LITHOLOGY AND STRATIGRAPHY OF THE CENOMANIAN/ TURONIAN BOUNDARY IN ZAGROS OROGENIC BELT EXAMPLES FROM KURDISTAN REGION, NORTHEASTERN IRAQ

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ABSTRACT

Cenomanian-Turonian (C/T boundary) is globally foci of intense geological study in the most part of the world due its organic matter content. In Iraq, the representative of the boundary is defined previously as bituminous black shale and named "Gulneri Formation" which is about 2.5 meters thick. In the country, the boundary is controversial both stratigraphically and lithologically; since it is assumed that its top and base are bounded by unconformity and deposited in euxinic and small relic basin.

In the present study, the previous studies are critically evaluated and many new results and new fact are documented about the formation through studying of nine sections. The new results include changing of the lithology and boundary condition (rejecting of underlying and overlying previously indicated unconformities). The lithology has amended to marl and marly limestone and the depositional basin is changed to large open basin in which Balambo and Kometan formations are deposited. Additionally, many fish remains are found in the formation. The remains are three types; the first is fish scales, which have circular shape with concentric rings and about 1 to 4 mm in diameters. The second is fish backbones (skeletons), four skeletons are found, which belong to small fish about 4 to10 cm long and 5mm to2 cm wide. The third is fish fins (pectoral fin), which are well preserved in hand specimens and have grey or brown color and consist of groves and ribs. The fish remains are evidence that a depositional environment of the Gulneri Formation was deep, large and open sea. Only the bottom of the sea was anoxic, which had preserved the organism remains that had fallen down from the surface of water and rested on the sea bottom.

Keywords: Gulneri Formation, Organic matter; early Turonian, Cenomanian-Turonian boundary, Zagros, Iraq

INTRODUCTION

The Gulneri Formation was first defined by Lancaster Jones (1957 in Bellen *et al*. 1959) near the Dokan Dam site in the upstream of Little Zab River in the High Folded Zone (Fig. 1). According to above authors, it consists of about 2 m of black, bituminous, finely laminated shale with some glauconite and collophane at the lower part. The age of the formation is Early Turonian and the high bitumen content and dwarfed fossils indicate a euxinic environment of the Gulneri Formation (Jassim and Buday in Jassim and Goff, 2006). The formation is separated by unconformities with overlying and the underlying Kometan and Dokan formations, respectively (Buday, 1980). Abawi *et al*. (2006) has recorded eight planktonic and six benthonic foraminiferal species in the type section of Gulneri Formation near the Dokan Dam site, indicating an Early Turonian age. In the type section of Gulneri Formation, Abawi et al. (2006) gave the age of Early Turonian to the formation by foramimiferal biozonation and mentioned that it represents oceanic anoxic Event 2. Baban and Sarraj (2007) in their palynofacies study of Kirkuk oil wells concluded that the Dokan and Gulneri formations are rich in organic matter and they were deposited in Shelf environment. The C/T boundary (Gulneri Formation) is about 2 – 4 m thick, which is mostly exposed along both limbs of most anticlines (along the sides of the mountains) in the studied area.

LOCATION AND GEOLOGY OF THE AREA

Geographically, the studied area is located between the northern latitudes of 35° 07' 90" and 36° 30' 60" and eastern longitudes of 46° 44' 22" and 44° 18' 53" in Sulaimaniya Governorate, Kurdistan Region, northwestern Iraq (Fig. 1). The area includes series of high mountains; most of them coincide with anticlines and they are trending northwest-southeast. In the studied area, the highest mountains are Piramagrun, Asos, Karokh, Kura Kazhaw and Shinarwe, which are more than 2000 m high above the sea level.

Structurally, most of the mountains and plains represent anticlines and synclines, respectively, and the cores of most anticlines are eroded forming deep valleys and gorges. Tectonically, the area includes High Folded Zone and Imbricate Zone (Buday, 1980; Jassim and Goff, 2006). The mountains' series are separated either by deep valleys or plains, which have dendritic drainage pattern and drain toward southwest. Proximally, the area is drained mostly by consequent ephemeral streams, which change distally to perennial streams; such as: upstream of Little Zab and Diyala rivers, which flow into the Dokan and Darbandikhan lakes (reservoirs), respectively (Fig. 1). The area

has semi-arid climate of Eastern Mediterranean region with the annual rain fall of more than 650 mm.

The study area includes towns; such as Ranyia, Dokan, Surdash, Qaladiza, Chwarta, Barzinja, Said Sadiq and Halabja town; from northwest to southwest (Fig. 1).

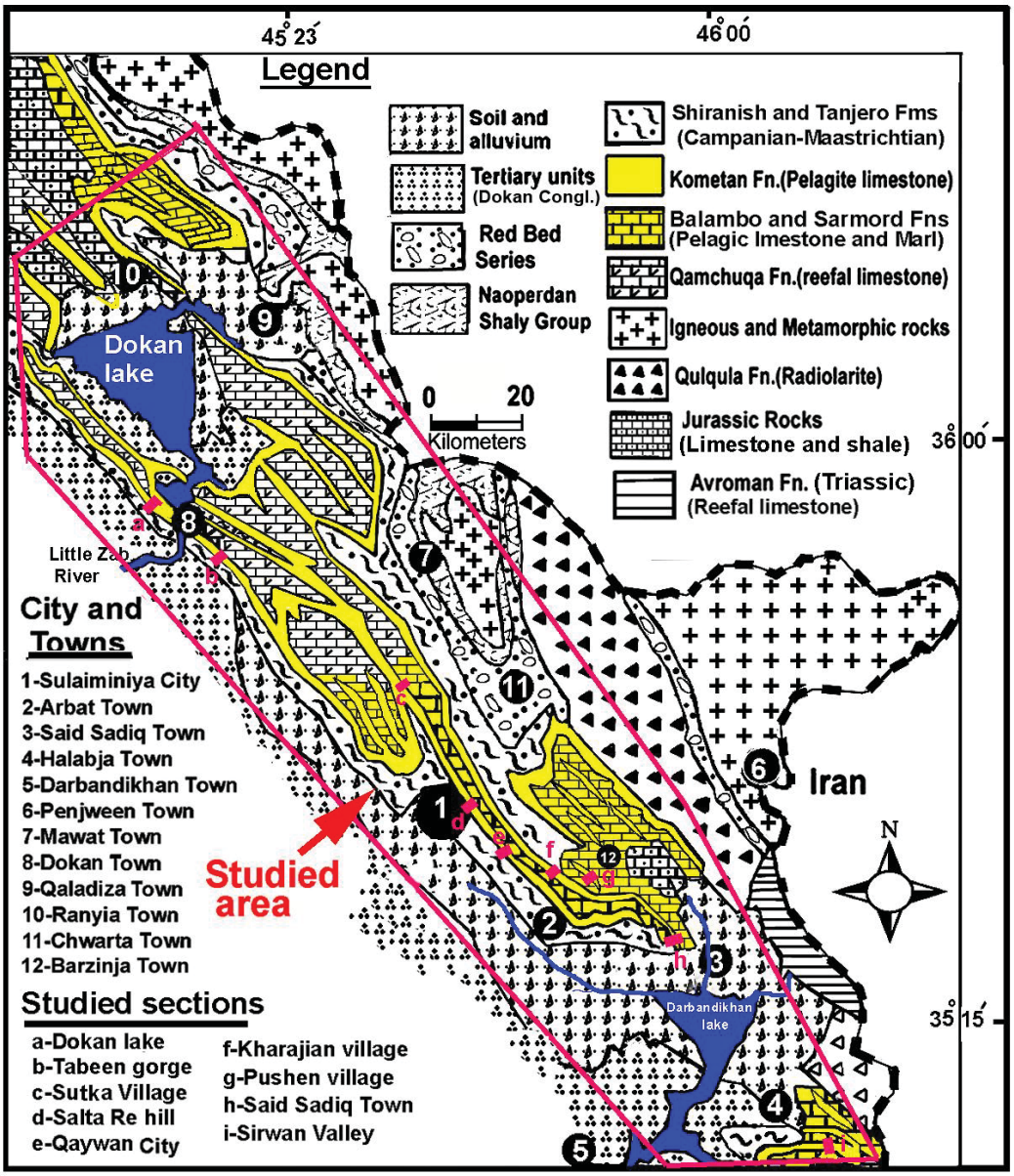

Fig. 1: Geological map of the studied area (modified from Sissakian, 2000 and Karim *et al.*, 2011) shows the studied sections of Gulneri Formation which are located between Balambo and Kometan formations and in between Qamchuqa and Kometan formations in the east and West of Sulaimaniyah city, respectively

MATERIAL AND METHOD

In this study, nine sections (Table 1) are inspected in the field and the collected samples are studied in the lab by hand lens and both stereoscope and polarized microscopes. The Gulneri Formation (C/T boundary) consists of alternation of well bedded and finely laminated marl and marly limestone; about 2 – 5 m thick. The laminated intervals have pink or milky color (Fig. 2), while the bedded intervals have greenish grey or black color. Due to softness of the rocks of the boundary, the black color is most possibly resulted from filtering of upward migrated oil and organic matters in the past. From nine selected sections, 25 samples are collected, which are preserved in Department of Geology, University of Sulaimani. The location of the samples are indicated by GPS, plotted on the geological map and inspected for fossils and lithological constituents. The present study is benefited from the study, Karim *et al*. (2013) and Al-Khafaf (2014) who differentiated Kometan, Gulneri, Dokan, Balambo and Sarmord formations for the first time in the north and east of Sulaimani city. Previously, in this area, the occurrence of Kometan and Balambo formations are mentioned by Bellen *et al*. (1959) and mapped by Sissakian (2000) from Satellite images.

The hand specimens of the laminated marl can be splatted by hand or knife, which shows random black spots on the lamination surface (Fig. 3). In the field the hand lens examination revealed the possibility of the spots to be remains of organism in the Gulneri Formation. For the identification of the type of remains, all available outcrop sections in the studied area are inspected and sampled. Through the type of organisms, the present study has given different ideas about the environment of the Gulneri Formation. Only three sections are described in detail due to similarity of the other seven sections to the described ones.

Table 1: The name, location and lithology of the nine studied sections

Section name	Location	Lithology	Thickness (m)
Dokan Dam	35° 57' 06.77" N 45° 57' 02.75" E	Grey marl and marly limestone with highly deformed bands of black bituminous marl	2.5
Tabeen Gorge	35° 50' 04.16" N 45° 06' 25.01" E	Deformed thin beds of limestone and dolomitic limestone	2.0
Sutka village	35° 41' 36.29" N 45° 19' 44.85" E	Grey and black marly limestone with finely laminated intervals	3.0
Salte Re hill	35° 36' 13.84" N 45° 28' 08.73" E	Alternation of light grey marly limestone and red finely laminated marl	3.5
Qaywan City	35° 32' 50.80" N 45° 29' 49.06" E	White laminated marly limestone, with pink spots on the laminae	3.5
Kharajyian village	35° 29' 49.60" N 45° 33' 40.09" E	Grey and green marl and marly limestone	3.0
Pushen village	35° 29' 58.41" N 45° 34' 44.92" E	Grey and green marl and marly limestone	3.0
Said Sadiq town	35° 21' 26.74" N 45° 51' 16.04" E	Deformed thin beds of limestone and marly limestone	2.5
Sirwan valley	35° 06' 08.41" N 45° 56' 33.67" E	Black and grey thin bed of marly limestone	2.0

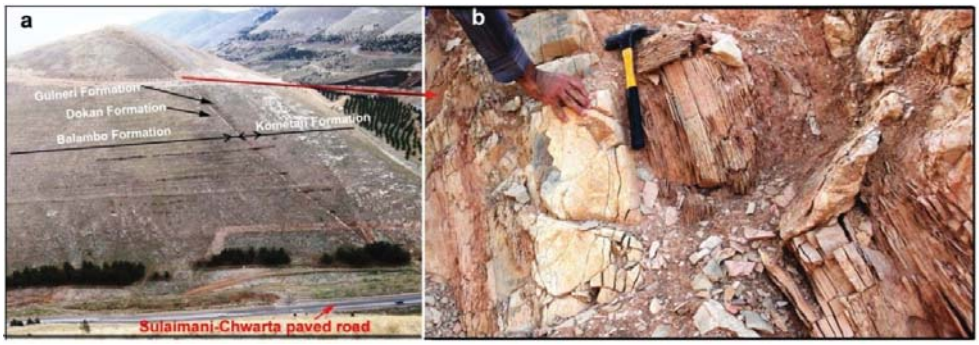

Fig. 2: a) Salta Re hill shows the Kometan, Balambo, Dokan and Gulneri formations, b) Red laminated marl in which fish scales and skeletons are found

Fig. 3: A laminae surface of the marly limestone of Qaywan Highs city section shows fish scales (dark brown spots)

RESULTS

The Cenomanian-Turonian boundary (C/T) is important in both globally and regionally since in Iraq, Karim *et al.* (2013) and Al-Khafaf (2014) have applied the boundary (Gulneri Formation) as marker beds for mapping and differentiation Balambo and Kometan formations in the areas to the north and east of Sulaimani city. The lithological representative of this boundary can be seen very clearly in the field and on Google Earth as dark ribbon (about 4 m thick) along the limbs of anticlines between the aforementioned two formations. Globally, it recorded in most of the world and described geochemically, stratigraphically, environmentally and ichnofacially on the oceanic bottom and on the continents (see Arthur *et al.*, 1987; Turgeon and Brumsack; 2006, Uchman *et al*., 2008 and Meyers *et al.*, 2012).

1. Stratigraphy of Gulneri Formation

The stratigraphy of Gulneri Formation (C/T boundary) is controversial; as previously Bellen *et al.* (1959) mentioned an unconformable contact of the Gulneri Formation with the overlying and underlying Kometan and Dokan formations at the dam site, is represented by the occurrence of micro-conglomerate. According to Buday (1980), thin bituminous shale of Lower Turonian is bounded at the bottom and top by erosional unconformities. He cited that these unconformities can be found locally around Dokan town and in I.P.C. oil well (K 116).

Recently, Lawa *et al*. (2013) cited the presence of these unconformities and mentioned that Dokan and Gulneri formation are not present (an unconformity with duration of 4.7 m.y) in the Tabeen Gorge 4 km to the southeast of Surdash village. The same claimed unconformities are mentioned by Omer *et al*. (2015) on Azmir anticline and they detected the absence of Dokan and Gulneri formations at the top of the Balambo Formation. They attributed the unconformity to the tectonic uplifting of the Mawat ophiolite obduction during the Turonian and reactivations of Chaqchaq fault.

The unconformable boundaries of Gulneri Formation are discussed in detail by Taha (2008) and Taha and Karim (2009) and they concluded that both boundaries of the formation are conformable. They added that neither erosional surface nor conglomerate is found in the boundaries and they have amended the lithology of the formation from

black shale to marl and marly limestone. They further recommended to be combined due to sharing same basin and aerial distribution with Kometan Formation but this recommendation is not followed by later papers.

At the northeast of Sulaimani Governorate (On the Azmir and Goizha anticlines) Karim *et al*. (2013) have recorded and defined C/T boundary (Gulneri Formation) for the first time which is located between Balambo (with Dokan) and Kometan formations. In this area, the Dokan Formation is very similar lithologically to the upper part of the Balambo Formation. Stratigraphically, the occurrence of the C/T boundary is divided in to two areas; the first area (western area) is located to the west of Sulaimani city and includes the area around Dokan reservoir and Arbil Governorates.

The second area (eastern area) includes all the area to the east and north of Sulaimani city and extends to the Iraq-Iranian border (Fig. 4). In both areas, Dokan Formation is located below Gulneri Formation, but due to its low thickness, it cannot be shown on the map. In the western area, the Gulneri Formation is located between Qamchuqa Formation and Kometan Formation and deposited on reef and forereef of Arabian Platform (shallow water of Neo-Tethys Sea).

In the eastern area, Gulneri Formation is located between Balambo Formation (with Dokan) and Kometan Formation and deposited in deep environment on the basin slope (continental margin of Neo-Tethys Ocean) (Fig. 5). Generally, in North Iraq, the depositional environment of C/T boundary is deepening gradually from west toward east and reaches its maximum depth near the border with Iran in Sirwan valley.

The variable thickness of the Gulneri Formation depends on two factors; the first one is the optional indication of the contacts with overlying and underlying formations. This type of indication is due to its gradational nature of the contacts and absence of unconformity (absence sharp change of lithology). The second is change of intensity of deformation from place to place and it is thin in the locality of intense compression stress.

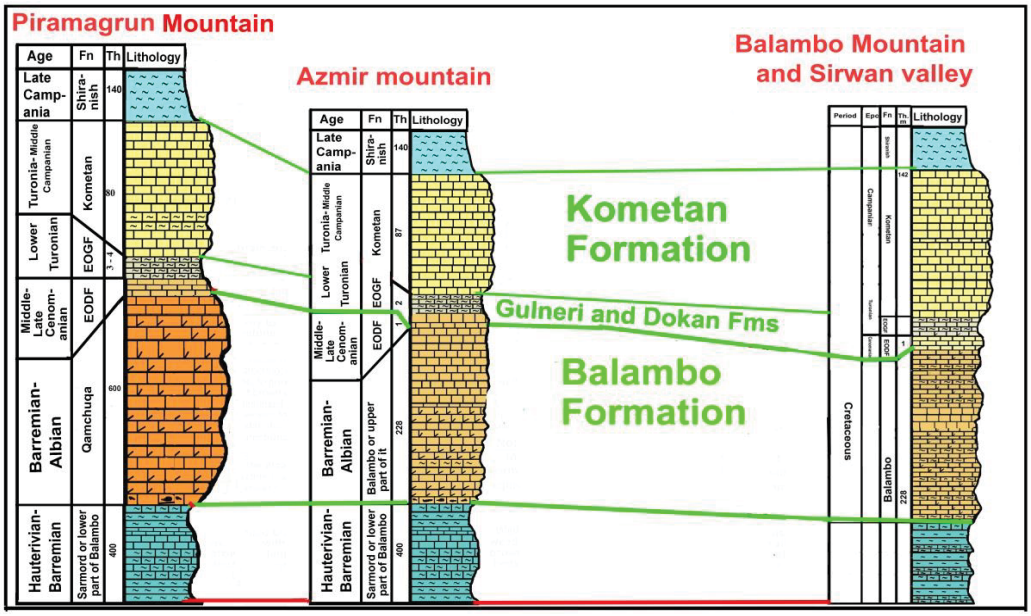

Fig. 4: Three stratigraphic columns of western, middle and eastern parts of the studied area shows correlation of Gulneri Formation (EOGF: equivalent of Gulneri formation)

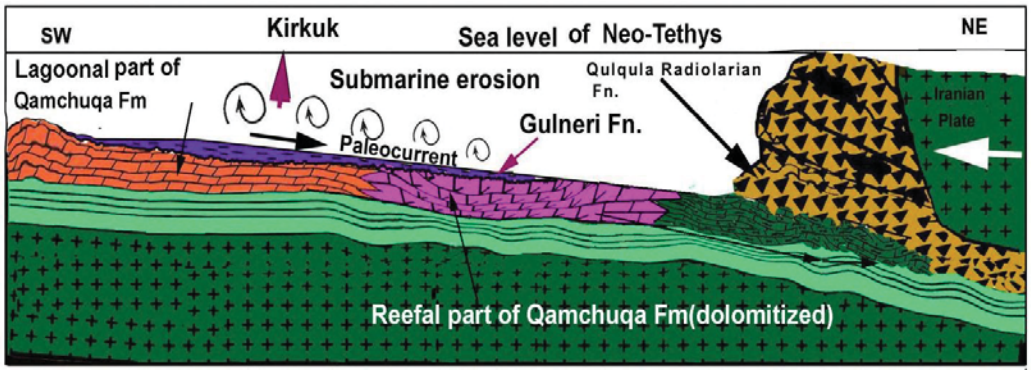

Fig. 5: Paleogeography of the end of Cenomanian shows deposition of a Gulneri Formation in a deep and an open basin of the Neo-Tethys (Taha, 2008 and Karim and Taha, 2009)

2. Lithology of Gulneri Formation

The lithology of the Gulneri Formation is changed from black shale to marly and marly limestone by Taha (2008) and Karim and Taha (2009). This change of the lithology is aided by the present study, which is clear from the photos of this study. In all nine sections (Table 1), black shale is not observed, in some section there are thin black beds of marly limestone and the black color is due to impregnation with oil and

even some sections show white or red color marly limestone, which is discussed later in the present study.

In all sections, the Gulneri Formation, as a soft lithology, is located between more stiff rocks of a Balambo and Kometan formations; it is always covered by soil; therefore, the sampling and photography must be a long road cuts. Generally, there are three types of the lithologies of the Gulneri Formation which are indicated in the following three sections.

2.1. Salta Re Section

This section is located along a car road that goes to the top of the Salta Re hill, which is the first hill of the Naugirdan hills at the 3.5 Km to the northeast of Sulaimani city at the southwestern foothill of Azmir Mountain (Fig. 1 and 2). Geographically, it is located at the latitude and longitude of 35° 36' 13.84" N and 45° 28' 08.73" E, respectively. In this section, the Gulneri Formation is 3.5 meters thick and located between the Kometan and Dokan formations (Fig. 6). The unusual lithology of the formation is one meter of laminated red marl in the middle of the formation (Fig. 2b); whereas, the rest of the formation consists of dark green marl and grey marly limestone. The laminated marl contains sparse fish scale and skeletons, which are discussed in detail latter on in the current study.

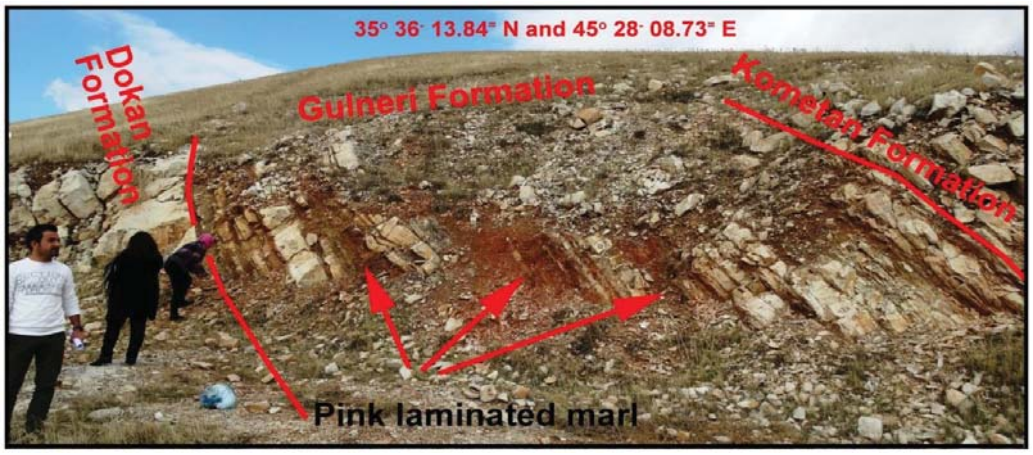

Fig. 6: Outcrop of the Gulneri Formation exposed along road cut on Salta Re anticline (Naugirdan hills) at the southwestern limb of Azmir anticline, the red color marl can be seen (see figure 2 for more detail)

2.2. Qaywan city section (Qaywan highs section)

In this section, the Gulneri Formation (C/T boundary) consists of 3.5 m of white laminated marl and marly limestone, which is located on the lower part of the southwestern limb of Goizha anticline. It is located exactly at the end of an unpaved road that goes directly to the northeastern boundary of Qaywan Highs city at the latitude and longitude of 35° 32' 50.80" N and 45° 29' 49.06" E, respectively. In this section, the Gulneri Formation contains abundant fish scale, fins and skeleton (Fig. 3 and 4).

Fig. 7: Outcrop of the Gulneri Formation (C/T boundary) on the southwestern limb of Goizha anticline near the northeastern boundary of Qaywan Highs city Section

2.3. Tabeen gorge section

This section is located in the Tabeen Gorge, at 1 Km to the northeast of Kani Shok village at the latitude and longitude of 35° 50' 04.16" N and 45° 06' 25.01" E, respectively. The Gulneri Formation is located between dolomitic limestone of the Qamchuqa Formation and white limestone of the Kometan Formation and consists of 2 m of deformed thin beds of partially recrystallized dolomitic limestone, which did not contain fish remains and other fossils (Fig. 1 and 8). But it has been assumed as Gulneri Formation (or its equivalent facies) due to its location in the same stratigraphic position and can be traced to its type locality near Dokan Dam at 10km to the northwest.

The absence of fish remains and soft rocks in this section is most possibly due to relative shallowness of its basin in this area. Previously, it is reported by Lawa *et al*.

(2013) that the Gulneri and Dokan formations are not deposited and their location is unconformity in this section.

Fig. 8: Outcrop of the Gulneri Formation in Tabeen Gorge on the southwestern limb of Piramagrun anticline

2.4. Fish remains in the Gulneri Formation

The results of field work and microscope inspection are revealed several parts of fish remains in the Qaywan city and Salte Re sections. These remains are not found in the rest of section (other 7 sections) in the present study.

2.4.1. Fish fins

The most distinct features of fishes are fins, which are usually composed of spines (bony) or rays extend from the body with skin covering and joining them together. Apart from the tail, fish fins have no direct connection with the spine and are supported by muscles only. In the samples of the Qaywan Highs city section, near Qrga village a clear pectoral fin is found which is eight cm long and 2 cm wide (Fig. 9). In hand specimen, it consists of bundle of needle-like spines, which are thin in one side and become thick in the others. They have black color in a hand specimen while under polarized microscope they have yellow color which is sign of phosphatization (Fig. 10).

Fig. 9: (a) Fish pictorial fin in the Gulneri Formation on the Salta Re Section, part of well-preserved fish scale in the lower part of the Gulneri Formation in the Qywan city Section

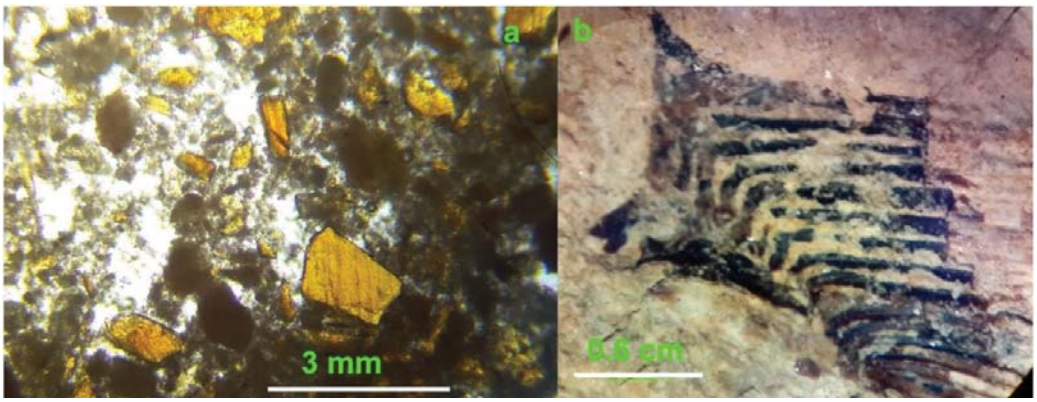

Fig. 10: a) Fragment of fish fins and skeleton under plane polarized light. b) Deformed dorsal fin showing the ribs, sample from Qaywan city Section

2.4.2. Fish scales

Fish scales are flattened rigid plates that are covering part of the body of many genera of fishes and have variable structures, sizes and shapes. The scale morphology can be used for identification of the species of fish. The scales' sizes range from 1 mm to 4 mm and those that are found in this study belong to bony fishes of the Late Cenomanian-Early Turonian (Fig. 11 and 12) as indicated by nannofossils by Karim *et al*. (2013).

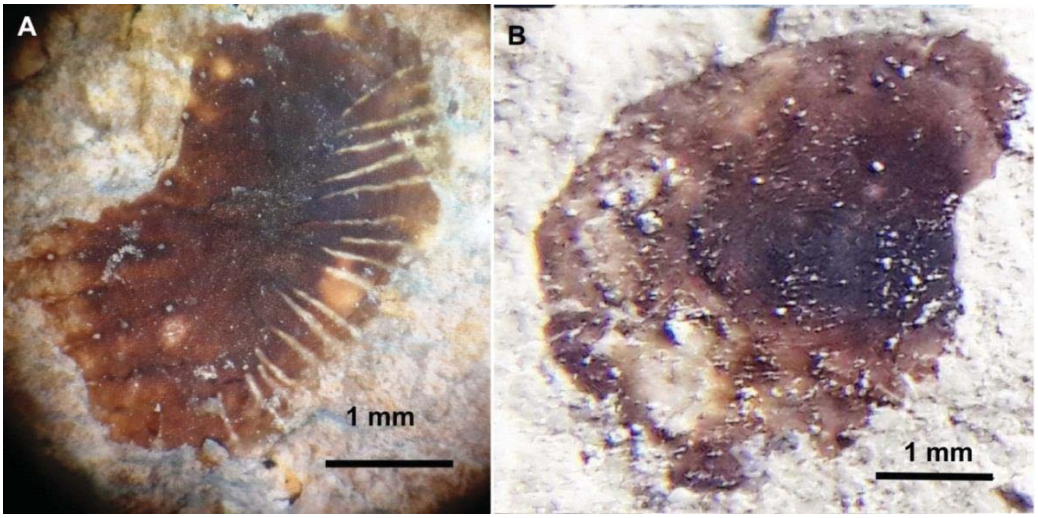

Fig. 11: Two types of Cycloid fish scales in Qaywan city Section, A) Fan shaped or corrugated edge fish scale. B) Cycloid (circular) scales, which have a smooth texture and are uniform, with a smooth outer edge or margin

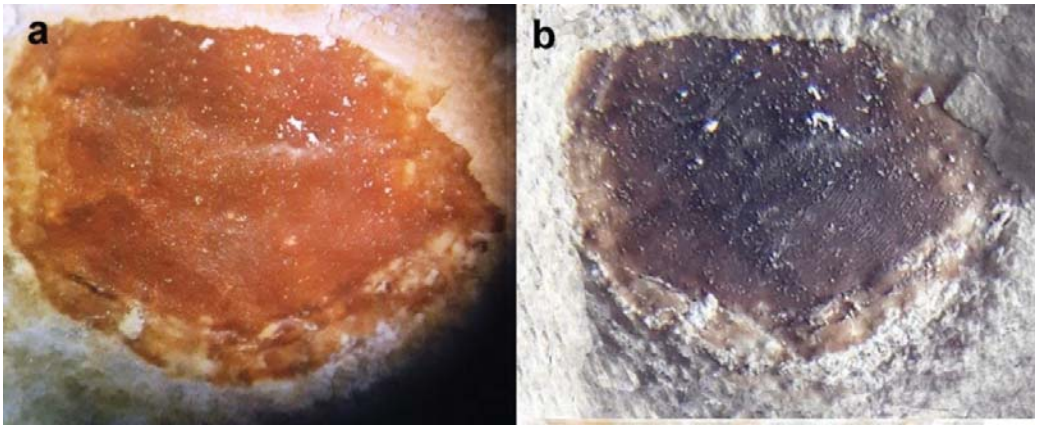

Fig. 12: a) Cycloid fish fin with smooth outer edge or margin in the Salta Re Section. b) Cycloid (circular) dark brown scales, which have a smooth texture and are uniform. The length of each photo is 4 mm

2.4.3. Fish skeletons in the Gulneri Formation

The skeleton of the fish is either made of cartilage (cartilaginous fishes) or bones (bony fishes). The latter type is found in the present study (Figs. 13, 14 and 15). The documented skeletons are relatively small and consist of vertebral column (also known as the spinal column or backbone) with or without ribs (fish spins). Like fish fins, the skeletons have yellow color under polarized microscope, which is sign of phosphatization (Fig. 10a). The fish skeletons are found only in the laminated marl

samples of Salta Re and Qywan Highs city Section on the southwestern limb of Azmir and Goizha anticlines, respectively (Fig. 5, 6 and 7).

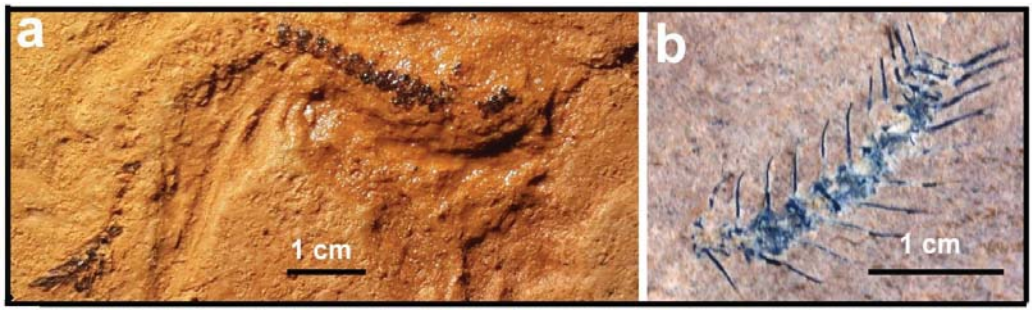

Fig. 13: a) A fish skeleton in the samples of Salta Re Section, b) A photo of the same sekeleton shows only tail of skeleton in Qaywan city Section

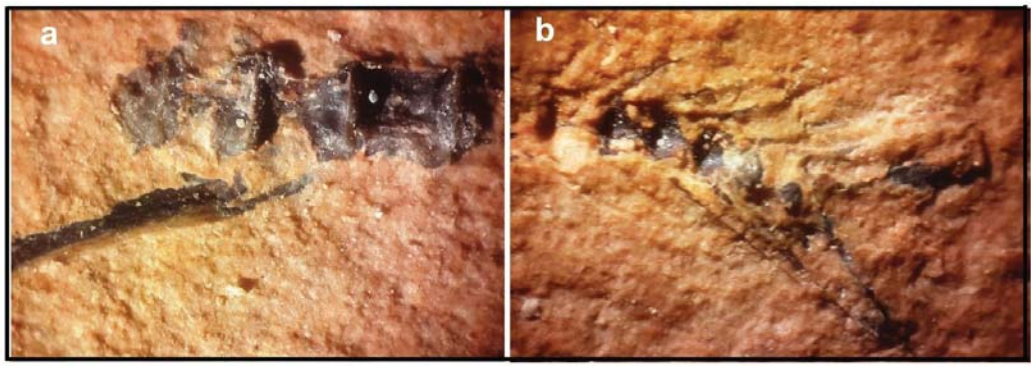

Fig. 14: well preserved fish rear part of fish sekeleton, Qaywan city Section

DISCUSSION

The field work across northeastern Iraq has revealed that the Gulneri Formation or its equivalent rock occurs between the Kometan and Balambo formations. The evidence of the previously assigned unconformities by many authors was not found in the whole northeastern Iraq. This is may be true in the Middle East since Mandur (2011) have not recorded missing zone of the nannofossils during Cenomanian and Turonian age in Sinai of Egypt. Same is true in Italy; as Turgeon and Brumsack (2006) has not recorded any unconformity in sediments of the two latter ages known as "Bonarelli sediments". They concluded that the depositional basin is a high productivity open marine but with oxygen-depleted bottom water conditions. In Jordan, Schulze *et al*. (2005) have summarized the geology of the sediments of Cenomanian – Turonian and cited that have

transgressive sediments and deposited on carbonate platform. In Poland, Uchman *et al*. (2008) have recorded that succession of red and green siliceous manganiferous shales were deposited during Turonian and represent sediments deposited in well oxygenated conditions under extremely low sedimentation rate. They added that most of the shales are parallel-laminated, and they do not include any benthic microfossils and trace fossils. In Pontic (pontides) Mountains, a belt in northern Turkey, Yilmaz *et al*. (2010) have indicated that C/T represents the OAE2 during which cyclic black shale and red marl/ chert alternations were deposited due to volcanism, productivity and small and large-scale sea level changes.

From the mentioned citation it is clear that the sediments in Italy and Poland are nearly similar to those in the eastern part of the studied area in term of environment and sediments, especially in the latter country there is red siliceous shale (red marl of the present study). But in Jordan and Egypt the environment was forming a platform during Cenomanian – Turonian and shallow open marine sediments were deposited, which are similar to the western part of the studied area (Dokan and Arbil areas). This wide distribution of the sediments of the boundary between Cenomanian – Turonian not aid presence of unconformity that is mentioned and concluded by many authors.

Recently, many studies are conducted on the formation, which have changed the lithology and the nature of upper and lower boundaries, among them are Taha (2008); Taha and Karim (2009) and Karim *et al*. (2013). In these three studies, the lithology has changed from black shale to marly limestone and the boundaries changed from unconformable to conformable. Additionally, in these three studies, the distribution of the formation is extended to most parts of the northern Iraq and proved that it has deposited in large open and deep basin on the continental margin of the Arabian Plate (Fig. 6). Karim *et al*. (2013) have recorded the formation for the first time at the area to the east, north and northwest of Sulaimani city. The nannofossils study on Azmir anticline revealed that the depositional age of the formation was during the Late Cenomanian-Early Turonian (Fig.1). Depending on the above mentioned studies, Al-Sagri (2015) has changed the depositional environment to oceanic and linked the formation with Oceanic Anoxic Event Two. Unfortunately, Al-Sagari (2015) has not referred to the above three studies and he did not mention how he changed the

environment to oceanic without refusing of the overlying and underlying previously established unconformities.

The present record of the fish remains has two consequences. The first one is that these remains are not associated either with clastic sediments (such as silt, sand or gravels) or boiclasts of the benthonic organisms such as mollusks and echinoderms. Additionally, no insect remains or plant debris are found in the Gulneri Formation. The absence of these materials is most possibly due to deepness of the environment which was far from any terrestrial area. The second consequence is the fish remains belong to small fishes, which may be transported during intense storms and hurricane to the basin of the formation. The presence of the fish remains, in the studied area and organic matters in other part of the world, may be ascribed to the switching of late Cenomanian-Early Turonian upwelling current (nutrients) from the bottom to the oceanic surface, which is summarized by Thomas and Tilghman (2013). They added that the organic productivity (such as fish production) on the surface increase and preserved on the bottom due to anoxic nature.

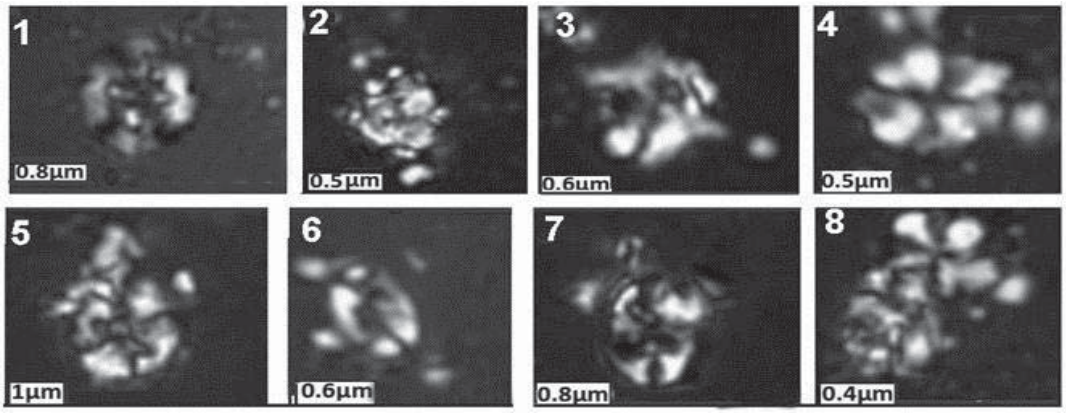

Fig. 15: Species of nannofossils in the equivalent of the Gulneri Formation (EOGF), which indicates the age of Early Late Cenomanian – Early Turonian.
1) *Retecapsa angustiformata* (S.2 MBK), 2) *Radiolithus planus* (S.2 MBK), 3) *Prediscosphaera columnata* (S.1 MBK), 4) *Eprolithus moratus* (S.5 MBK), 5) *Eiffellithus eximius* (S.4 MBK), 6) *Eiffellithus gorkae* (S.4 MBK), 7) *Eiffellithus turriseiffelli* (S.4 MKB) and 8) *Eprolithus Moratus* (S.4 MBK) (Karim *et al*., 2013)

CONCLUSIONS

1. The Formation consists of marl and marly limestone (2 – 4 m thick) it is overlain by the Kometan Formation and underlain by the Dokan Formation conformably.
2. Three types of fish remains are found that are pictorial fin, fish scale and fish skeleton.
3. The environment of C/T boundary was anoxic in which organic maters are preserved.
4. From west (Erbil Governorate) to the east (Sulaimani Governorate), the environment is changing from shallow platform to deep basin of continental margin, respectively.
5. The fish remains are settled from surface to the sea bottom.
6. The sediments of Cenomanian – Turonian are nearly similar in the Middle East and Europe and consist of limestone or laminated shale and marl, which are deposited during OAE2.

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