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STRATİGRAPHY AND STRUCTURE OF THE SOUTHEASTERN PART OF PİRAMAGROON ANTİCLİNE, SULAİMANİ AREA, NORTHEAST IRAQ

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Abstract

The Piramagroon anticline (or Pira Magrun Mountain) elongates directly to northwest of Sulaimani city, Northeast Iraq and its southeastern part contains two other anticlines, named Harmetool and Yakhyian anticlines in addition to their complementary synclines and many other smaller folds. The anticline has experienced intense search for oil in the last few years and a well is drilled to depth of 3000 meters without reaching oil or gas. In the present study, the southeastern part has been studied stratigraphically and structurally and the previous studies are critically reviewed which may help reveal the reason for absence of oil in the area. The stratigraphy of the anticline has been differentiated and Kometan, Gulneri and Dokan, Balambo and Sarmord formations are plotted on a geological map and stratigraphic column and the nannofossils are used for aging of intervals that their ages are no determined previously. The thickness of the Gulneri Formation is 2-4m and the nannofossils analysis showed that its age is Late Cenomanian-Early Turonian. Lithology and bedding styles of the Dokan and Upper part of the Balambo formations are very similar to Kometan Formation and they can be differentiated either by fossils or by using Gulneri Formation as marker bed. The outcrop of the Gulneri Formation is helpful for differentiation since it is soft and can be recognized easily in the field by its darker color. The structure of the anticline is relatively complex as it consists mainly of asymmetrical anticlines with southwest vergen in few places while it changes to overturned folds in others and are deformed by reverse fault. The anticlines are shaped by detachments on the Gulneri and Sarmord formations and other older soft rocks. The resulted anticlines have style of multi-detachment fold or multi-detachment faulted fold.

Key words: Gulneri Formation, Dokan Formation, Kometan Formation, nannofossil, Piramagroon anticline, Sulaimani stratigraphy

1. Introduction

The Piramagroon anticline (or Piramagrun Mountain) is one of the largest anticlines of Zagros Orogenic Belt in Northeast Iraq and has the length, width and elevation of about 45, 6 and 2.4 kms respectively. It is located between Sulaimani city, from southeast, and Surdash town, from northwest which coincides with the latitude and longitude of 35^{o} 36^{-} $57.30^{=}$ N , 45^{o} 22^{-} $58.33^{=}$ E and 35^{o} 51^{-} $33.11^{=}$ N , 45^{o} 05^{-} $21.76^{=}$ E respectively. Qamchuqa (or Balambo), Kometan, Shiranish and Tanjero Formations are exposed on and around the anticline while its core is occupied by Jurassic rocks (Fig.1). The present study is concerned with its southeastern part which is equal to the half of the surface area of the anticline. This part is located between Zewy valley at the northwest and Farouq Hotel inside Sulaimani city at the southeast which correspond to the latitude and longitude of 35^{o} 44^{-} $58.43^{=}$ N, 45^{o} 14^{-} $57.88^{=}$ E and 35^{o} 34^{-} $15.40^{=}$ N , 45^{o} 24^{-} $25.17^{=}$ E respectively. This part consists of many anticlines; the largest one is called Piramagroon anticline which plunges near Sutka village (Fig.1). The second largest one is locally famous as Harmetool anticline (mountain)) which is located at the east and southeast of Piramagroon anticline.

Previously, Harmetool anticline is called Sulaimani Anticline by Ma·ala (2008) and Al-Hakari (2011). Other anticlines are Sherkuzh and Yakhyiana which are located at north and south of the Harmetool anticline respectively with more than four other smaller anticlines (Fig.1).

Very recently an oil company has drilled an oil well on the core of the anticline to depth of 3000 meters. The well is drilled on Sarmord Formation and reached Triassic Formation without striking oil or gas. The present study is focused on the stratigraphy and structure of the southeastern part of Piramagroon anticline. The study is based on geologic mapping and structural analysis in addition to stratigraphic differentiation by nannofossils. Additionally, it tries to add more useful data and geologic facts to the previous studies such as Aziz et al. (1999) (Fig.2), Ma, ala (2008), Al-Hakari, (2011) (Fig.3) and Omer et al (2015).

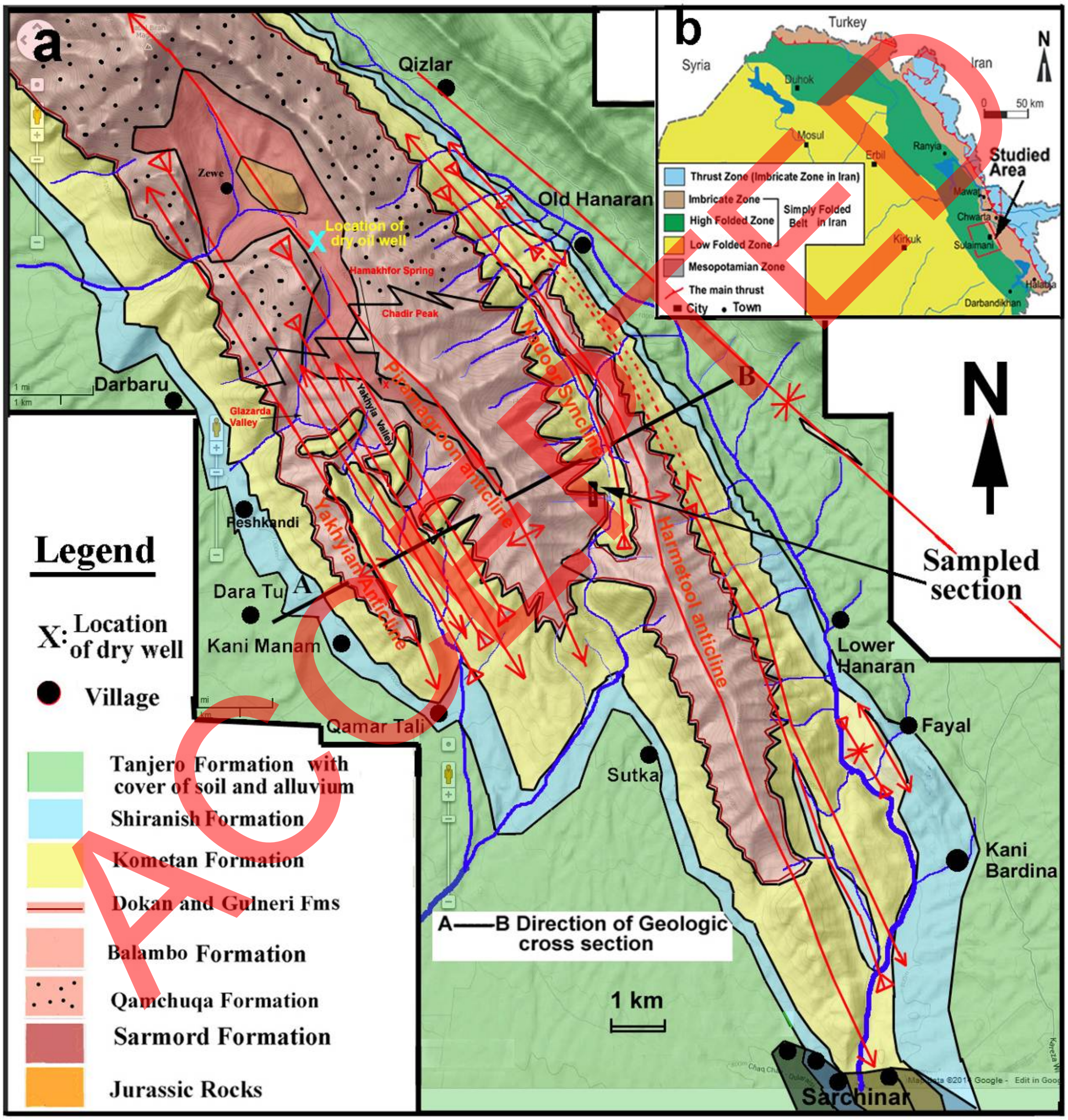


Figure (1) a) Geological and b) tectonic maps of the studied area.

1.1. Geological setting

Tectonically, the studied area is part of the northeastern margin of the Arabian Plate, where the previous Early Cretaceous platform has transformed to a foreland basin during the Late Cretaceous (Karim, 2004). According to tectonic subdivision of Iraq by Buday (1987) and Jassim and Goff (2006) the studied area is located in the High Folded Zone while it located in the Simply Folded Zone when the classification of whole Zagros belt, by Ghasemi and Talbot (2006), is considered (Fig.1b).

In the north of the studied area (Mawat-Chwarta area) a large graben is located in which ophiolite, Tertiary, and Upper Cretaceous formations are exposed. In the Graben, the Main Zagros Thrust can be recognized between Qulqula Radiolarian Formation and Red Bed Series. The Upper Cretaceous Formations are Shiranish (marlstone), Tanjero (sandstone, marl and conglomerate) and Aqra (fossiliferous and detrital limestone) Formations (Karim, 2004; Al-Kubaysi, K. N. (2008), Sadiq, 2009, and Sacit et al. (2013) Karim and Khanaqa (2014).

Between the Garben and studied area, Azmir anticline and Chaqchaq syncline are located which are dissected by consequent valleys in which best out crops of Cretaceous and Jurassic rocks are available for geological studies. The formations, on the anticline and in the syncline, are same as those that ate exposed on and around Piramagroon anticline and discussed in this paper in detail in the next sections.

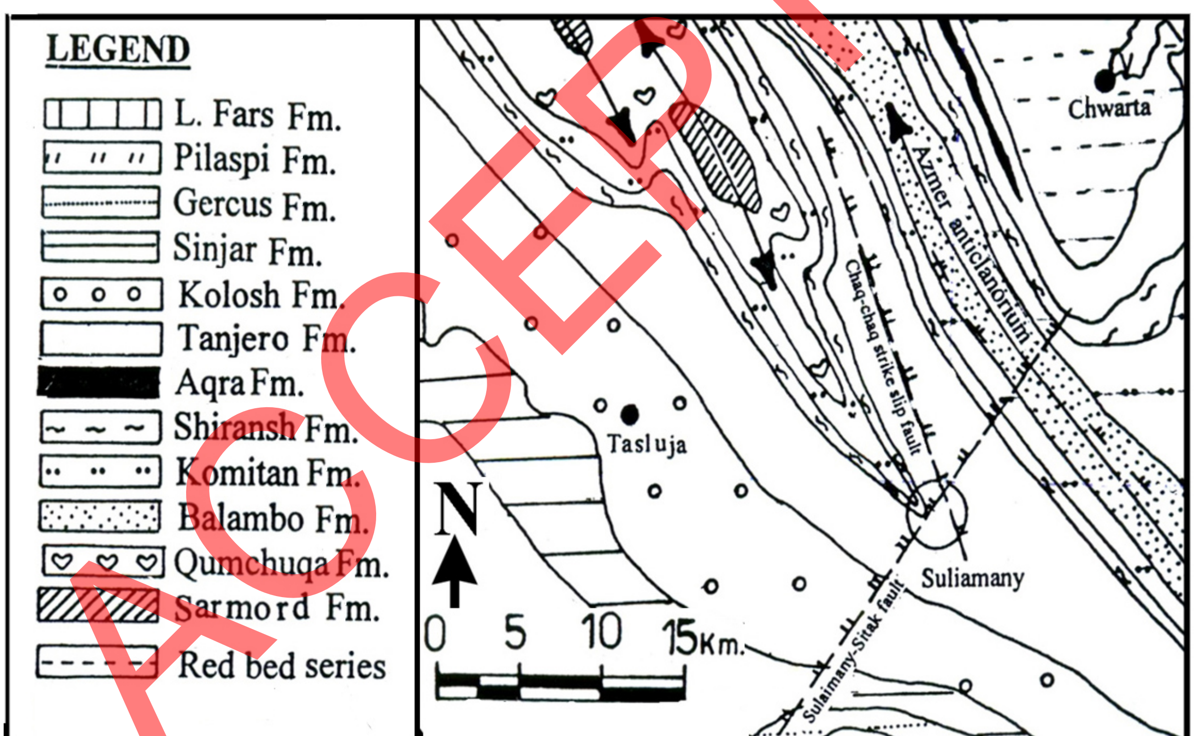


Figure (2) Geological map of the studied area shows two strikes slip faults (Aziz et al, 1999).

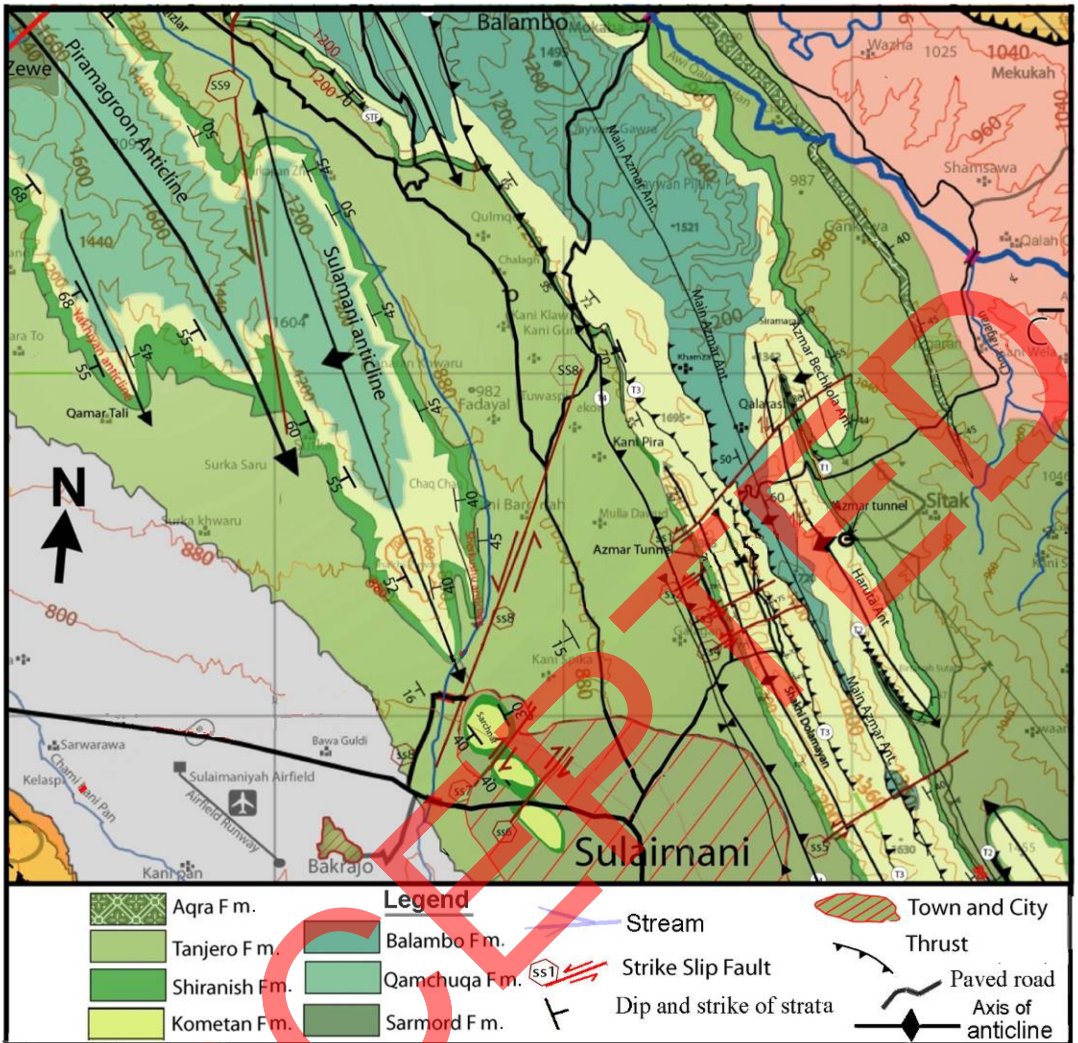


Figure (3) Geological map of the studied area (Sissakian, 2000 and Ma׳ala, 2008 and modified by Al-Hakari, 2011) showing the strike slip faults that indicated by the latter authors.

2. Result and discussion

2.1. Stratigraphy of the area

The stratigraphic study of the southeastern part of Piramagroon anticline is very important due to four points. The first is that the area is zone of facies change between Qamchuqa and Balambo formations (Ameen, 2008). In this area, the thick and massive dolomitic limestone (competent beds) of the Qamchuqa Formation, from the west, changes to well bedded limestone and marly limestone (incompetent) of Balambo Formation. Therefore, the phrase "Qamchuqa/Balambo transition or QBT" is used for the equivalent of Qamchuqa Formation in the transition zone. The second is that the transitional zone, structurally, consists of alternation of competent and incompetent beds which reflect different deformational patterns that are the combination of the two end members. The third is expanding of the urbanization of the Sulaimani city toward the studied area which may cover most parts during the forthcoming decade. Fourth is that the boundary between Balambo (or its reefal equivalents of Qamchuqa Formation) and Kometan Formation (Turonian-Campanian) is well exposed in the area.

The boundary must contain either the rocks of Cenomanian- Turonian ages or events (unconformities). Many authors (Sharland et al., 2001; Al Hussaini and Matthews, 2008, Al-Qayim et al., 2012, Lawa and Gharib, 2009 and Omer et al 2015) have cited major unconformity in this boundary. Lawa et al. (2011 in Al-Hakari, 2011) have cited that during the early Turonian, the Qulqula Radiolarian and main igneous complexes were uplifted and acted as

Hinterland for Kurdistan Foreland basin. Buday (1980) and Jassim and Goff (2006) have refereed also to this events in the Cenomanian-Turonian age during which Qulqula conglomerate Formation had deposited at the top of Qulqula Radiolarian Formation. This deposition is recently referred to by Ibrahim, 2009 and Al-Qayim et al (2012).

The present study, field inspection, across many sections, has not revealed any of the above signatures. Moreover, the nannofossils analysis of the boundary between Qamchuqa (or Balambo) and Kometan formations

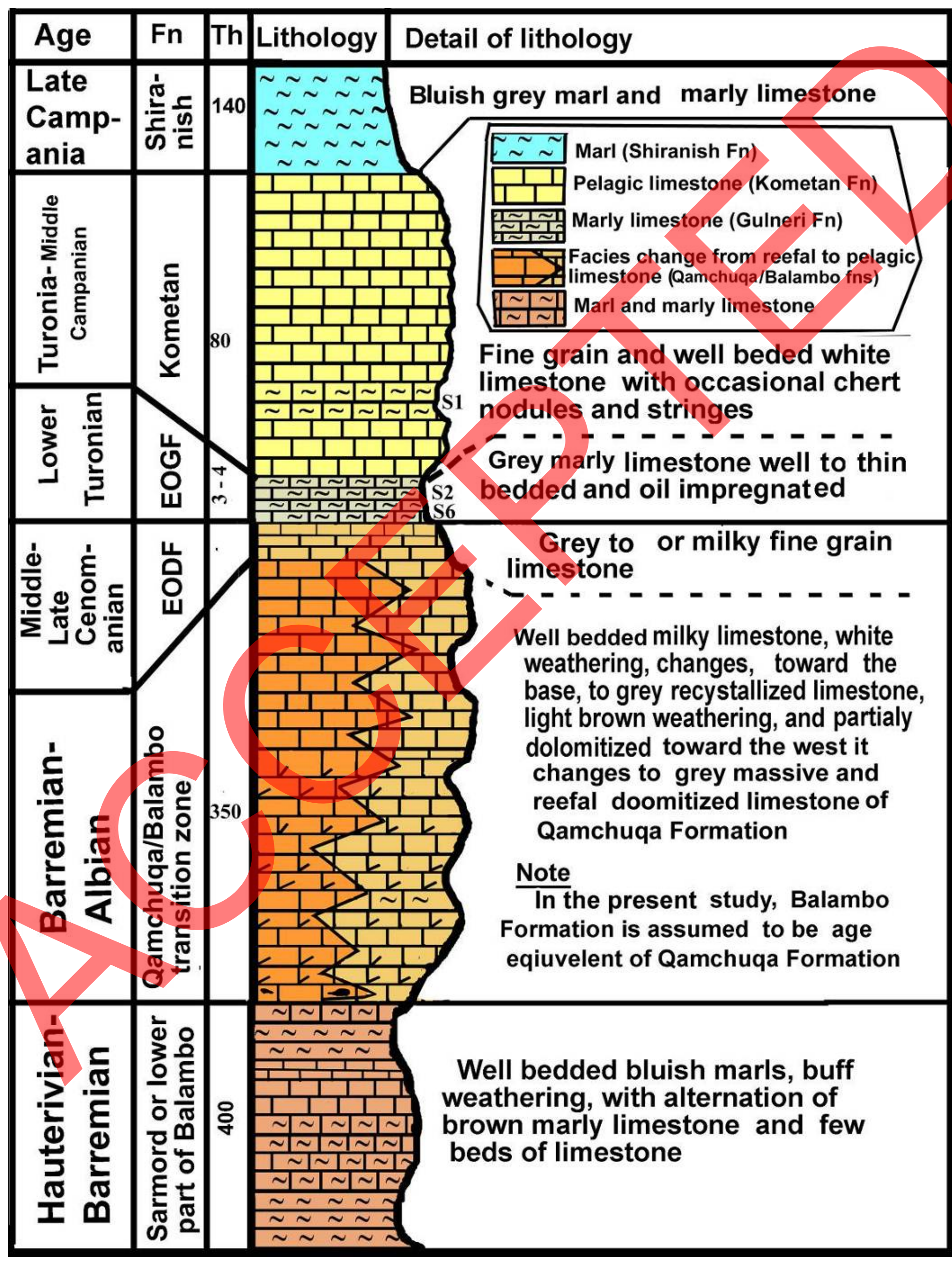


Figure (4) Stratigraphic column of the studied area drawn from the result of the present study showed that the Gulneri and Dokan formations exist in the boundary and unconformities are not observed (Fig.1 and 4). This result agree with the conclusion of the Taha and Karim (2009) who refused the unconformities that previously established at the base and at top of the Gulneri Formation in Dokan area. The latter study concluded that the formation consist of marl and marly limestone without black shale. Karim et al. (2013) found both formations on the Azmir and Goizha anticlines and prepared a detail map of the area to the north and east of Sulaimani city which show the outcrops of the two formations.

Previously, Aziz et al. (1999), Ma·ala (2008) and Al-Hakari, (2011) mapped the study area and indicated Qamchuqa, Kometan, Shiranish and Tanjero formations on the crest, upper and lower limbs of the anticline respectively (Fig.1 and 2). The above authors have not recorded the Gulneri and Dokan Formations. Al-Hakari (2011) and Omer et al (2015) in their study of the area around Sulaimani City indicated (by stratigraphic column) that there are unconformities between Qamchuqa and Kometan formations by which both Dokan and Gulneri formations are missed in the area. About the contact between Kometan and Shiranish Formations, they showed that there is an unconformity between the two formations while the present study not recorded the two unconformities and field and fossils analysis are indicated conformable nature of the boundaries of the above four formations.

2.1.1. Gulneri Formation

The Gulneri Formation was first described by Lancaster Jones (1957 in Bellen et al. 1959) near the Dokan Dam site to west of Sulaimani city, which it consists of about 2 m of black, bituminous, finely laminated, calcareous shale with some glauconite and collophane at its lower partand without shale. The age of the formation is Early Turonian (Bellen et al., 1959).

The high bitumen content and dwarfed fossils indicate that the Gulneri Formation was deposited in a euxinic environment (Jassim and Buday in Jassim and Goff, 2006). The formation is separated by unconformities with both the overlying and the underlying Kometan and Dokan formations, respectively (Buday, 1980). The present study found that it consists mainly of well bedded marly limestone and occasionally laminated and oil impregnated. In all sections, shale has not found and the observed lithology of marly limestone is agree with what concluded by Taha and Karim (2009) who reused the previous lithology (black shale) of Gulneri Formation at type section near Dokan dam site. . Karim and Taha (2009, p.6) has showed by model that the formation is deposited in the large basin in which Balambo and Kometan Formations are deposited.

In the studied area, the upper part of Balambo Formation, Dokan and Kometan formations are very similar in lithology and bedding patterns (Fig.5). They can be separated either by foraminifera study or by identifying Gulneri Formation which located between the two formations. The latter Formation can be observed in the field which appears as a covered dark ribbon between white limestones of Kometan and Balambo Formations. The thickness of Gulneri Formation is about 2-4 m. Between Dokan and Surdash towns, it is located between Dokan and Kometan Formation and consists of dolomitic limestone without marl and marly limestone but it is thinly bedde and due to this property, it is highly deformed as cab be seen in Tabeen Gorge where Karim (2014) showed a photo of the formation to prove, its existence. Therefore, the result of the present study refuses the presence of the Turonian unconformity in North Eastern Iraq that mentioned previously. Lawa et al. (2013) cited an unconformity and mentioned that Dokan and Gulneri formation are not present (an unconformity with duration of 4.7 m.y) in the Tabeen Gorge 4km to the southeast of Surdash village. Similarly, Omer et al. (2015) have recorded the unconformity and they noted the absence of Dokan and Gulneri Formations (Late Cenomanian to Early Turonian age) at the top of the Balambo and Qamchuqa Formations. They are attributed this absence to the reactivations of ChaqChaq fault and tectonic uplifting of the Mawat ophiolite obduction during the Turonian. They further added that the top of the latter two formations are characterized by the disappearance of planktonic foraminiferal, nannoplankton and palynomorphs. They assigned this gap as pre-Aruma unconformity and attributed it to ophiolite obductions. In the present study, the sediments of the Gulneri and Dokan Formations are found and contain, in many place, both nannofossils and planktonic forams.

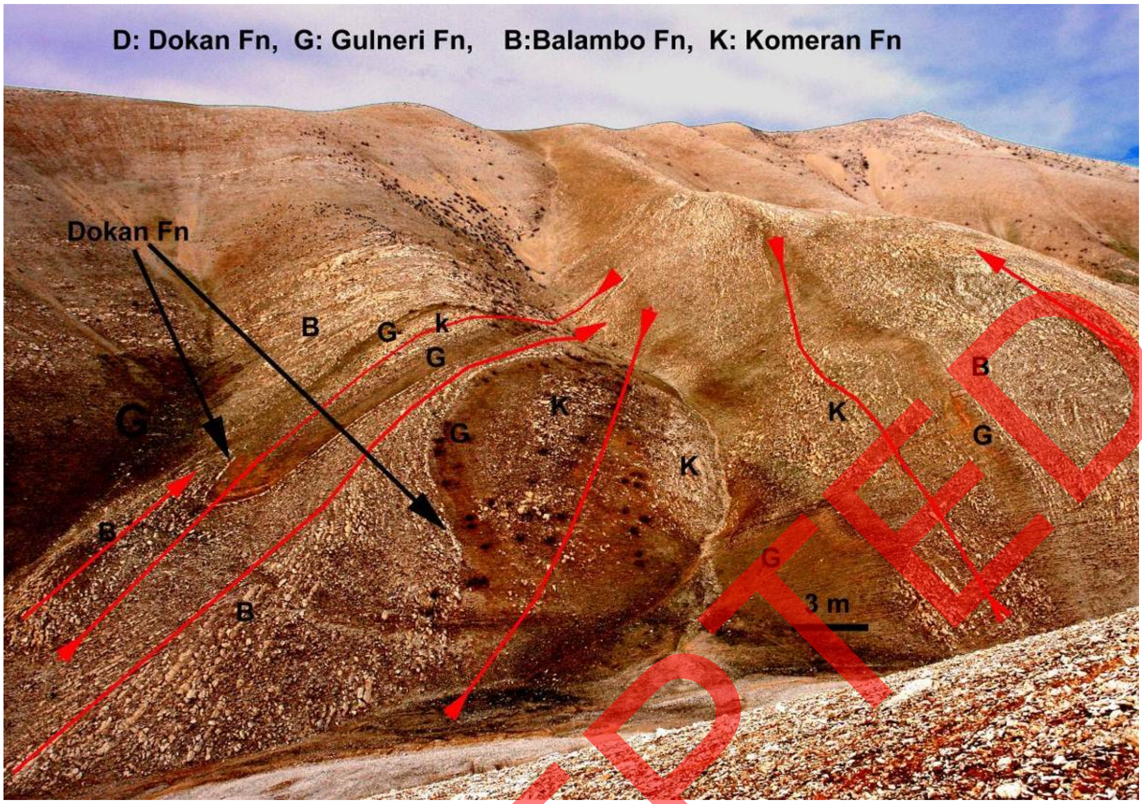


Figure (5) Southwestern side of the Nadoor valley shows the minor folding and stratigraphic differentiations.

2.1.2. Nannofossils analysis of Gulneri Formation

Omer et al (2015) cited that the top of Balambo Formation is unconformity and does not contain nannofossils while the present studied has found many index nannofossil species in the formation which are representing the age of Gulneri and Dokan formations.

In the studied area, the outcrops of Gulneri Formation equivalent are mostly covered and weathered; therefore, fresh sampling is difficult. For obtaining fresh sample six 1m deep holes are excavated on the outcrop of the formation for taking samples. The six samples have been sent to Romania for nannofossils analysis and age determination. A detail report is prepared by Dr Ramona Balc (ramona.balc@ubbcluj.ro) for the samples which gave the age of Late Cenomanian-Early Turonian for the sampled interval (Fig.6 and 7).

Nannofossils Species

The age of the studied samples is given by the presence of *Corrolithion kennedyi* and *Quadrum intermedium*. The first mentioned species was identified only in one sample (sample 5). Thus, this level falls in UC3d Nannofossil Subzone (Burnett, 1998), which is Late Cenomanian in age. The top of this subzone is defined by the last occurrence (LO) of *C. kennedyi.* Next level (sample 4 and sample 3) cover the Uc3d – UC5b Nannofossil Subzones, the bioevent marking the base of the UC5b which is represented by the first occurrence (FO) of *Quadrum intermedium*. The age of the above mentioned interval is Late Cenomanian. The last level (samples 2 and 1) falls in UC5c Nannofossil Subzone, the base of this subzone being defined by the FO of Q. intermedium (Fig.6). The age of this subzone is Late Cenomanian-Early Turonian.

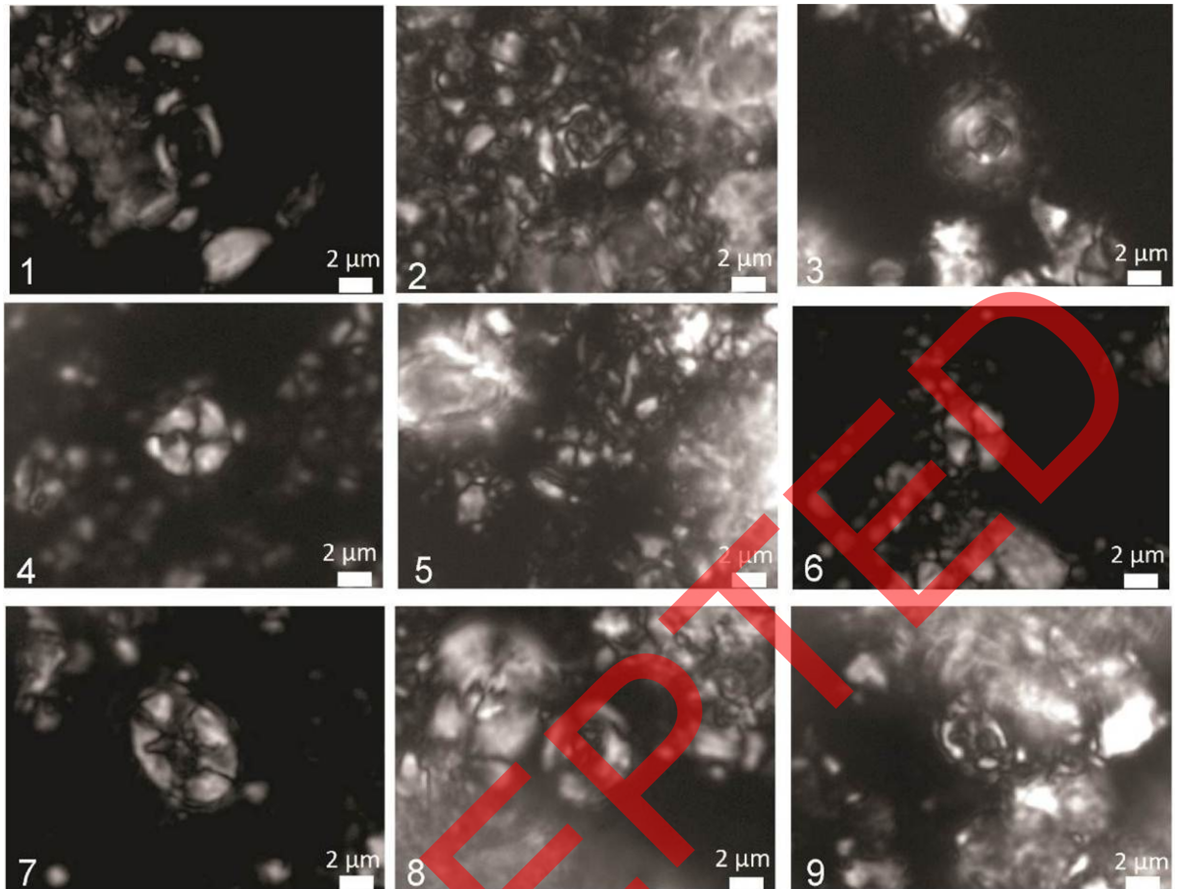
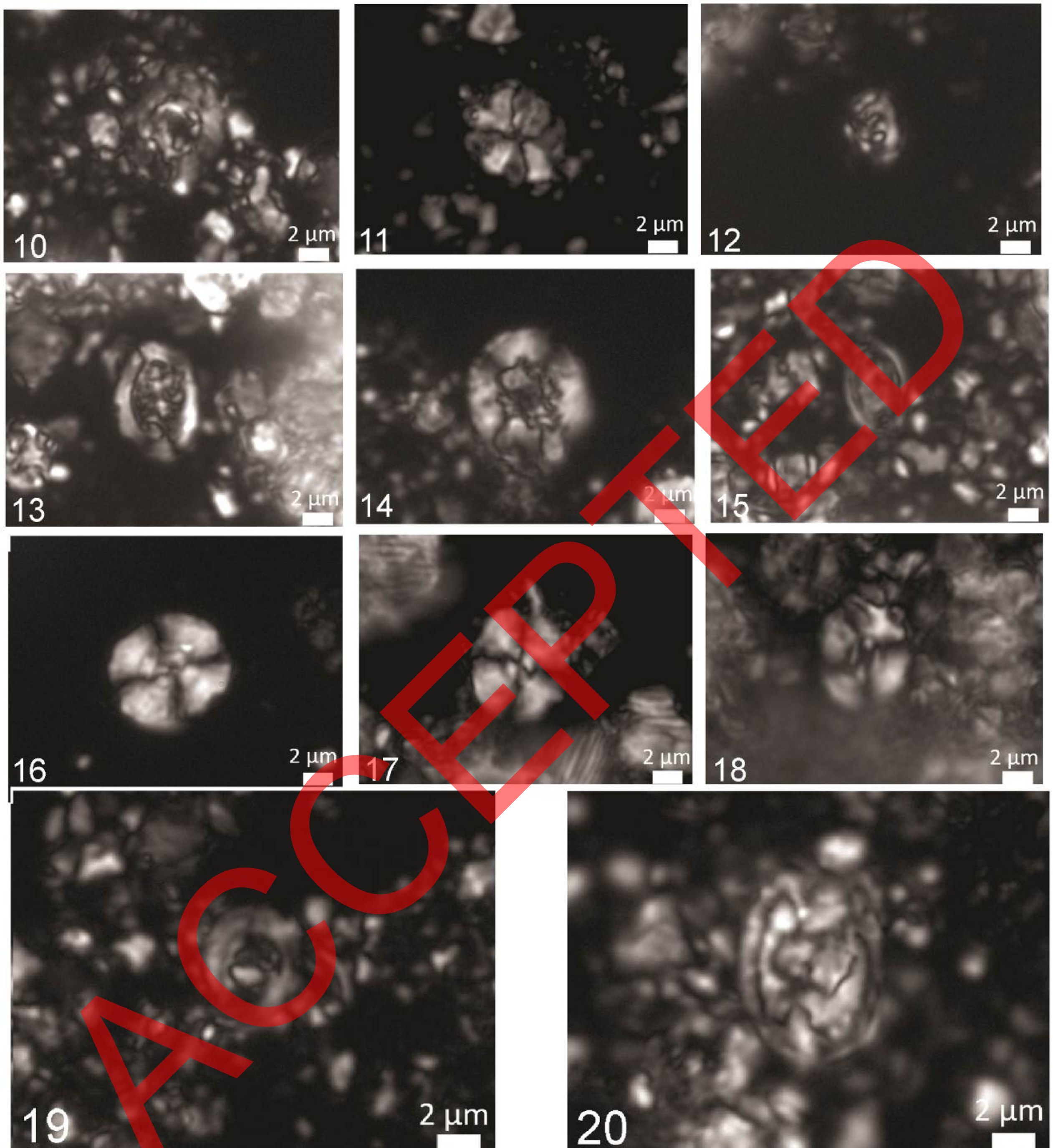


Figure (6) Species of the result of the nannofossils analysis which give the age of Late Cenomanian-Early Turonian. Species are: **1.** *Broinsonia enormis* (Sample 1); **2.** *Corrolithion kennedyi* (Sample 5); **3.** *Cylindralithus* sp. (Sample 5); **4.** *Cylindralithus nudus* (Sample 5); **5.** *Discorhabdus ignotus* (Sample 5); **6.** *Eprolithus floralis* (Sample 2); **7.** *Eiffelithus turriseiffelii* (Sample 2); **8.** *Helenea chiastia* (Sample 5); **9.** *Helicolithus trabeculatus* (Sample 5); All photos ate taken under XP light.



Figure(7) *Prediscosphaera cretacea* (Sample 1); **11.** *Quadrum intermedium* (Sample 3); **12.** *Rhagodiscus achlyostaurion* (Sample 5); **13.** *Rhagodiscus asper* (Sample 4); **14.** *Retecapsa crenulata* (Sample 3); **15.** *Tranolithus orionatus* (Sample 5); **16-17.** *Watznaueria barnesiae* (Sample 2); **18.** *Watznaueria ovate* (Sample 1); **19.** *Zeugrhabdotus diplogrammus* (Sample 4); **20.** *Zeugrhabdotus embergeri* (Sample 3). All photos ate taken under XP light.

2.2. Structure of the area

Due to the accurate analysis of the stratigraphy of the studied area in the preceding sections, the structure analysis was possible in more update condition than previous studies.

2.2.1. Strike slip and reverse faults

Aziz et al (1999) have recorded two strike slip faults and called them Sulaimani-Sitak and Chaqchaq strike slip faults. They have indicated the two faults intersecting beneath western part of Sulaimani city ($35^{o}\ 34^{-}\ 15.40^{=}$ N and $45^{o}\ 24^{-}\ 25.17^{=}$ E) (Fig.1). They added that the facies change from reefal Qamchuqa Formation to Pelagic Balambo Formation is controlled basically by deep seated fault of Chaqchaq strike slip fault. The same idea is accepted by Ibrahim (2009), Hakari (2011) and Omer et al. (2015) but they showed it diagrammatically as normal listric fault (Fig.8).

The present study not agree with the citation of the above authors about effect of the fault on the facies change from reeefal limestone to deep pelagic limestone or marl during Early Cretaceous. This disagreement is due to fact that this facies change is not restricted to area at north and northeast of Piramagroon anticline but exist in the whole northern Iraq. On the tectonic map of Jassim and Goff (2006), this facies change is indicated which is located between the Balambo-Tanjero Zone and High Folded Zones and start from Chachaq valley to north of Rawndoz town.

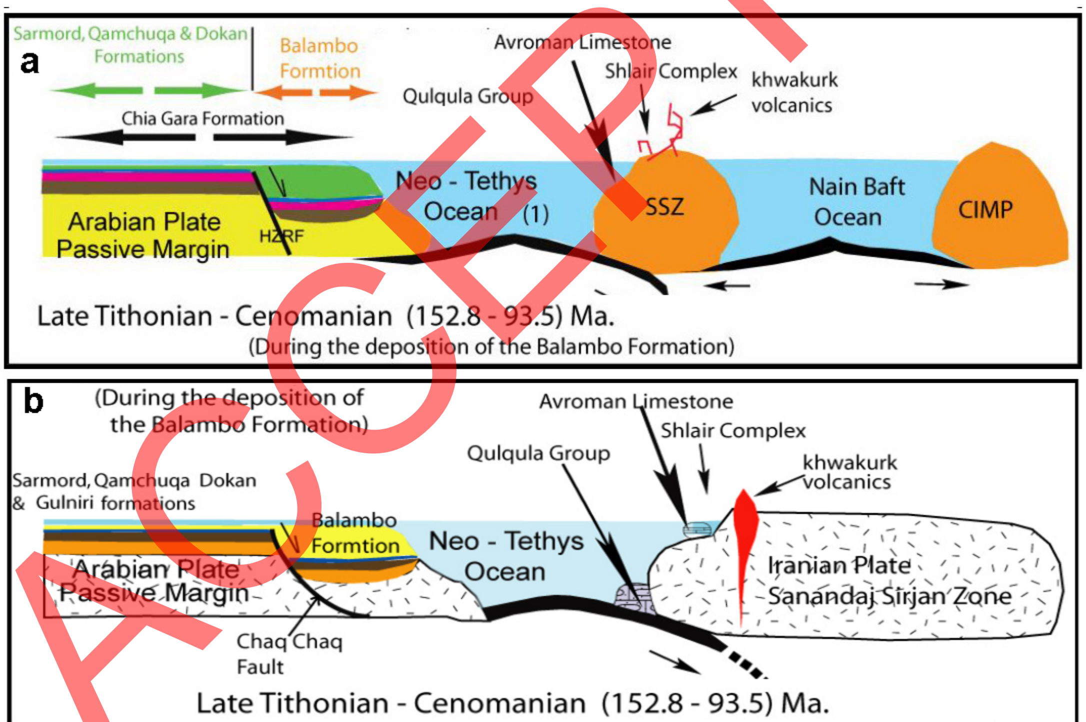


Figure (8) Paleogeography and tectonics of Late Tithonian-Cenomanian in which listric fault is indicated by: a) Ibrahim (2009), b) Al- Hakari (2009) and Omer et al. (2015).

The facies changes of Qamchuqa Formation (shallow reefal limestone) to Balambo Formation (deep pelagic limestone or marl) need not to be controlled by fault because this facies change is very common on the continental margin of the present day oceans where the reefal carbonate on the shelf rapidly (relatively) changes to pelagic limestone or mud on the slope or continental rise. During Early Cretaceous the Arabian platform was part of the continental margin of the New Tethys Ocean. Ameen (2008); Ameen and Karim (2009) and Karim and Taha (2009) have discussed and indicated this facies change without connecting it with faults (Fig.9).

Al-Hakari, (2011) has found two other strike slip faults in the area to the west of the Sulaimani-Sitak fault (Fig.3). The present authors, as a result of the fieldwork, have not found the evidence of these four faults at the west and northwest of the Sulaimani city. The geological mapping has not detected shifting of the axes of folds and the topographic features in the studied area (Fig.3). Two reverse faults are observed which has the displacement less than 20m, one of them cut the southwestern limb of the Piramagroon Anticline and observed inside the Yakhyian valley (Fig.10). Another reverse fault is seen on the northeastern limb of Harmetool anticline near the mouth of the Nadoor valley (Fig.11a). These two faults may be anticline break through fault due to fact that the anticlines are detachment folds and this type of fault is common in this type of fold.

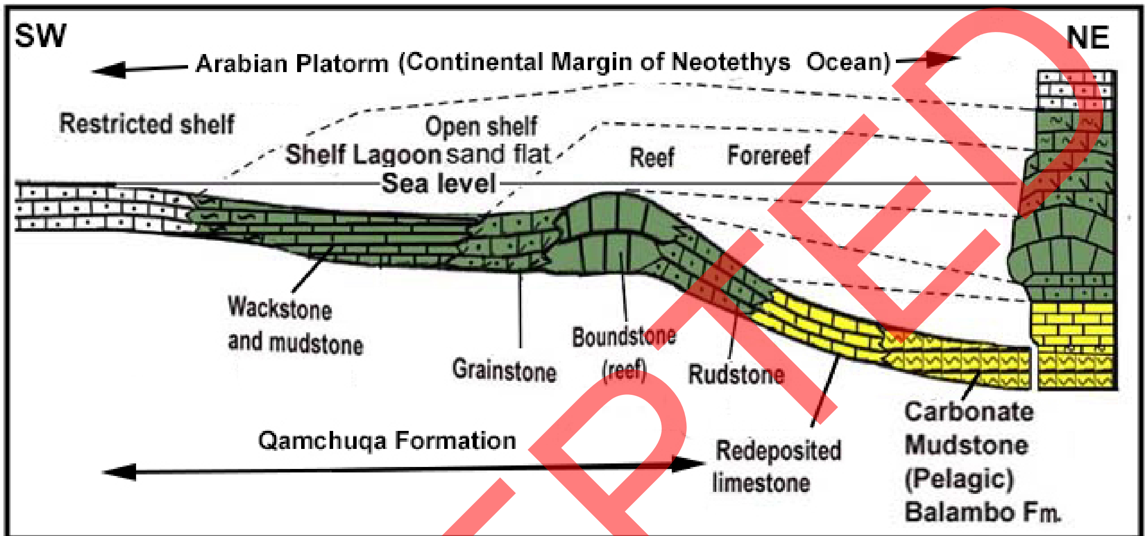


Figure (9) Paleogeography of the Arabian Platform during Early Cretaceous shows facies changes which are not related to fault (Ameen, 2008; Karim and Ameen, 2009).

2.2.2. Type of anticlines

There are two main anticlines in the studied area which are named Piramagroon and Sulaimani (Harmetool in the present study) anticlines by Ma·ala, (2008) and both of them are recently mapped by Al-Hakari, (2011) who has indicated all the main anticlines as southwest vergent asymmetrical anticlines. It was observed that the above indications are true for those found inside QBT. In some cases the anticlines are reversely faulted which may be belong to anticline breakthrough fault. However, the folds inside Kometan Formation are more or less behaved differently. In addition to asymmetrical anticlines, Kometan Formation contains box and recumbent anticlines (Fig.11d).

Al-Hakari (2011) and Omer et al. (2015) have assigned the anticlines in the studied area as fault propagation folds (Fig.1) but the present study thought that it is detachment fold. The proof for detachment fold is discussed in detail in the north of Sulaimni city by Karim and Ahmad (2014) during the study of Azmir-Goizha anticline. The detachments of the anticlines were occurred on the Gulneri and Sarmord formations and other older soft rocks. The resulted anticlines are in style of multi-detachment fold or multi-detachment faulted fold. Al-Hakari (2011) mentioned that the cores of the anticlines in the studied area occupied by Qamchuqa Formation but the present study showed that Balambo and Sarmord Formations exist in the core (Fig. 2, 10 and 12).

The absence of the oil in the core of the anticline is attributed, according to result of the present study, to refolding and intense deformation of the core of Piramaroon anticline by detachment folding which include rotation of both limbs and squeezing of the core of the anticline. This refolding (parasitic folding) and squeezing, by the above processes, has destroyed any existed reservoir (Fig.5) and its seal more intensely than previous model of fault propagation folds by Al-Hakari (2011) and Omer et al. (2015). The latter authors, showed in the figure 13, open folds without parasitic folding which is more suitable for keeping accumulated oil than detachment folding of the present study. Another reason for absence of oil is deep burial of the targeted rocks which are more than 10 km buried during Pliocene below Cretaceous and Tertiary rocks before exhumation. The burial temperature was so high that degraded the possible existed oil.

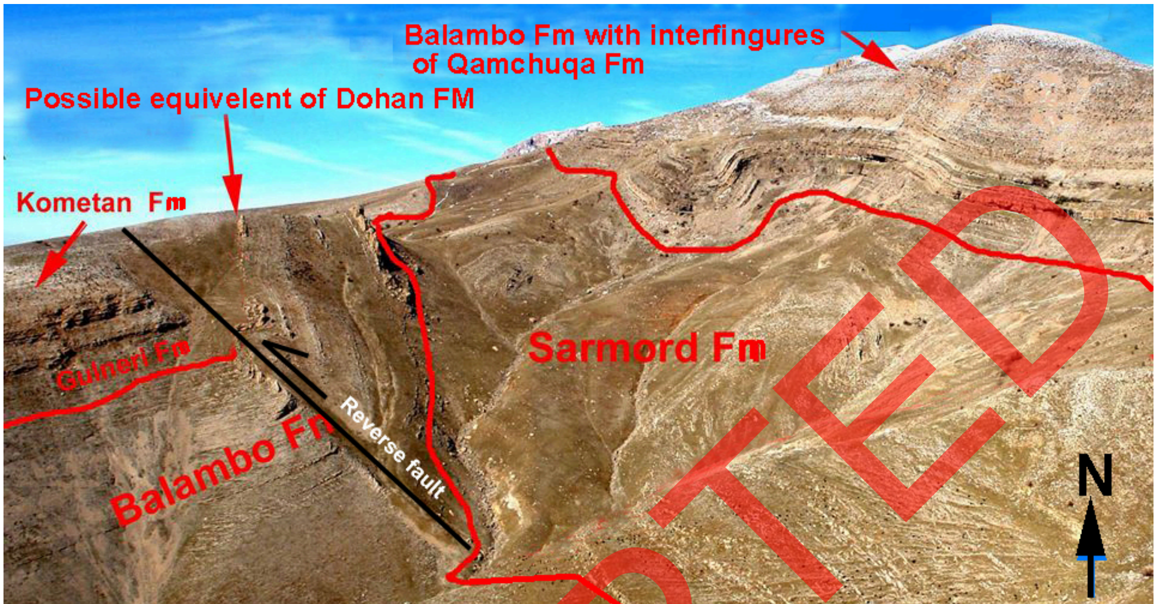


Figure (10) Folds in the south eastern limb of Piramagroon anticline, Yakhyian valley, 15 kms to the northwest of Sulaimani city, 3km to the north of Qamar Taly village.

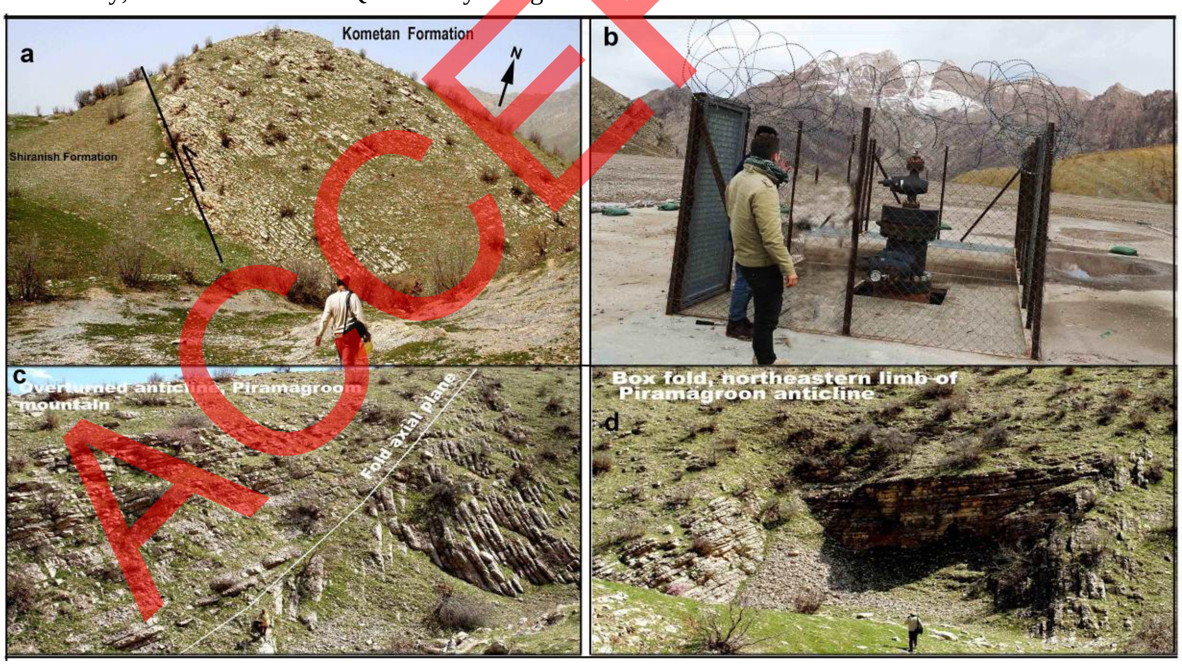


Figure (11) a) A reverse faults on the northeastern limb of Harmetool anticline near the mouth of the Nadoor valley, b) The oil well about 3000 meter deep which is dry. (c) Recumbent and box, (d) folds on the northeastern limb of Harmetool anticline at south west of Old Hanaran village.

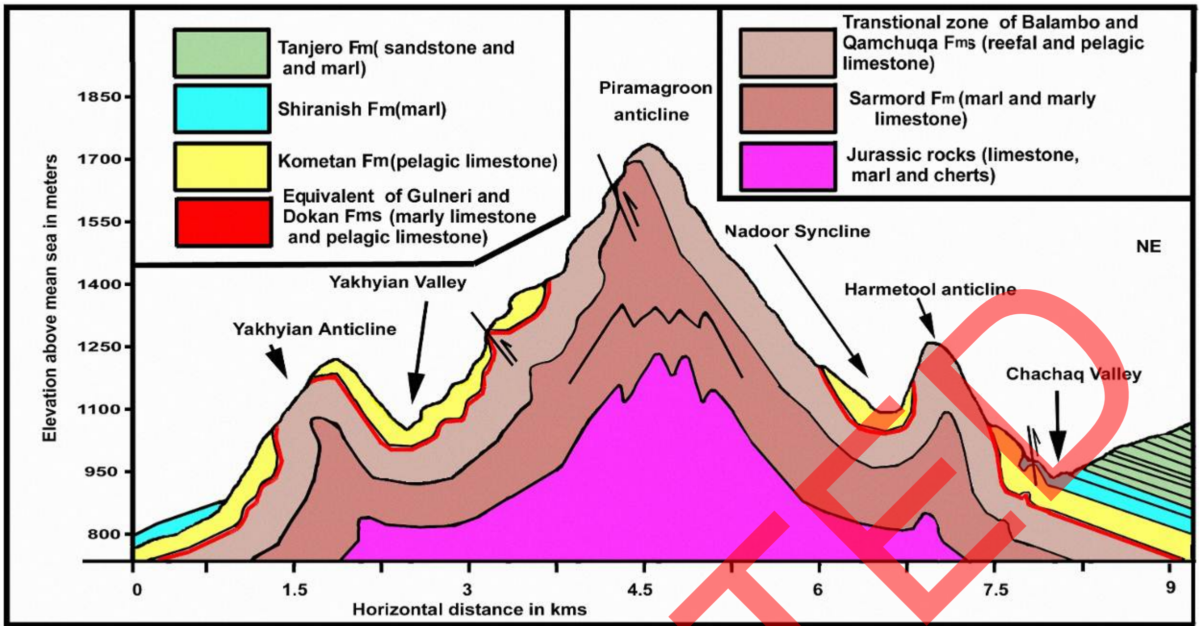
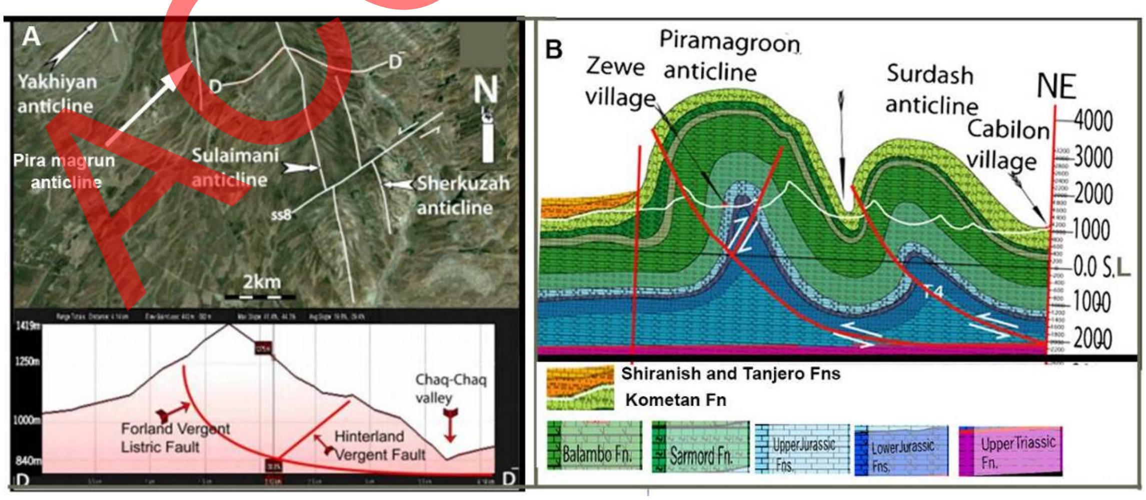


Figure (12) Geological cross section of the southeastern part of Piramagroon anticline (A----B line in the fig.1) the miner deformation is not shown.

2.2.3. Sulaimani anticline

This anticline is located inside the western part of Sulaimani city (35º 34' 15.50" N and 45º 24' 25.15" E) and geomorphologically consists of three low hills such as UN and Farouk hills (Fig.14). The plotting of its axis indicates that this anticline, most possibly, is an independent anticline. Previously this anticline is assigned as southeastern plunge of Harmetool anticline by Ma'ala (2008), Al-Hakari (2011) (Fig.13A) and Aziz et al, (1999). The elongation of the axis of Sulaimani anticline coincides with the Sherkuzh anticline (Fig.14a). Al-Hakari (2011) had indicated two strike slip faults that cut this anticline (Fig.3). In this study, only a small strike slip fault was found that strikes nearly east-west (Fig.14b)



Figure(13)Two geological cross sections of A)Al-Hakari (2011) and B)Al-Hakari (2011); Omer *et al.*(2015)shows that they assigned the anticlines in studied area as fault propagation folds which uplifted through the reverse slipping of the hanging wall of the blind foreland vergent listric thrust fault associated with the hinterland-vergent-fault.

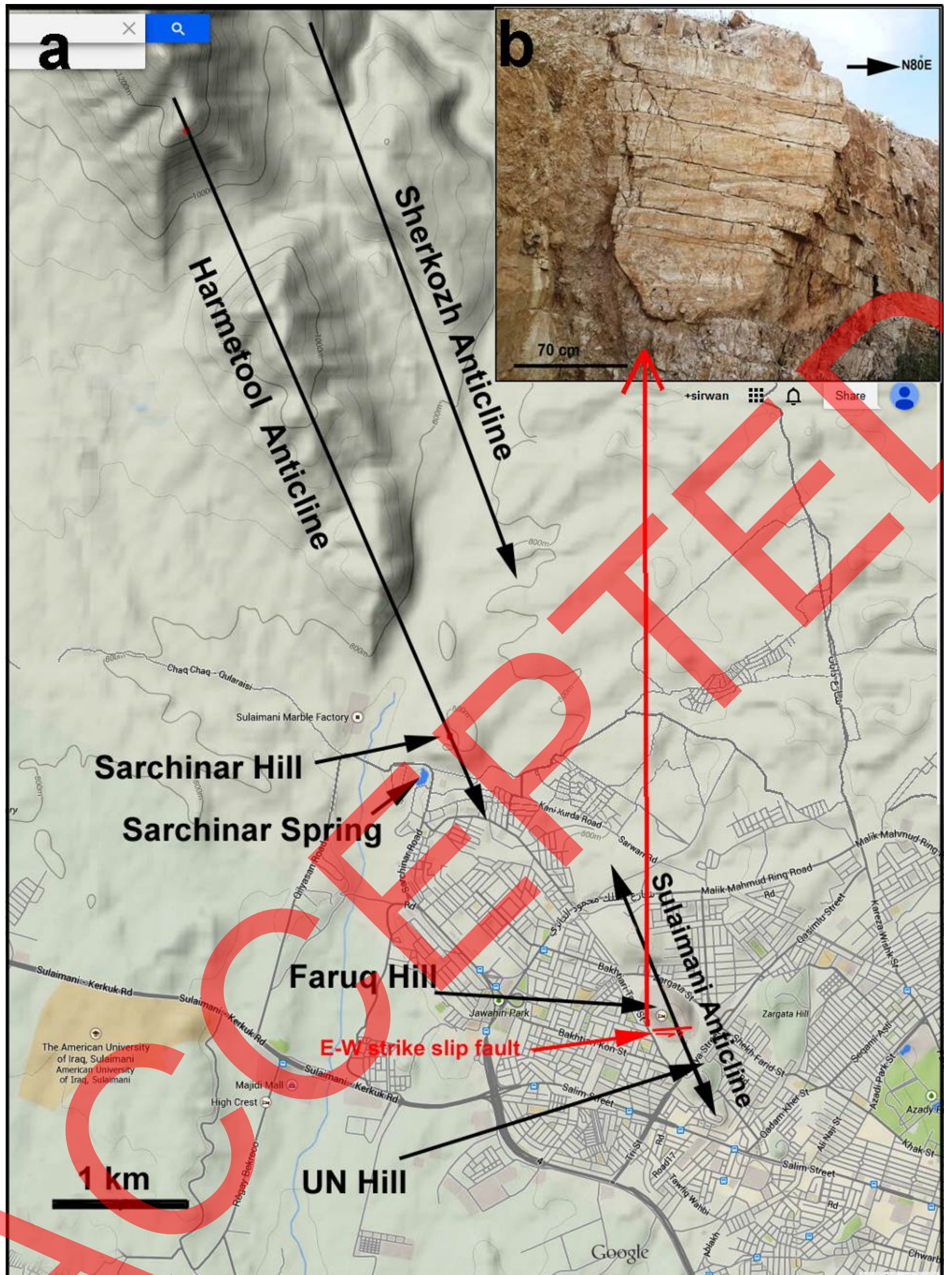


Figure (14) a) Topographic map of western part of Sulaimani city (From Google Earth) shows the anticlines. (b) Strike slip fault between the UN and Faruq hills

3. Conclusion

1-The equivalents of the Dokan and Gulneri Formations are found in the studied area for the first time in the studied area.

2-The unconformities below and above Kometan Formation were not found.

3-The age of the Gulneri Formation is Late Cenomanian-Early Turonain

4-A new and updated geological map is drawn for the area on which all the formations are differentiated.

5-The most realistic structural analysis of the area is shown on which new folds and fault is recorded for the first time.

6- The folds of the area consist of detachment anticlines and synclines and detachment was occurred on marls of the Gulneri, Sarmord Formation and other older rocks.
7- The main faults are reverse faults
8-The probable reason for absence of oil is intense refolding and squeezing of the core of the anticline by detachment folding.

Acknowledgment

The authors thank Dr Ramona Balc (ramona.balc@ubbcluj.ro) for her nannofossil analysis and age determination

4. References

Al-Hakari SHS (2011). Geometric Analysis and Structural Evolution of NW Sulaimani Area, Kurdistan Region, Iraq. Unpublished PhD Thesis University of Sulaimani.

Al-Kubaysi, K. N. (2008). Biostratigraphy of Aqra, Tanjero and Shiranishs Formation in Chwarta Area, Sulaimanyah Governorate, NE-Iraq. Iraqi Bulletin of Geology and Mining, Vol.4, No. 5.p.`-23.

Al-Qayim B, Omer, A, Koyi H (2012) Tectonostratigraphic overview of the Zagros Suture Zone, Kurdistan Region, Northeast Iraq, GeoArabia, 17(4) :109-156

Aziz BK, Lawa FA, Said BM (2001) Sulaimani Seismic Swarm during spring 1999, NE Iraq. Journal of Zankoy Sulaimani. 4(1):87-100.

Buday T (1980) The Regional Geology of Iraq, Stratigraphy and paleogeography, Dar AL-Kuttib Publication House. University of Mosul, Iraq

Buday, T., and Jassim, S.Z., (1987). "The Regional geology of Iraq, Tectonism Magmatism, and Metamorphism". I.I. Kassab and M.J. Abbas (Eds), Baghdad.

Jassim SZ, Goff T (2006) Phanerozoic development of the northern Arabian Plate, In: Jassim SZ and Goff JC Geology of Iraq, publication of Dolin, Prague and Moravian Museum, Brno.

Karim KH, Ahmad SH (2014) Structural analysis of the Azmir–Goizha anticline, north and northeast of Sulaimani city, Kurdistan Region, Northeast Iraq, Journal of Zankoy Sulaimani–Part A.16 (1):11-25.

Karim KH, Ameen BM (2009) Facies Analysis of Early Cretaceous Arabian Platform from Northeastern Iraq, Kurdistan Region, GERMENA III.

Karim KH, Salih AO, Ahmad, SH (2013) Stratigraphic Analysis of Azmir-Goizha anticline by Nannofossils. Journal of Zankoy Sulaimain (JZS), Part A, 15(2):103-124.

Karim KH, Taha ZA (2009) Tectonical history of Arabian platform during Late Cretaceous An example from Kurdistan region, NE Iraq. Iranian Journal of Earth Sciences 1 (1): 1-14

Karim KH (2004) Basin analysis of Tanjero Formation in Sulaimanyia area, NE-Iraq, Ph.D. thesis, University of Sulaimaniyai, 135 p.

Karim KH and Khanaqa PA (2014) Association of rudists and red clastic facies in the upper part of Aqra Formation, Mawat area, Kurdistan Region, NE Iraq. Arabian Journal of Geosciences. Volume 8, Issue 5, pp. 2751-2759

Karim KH and Khanaqa, PA (2014) Association of rudists and red clastic facies in the upper part of Aqra Formation, Mawat area, Kurdistan Region, NE Iraq. Arabian Journal of Geosciences. Volume 8, Issue 5, p. 2751-2759.

Lawa FA, Koyi H, Ibrahim A (2013) Tectono-stratigraphic evolution of the NW segment of the Zagros fold-thrust Belt, Kurdistan, NE Iraq. Journal of Petroleum Geology 36 (1): 75–96

Ma,ala KA, (2008) Geological map of the Sulaimaniyah Quadrangle, sheet N1-38-3, scale 1:20000, GEOSURV, Baghdad.

Omar AA, Lawa FA, Sulaiman SH (2015) Tectonostratigraphic and structural imprints from balanced sections across the north-western Zagros fold-thrust belt, Kurdistan Region, NE Iraq. Arab J Geosci, DOI 10.1007/s12517-014-1682-6.

Sacit (Sajit), O and Karim KH and Sadiq, D.M. (2013) First determination of rudists (bivalvia) from NE Iraq: Systematic palaeontology and palaeobiogeography. Bulletin of MTA, 147: 31-55. (Bulletin of the Mineral Research and Exploration of Turkey)

Sadiq D M (2010) Facies analysis of Aqra Formation in Chwarta-Mawat Area from Kurdistan Region, NE-Iraq. Unpublished MSc thesis, College of Science, University of Sulaimani.105p.

Sissakian VK (2000) Geological map of Iraq, sheet No.1- 3-307 rd edition, Geol. Surv. Min., Invest., Baghdad, Iraq.