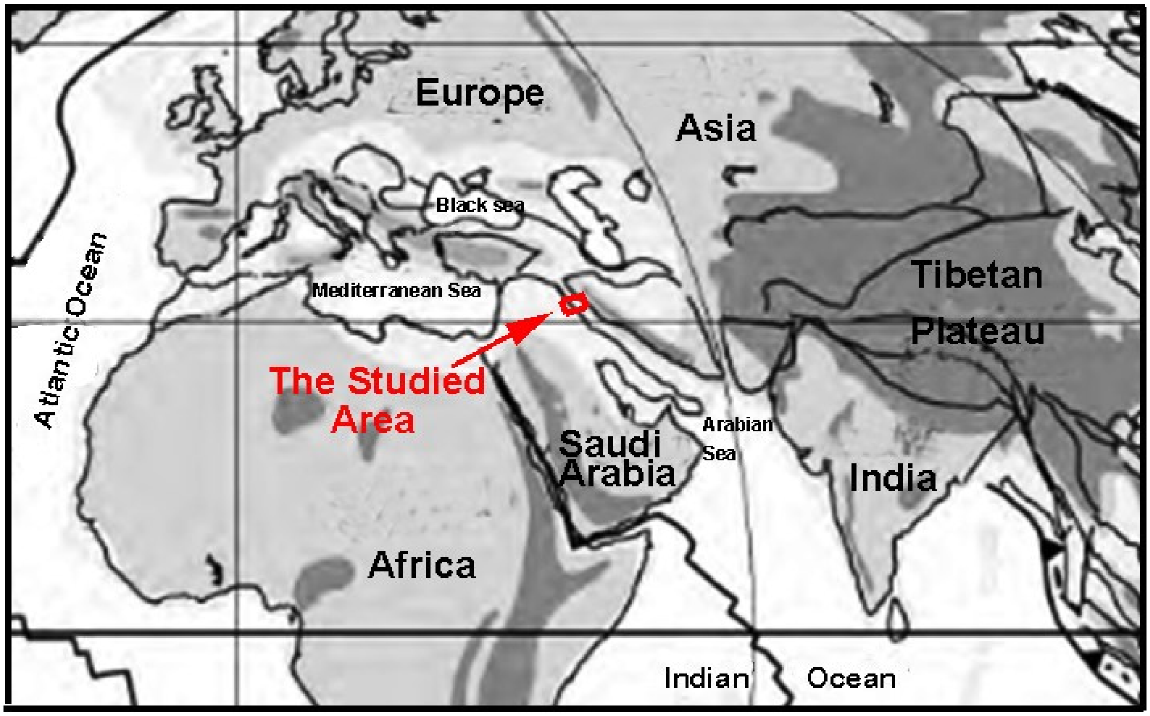

Fig. (25) Paleogeographic map of Middle East during Middle Miocene shows connection of the studied area to Arabian Gulf, Mediterranean and Arabian Sea (Scotese, 2001)

4. Conclusion

1- The upper boundary of the formation is erosional (not exist) while the lower is tectonic and rest on Qulqula Radiolarian Formation in angular unconformity relation and rest on Red Bed Series in Rashan Section.
2- The main facies of the formation are pelecypod floatstone Facies, coral and lithoclast rudstone, coral bufflestone, stromatolitic bindstone, Foraminifera and red algae bioclasts, packstone–wackstone, reworked Foraminetral-lithoclast grainstone-packstone, lithoclast grainstone and terrigneous lime sandstone.
3- Detailed Facies analysis indicates that the formation was deposited in high energy shallow normal marine of fore-reef, reef and backreef environments.
4- The Sanandij-Sirjan Zone was subjected to extension not compression (continental-continental colliding) as cited in some studies
5- The richness of the basin with fauna indicate that the formation was connected to normal marine of both Indian Ocean and Mediterranean sea

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