**Iraqi National Journal of Earth Science**

www.earth.mosuljournals.com

# Record of the Equivalent of The Upper Bakhtiari (Bai Hassan) Formation in The Chwarta-Mawat Area Within Zagros Thrust Zone, Kurdistan Region, NE−Iraq

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**Article information**

**Received:** 22- Nov -2023

**Revised:** 25- Dec -2023

**Accepted:** 28- Jan -2024

**Available online:** 01- Jan – 2025

**Keywords**:
Bai Hassan Formation
Upper Bakhtiari Formation
Conglomerate
Chwarta area
Naopurdan Formation

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## ABSTRACT

This study is concerned with a thick succession of polymictic conglomerates which is exposed in the Chwarta, Mawat and Qandil areas inside the Imbricated and Thrust Zone. It is about 1500 m thick and comprises pebbles of boulders of chert, limestone and metamorphic rocks which was previously considered as unit three of the Red Bed Series of the Eocene age. This unit is located inside the trough of a deformed syncline (Chwarta-Mawat syncline) and the youngest succession in the area. The limestone boulders and gravels contain Nummulite and Alveolina of Middle Eocene which belong to the Naopurdan Formation. The limestone clasts of this conglomerate and those of the Upper Bakhtiari Formation (in the Chamchamal area) are compared with those outcrops of the Naopurdan Formation in the Thrust Zone. This comparison is achieved in the field and by thin sections under stereoscopic and polarized microscope showing the same degree of lithification, the content of fossils, fractures and faults in the three units. Therefore, depending on these features, and stratigraphic position, the present study concludes that the Upper Bakhtiari Formation occurs in the Chwarta, Mawat and Qandil areas. The fossil-bearing limestone clasts are derived from erosion of the outcrop of the Naopurdan Formation in the Thrust Zone in the north of Mawat and Chawrta towns. There is agreement that this formation was uplifted (with many older formations) in the Late Miocene- Pliocene and its erosion supplied fossiliferous limestone boulders and gravels to the basin of Upper Bakhtiari in the Thurst, Imbricate, High and Low Folded Zones. This study is the first study to prove (with evidence) the presence of the Upper Bakhtiari Formation inside the Imbricated and Thrust Zone in the Mawat-Chawrta and Qandil area in addtion to its outcrops of the formation in the Low Folded Zone.

DOI: 10.33899/earth.2024.144691.1178, 

# تسجيل ما يقابل تكوين البختياري الاعلى في منطقة جوارتا–ماوت ضمن نطاق اندفاعات زاجروس، اقليم كردستان، شمال شرقي العراق

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**معلومات الارشفة**

**تاريخ الاستلام:** 22– نوفمبر –2023

**تاريخ المراجعة:** 25– ديسمبر –2023

**تاريخ القبول:** 28– يناير –2024

**تاريخ النشر الالكتروني:** 01– يناير –2025

**الكلمات المفتاحية:**

تكوين باي حسن

تكوين البختياري الأعلى

الكونكلومريت

منطقة جوارتا

تكوين ناوبردان

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## الملخص

تهتم هذه الدراسة بسلسلة سميكة من مدملكات متعددة الحصوات والمكشوفة في منطقة جوارتا وماوات وقنديل داخل نطاقي الاندفاعات والتراكب. يبلغ سمكها حوالي 1500 متراً، وتتكون من حصى صخور الصوان والحجر الجيري والصخور المتحولة التي كانت تعتبر سابقًا الوحدة الثالثة من سلسلة الطبقات الحمراء التابعة للعصر الأيوسيني. تقع هذه الوحدة داخل قعر طية مقعرة مشوهة (طية مقعرة في جوارتا– ماوات) كاحدث تعاقب صخري في المنطقة. تحتوي جلاميد وحصى الحجر الجيري على فورامينفرا من نوع نيوميلايت وألفولينا تابعة للأيوسين الأوسط والتي تنتمي إلى تكوين ناوبردان. تمت مقارنة حصوات الحجر الجيري لهذه المدملكات وتلك الموجودة في تكوين بختياري الاعلى ( باي حسن) (في منطقة جمجمال) مع مكاشف تكوين ناوبوردان في منطقة الاندفاع. وقد تمت هذه المقارنة ميدانياً في الحقلّ وكذلك بواسطة المقاطع الرقيقة تحت المجهر المجسم والمستقطب والتي أظهرت نفس درجة التحجر ومحتوى الحفريات والكسور والفوالق في الوحدات الثلاث. وبناءً على هذه المعالم، استنتجت الدراسة الحالية إلى أن تكوين بختياري العلوي يوجد في مناطق جوارتا وماوات وسفوح جبال قنديل. تعود حصاة الحجر الجيري الحاملة للحفريات الى تعرية مكاشف تكوين ناوبوردان في منطقة الاندفاع في شمال مدينتي ماوات وجوارتا. هناك اتفاق على أن هذا التكوين قد ارتفع (مع العديد من التكوينات القديمة ) في أواخر العصر الميوسيني–البليوسيني، وقد أدت تعريته إلى تغذية حصى الحجر الجيري الأحفوري لحوض بختياري الاعلى في مناطق الطيات الواطئة والعالية والاندفاع و التراكب. تعتبر هذه الدراسة هي الأولى التي تثبت (بالدليل) وجود تكوين بختياري الاعلى داخل نطاق الاندفاع و التراكب في مناطق ماوات جوارتا وسفوح جبال قنديل اضافةً الى مكاشف التكوين في نطاق الطيات الواطئة.

DOI: 10.33899/earth.2024.144691.1178, 

## Introduction

Jassim and Goff (2006) mentioned that the Upper Miocene- Pliocene Upper Bakhtiari Formation (UBF) was defined first by Busk and Mayo in 1918 from Iran, and Bellen *et al.*, (1959) adopted the same term in Iraq too for the formation. The name of the Upper Bakhtiari Formation was changed in Iraq to Bai Hassan Formation by Al-Rawi *et al.*, (1993). Nevertheless, we prefer the old name due to its extensive use in literature by oil companies and academicians in addition to the absence of reasons for name changing. Buday (1980) cited that the formation mainly consists of a coarse and thick succession of conglomerates, produced from erosion of the uplifted mountain ranges and laid down in one or more sinking basins in front of the ranges. The studied outcrops of the formation, in the present study are composed almost of red terrestrial clastic sediments such as conglomerate, sand, silt, and claystones. The conglomerate is comprised of boulders, gravels, and granules of chert and limestone and metamorphic rocks. In general, the grain size of the clastics increases upward. According to Bellen *et al.*, (1959), the prevalence of the conglomerates in the upper part of the formation was the main reason for considering the (upper) part of Bakhtiari Group as an independent

formation. The main distribution of the UBF is in the Low Folded Zone which includes the areas around Kirkuk and Erbil towns in addition to areas around Kalar, Darbandikhan, Chamchamal, Taqtaq, Zakho and south of Aqra towns (Fig. 1).

There are two outcrops in the High-Folded Zone, the first is between Said Sadiq and Darbandikhan towns on both sides of the Darbandikhan Dam, whose lithology is like other outcrops of the Low-Folded Zone. The second one is very different from other outcrops since it consists exclusively of gavels and boulders of limestone (limestone conglomerate) which is found and studied by Karim and Taha (2012). This outcrop is located around Dokan reservoir at the foothill of Kosrat and Qara Sard anticlines.

The Upper Bakhtiari Formation has a gradational boundary with the Lower Bakhtiari Formation and starts with the first appearance of a thick conglomerate bed (Al-Musawi, 2008). The thickness of this formation is variable ranging 100- 1500 m and is located mainly in the Low folded Zones. According to Karim *et al.*, (2009), the direction of sediment transport (paleocurrent) of this conglomerate is towards the southwest. In addition to conglomerate, the Upper Bakhtiari Formation contains thick beds of claystone and sandstone in fining upward cycles.

The formation, as very thick polygenetic conglomerates, is an important stratigraphic unit of Iraq and Iran, yet it has not been studied sufficiently and only a few old studies are available about it. The present study aims to record the occurrence of UBF inside the Thrust and Imbricated Zones in Iraq for the first time depending on lithologic, stratigraphic, structural and paleontologic evidences. This record is significant for the tectonic and paleogeographic setting, in addition to the geologic mapping of the Iraqi Zagros Belt.

## Location and geology of the studied area

The area of the new outcrop of the UBF is located between Mawat and Chwarta towns north of the paved road that connects the two towns. The area is about 35 km far from Sulaimaniyah City (at northeast) in the boundary of Imbricated and Thrust Zones (Jassim and Goff) (Fig. 1). The area extends parallel to the northern bank of the Qalachwalan- Mawat stream and passes through villages such as Shamsawa, Wazha, Sinke, Kele, Dashti Tele and Zaynal (Fig. 2). The area is a part of the Zagros Orogenic Belt and located at northeastern Iraq, which is included in the outer part of Sanadaj-Sirjan Zone. The latitude and longitude of the western and eastern boundaries of the new main outcrop of Upper Bakhtiari Formation in the Mawat-Chwarta valley is 35º 51' 37.00" N, 45º 25' 52.51" E and 35º 41 ' 58.77" N and 45º 35' 09.44 "E.

In the above valley, the soft and young stratigraphic units are exposed; these units are Red Bed Series, Tanjero, Aqra and Shiranish formations, while to the south, the resistive limestone such as Kometan and Balambo formations occur in the Azmar, Goizha, Qaywan, Ahmad Romi and Shakha Rukhaw mountains. The outcrops of the Red Bed Series occupy the central part of the Chwarta-Mawat valley, and according to Al-Mehaidi (1975), it consists of four units: 1. Lower Red Beds, 2. Sandstone unit, 3. Conglomerate unit and 4. The Upper Red Beds. There is another new outcrop of the Upper Bakhtiari Formation in the Qandil mountain foothills located at 17 km north of Qaladiza town including the area around many villages such as Tutma, Suraglla, Basta and Sarkhan. Its central part is located at the latitude and longitude of 36º 20' 06.76" N, 45º 10' 21.78" E.

The present study concerns with unit three (the conglomerate unit) of the Red Bed Series, which is according to Al-Mehaidi (1975) about 1500 m thick and consists of poorly sorted polymictic conglomerate containing gravels and boulders of limestone, igneous and metamorphic rock fragments. This study tries to prove that the studied unit was deposited during the Upper Miocene-Pliocene and belongs to the Upper Bakhtiari Formation

## Materials and Methods

The present study depends on the field and laboratory works for three different areas in Sulaimanyiah Governorate using hand lens, polarizer and stereoscopic microscopes. The first area of the occurrence of the Upper Bakhtiari Formation is located in the Low Folded Zone, where the lithology of the formation is investigated to examine the type of gravels, boulders and their fossil types. In these clasts, it is focused on the age and types of fossils, the type of deformation that affected the clasts, in addition to determine the stratigraphic position. The significant clasts are those of the Naopurdan Formation, which contain Middle Eocene fossils and deformation features (fractures, micro-faults and veins) that can correlate the clasts with the other two areas. Although most of the outcrops of the UBF area were inspected; however, for a more detailed study, two sections are selected for sampling. One of them is located 10 km south of Chamchamal town and 1 km west of Qara Wais village on the southern side of the road to Qadir Karam town. The second section is situated inside Tuni Baba area, 5 km southwest of Darbandikhan town.

The second area is located inside the Imbricated and Thrust Zone which is indicated in the section of "location and geology of the area" of this study. A section is selected for sampling unit three of the Red Bed Series (present UBF) inside Mekukan Valley at 1 km northwest of Shamsawa Village (Fig. 2). The third area is the area of the outcrops of the Naopurdan Formation in the Thrust zone of Mawat, Chwarta and Penjween areas. In these areas, the outcrops are inspected to have similar fossils and deformations that are observed in the outcrops of the UBF and unit three of Red Bed Series to find spatial and temporal relations between them. From these three units (UBF, Red Bed Series and Naopurdan Formation), a total of 40 samples are collected for thin section studies of Naopurdan outcrops, UBF in the Chamchamal and Mawat-Chwarta areas (Fig. 1).

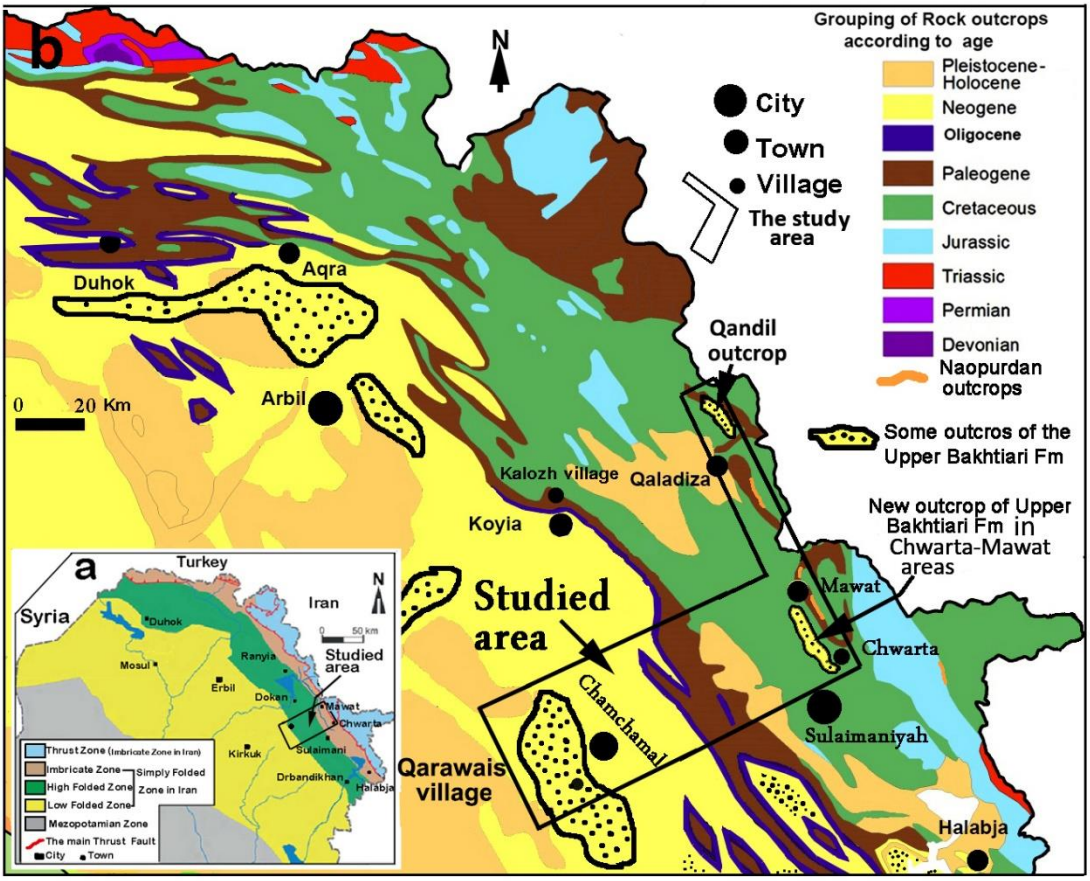


**Fig. 1. (a) Tectonic map of Northern Iraq (Jassim and Goff, 2006), (b) simplified geological map of northeastern Iraq showing the studied area (Modified from Sissakian, 2000).**

# Results

## Unit three of Red Bed Series (conglomerate unit)

This unit occurs in the Chwarta-Mawat area and foothill of the Qandil Mountain, 17 km north of Qaladiza town (Fig. 1). This unit is described by Al-Mehaidi (1975) as unit three of the Red Bed Series (or Swais Red Beds) of Lower Miocene. While Bolton (1958; in Buday, 1980) included the same unit in the Swais Red Bed and referred to as a deposit of Middle Eocene age. Al-Barzinjy (2005) considered it as unit five of the series of Upper Eocene age. In the Chwarta-Mawat area, this unit is comprised of a thick succession of polymictic conglomerates and is located between the Imbricated and Thrust Zones of Jassim and Goff (2006) and is about 1500 m thick. The best outcrop of the formation is exposed directly south of the Chwarta town at 200 m north of Qalachwalan village. This conglomerate comprises pebbles and boulders of chert, limestone and metamorphic rocks, and is located inside the trough of a deformed syncline (Chwarta-Mawat syncline) and unit three is the youngest succession in the area. The conglomerate is massive and faintly bedded and dipping 25 degrees toward the northeast (Fig. 2a).

The boulders and gravels of limestone contain Nummulite and Alveolina foraminiferas of Middle Eocene which belongs to the Naopurdan Formation (Fig. 3). The deformation of the clasts includes two types, the first is brittle which includes fracturing, dissolution and faulting, whereas the fractures are filled with secondary calcite forming macro and microscopic veins (Fig. 3a). These deformations have mostly affected the shells of Alveolina which has non-crystalline micritic limestone structure, while the shells of Nummulite and other fossils have crystalline calcitic structures that are more resistive to stress (Fig. 2b). The second type of deformation is the ductile deformation which includes bending (folding) of Nummulite (Fig. 4c and d). The same fossils and deformation are present also in the pebbles and boulders of the Qandil mountain toe that was studied previously by Ghafor and Qadir (2009).

Bolton (1958) considered the sediments of unit three of talus, deltaic and fluviatile deposits. Al-Barzinjy (2005) mentioned the absence of the relation of this unit with another unit of the Red Bed Series. He added that the dip of the conglomeratic layers is less than the dip of the other units of the Red Bed Series which is 20 degrees, while the dip of other units reaches 30 degrees. He further added that it has no stratigraphic relation with other units of the series and he asked for an assignment of it as a formation and he named it “Chwarta Conglomerate”. Al-Omari and Sadiq (1977) recorded fossiliferous pebbles and boulders in the UBF and returned them to the Naopurdan Formation, so they considered its age to be younger than the Eocene.


**Fig. 2. (a) An outcrop of the UBF in Chwarta area 1 km northwest of Shamsawa village inside Mekukan valley. b) A pebble of the formation showing deformation (fractured Nummulites)**

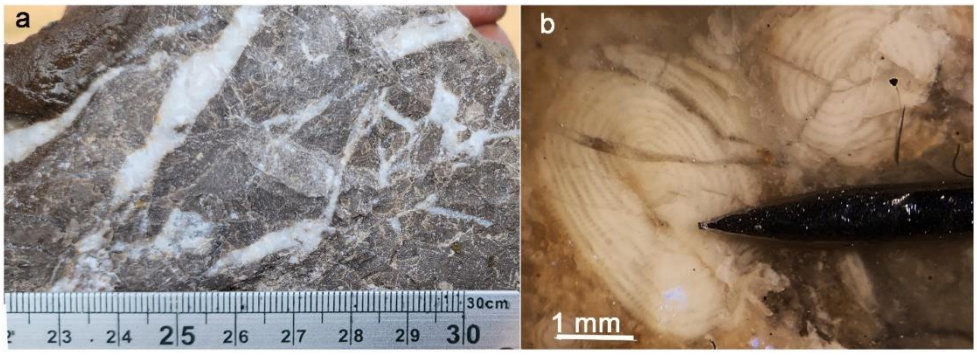


**Fig. 3. (a) A surface of a broken boulder of the UBF in the Chwarta area showing fractures filled with calcite, (b) the same type of deformation inside a pebble of the latter formation showing fractured Alveolina.**

## Outcrops of Naopurdan Formation

Naopurdan Formation (Middle Eocene) was first described as a group by Bolton (1958) and Buday (1980) in the Soran area near Naoperdan village 2 km south of the Choman town. Recently, many articles have been published and changed its stratigraphic status to formation. They indicated the formation at the top of the Walash Formation (Paleocene); these articles are such as given by Karim and Al-Bidry (2020), Karim and Ghafur (2021), Karim (2021) and Karim and Hamza (2022 and 2023). They concluded that the formation (with Walash Formation) was deposited in the Zagros foreland basin and is similar to Kolosh and Sinjar formations (in the high Folded Zone) concerning stratigraphic properties, age (nearly), lithologies, basin, and source areas. They mentioned that the reason for previously considering the formation as a group was due to the tectonic repetition of several parts which complicated its outcrop, especially in its type locality around the Choman Town.

Now, the outcrops of the formation are widespread in the Thrust Zone of Mawat, Penjween, and Bulfat areas. In their depositional areas, the formation consists of fossiliferous reefal limestone and contains forams, coral and algae (Fig. 4a). The outcrops show the same fossils and deformations that are present in the pebbles of the conglomerate of unit three of the Red Bed Series (present UBF) (Fig. 4b, c, d) and those of UBF in Low Folded Zone. Contrary to the foreland basin of the latter four articles, many authors considered and modeled the Naopurdan Formation (Group) as sediment of the Island arc of oceanic setting. The authors that believe in the oceanic setting are Numan (1997, 2000) (Fig. 5 a), Ali *et al.,* (2013) (Fig.5 b), Aswad *et al.,* (2016), Ali *et al.,* (2017), while the present study strongly aids the foreland basin setting of the Naopurdan and Walash formations.


**Fig. 4. (a) Outcrop of Naopurdan Formation on the Zaynal Mountain south Amadin Village. (b) deformation inside a sample of the latter formation showing fractured Alveolina. (c and d) A surface of a**

**broken boulder of the UBF in the Chwarta area shows faulted, fractured and bent (folded) Nummulites; the fractures are filled with calcite (forming veins).**

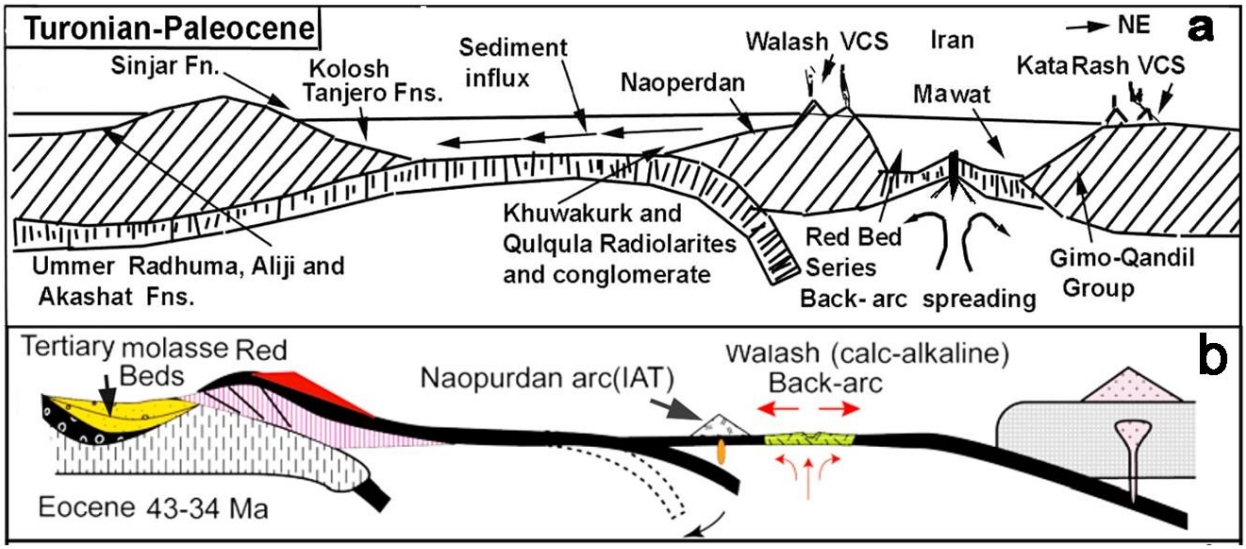


**Fig. 5. Tectonic and depositional settings (on a volcanic arc) of the Naopurdan Formation by (a) Numan (1997) and (b) Ali *et., al.* (2013). The present study considers a foreland basin as a basin and tectonic setting of the formation.**

## Upper Bakhtiari (Bai Hassan) Formation (Late Miocene-Pliocene)

The main outcrops of the Upper Bakhtiari Formation (Bai Hassan Formation) are distributed in the Low Folded Zone of the Sulaimaniyia, Erbil, Kirkuk and Duhok Governorates. The present study investigates the formation in some selected outcrops in the later zones in Chamchamal, Qadir Karam, Darbandikan, Haibat Sultan, and Taqtaq areas. This investigation focuses on finding similarities and differences between the UBF and unit three of the Red Bed Series.

In these areas, UBF is comprised of polymictic conglomerate and consists mainly of cobbles and pebbles of limestone, variegated chert and foliated metamorphic rocks. These clasts show different degrees of roundness due to their stiffness, whereas the limestone and chert pebble shave well and moderate roundness due to more stiffness of chert than that limestone. The matrixes of the conglomerate are mainly sand, silt and carbonate cement materials. The limestone pebbles and cobbles contain nummulite and alveolina foraminifera of the middle Eocene (Figs. 6c, d and 7). The color of the conglomerate is brown to buff. However, in some cases, the conglomerate contains laminated lenticular grey coarse sandstone beds with thickness ranging from 10 to 70 cm and extending laterally to about 2 m (Fig. 7 b, c). These sandstone beds contain cobbles scattered erratically in lenses. Other places, the UBF rests on red claystone with a clear erosional surface and channelized form (Fig. 6b). In many horizons, the conglomerate of UBF contains imbricated bubbles indicating high energy of the flow of sediment transporting streams during Miocene-Pliocene (Fig.7 e).

Our field study in the Thrust Zone and office investigation reveals very close similarities between UBF and unit three of the Red Bed Series and manifested the possibility of the occurrence of the Upper Bakhtiari Formation in Chwarta and Qandil areas. This possibility is observed inside the Red Bed Series (its unit three), which contains the same fossils, deformation and type of clasts that are found inside the UBF in the Low Folded Zone. Furthermore, the outcrops of unit three of the Red Bed Series (in the Thrust Zone) and UBF (inside Low and High Folded Zones) occupy the trough of the synclines and they are the youngest stratigraphic units in these areas (Fig. 8). Recently, Karim (2023) concluded that the Chwarta-Mawat valley is a syncline too and our observation manifested that the unit three of the Red Bed Series (present UBF) is cropped out in this syncline (Fig. 9). Inside this Chwarta -Mawat syncline, Shiranish Tanjero, Aqra, and Kolosh formations are cropped out in addition to Red Bed Series.

The southeast and northwest plunges of this syncline are located southeast of Chwarta town (near Harmn village) and inside Shinke village respectively. Therefore, its stratigraphic position lithology, structure, fossil content (inside the pebbles), level of lithification (stiff) and types of the deformation of pebbles are like those of UBF of Chwarta-Mawat area (unit three of the Red Bed Series) (Fig.6c, d). The only differences between the latter two units are the small caliber and more roundness of the clasts in the Low Folded Zone due to more distant transportation as compared to the Bakhtiari of the Chwarta area. Therefore, unit three of the Red Bed Series in the Thrust and Imbricate Zones is considered in this study as an outcrop of the Upper Bakhtiari Formation and correlated in the drawn stratigraphic column of the studied area (Fig. 8).

Its provenance is located inside the Iraqi and Iranian Sandandaj-Sirjan Zone such as Chwarta-Mawat, Penjween, Haji Omran areas. It is possible that during the Upper Miocene-Pliocene stratigraphic units of the High Folded Zone, there was no exposure to be eroded since pebbles and boulders of Sinjar, Qamchuqa and Kometan Formations are not observed inside UBF. There is an exception in Dokan area, where Karim and Taha (2012) found pebbles of the Qamchuqa Formation inside a limestone conglomerate (Dokan conglomerate), which was considered UBF by the latter authors.

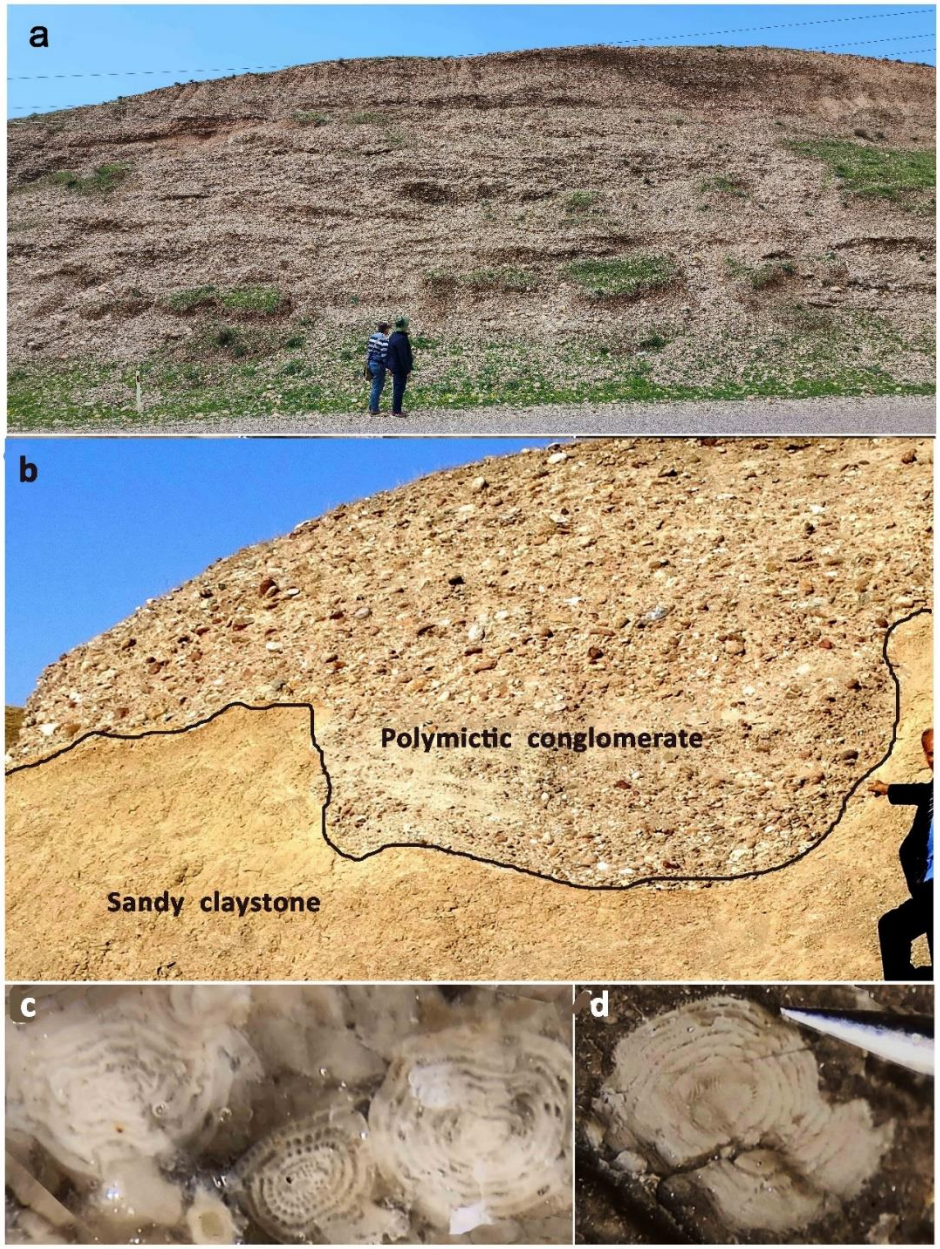


**Fig. 6. (a) An Outcrop section (the sampled section) of the UBF at 10 km south of Chamchamal town and 1 km west of Qara Wais Village, on the southern side of the road to Qadir Karam town. (b) channelized**

**conglomerate of the UBF in Chamchamal area near Qadir Karam Town. (c, d) deformed *Alveolinids* in the UBF in the latter section.**


**Fig. 7. (a) An outcrop section (another sampled section) of the UBF in the Tuni Baba area, 4 km southwest of Darbandikhan Town. (b, c) channelized lenticular sandstone bed inside the conglomerate of UBF latter area inside Low Folded Zone. (d) Imbricated pebbles in the above the conglomerate and area. (e) *Alveolina* and Nummulite in pebbles of limestone (belong to Naopurdan Formation). of the UBF conglomerate in Tuni Baba area.**

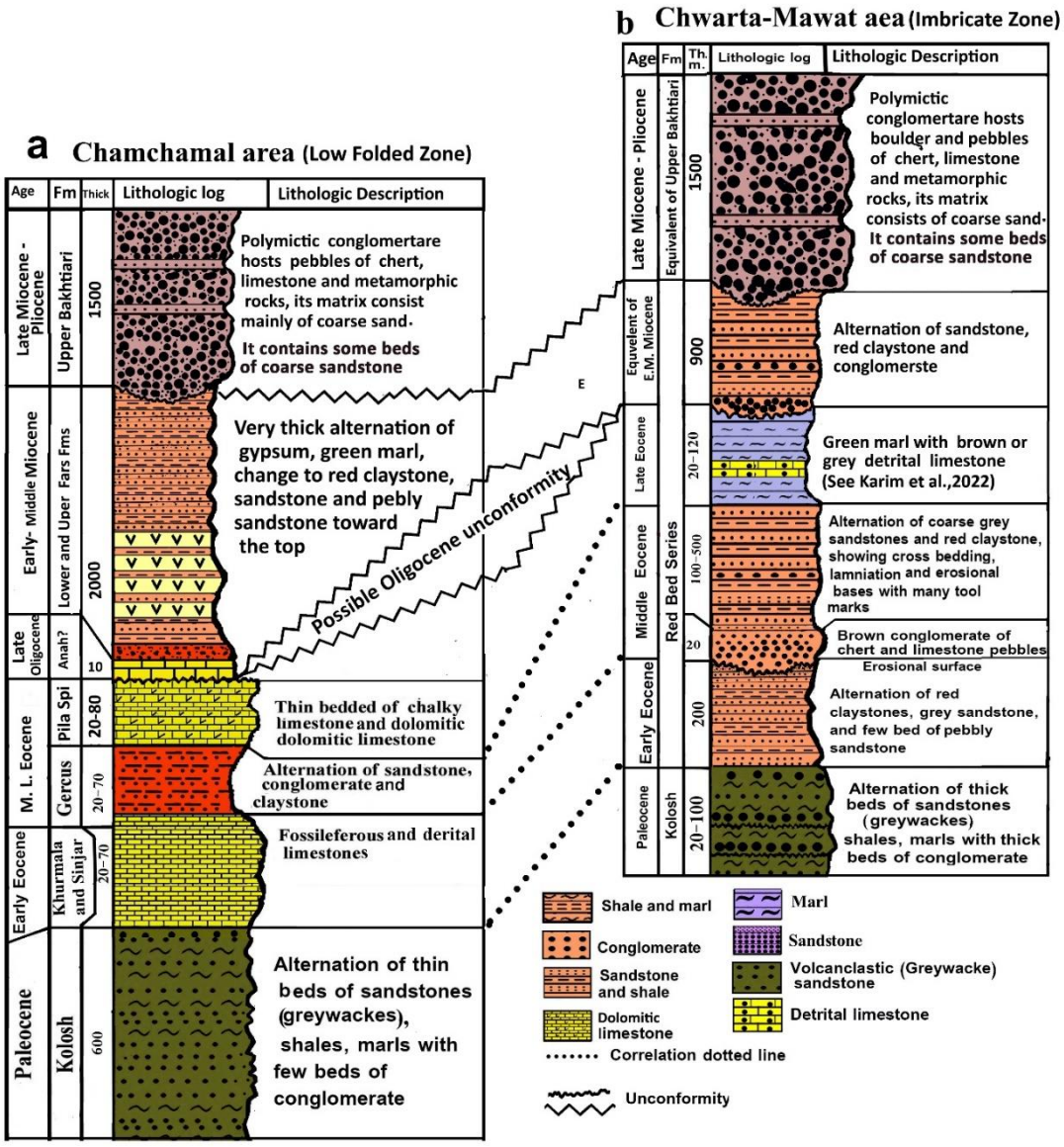


**Fig. 8. Stratigraphic columns of the studied area depicting the occurrence of UBF in: (a) the Low Folded Zone of Chamchamal area, (b) the Imbricated Zone of Chwarta-Mawat area**

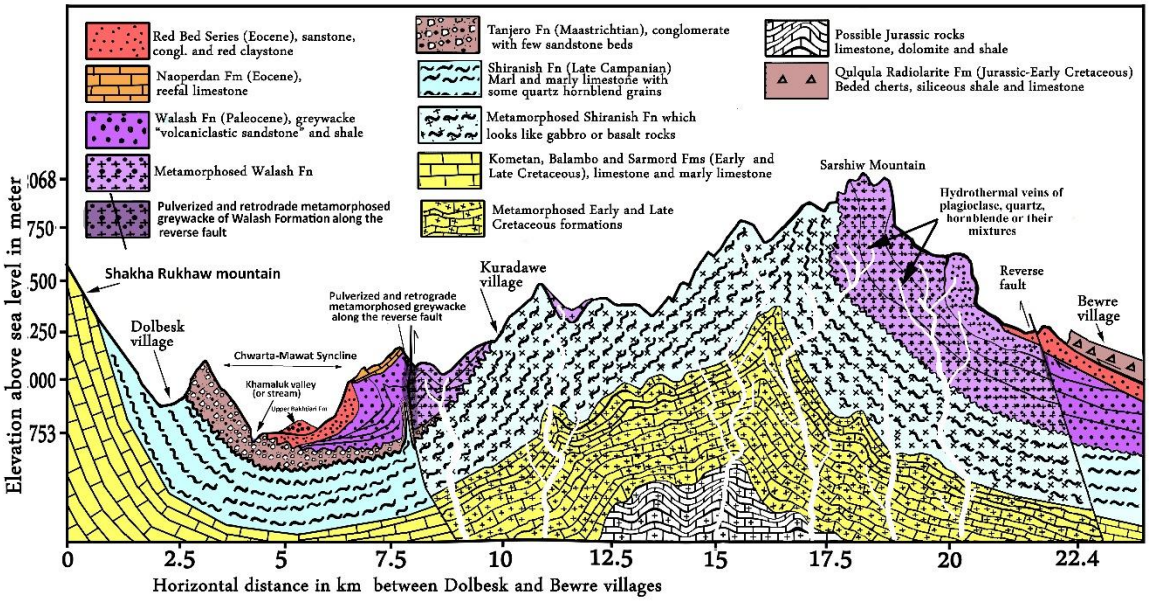


**Fig. 9. A Cross section of Chwarta -Mawat area showing a syncline in which the Upper Bakhtiari Formation deposited.**

## Discussion

There are two main phases of the uplift and conglomerate deposition, which are widespread in Iraq, Iran and Turkey. The first one was deposited during Maastrichtian as proximal facies of the Tanjero Formation and consists of chert and limestone pebbles of Avroman and Qulqula Radiolarian Formation. This conglomerate is about 300 m thick and crops out near the Iraq-Iran borders in Chwarta, Mawat, Bulfat, Qandil and Soran areas. Karim (2004) and Karim and Surdashy (2005) called it (Kato conglomerate) and attributed its deposition to the closing of the Neotethys Ocean and the continental colliding of the Iranian and Arabian plates, by which the Zagros Foreland Basin was developed.

The second phase is the deposition of the conglomerate of the UBF during Late Miocene-Pliocene, and this conglomerate nearly has a similar thickness and caliber to the conglomerate of the Maastrichtian. The only differences between the two conglomerates are the hosting of pebbles of the metamorphic rocks and the Tertiary pebbles of the Naopurdan Formation in the UBF. The reason for the deposition of UBF conglomerate and the uplifting of its source area is not yet certain. Al-Mehaidi (1975) referred a possible contribution to the Mawat Nappe movement, while recently Karim and Al-Bidry (2020) ascribed its deposition to the uplift of the Metamorphic Core Complexes of the Iraqi Sanandaj-Sirjan Zone including Bulfat, Mawat, and Penjween areas. The age of this uplift is Upper Miocene-Pliocene, by which the Zagros Foreland basin had been closed and transformed into continental terrains. This uplift was the most intensive and extensive uplift in the history of the Zagros Orogenic Belt and most possibly resulted from the coalescing of the tectonic and epirogenic uplifts.

Lateef (1992) attributed the deposition of the UBF mainly to the stream regime that had enormous transporting kinetic energy and was characterized by and widespread mosaic of anastomizing-braid river systems. He added that this system had resulted in a huge deposition of channel lag (lateral accretion) deposits. English *et., al.* (2018) argued that the strata of the Bakhtiari Formation appeared to be highly folded in the front of the anticlines of the Iraqi Zagros Collisional Belt indicating that the main phase of deformation and here largely postdates the deposition of the Bakhtiari Formation. This argument agrees with the result of the present study which proved that the formation occurs in Thrust, Imbricated and Low Folded Zones (Fig. 10).

Pirouz (2018) considered the UBF as proximal wedge-top deposits consisting of two main lithofacies associations including shallow marine and fluvial deposits. He added that a considerable part of the Arabian plate of old foreland deposits, near the Zagros suture, had been removed at the northern edge by underthrusting and erosion. However, the finding of the UBF conglomerate in Thrust and Imbricated Zones in the present study neither aids proximal wedge-top deposits nor considerable removal of old sediment by underthrusting and erosion. The present study considers the conglomerate of the Maastrichtian Tanjero Formation (Kato Conglomerate) as a wedge-top deposit not the conglomerate of the UBF. Moreover, the UBF conglomerate is a deposit of vertical uplift of the Zagros belt as several Metamorphic Core complexes via high-angle reverse faults (Fig. 9 as an example).

Therefore, the conglomerate of the UBF deserves more studies to resolve the tectonic scenario associated with its deposition and provenance. The deposition of the UBF in the Chwarta-Mawat area uncovers new facts about the paleogeography of the Zagros belt during the Upper Miocene and Pliocene. During these ages, the whole Zagros belt was controlled by one system of erosion and transportation, whereas there were no longitudinal compartments such as intermountain basins and barriers (paleo highs) in front of sediment transport. The sediment was carried from the uplifted interior of the Sanadaj-Sirjan Zone by streams and bypassed freely long distances to the site of deposition. In Iraq, this bypass included the present Thrust, Imbricated, High Folded Zones and mainly deposited in the Low Folded Zone (Figs. 1 and 10). Along its transport to the Low Folded Zone, the UBF was deposited whenever the river

energy decreased and some accommodations were available such as Chwarta-Mawat and Qandil areas.

The sediment of the UBF in the Chwarta-Mawat area may be the youngest part of the formation of Pliocene which was most possibly deposited inside a recently shaped syncline of the Chwarta-Mawat area as an area of accommodation (Fig. 10). Now the eastern plunge of this anticline is observable at the southeast of Chwarta town as a wide curve shaped by the conglomerate of the Tanjero Formation along Kani Sard, Dola Tu, Suerala, Sherawezha, Plinga and Khumana villages. In addition to the Chwarta-Mawat area, there is evidence that the UBF conglomerate is present in other places in the Thrust Zone. In this Zone, Koshnaw *et., al.* (2019) recorded the age of 26 Ma (Middle Oligocene) of detrital zircons at the base of the Red Bed Series in the Thrust Zone of Erbil Governorate. According to our estimate, this age is not the age of the deposition but the age of crystallization of the zircon in the deep crust burial. After this burial, its uplift, erosion and deposition needed considerable time. Therefore, most possibly, the aged section of the claim Red Bed Series belongs to the UBF. There is another study that indirectly aids the occurrence of the UBF in the Chwarta-Mawat area, which is the study of Karim *et al.*, (2022) who recently studied a middle part of the Red Bed Series in the latter area and proved that its age is Upper Eocene. This part is located below unit three of the Red Bed Series (UBF of the present study) and there is about 200 m of clastic sediment between the latter two units.

Another place for the presence of UBF is the Qandil mountain toe, north of the Qaladiza town inside the Thrust Zone, where Ghafor and Qadir (2009) studied an assemblage of larger foraminifera such as Alveolinidae, Soritidae and Nummulitidae inside pebbles of the conglomerate of the Red Bed Series in the area (Fig. 11). They concluded Paleocene-Middle Eocene age for the studied foraminifera assemblage but they were not sure about the depositional age of the conglomerate of the Red Bed Series but they mentioned possible Late Eocene age of the deposition. The interpretation of the current study is that the deposition of this conglomerate belongs to the age of Late Miocene-Pliocene due to two facts. The first is hosting of the same fossils, degree of lithification, and deformations as the conglomerate of the Chwarta and Chamchamal area. The second is the absence of these fossils and deformations in all conglomerates that are older than the Late Miocene and exposed in the Low and High Folded Zones. These older conglomerates are inspected in two stratigragraphic postions in the field. The first is conglomerate is located inside the top of the Gercus Formation (Middle Eocene) in the Haibat Sultan, Darbandikhan, Deleza areas (Fig. 12). The second is the Late Oligocene conglomerate at top of the Pila Spi Formation and exposed near the boundary between the above two zones (Fig. 13). These Eocene and Oligocene conglomerates are very different from the conglomerate of the UBF in Thrust, Imbricated, High and Low Folded zones in all aspects and they contain chert and limestone pebbles derived from Avroman and Qulqula Radiolarian Formation (Figs. 12 and 13). The exception is the Oligocene conglomerate, which contains some limestone pebbles derived from the erosion of older Oligocene limestones.

In northern Iraq, the provenance of the UBF consists of uplifted Qulqula Radiolarian, Avroman, and Naopurdan formations in addition to metamorphic and igneous rocks. This provenance is different for the UBF in southern Iraq since Mahdi and Soltan (2021) studied the formation in the Teeb area and concluded that all gravels of the formation were derived from the Qulqula Radiolarian Formation and not mentioned gravels of igneous, metamorphic rocks. In their thin sections, they did not find any fossil of the Naopurdan Formation.

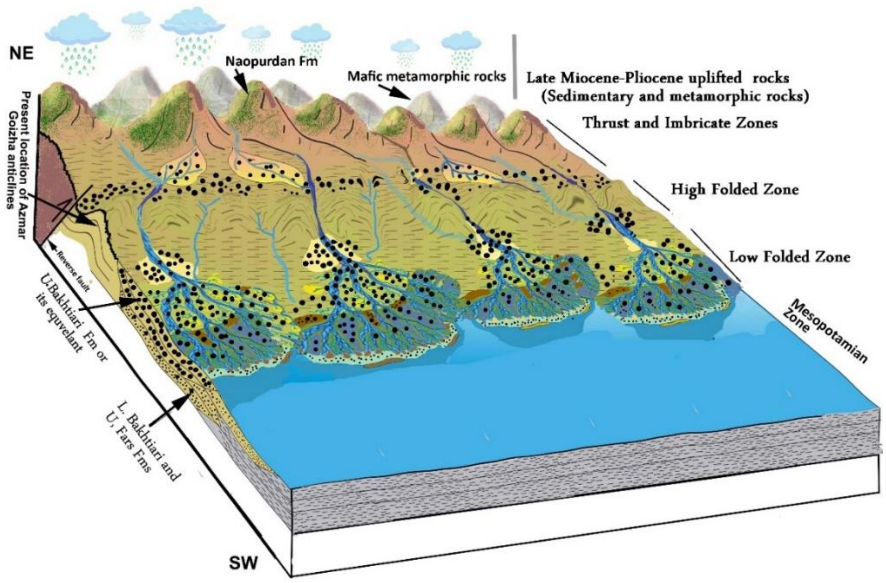


**Fig. 10. A depositional and tectonic model of the Upper Bakhtiari Formation showing its deposition in the Thrust Zone in addition to Low Folded Zone.**

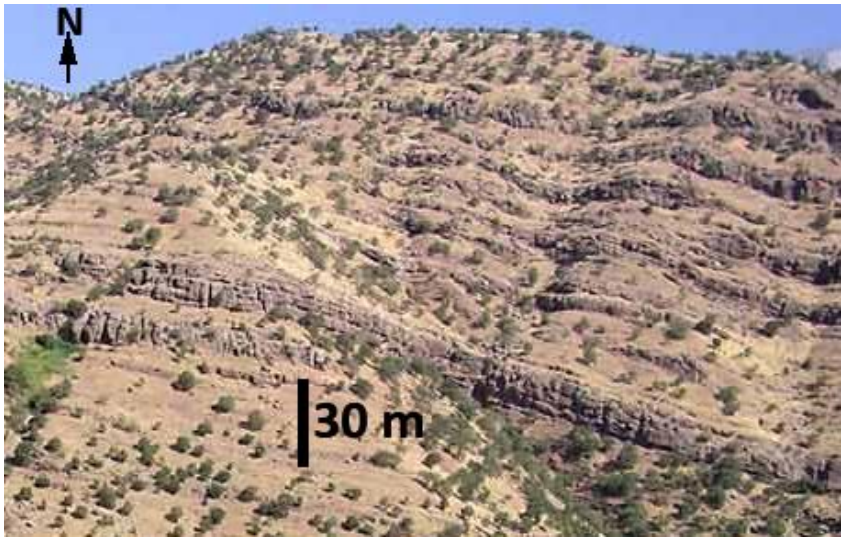


**Fig. 11. An outcrop of unit three of Red Bed Series (present UBF) at the Qandil mountain toe, 17 km north of Qaladiza Town, Qulqula Valley.**

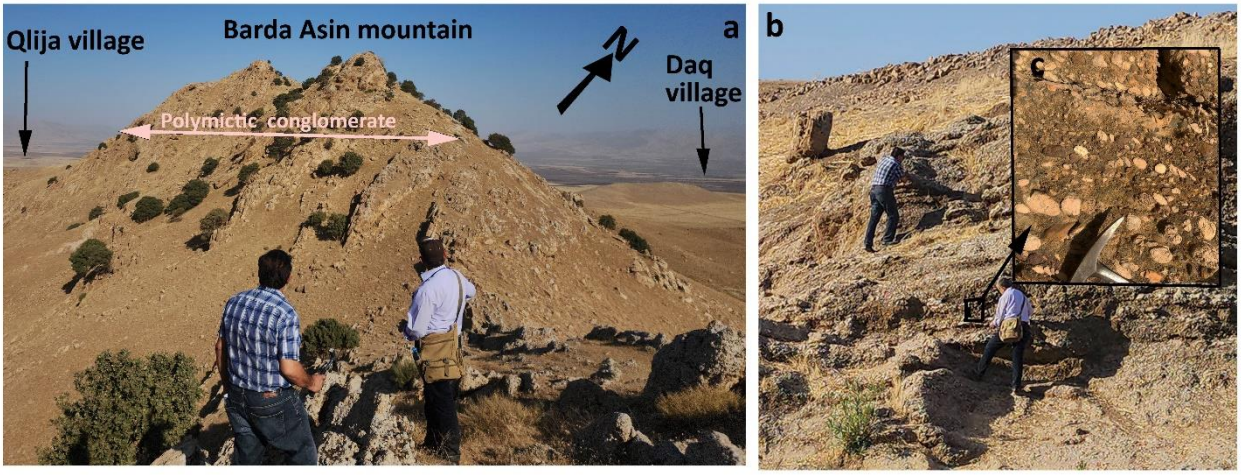


**Fig. 12. All conglomerates of northern Iraq are inspected to find their relation with Unit three of Red Bed Series (a) Middle-Late Eocene conglomerate (60 m thick) of Gercus Formation on the Barda Asin mountain at 10 km southeast of Zarayin town, the south boundary of the Sharazoor plain. (b) the same conglomerate near Qlija village, (c) a close view of the conglomerate showing imbricated pebbles.**

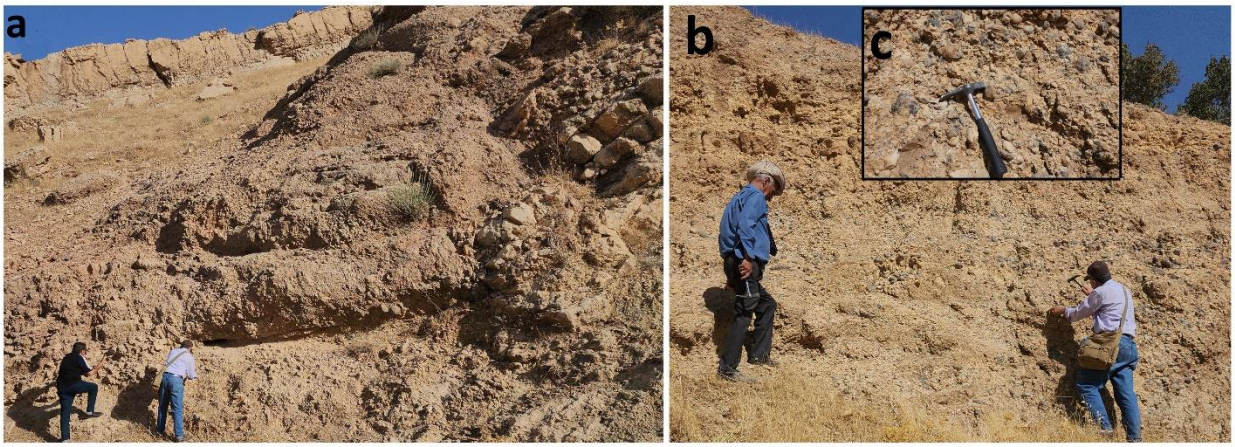


**Fig. 13. (a) Oligocene conglomerate at the outlet of the Basara Gorge southwest of Delezha village, (b) late Eocene conglomerate at the base of Pila Spi Formation between Khewata and DeleZha village, (c) Close view of the latter conglomerate.**

## Conclusions

In this study, for the first time, the occurrence of the Upper Bakhriari Formation is proved in the Chwarta, Mawat and Qandil mountains inside the Imbricated and Thrust Zone. It is about 900 m thick and comprising pebbles and boulders of chert, limestone and metamorphic rocks which were previously considered as unit three of the Red Bed Series of the Eocene age. This unit is located inside the trough of a deformed syncline and is the youngest succession in the area. The proof of the presence of the UBF in Chwarta area depends on the stratigraphic position, lithology, pebble deformation, and type of fossils in both Zones. The boulders and gravels of limestone contain Nummulite and Alveolina of the Middle Eocene, which belongs to the Naopurdan Formation. The limestone clasts of the formation in the above areas are compared with its normal occurrence in the Low Folded Zone and with outcrops of Naopurdan Formation in the Thrust Zone. This comparison is achieved in the field and by thin sections under stereoscopic and polarized microscopes, which shows the same degree of lithification, same fossil content, fractures and faults in the three units. Therefore, depending on these features and stratigraphic position, the present study concluded that the Upper Bakhtiari Formation occurs in the Chwarta, Mawat and Qandil areas. The fossil-bearing limestone clasts are derived from erosion of the outcrop of the Naopurdan Formation in the Thrust Zone in the north of Mawat, Chawrta and Qaladiza towns.

## Conflict of Interest

The authors have no conflict of interests

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