Geology of Iraq

University of Anbar- College of Science-

Applied Geology Department

3ad Class

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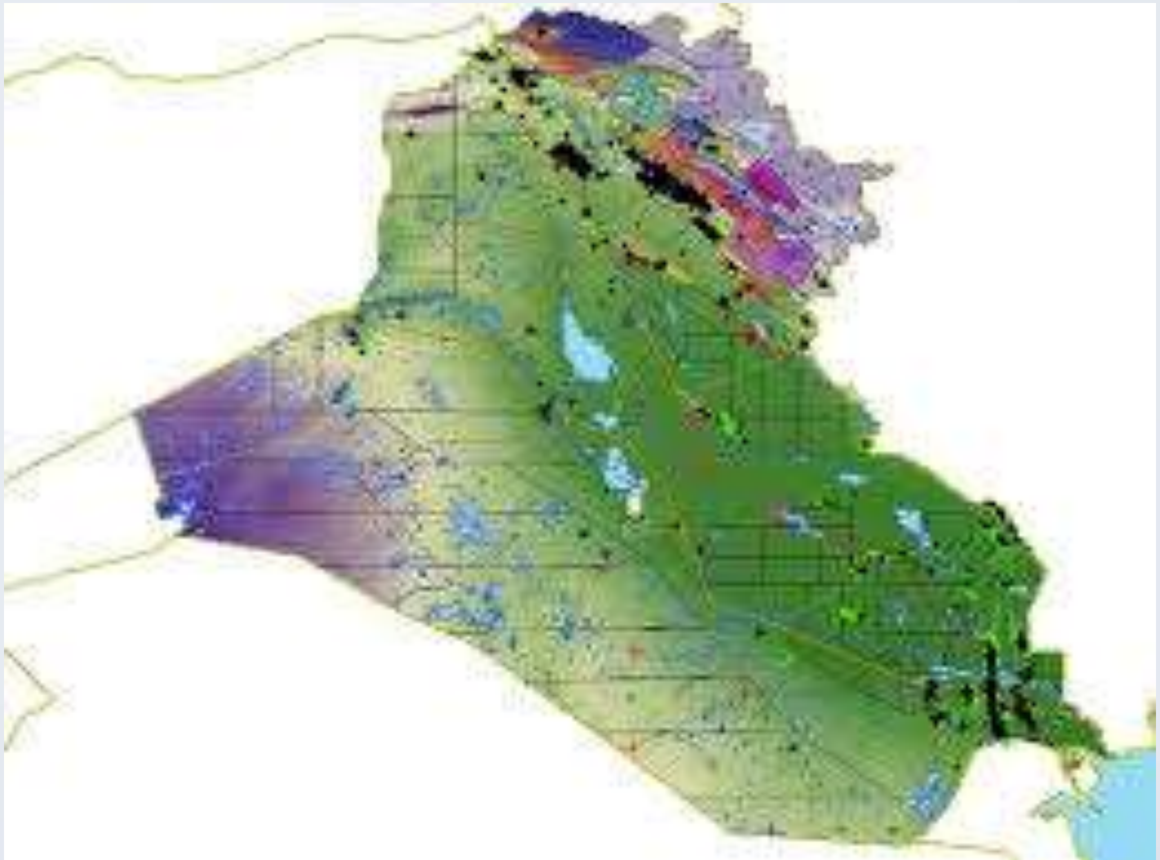
Reference of Presentation

Geology of Iraq

S.Z. Jassim & Goof , 2006



Surface geology

- The surface geology of Iraq roughly reflects it’s morphology.
- Generally, the youngest sediments (Quaternary and Neogene) lie within the central depression while the flanks expose older strata of Palaeogene to Palaeozoic age (Fig. 1-2).

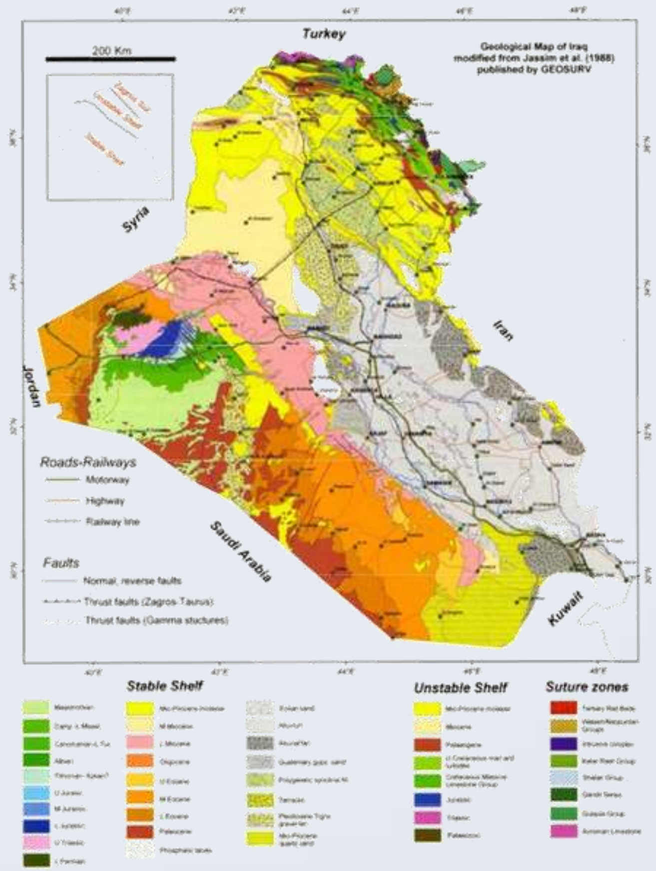


Fig. 1-2: Geological map (after GEOSURV Geological maps of Iraq)

- The geology of the ***desert area*** to the SW of the Euphrates River is generally characterized by NE-dipping strata.
- However, in W Iraq near Rutba Town the strata dip to the west away from the axis of a major ENE-WSW trending anticlinorium in which rocks as old as Permian outcrop (Fig. 1-2).
- The erosion of the crest of the anticlinorium has created the Ga'ara depression.
- The geology of the ***Mesopotamian depression*** is produced by a complex system of river channels, levees, flood plain, marshes, sabkha and deltas, bordered on both sides by alluvial fans.
- The ***Jezira area*** in NW Iraq is dominated by a massive uplift (Tayarat).

  -Middle Miocene sabkha deposits, exposed in the core of the uplift, are flanked in the E , N and W by Upper Miocene clastics.

  -To the south erosion by the Euphrates River has exposed Oligocene and Lower Miocene carbonates along tight anticlinal structures controlled by E- W faults.

- The ***foothills*** NE of the Mesopotamian depression;
- comprise narrow (roughly 5-10 km wide) anticlines;
- Upper Miocene to Pleistocene molasse sediments or Middle Miocene evaporites are exposed in their cores.
- Some higher amplitude anticlines within the zone such as Sinjar and Qara Chauq have exposures of Palaeogene and locally Upper Cretaceous formations in their cores.
- The foothill anticlines are usually asymmetrical towards the SW and are often associated with decollement thrust faults (controlled by Middle Miocene evaporites) in the area south of the Lesser Zab River (Fig. 1-2).

The mountainous region to the NE of Kirkuk is characterised by :-

- *-harmonic folds. Cretaceous or older rocks are exposed in their cores; Palaeogene and Neogene rocks form the adjacent synclines.*
- *-The amplitude of the folds increases towards the NE until the anticlines override each other due to thrusting with elimination of the intervening synclines.*
- *In N Iraq along the Turkish border, Palaeozoic to Cretaceous rocks are exposed in the cores of tight anticlines bounded by thrust faults.*
- *Along the Iranian border there are thrust sheets of sedimentary and igneous rocks which where formed in the Neo- Tethyan oceanic domain.*

Fault Systems

- *The three major fault systems in Iraq are:-*

1- The N-S Nabitah (Idsas) System,

2- The NW-SE Najd System

3- The NE-SW or E-W Transversal System.

(***Five major transversal blocks are identified bounded by major transverse faults***).

- ***These fault systems formed during Late Precambrian Nabitah orogeny.***

Fig. 4-7: Distribution of faults and fault zones (see text for description of individual systems)

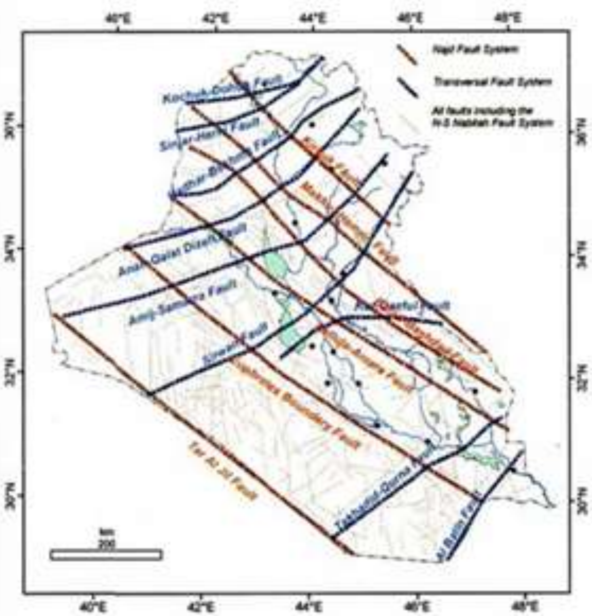
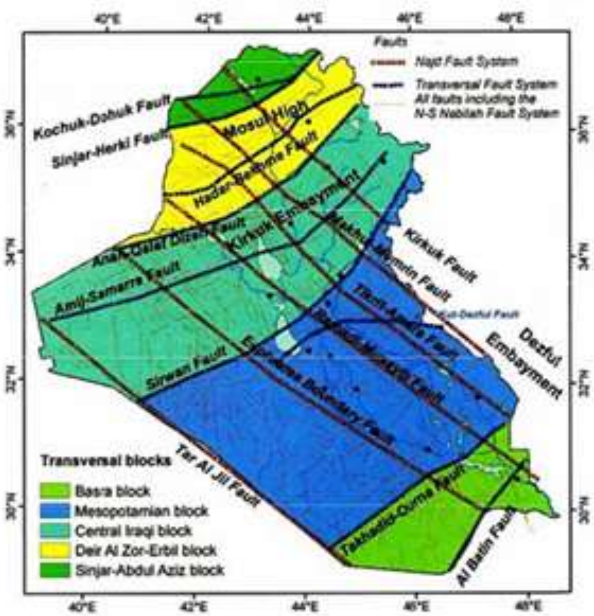


Fig. 4-8: Transversal blocks



Nabitah (1dsas) Fault System

- *The N-S trending Nabitah Fault System is prominent in(**S** and **W** Iraq).*
- *It affects the thickness of the Infracambrian and Palaeozoic sections .*
- ***The fault system resulted from E- W compression, which formed major N-S trending thrust anticlines and associated molasse -filled fore deep (collapse) basins during the Nabitah Collision(680-620 Ma).***
- *The system in Iraq has been mostly identified from gravity data and is most commonly observed in (SW, S and W Iraq and less commonly in NW Iraq.*
- ***The Nabitah System is older than the Najd system and originated around 680 Ma.***
- ***'Extension probably occurred along this trend to form the NS Infracambrian rift basins (Fig. 4-8A).***
- ***It was reactivated during the "Hercynian" events in Late Carboniferous time.***
- *Further **reactivation** of the Nabitah system occurred in the Late Cretaceous as indicated by depositional thinning and the presence of unconformities over some of the **N-S** trending structures of Kuwait and E Saudi Arabia.*
- ***Neotectonic movements may have occurred along some structures of this system, including the Abu Jir and Tharthar faults in central and N Iraq and the Nukhaib Graben in SW Iraq (Fig. 4-7).***

Q. WHAT ARE THE INDICATIONS of the reactivation of Nabitah system during late cretaceous?

2- Najd Fault System

- *The Najd Fault System is very significant in Iraq as it forms boundaries not only of the Precambrian terranes but also of the **tectonic zones**, especially in central, **E** and **NE** Iraq.*
- *The system developed in a sinistral transpressional shear zone during the Nabitah orogenesis .*
- *The Najd System originated as **a strike-slip faulting system** around 670 Ma and was associated with deep ductile deformation that resulted in the rise of gneiss domes .*
- *It later developed as an **extensional system** from 640 Ma to 530 Ma.*
- *Vertical movement along the Najd Fault System occurred during Jurassic to Quaternary time*

The following fault zones are related to the Najd Fault System;

1-The Tar Al Jil Fault Zone:-

runs along the Iraqi-Saudi border ,It is associated with an escarpment of Palaeocene strata, facing a depression to the SW filled in with Mio-Pliocene clastics and fresh water limestones.

-The fault has thus been active in Late Tertiary time. It continues into W Iraq, NE Jordan and SE Syria.

2-The Euphrates Boundary Fault Zone:-

*is one of the most prominent Najd fault zones. It runs along the Euphrates River in **S** Iraq and continues towards the Rutba area in **W** Iraq.*

*-In the **S** the fault zone comprises a series of step faults sometimes associated with grabens, and forms the boundary between the Quaternary Mesopotamian Plain and the rocky desert of SW Iraq.*

-It is associated with a large number of sulphur springs.

*-In **W** Iraq the fault zone was **reactivated** during Late Jurassic and Cretaceous time forming small fault bounded depressions filled in with fluvial sandstones.*

3-The Ramadi-Musaiyib Fault Zone;-

- *It controls the course of the Tigris River between Baghdad and Kut.*
- *It is associated with long NW-SE buried anticlines in S Iraq and controls the location of the buried W Baghdad structure.*
  - *It continues NW toward Anah in W Iraq to the point where the Euphrates River changes direction from E to SE.*
  - *The fault zone was probably active during the Mio-Pliocene time.*

4-The Tikrit-Amara Fault Zone :-

- *extends from the Jezira region in NW Iraq through Tikrit and Balad into Baghdad and Nahrawan.*
  - *It continues along the SE trending stretch of the Tigris River between Kut and Amara.*
  - *Major buried anticlines are located along this fault zone (**Rafidain, Nahrawan, E. Baghdad, Balad and Tikrit**).*
  - *Seismic and gravity data indicate that the zone is associated with a Late Cretaceous graben system .*

5-The Makhul-Hemrin Fault Zone:-

- *has a magnificent surface expression represented by **one of the longest anticlinal chains** in the Middle East that includes (Makhul in the NW, Hemrin North and Hemrin South in the Middle and Pesht-i-Kuh along the Iraq-Iran border in the SE).*
- *This fault zone may be the boundary between the Eastern Arabian and Zagros Precambrian terranes & also formed Boundary between the Stable and Unstable Shelf.*
- *Late Cretaceous **extension** may have occurred along this fault zone. It was strongly **reactivated** during the Pliocene and forms the SW boundary of the area affected by Late Tertiary folding.*
- *It is still active at the present day.*

6-The Kirkuk Fault Zone :-

- *is expressed on the surface by the 300 km long anticlinal range of Kirkuk and forms the boundary between two subzones of the Foothill Zone.*
- *It was active during the Plio-Pleistocene.*

3- Transversal Fault System and transversal blocks

The Transversal system includes two main trends;-

*A- The **easterly** trend which is more dominant in W & NW Iraq.*

*B-The **northeasterly** trend that dominates the E and N parts of Iraq.*

These two trends merge into each other to form arcuate faults.

- ***The Transversal systems may have formed in Late Precambrian times.***
- ***The Transversal System was reactivated from Late Jurassic times onwards resulting in the formation of transversal blocks.***
- ***Some faults of this system underwent sinistral strike slip movement in Quaternary time; at least 2 km of horizontal displacement has occurred along the Anah-Qalat Dizeh Fault at Al Fatha in the last few million years.***
- ***Many Foothill Zone anticlines are segmented into separate domes and their fold axes are bent at the intersections with transversal faults.***

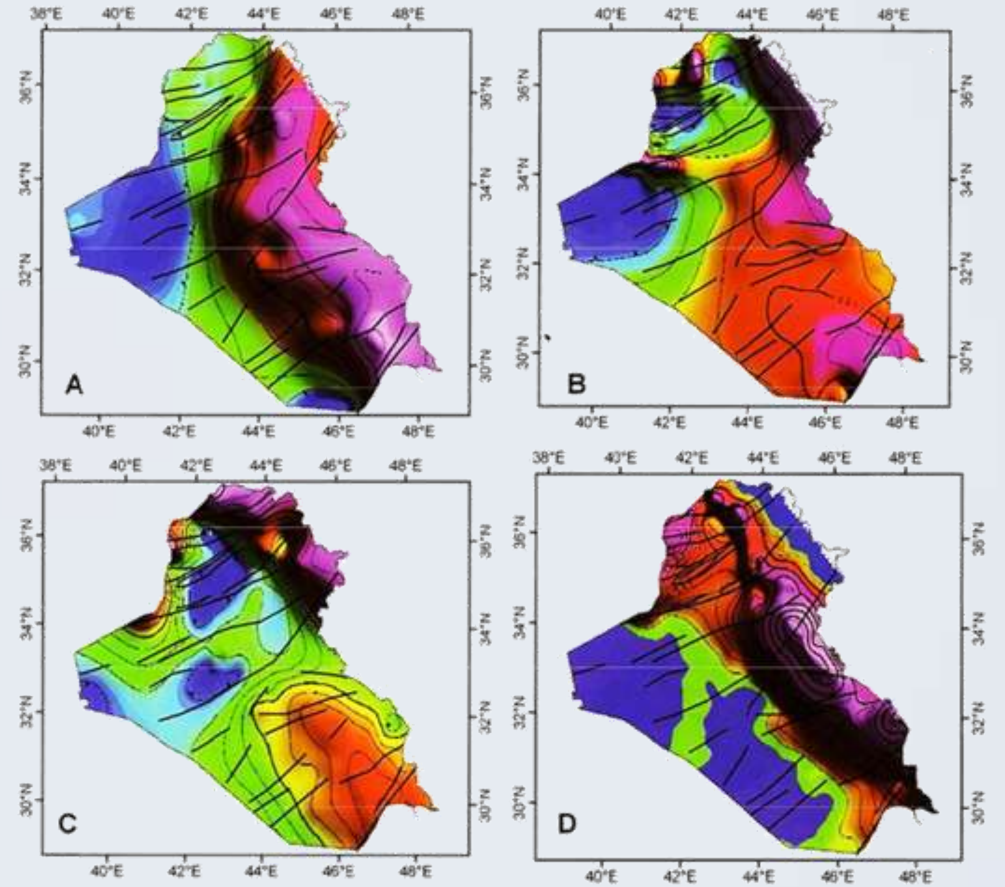
-The Transversal Fault System may represent old planes of weakness which controlled the position of transform faults active during Neo- Tethyan Ocean spreading, and during the opening of the Red Sea.

- ***This fault system extends from the Arabian Plate into the African plate.***
- ***The transversal faults influenced the thickness of the Jurassic to Neogene sequences.***

The system has been divided into major fault zones, starting from the south:

1-The Sirwan Fault Zone :-

- *runs along the Sirwan (Diyala) River in N Iraq.*
- *It extends into central and SW Iraq.*
- *It forms the SE limit of the Kirkuk Embayment.*
- *The Sirwan Fault forms the **N** boundary of the Mesopotamian Transversal Block (Fig. 4-8) whose **S** boundary is controlled by the Takhadid-Qurna fault.*
- *The Mesopotamian Block contains thick Cretaceous and Palaeogene sequences (Fig. 4-10 A, Band C) that thin to the NW of the Sirwan Fault.*
- *In NE Iraq the axis of the Cretaceous basins swings to the NE to the N of the Sirwan Fault.*
- *The Mesopotamian block is the largest Transversal Block with the deepest basement which dips uniformly to the NE.*



Isopach maps

A) Lower Cretaceous **B) Upper Cretaceous** **C) Palaeogene** **D) Neogene**

(Transversal fault system shown in black lines)

Fig. 4-10: Isopach maps with superimposed transversal faults for the Lower Cretaceous-Neogene. The colours indicate the relative thickness (purple/red is thick, blue is thin)

2-The Amij-Samarra Fault Zone :-

*- runs from the **W** towards central Iraq, just **N** of Samarra.*

3- The Anah-Qalat Dizeh Fault Zone ;-

- *is the most impressive transversal fault both morphologically and tectonically.*
- *It controls the course of the Euphrates River for a distance of over 100 km.*
- *The fault zone starts in **W** Iraq as a series of E- W trending step faults producing the so-called Anah Graben.*
- *They were active during the Late Cretaceous, producing a graben with over 2000 m of Upper Cretaceous sediments; on the adjacent footwall blocks the Upper Cretaceous section is less than 300 m thick.*
- *The **E- W** trending faults seem to continue into central Iraq but without significant displacement.*
- *They pass into a fault zone that intersects and displaces the Makhul-Hemrin range at Al Fatha.*
- ***Plio-Pleistocene tectonic activity in the Stable Shelf is indicated by monoclines along the southern fault of the Anah-Qalat Dizeh Fault zone**.*
- ***Neotectonic activity** is proven by several recorded earthquakes .*
- *The fault forms the **N** limit of the Kirkuk Embayment, the Central Iraqi Block (Fig. 4-8) and the **SE** boundary of the Mosul High.*

4-The Hadhar-Bakhme Fault Zone :-

- *starts in Syria and NW Iraq.*
- *Its strike changes from W-E to NE-SW towards the folded belt.*
- *It passes through Qaiyarah and runs along, and slightly S of, the Greater Zab River.*
- ***Recent salt playas(Al-Sharrey) are located along the fault zone suggesting that it is active at present.***
- *The overall vertical displacement of the fault zone is towards the south.*
- *The fault forms the southern boundary of the crestal block of the Mosul High.*

5- The Sinjar-Herki Fault Zone :-

forms the southern boundary of the Foothill Zone of NW Iraq and the Sinjar-Abdul Aziz Basin of Syria.

It was active during Late Cretaceous time and probably during the Triassic.

The fault zone has an easterly trend in the Stable Shelf area and a northeasterly trend in the folded belt.

It forms the N boundary of the crestal block of the Mosul High with an overall displacement towards the N.

The Sinjar-Herki transversal fault forms the N boundary of the Deir Al Zor-Erbil block (Fig. 4-8) whose S limit is located along the Anah-Qalat Dizeh transversal fault.

6-The Kutchuk-Dohuk Fault Zone :-

- *is traced on gravity gradient maps as an E- W trending structure.*
- *However, very little is known about this fault zone.*
- *It may have an overall displacement towards the south and hence may form the N limit of the Sinjar-Abdul Aziz Upper Cretaceous basin.*

The Deir Al Zor-Erbil block consists of two sub-blocks:-

A- The northern higher Khlesia-Mosul Subblock .

B- The southeastern Anah-Kirkuk Sub-block.

The former is the most prominent; it forms the main divide between the Taurus and Zagros segments and divides the fore deep area into the Taurus and Zagros Fore deeps.

The Khlesia-Mosul Sub -block is the most prominent and highest transversal structural unit in Iraq.

Fig. 4-7: Distribution of faults and fault zones (see text for description of individual systems)

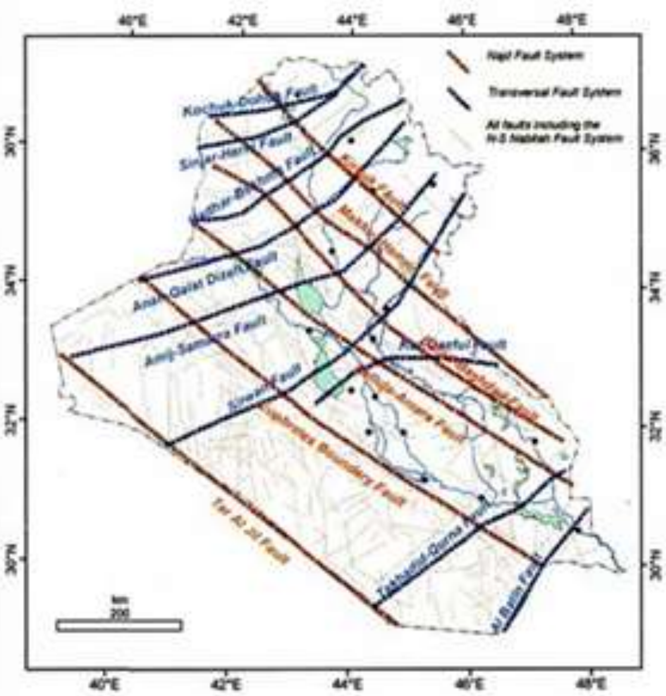
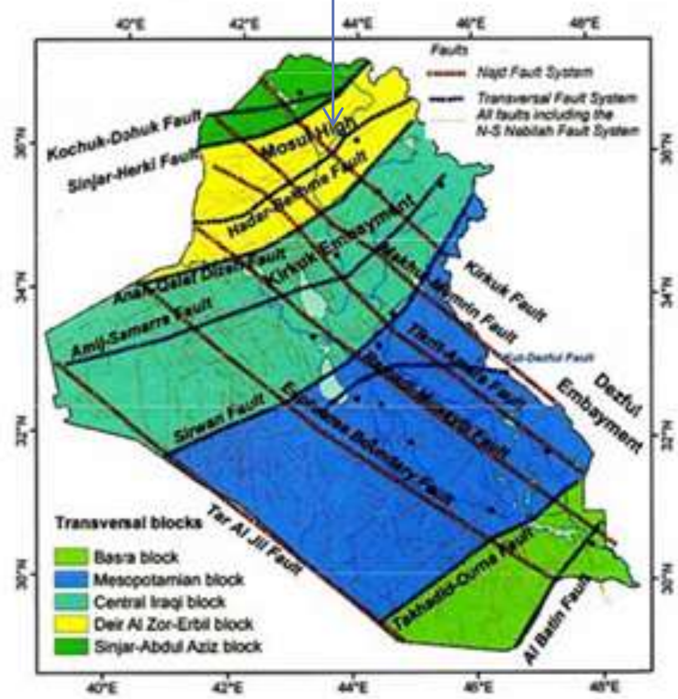


Fig. 4-8: Transversal blocks



Basic structural units of Iraq and basis of zonation

***The two basic tectonic units of Iraq are** :-*

A- Arabian Shelf

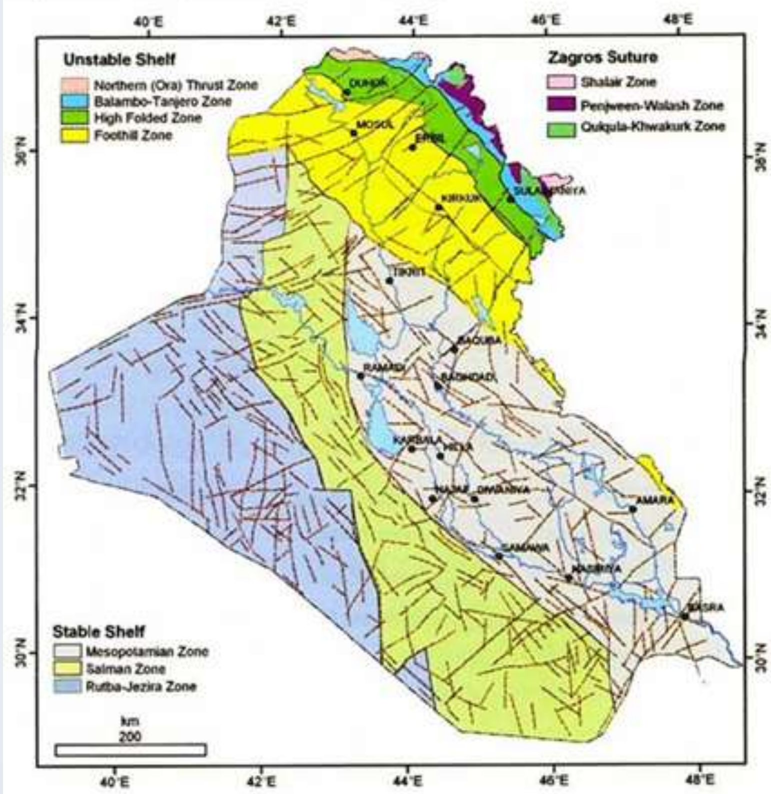
B-Zagros Suture Zone

The Arabian Shelf divided into two major units :-

1- The Stable Shelf

2- Unstable Shelf (Fig. 4-14).

Fig. 4-14: Longitudinal Zones of Iraq



The boundary between them was located at the western boundary Of the Mesopotamian depression.

It continues along the ***Euphrates River near Nasiriya****, then follows the Euphrates Boundary Fault to* ***Razzaza Lake****, and the* ***Abu Jir Fault*** *line to* ***Hit****.*

To the north of Hit it swings along a transversal fault system towards the E and then swings N, running along the ***Tharthar*** *Line until* ***Hatra****. From Hatra it swings NW towards the Sinjar-Herki Fault changing direction towards the Syrian boarder.*

- ***The definition of the boundary of the Stable Shelf has been changed : the Mesopotamian Zone is now considered to be part of the Stable Shelf.***

The Alpine longitudinal units of the Unstable Shelf define the zones&subzones.

In the stable shelf the zone boundaries generally follow N-S trending lineaments; subzones are delineated by transversal faults.

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Longitudinal Zones

Iraq can be divided into three tectonically different areas:

*1- **The Stable Shelf** with major buried arches and anti forms but no surface anticlines.*

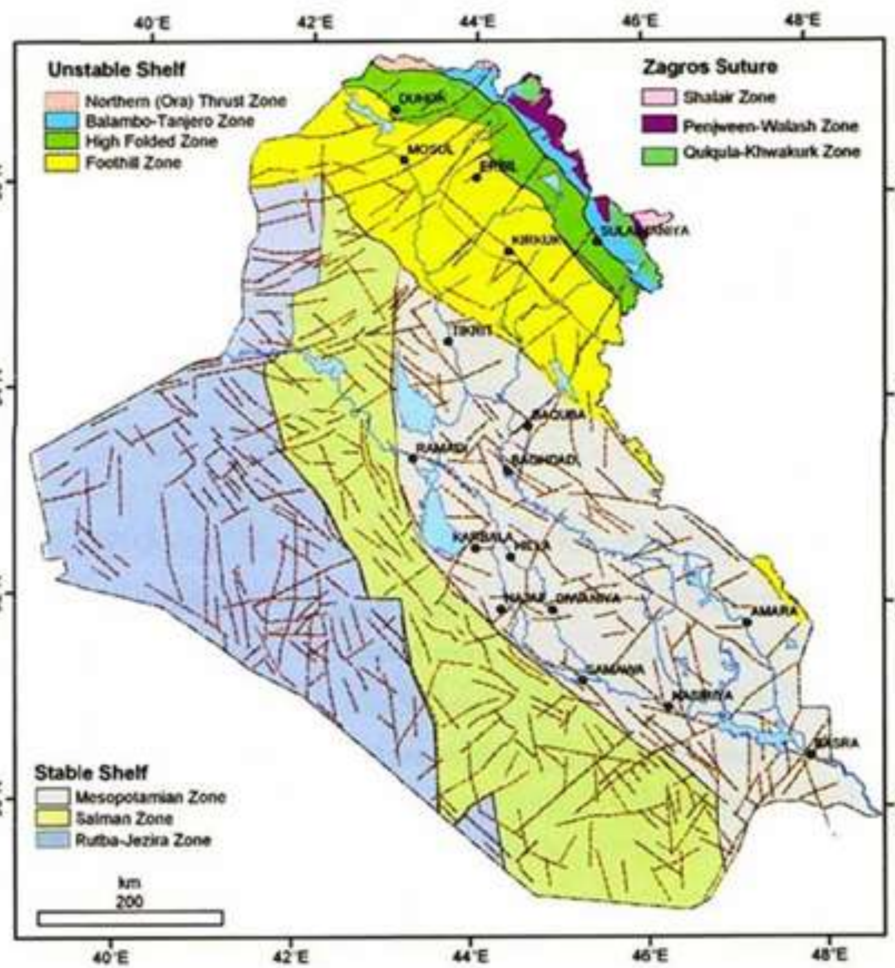
*2- **The Unstable Shelf** with surface anticlines.*

*3- **The Zagros Suture** which comprises thrust sheets of radiolarian chert, igneous and metamorphic rocks.*

- *These three areas contain tectonic subdivisions which trend N-S in the Stable Shelf and NW-SE or E-W in the Unstable Shelf and the Zagros Suture.*
- ***The N-S trend is due to Palaeozoic tectonic movements; the E- W and NE-SW trends are due to Cretaceous-Recent Alpine orogenesis***

longitudinal Tectonic zones of Iraq

Fig. 4-14: Longitudinal Zones of Iraq



Stable Shelf

*The **Stable Shelf** which covers most of Central, S &W Iraq extends west wards into Syria & Jordan & southwards into Kuwait.*

It is divided in Iraq into three major tectonic zones :-

a-The Rutba-Jezira Zone in the W,

b-The Salman Zone,

c- The Mesopotamian.

The Rutba- Jezira Zone

- an inverted Palaeozoic basin with a Syn-Hercynian basin.

- *It is dominated by the Rutba Uplift which is a major dome.*
- *The flanks of the dome dip to the E and SE towards the Euphrates River and to the W and NW towards Jordan and Syria.*

The Salman Zone.

- is a syn-Hercynian high.

- *It subsided strongly in latest Palaeozoic-Triassic time.*

- It forms 'a monocline; the Tertiary section dips towards the Euphrates River

The Mesopotamian Zone

- *contains the Tigris and Euphrates rivers in central & South Iraq and is covered with Quaternary sediments which overlie a complete Mesozoic and Cenozoic section.*

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- *The* ***Unstable Shelf*** *can be divided into* ***four tectonic zones****:-*

a- The Foothill Zone:--

characterized by long anticlines with Neogene cores and broad synclines containing thick Miocene-Quaternary molasse.

b-The High Folded Zone:-

- *characterized by anticlines of high amplitude with Palaeogene or Mesozoic carbonates exposed in their cores.*

-The zone was uplifted in Cretaceous, Palaeocene and Oligocene time but was also the site of an Eocene molasse basin.

c- The Balambo - Tanjero Zone:-

- *formed a basin near the plate boundary, which subsided strongly from the Tithonian (late Jurassic) onwards.*

- *It was filled in by thick fluvial and marine clastics from Maastrichtian time onwards.*
- *It is characterized by imbricated structures with overriding anticlinal structures.*

What is Molasse ?

d- The Northern Thrust (Ora) Zone

***-** an uplifted zone which developed along the plate margin during the Cretaceous and is characterized by thrusted anticlinal structures.*

Zagros Suture Zone

Fig. 16-1: Geological map of the southern part of the Zagros Suture

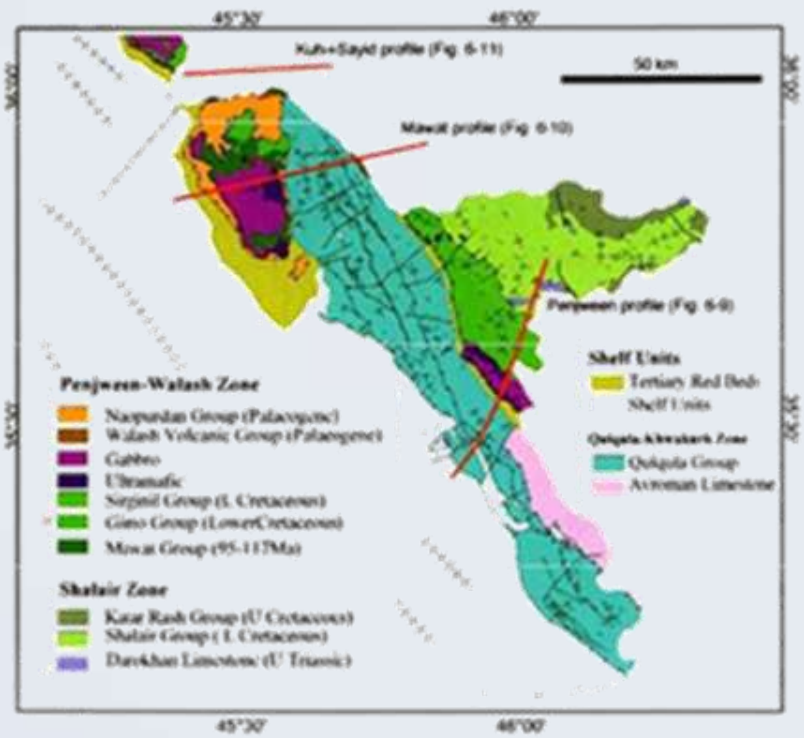


Fig. 16-2: Geological map of the northern part of the Zagros Suture

Zagros Suture

The Zagros Suture can be divided in Iraq into three tectonic zones, From SW to NE these are the:

A- Qulqula-Khwakurk,

B-Penjween- Walash

C- Shalair zones.

A-The Qulqula - Khwakurk Zone

-characterized by isoclinally folded radiolarian cherts with volcanic and occasional ultramafic rocks (Coloured Melange) with imbricates of the underlying Arabian Shelf carbonates (Permian to Jurassic).

-It is over thrust in the SE by Triassic carbonates.

-Its sediments were deposited on the margin of the Southern Neo-Tethys Ocean during the Tithonian-Cenomanian and obducted onto the Arabian Shelf in Late Cretaceous time.

An isoclinal fold is a fold in which the limbs are parallel. It may be upright, overturned, or recumbent.

B-The Penjween Walash Zone

- *comprises metamorphosed volcanic and sedimentary rocks of Cretaceous age derived from the NeoTethys, and Eocene arc and fore-arc units.*

C-The Shalair Zone

- *is part of the Sanandaj-Sirjan Zone of Iran.*
- *It is characterized by metamorphosed Palaeozoic sequences of the Sanandaj-Sirjan micro plate, overlain by Triassic to Cretaceous low grade meta-sediments and meta-volcanics formed at the margin of the Neo-Tethys, including Upper Cretaceous arc volcanic.*

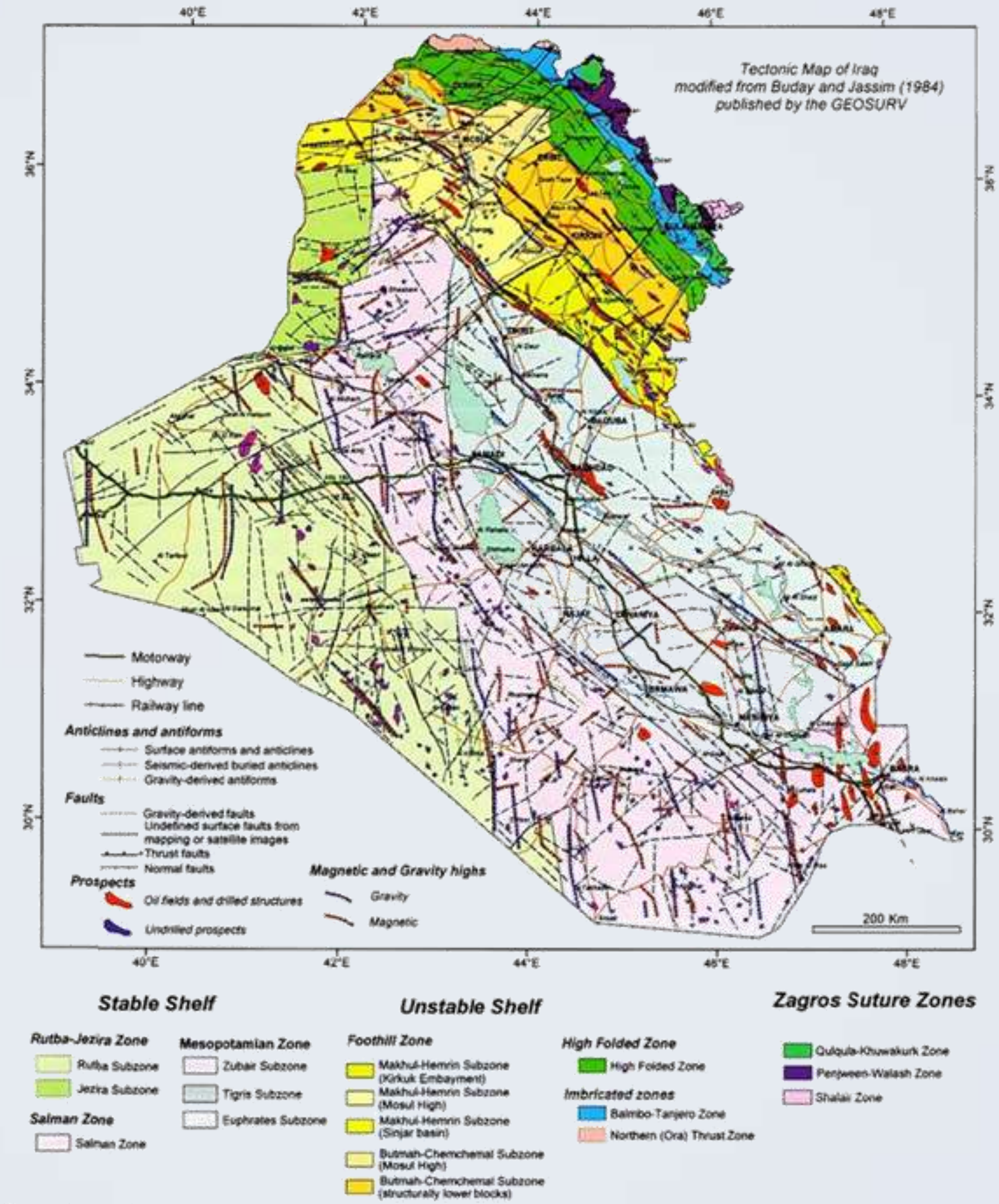


Fig. 4-15: Tectonic map

Units of the Stable Shelf

- ***The Stable Shelf***

-is a tectonically stable monocline little affected by Late Cretaceous and Tertiary deformation.

- ***The orientations of the structures in this tectonic unit were influenced by:-***

1-the geometry of the underlying basement blocks and faults,

2- Palaeozoic epirogenic events and Mesozoic arching.

- *The depth of the Precambrian basement varies between 5 km in the centre of the shelf to 11 km in the W and 13 km in the E.*

-The original definition of the Stable Shelf (Buday and Jassim, 1987) has been modified to include the Mesopotamian Zone.

- *The **E** boundary of the Stable Shelf is now located along the SW flank of the long anticlinal range of Makhul- Hemrin- PeshtI -Kuh.*

The Stable Shelf is now divided into three major tectonic zones, from the west, these are:

a- Rutba-Jezira zone,

b- Salman zone.

c- Mesopotamian Zone.

a-The Rutba-Jezira Zone

- *The **Rutba-Jezira** Zone is an **inverted Palaeozoic basin**; the inversion began in the Late Permian.*
- *Its basement was relatively **stable** during Mesozoic-Tertiary time and **more mobile** during Infracambrian and Palaeozoic times.*
- *Basement depth ranges from 5 km in the Jezira area to 11 km S of Rutba .*

The Jezira area was part of the Rutba Uplift domain in Late Permian to Early Cretaceous time.

- *Following the Cretaceous the Jezira area **subsided** while the Rutba area remained **uplifted**; these two areas are thus differentiated as separate subzones.*
- *The Rutba Uplift dominates the Rutba-Jezira Zone.*
- *It has previously been linked to the wider Hail-Rutba-Mardin High.*
- *the Rutba -Jezira Zone represents a syn-Hercynian depression.*

The Anah-Qalat Dizeh Fault divides the Rutba-Jezira Zone into:

a- The more stable Rutba Subzone in the S.

b-The Jezira Subzone in the N; the latter being more mobile since the Late Cretaceous.

Both subzones contain large basement highs:

****The Rutba-Ga'ara high in the S***

**** The Deir Al Zor - Khlesia high in the N.***

- *The unit between the two highs is the Anah Trough (often referred to as the Anah Graben).*

- *The **Rutba-Jezira Zone** contains thick Palaeozoic sediments.*
- *Upper Permian, Lower to Middle Triassic and pre- Albian Lower Cretaceous sediments are absent.*
- *The **Jezira subzone** was **uplifted** and **eroded** during Mid- Devonian (**Caledonian**) time;*
- *the **Rutba Subzone** was mostly not affected by this deformation.*
- *The **Jezira Subzone** also subsided during Late Eocene to Miocene time when the Rutba Subzone was uplifted.*

1- The Rutba Subzone

- *The Rutba Subzone is the most extensive and uplifted part of the Rutba-Jezira Zone, dominated by the huge Rutba Uplift **active** in Late Permian- Palaeogene time, the Cretaceous Ga'ara anticline and the ENE- WSW trending Hauran anticlinorium .*

Geological and geomorphological characteristics

*The Rutba Subzone contains the **Ga'ara depression** which is located above the broad N-S trending **Rutba Uplift**, and the E-W trending **Ga'ara a nticline**.*

*Numerous **unconformities** occur within the Mesozoic and Palaeogene section.*

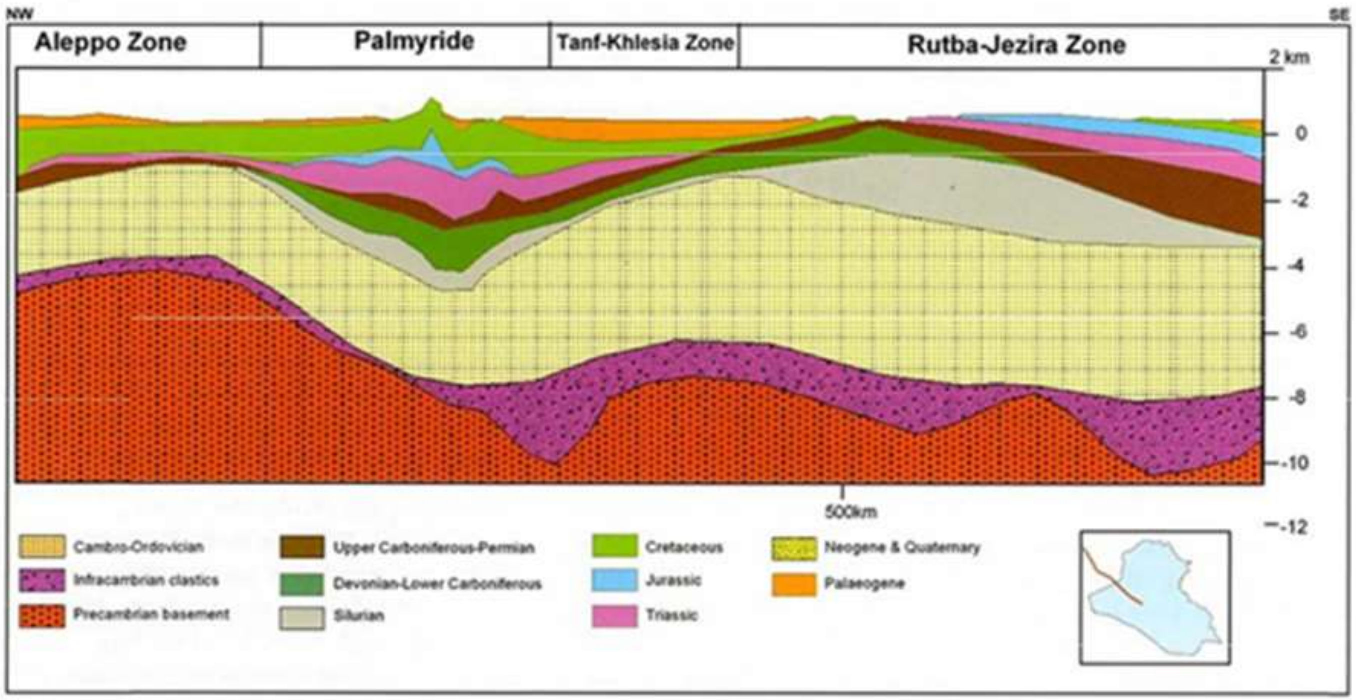
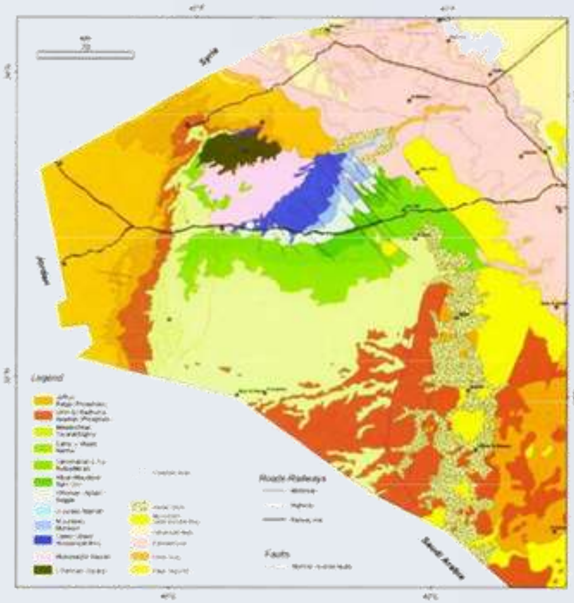


Fig. 5-1: Cross section within the Stable Shelf of Western Arabia starting from Aleppo in the NW and terminating at the Nukhaib Graben in the SE

- *The Lower Permian Ga 'ara Formation is unconformably Overlain by Upper Triassic carbonates(Mollusa, Zor Hauran) that form the cliffs on the southern rim of the depression (oldest formation in Iraq).*
- *The succession is from Permian- Up. Cretaceous out cropped in the depression.*
- ***The area W of Rutba is dominated by N-S trending Campanian-Palaeogene strata that are characterized by relatively deep water phosphorites.***
- *The western desert of Iraq has a NE-inclined land surface with a gradient of 10-20 m per kilometer from the Iraq Jordan-Saudi border point (980 m elevation) to the Euphrates River (l00-200 m elevation).*
- *It is usually a plane surface mostly covered by desert pavement (**Serir**) but locally it is very rocky where dissected by active wadis producing the **Hamada** land surface (Central and SE parts, Fig. 5-4).*

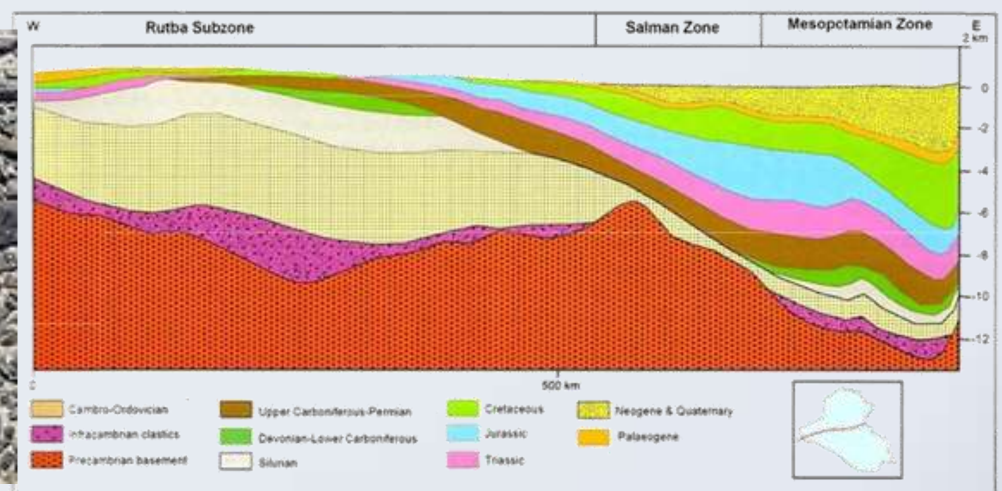
Geologic Map Of Rutba Subzone

Fig. 5-2: Geological map of the Rutba Subzone. Solid purple lines are mapped faults



A desert pavement:-, *also called reg (in the western Sahara), serir (eastern Sahara), gibber (in Australia), or saï (central Asia) is a desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size. They typically top alluvial fans. Desert varnish collects on the exposed surface rocks over time.*

Fig. 5-3: Profile between Risha, NE Jordan to the Iranian border near Naft Khana



- ***There are four distinct drainage systems*:**

1) *a **strongly incisive** E- W wadi system to the S& SE of Rutba.*
2) *2) the **incisive** NE-SW trending Wadi Hauran and its tributaries which are controlled by the strike of the Triassic and Jurassic sequences that contain alternating softer clastics and relatively harder carbonates (Fig. 5-8 inset B).*
3) *a **shallow, broad** N-S trending system W& SW of Rutba controlled by the N-S strike of Palaeogene strata (Fig. 5-8, inset C) .*
4) *a **moderately incisive** NNE-SSW trending system north of the Ga'ara area flowing through Miocene outcrops to the Euphrates River.*

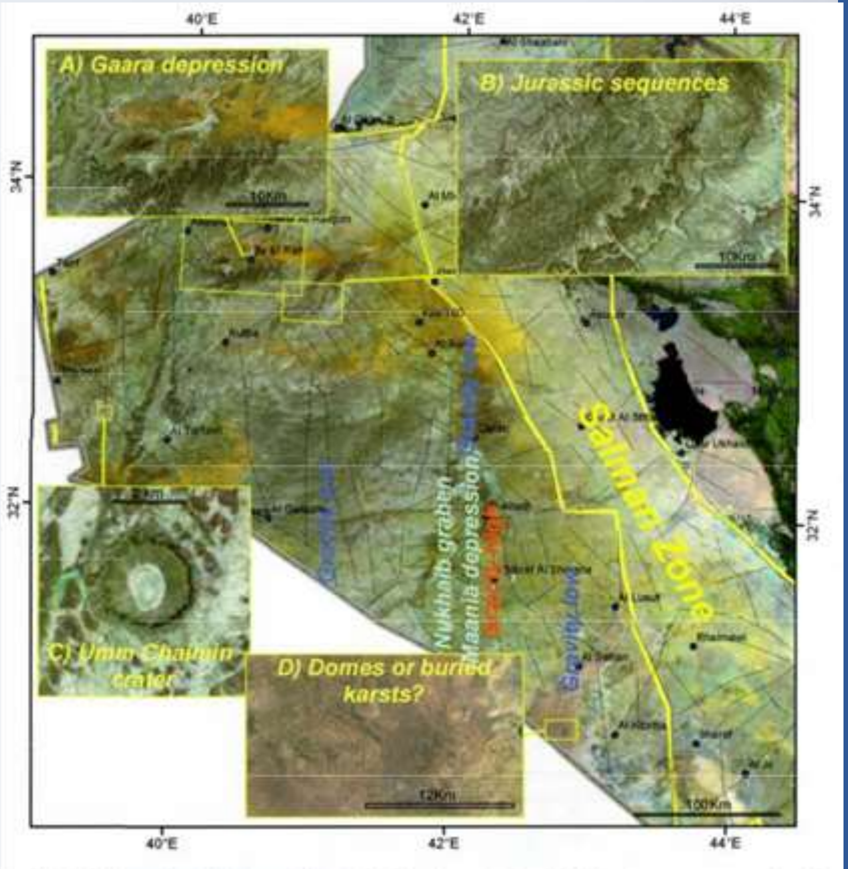
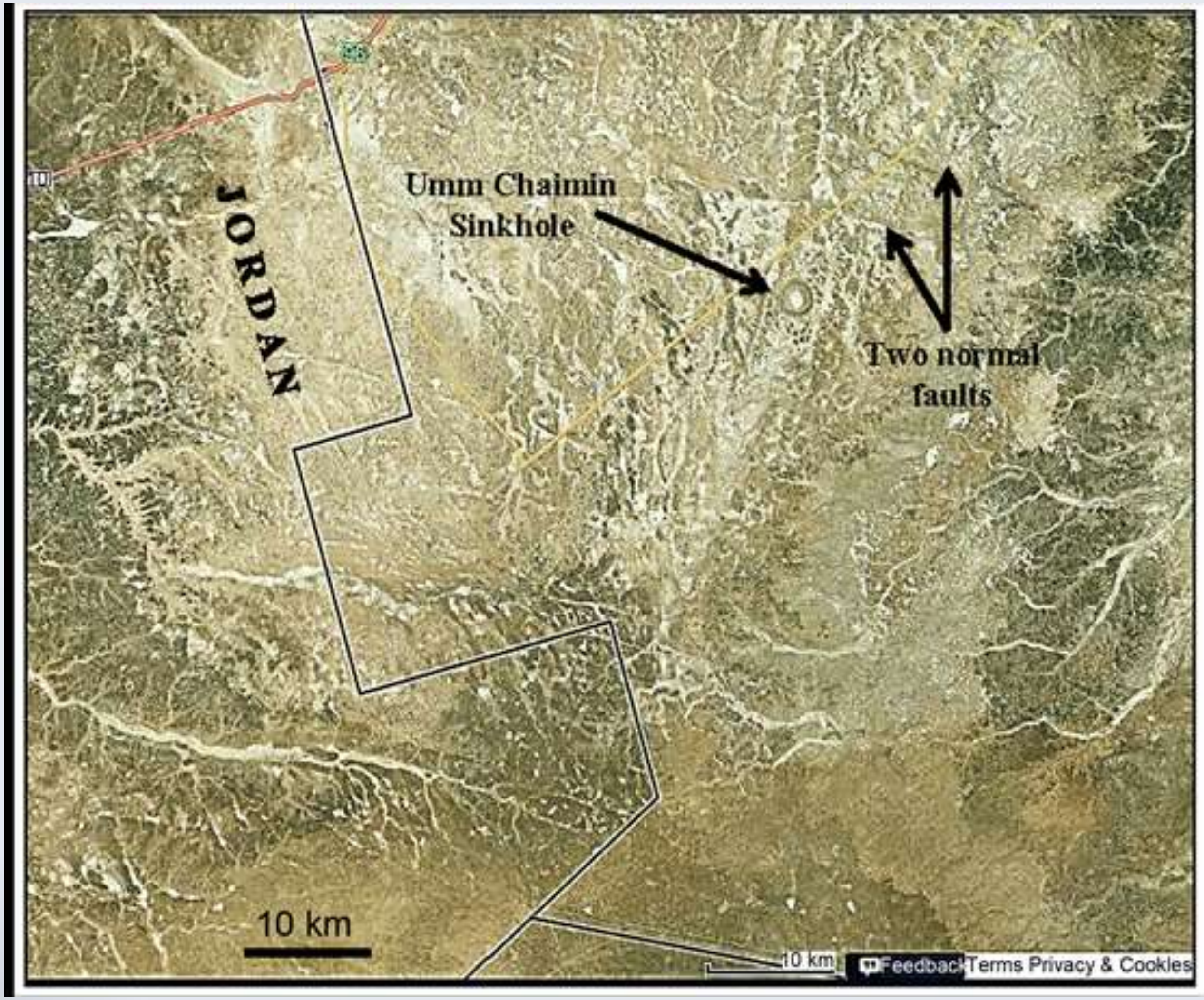


Fig. 5-4: Satellite image of the Rutba Subzone with inset for the Ga'ara depression (Inset A), the Jurassic system exposure area (Inset B), the Umm Chaimin crater (Inset C), and the contorted Palaeogene sequence east of the Nukhaib graben (Inset D)

Umm Chamin Sink hole

Wadi Hauran Flood Plain

Sw Rutba Area - Wadies



Important depressions within the Rutba Subzone comprise;-

***1-** the Ga'ara depression (**a structural-denudational unit**),*

***2**- the Umm Chaimin crater (**formed by an impact or gas explosion**).*

***3**- the Ma' ania depression (**a structural depositional unit**).*

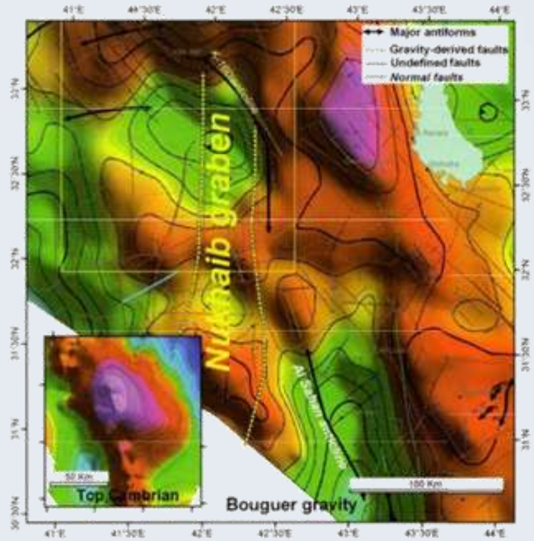
****The Ga'ara depression formed by erosion of thin carbonate beds which overlie softer less resistant Permocarboniferous clastics**.*

****The Ma'ania depression** which lies above the Nukhaib Graben (Figs. 5-8 and 5-9) is over 100 km long, 20 km wide and 20 m deep.*

- *Palaeocene rocks outcrop on both sides of the depression; Middle Eocene limestone occur in isolated outcrops protruding through -20 m of gravel (Nukhaib Gravel) in the middle of the depression.*
- *All the E- W wadis SE of Rutba drain into the depression forming coalescing fans which lead into one exit drainage point (Wadi Ubayidh).*
- ***The depression is structurally controlled by the Nukhaib Graben.***
- *Al-Bassam et al. (1992) indicated that 50 m of extension has occurred in the graben.*
- *They noted that a gravity low in the northern part of the graben is associated with a major dome at Top Cambrian level (Fig. 5-5).*
- *They suggested that the gravity low may indicate the presence of Infracambrian salt.*
- *Getech and Jassim (2002) modeled the gravity low to the east of the Nukhaib Graben and also concluded that Infracambrian salt is probably present.*

-a gravity low in the northern part of the Nukab graben is associated with a major dome at Top Cambrian level (Fig. 5-5).
-They suggested that the gravity low may indicate the presence of Infracambrian salt

Fig. 5-5: The gravity low associated with the northern part of the Nukhaib Graben and the inset Top Cambrian map (modified from Al-Bassam et al., 1992). Red (main map is high gravity, in inset map is structural high) blue (main map low gravity, in inset map structural low)



The **Um Chaimin crater is located about 45 km WSW of Rutba.*
- It is 2 km wide (Fig. 5-8, inset B and Fig. 5-6) and was previously assumed to be an impact feature.
-The crater i s hidden in a flat desert plain formed of Lower Eocene carbonates.

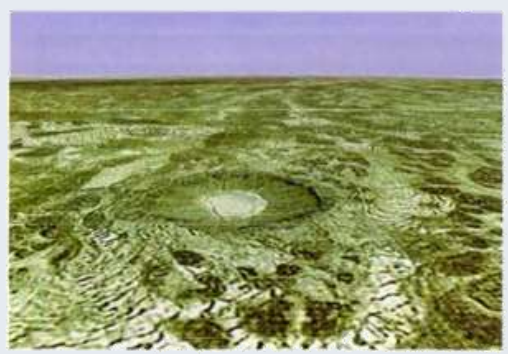


Fig. 5-6: Inclined view of the Umm Chaimin crater with 3 times vertical exaggeration. Note the N-S trails of the Walaj and Wulaij wadis on both sides of the crater (Courtesy of Earth Google)

Structures of Rutba Subzone

- *The **Rutba Subzone** is dominated by the mega Rutba Uplift which formed due to inversion of the Palaeozoic basin of W Arabia during Latest Permian-Middle Eocene time.*
- ***The most prominent structures were active during the Cretaceous and Palaeogene.***

They include:-

- the E NE-WSW trending Hauran anticlinorium,

- the E- W Ga'ara anticline,

- the NW-SE t rending Akashat anticline,

- the Traibeel anticline in the NW

- and the E- W trending Tlaiha and Qatari anticlines in the SE.

- *The **Hauran anticlinorium** is over 300 km long and consists of a series of culminations (Fig . 5-7) cut by several NW-SE trending*

normal faults forming horst and grabens displacing pre- Campanian strata.

*The **Ga'ara anticline** is an E- W trending 130 km long structure associated with a 1 km high subsurface elevation on top of the Precambrian basement that extends into SE Syria through the Akashat anticline (see Fig. 5-7).

-***Facies changes within the Upper Cretaceous and Palaeogene sediments around these structures suggest that it was active in Late Cretaceous-Palaeogene time.***

*The E- W trending **Traibeel anticline** deforms the Eocene strata and is associated with a well-defined surface lineament.

*There are two smaller E- W trending antiforms SE of the Hauran anticlinorium (**Tlaiha and Qatari anticlines**).

*Two important antiforms were mapped near the E boundary of the Rutba Subzone; these are the NNW-SSE trending **Kilo160** and the N-S trending **Al Sahan antiforms** (Fig. 5-9).

Fig. 5-7: Structural map of the base of the Cretaceous (metres from Sea Level) based on data of Al-Bassam et al. (1999)

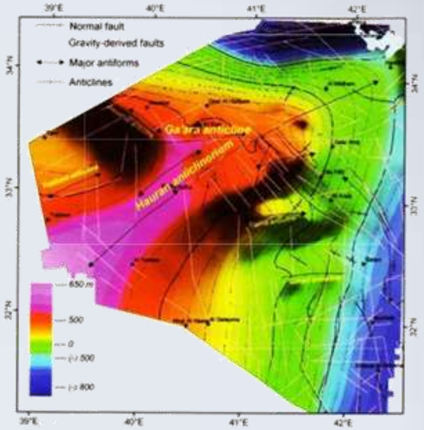


Fig. 5-8: Residual gravity anomalies (grey polygons) and undrilled structures (red polygons) and the fault systems of the Rutba Subzone

The fault systems of the Rutba Subzone:-

1*- The N-S Nabitah (Idsas) system which is a Precambrian system reactivated during the Late Carboniferous and Early Permian (Syn-Hercynian).*

2*-The NW-SE Najd system which is well developed near and E of Rutba (extension of the Euphrates Boundary Fault), and along the Iraq-Saudi border (extension of the Al Tar Fault).*

These faults formed in the Late Precambrian and were probably reactivated during the Cretaceous.

3*-The E-W fault system is best developed in the SE and S part of the Subzone where it controls the Widyan drainage system (extension of the Sirwan and Amij-Samarra Transversal Faults), and along the northern margin of the subzone near the Euphrates River (Anah-Qalat Dizeh Fault).*

2- The Jezira Subzone

- *The **Jezira subzone** was part of the greater W Arabian Palaeozoic basin until the Late Silurian.*
- *It was uplifted in Late Silurian-Mid Devonian time forming a NE-SW trending arch.*
- *It formed part of the Rutba-E. Palmyride Permocarboniferous N-S trending basin.*
- *It was part of the Rutba Uplift from Late Permian to Early Eocene time though it was intermittently submerged.*
- *It subsided during Eocene to Middle Miocene time.*
- *It was uplifted in Late Miocene-Recent time.*
- *It is dominated by the Khlesia Basement Uplift which is part of the N-S trending Rutba Uplift.*
- *It is segmented by two E- W trending grabens and a trough; these are:-*

**** The Anah Trough.***

**** The Tayarat and Khlesia Grabens.***

Geological and geomorphological characteristics

- *The oldest rocks outcropping in the Jezira Subzone are **the Upper Oligocene Kirkuk Group**, which outcrops at the **S** boundary of the subzone along the E- W section of the Euphrates River between the Syrian border and Anah.*
- *The Middle Miocene Fatha and the Upper Miocene Injana formations outcrop over most of the subzone.*
- *One major surface anticline is observed north of the Euphrates river (the ENE-WSW trending Tayarat anticline); the N flanks of this anticline are visible on satellite images (Fig. 5-9, inset B).*
- *The Tayarat anticline forms a topographic high.*
- *It drains towards the Euphrates River in the **S**, the Khlesia Graben in the **N**, the Tuwaila playa in the **W** and the Tharthar valley in the **E**.*
- ***The short drainage systems end in small playas which suggest active karstification in the evaporites of the Fatha Formation is occurring.***

Tayarat Anticline& Sunasila playa

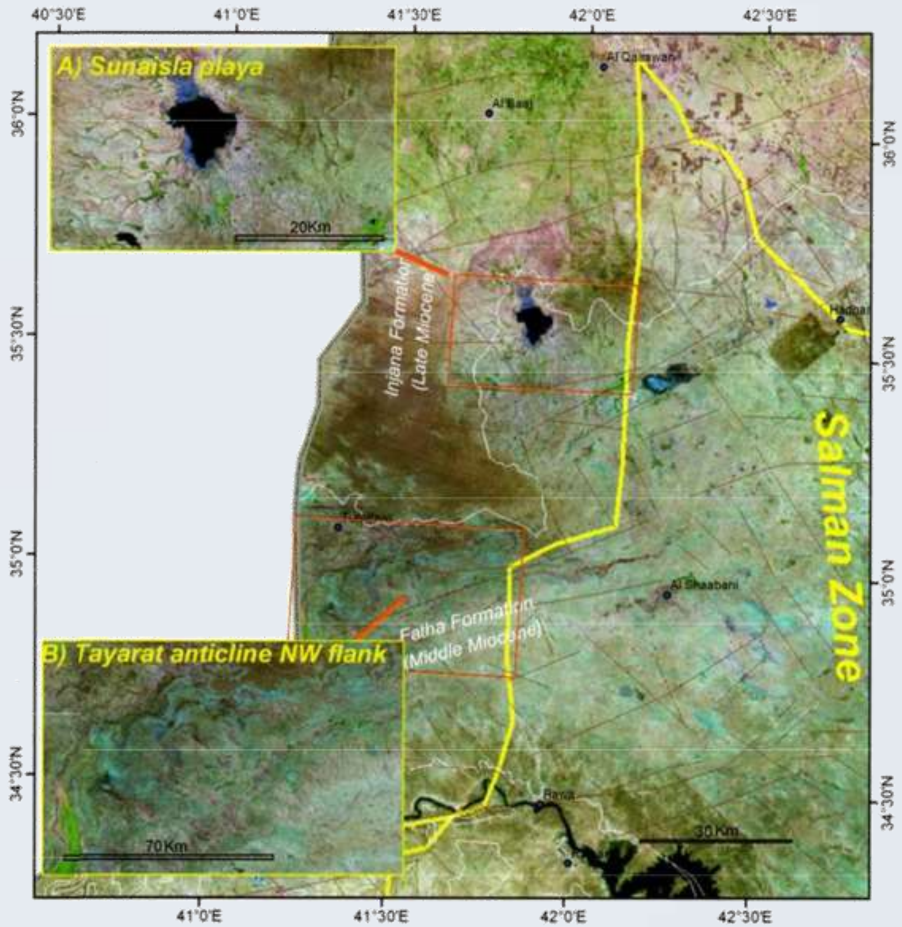


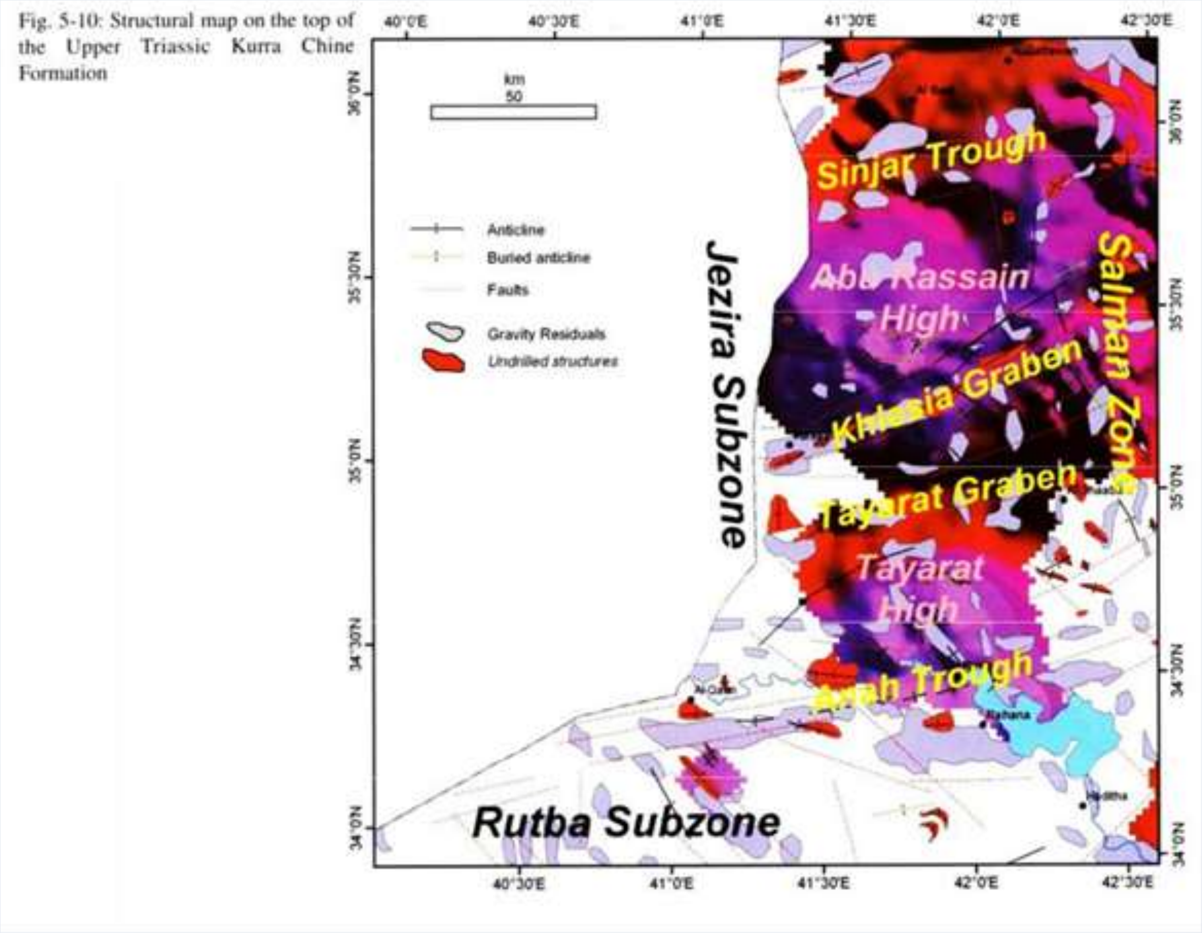
Fig. 5-9: Satellite image of the Jezira Subzone with insets showing the Sunaisla playa (A) and the NW flank of the ENE Tayarat anticline (B)

Structures of Jezira subzone

- *The Jezira Subzone is part of the ancient wider Rutba Uplift.*
- ***It is segmented into two highs by the Tayarat Graben:***

****The Tayarat High in the S .***

**** The Khlesia (Abu Rassain) High in the N.** (Fig. 5-10).*



*-The **Anah Trough** lies between the Rutba and Jezira Subzones.*

- *The trough appears narrow at the surface.*
- *At depth it is bounded by a series of E- W trending step faults.*
- *The Anah Graben formed by transtension in Late Cretaceous time; it contains up to 2000 m of Upper Cretaceous sediments.*

*-The **Tayarat Graben** strikes E- W and probably formed*

synchronously with the Anah Graben.

- *Its bounding faults have 1700 m of displacement on the top of the Triassic Kurra Chine Formation.*

*-The **Khlesia Graben** (Fig. 5-9) shows very little displacement at the*

Top of the Kurra Chine Formation (-150 m).

- *Drainage patterns suggest it was active in the Quaternary; salt playas developed along it.*
- ***The northern boundary of the sub zone is located along the Sinjar-Herki Transversal Fault which defines the southern boundary of the Foothill Zone and the Late Cretaceous Sinjar-Abdul Aziz basin which extends into N Syria.***
- *Small anticlines occur throughout the zone.*

B-Salman Zone

*The **Salman Zone** is part of the Salman-Summan Zone of Getech and Jassim (2002) which extends into W Kuwait and central **E** Saudi Arabia.*

- *It is generally associated with gravity and magnetic highs indicating a shallow basement at a depth of 5-7 km.*
- *It was **formed** during the Late Precambrian **Nabitah orogeny**, and **reactivated** during Late Carboniferous and Early Permian time.*
- *The Salman Zone has a shallower basement than the Rutba Jezira Zone to the west and the Mesopotamian zone to the east.*
- *It is part of the Upper Precambrian Ar Rayan Terraine that was*

*uplifted during the Late Carboniferous (**Hercynian**) time and partly during the Early Permian.*

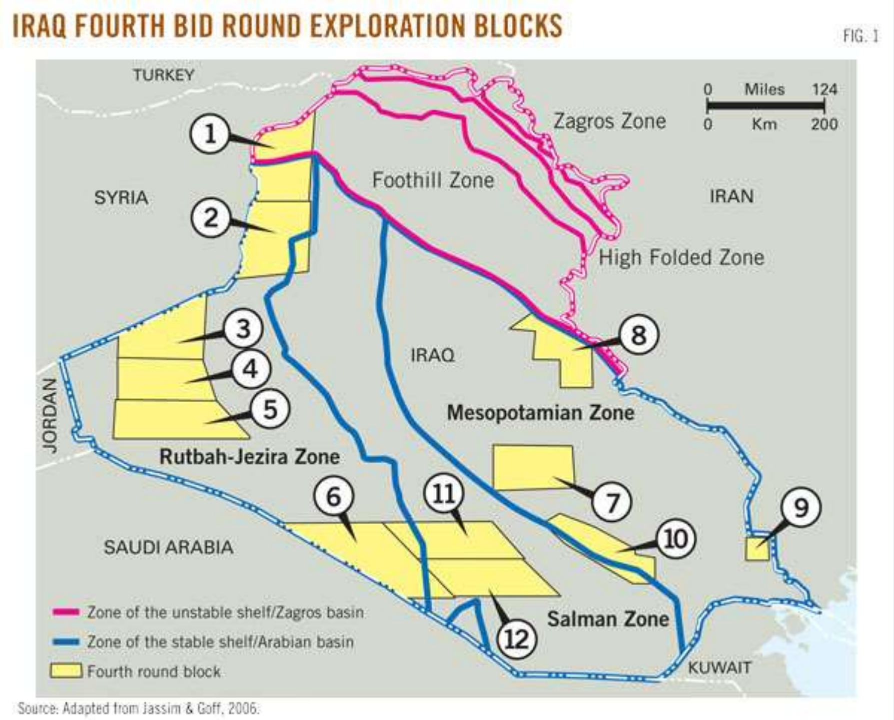
- *Basement depth in the Salman Zone is **5-8 km**, mostly 6-7 k m; along the boundary with the Mesopotamian Zone the basement depth increases to **8 -9 km**.*

Geological and geomorphological characteristics of Salman Zone

The Salman Zone is a monocline dipping towards the Euphrates River;

- *Middle-Upper Eocene strata outcrop in the* ***W*** *and Lower and Middle Miocene beds outcrop in the* ***E****.*
- *The* ***S*** *part of the zone is a sandy plain formed by Miocene clastics. Eocene carbonates are pock-marked; depressions are filled by*

Pliocene fresh water limestone and clastics(Zahra Fn.) (Fig. 5 -13 B).



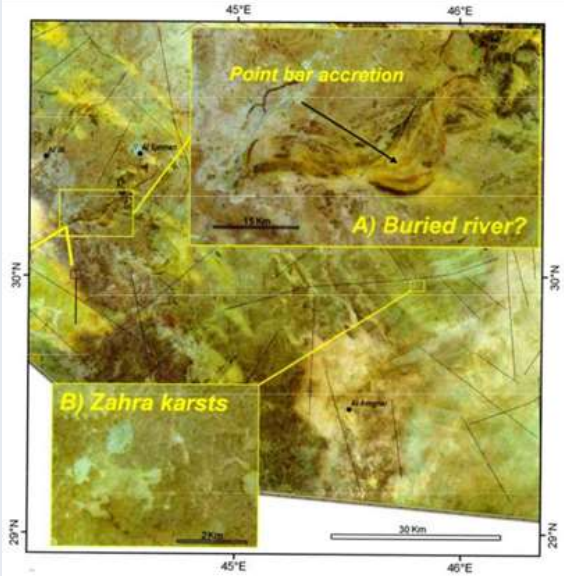


Fig. 5-13: Satellite image of the southern part of Salman Zone with insets showing buried river beds W of Salman depression (A) and the typical karsts scattered throughout the zone (B)

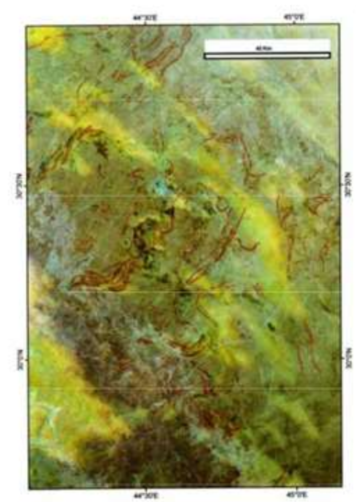


Fig. 5-14: Satellite image of the Salman Zone with tracing of some of the arcuate features that may be related to buried or abandoned river systems

Structures of Salman Zone

- *The Salman Zone subsided from Late Permian time onwards.*
- *It comprises NE-SW and prominent NW-SE trending uplifts and depressions, bounded by faults.*
- *They are relatively narrow, long anticlines, often accompanied by faults.*
- *Broader N-S trending structures, indicated by gravity data are* ***buried Hercynian horsts*** *which are mostly restricted to the S and SW part of the zone.*
- *Other parts of the zone contain relatively short anticlines and structural noses, many of which are located along transversal faults.*

Q. What are the transversal faults affected Salman Zone?

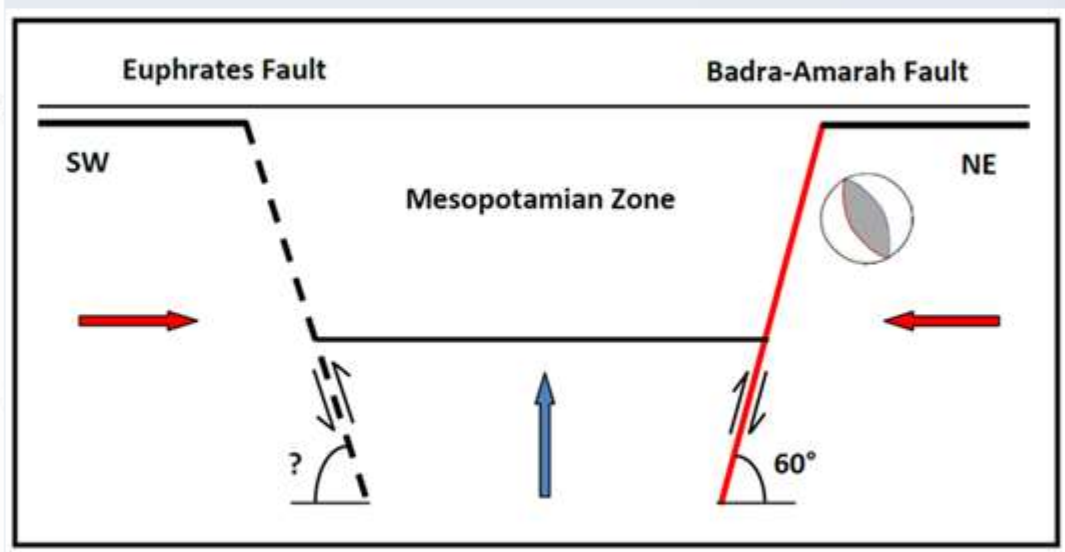
C- Mesopotamian Zone

The Mesopotamian Zone is the eastern most unit of the Stable Shelf.
It is bounded in the NE by the folded ranges of Pesh -i-Kuh in the **E, and Hemrin and Makhul in the **N**.*

**The SW boundary is controlled by faults (Fig. 5-15).*

The zone was probably **uplifted during the **Hercynian** deformation but it **subsided** from Late Permian time onwards.*

Fig. 5-15: Residual gravity anomalies (grey polygons) and undrilled structures (red polygons) of the southern part of the Salman Zone



Geological and geomorphological characteristics

- *Quaternary sediments of the Mesopotamian Zone were deposited by the interacting Tigris, Euphrates, Diyala and Adhaim Rivers, on the alluvial fans emanating from the surrounding elevated areas, and following marine incursions from the Arabian Gulf.*
- *Flood plain deposits include channel deposits, levees and crevasses plays, flood plain depression, marsh, sabkha and deltaic deposits.*

The alluvial fans are derived from rivers passing through the Foothill Zone (Fig. 5-16 B) in the NE or from desert wadis flowing from the desert plain in the W.

Satellite image of Mesopotamian Zone

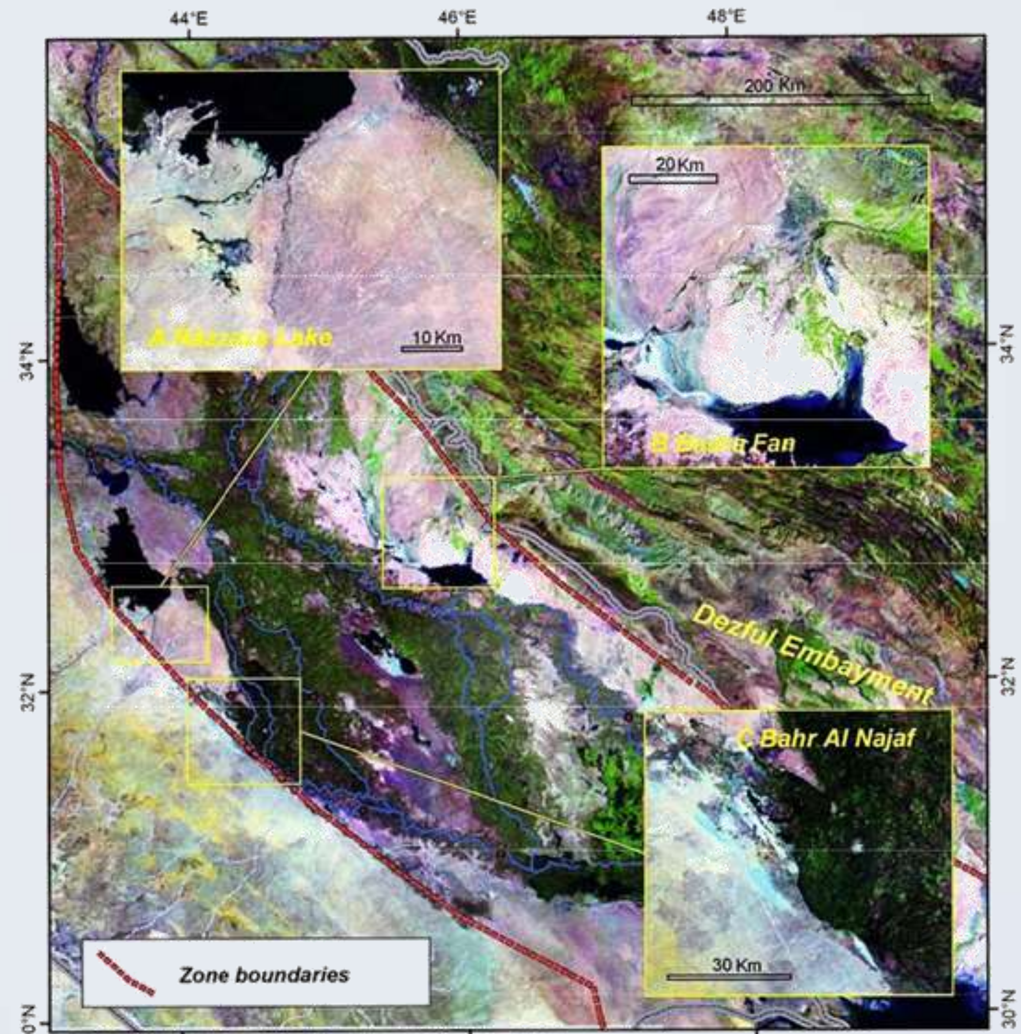


Fig. 5-16: Satellite image of the Mesopotamian Zone bound by the Foothill Zone in the NE and the Salman Zone in the SW Inset maps show alluvial fans on both side of the zone (see text)

Structures of Mesopotamian plain

- *The Mesopotamian Zone contains buried faulted structures below the Quaternary cover, separated by broad synclines.*
- *The fold structures mainly trend NW -SE in the eastern part of the zone and N-S in the southern part; some NE-SW trending structures occur (Fig. 5-15).*
- ***The Mesopotamian Zone is divided into three subzones**:*

***1- The Zubair Subzone** in the S with N-S trending structures in the S,*
***2-The Euphrates Subzone** in the W,*

***3-Th e Tigris Subzone** in the NE with NW- SE trending structures.*

1- Zubair Subzone

The Zubair Subzone is bounded in the north by the Takhadid-Qurna Transversal Fault.

The southern boundary of the subzone is either located at the

Al- Batin fault or along a transversal fault in Kwait.

- *It contains prominent N-S trending structures which continue hundreds of kilometres south wards into Kuwait and E Saudi Arabia.*
- *These structures originated during the Late **Nabitah orogeny** and were **reactivated** during Permocarboniferous, Mesozoic and Tertiary time.*
- *The association of negative gravity residuals with the main structures of S Iraq Fig. 5-18) strongly suggests they are underlain by Infracambrian salt.*
- *The **Sanam salt** plug (Fig. 5-19) indicates Infracambrian salt is present in the south of the subzone.*
- *The most prominent narrow elongated antiforms are the(Zubair and Rumaila structures).*

- *Shorter, often broader structures include*

(NahrUmr, Majnoon, Rachi, Ratawi, Subba and Luhais).

The Zubair Subzone is the most prolific petroleum region in Iraq.

Fig. 5-18: Structural map to the top of the Ahmadi Formation showing the position of residual gravity anomalies (open polygons) in relation to the anticlines. Most of the residual gravity highs are associated with structural lows

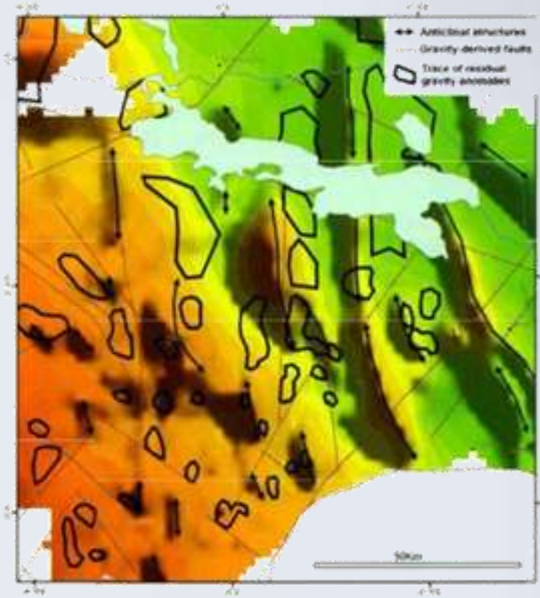
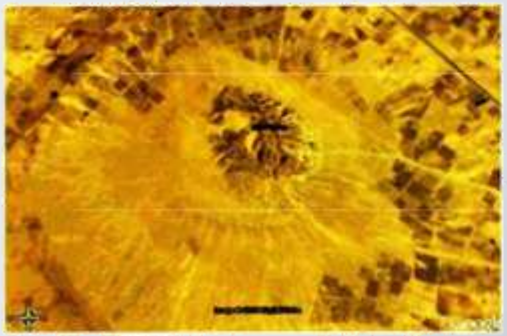


Fig. 5-19: Oblique view of Sanam Plug in S Iraq, 5 km W of Safwan Town on the Basra-Kuwait High way. Steeply dipping, locally vertical Upper Miocene grit beds of the Dibdibba Formation form visible circles around the central salt extrusion (Courtesy of Google Earth)



2-Tigris Subzone

- *The Tigris Subzone is the most extensive and mobile unit of the Mesopotamian Zone.*
- *It contains broad synclines and narrow anticlines trending*

predominantly NW -SE, accompanied by long normal faults.

- ***The Tigris subzone contains two NW-SE trending groups of buried anticlines of relatively low amplitude associated with longitudinal faults (confirmed by seismic surveys) and an EW transversal trend.***
- *These anticlines lie on the Ramadi Musaiyib and the Tikrit-Amara Fault Zones of the Najd Fault System and on the Kut-Dezful Fault.*
- ***The first** line of anticlines runs from Tikrit to Amara.*

- The total length of anticlinal line from Tikrit to Amara is over 500 km; it is segmented into shorter domes about 20 to 70 km in length.

- ***The second**, less pronounced, line of anticlines is the Ramadi-Musaiyib anticlinal trend corresponding to the West Baghdad basement structure of Ditmar etal.*

-It is roughly 150 km long, and extends from Ramadi to Musaiyib.

- ***The third** anticlinal structural trend of Najaf-Kut is an oblique structure trending approximately E-W. It comprises a series of faulted anticlines.*

3-Euphrates Subzone

- *It is a **monocline** dipping to the NE with short anticlines « 10 km) and structural noses.*
- *Some longer NW- SE oriented anticlines (20-30 km long) lie near to and parallel with the Euphrates Boundary Fault especially between Samawa and Nasiriya.*
- *They are related to horsts & grabens developed along the fault zone.*

The Euphrates Subzone is the shallowest unit of the Mesopotamian Zone.

- *The basement is generally 7-9 km deep but has thicker Quaternary sediments compared with the Tigris Subzone.*

Units of the Unstable Shelf and the Zagros Suture

The Unstable Shelf in Iraq is di vided into four zones:

1- the Foothill Zone,

2-the High Folded Zone

3- the imbricated Northern (Ora) Zone

4- Balambo- Tanjero Zone.

The Mesopotamian Zone of Buday and Jassim (1984 and 1987) is now included in the Stable Shelf.

The Zagros Suture Zone comprises three tectonic units:_

1-the Qulqula – Khwakurk zone,

2-the Penjween - Walash Zone

***3-the Shalair zone** (Fig. 6-1).*

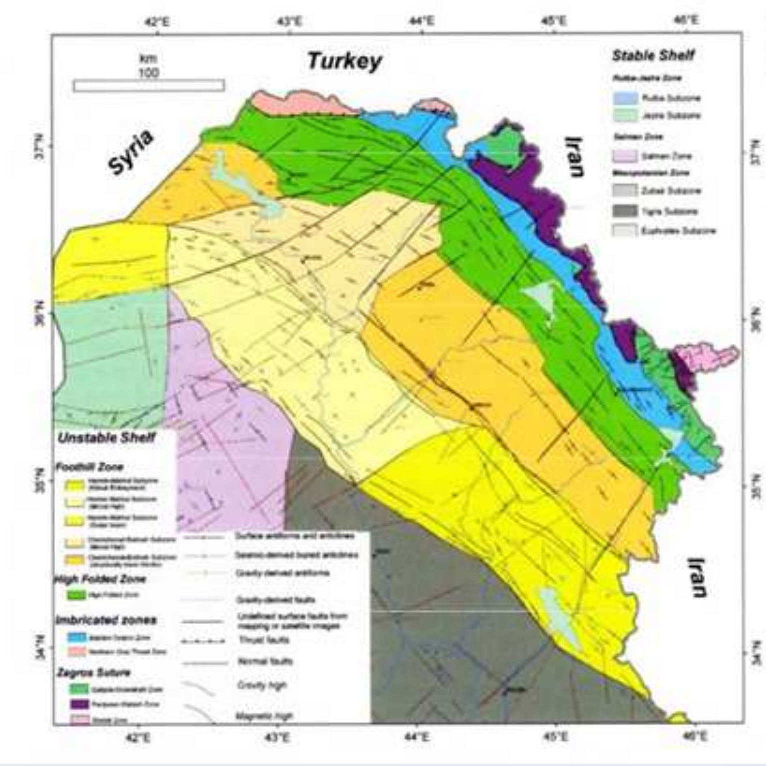


Fig. 6-1: Tectonic zones and structur: elements of the Unstable Shelf unit (modified form Buday and Jassin 1984)

Units of the Unstable Shelf

- ***The Unstable Shelf*** *had been the most strongly subsiding part of the Arabian Plate since the opening of the Southern Neo-Tethys in the Late Jurassic.*
- ***Maximum subsidence*** *occurred during:-*

- *the Late Cretaceous ophiolite obduction onto the NE margin of the Arabian Plate.*

  - and during Mio-Pliocene continental collision.

Q.1- When did maximum subsidence of unstable shelf happened?

- ***The Unstable Shelf is thus characterized:-***

-by structural trends -and facies changes that are parallel to the Zagros-Taurus suture belts.

-Surface folds are a characteristic feature of the unit.

Q.2 . What are the main characteristic of unstable shelf?

1- The Foothill Zone

- *The SW boundary of the Foothill Zone lies along the SW flank of the impressive anticlinal line of Makhul, Hemrin and Pesht-i-Kuh.-*

-North of Hatra the boundary of the Zone runs along the Tharthar valley then west wards in to Syria along the southern flank of the Sinjar anticline (Fig. 6-1).

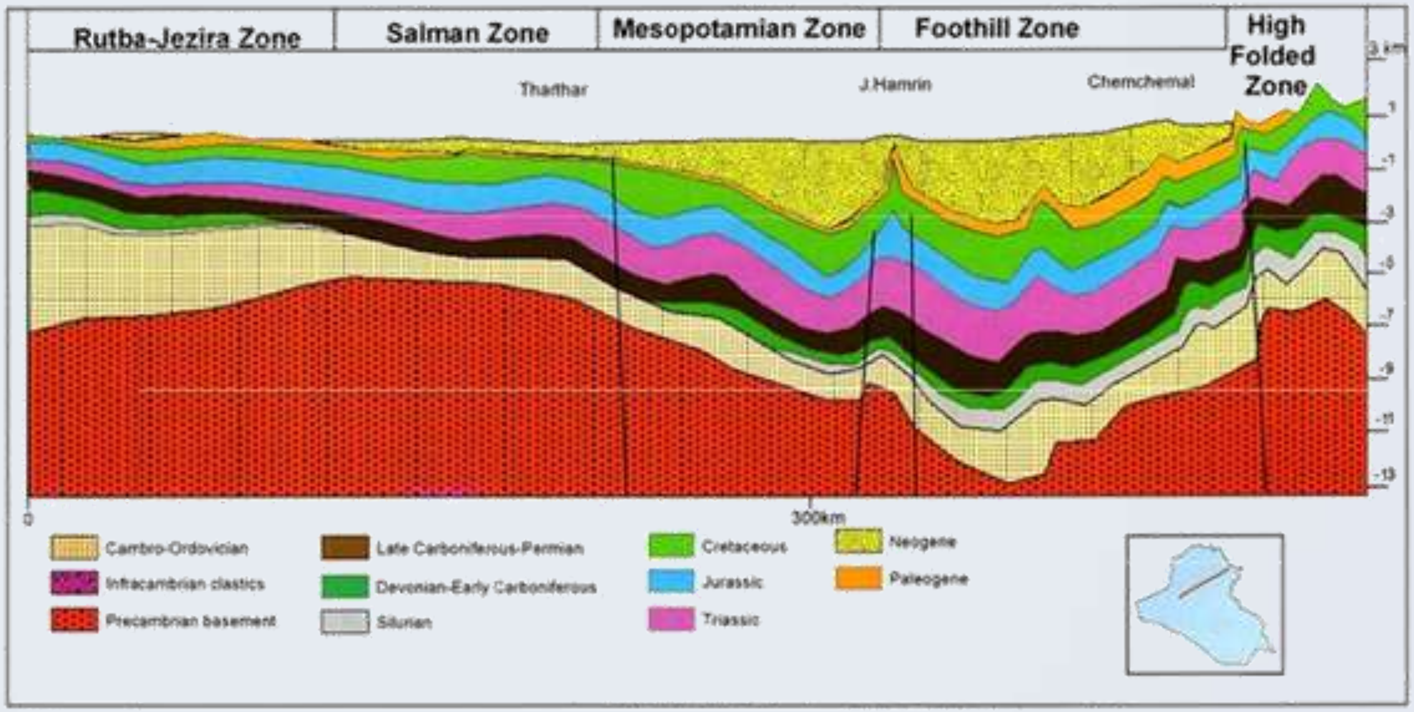
- *To the SE the boundary passes through the Dezful Embayment in SE Iran and along the eastern coast of the Arabian Gulf.*
- *Its eastern boundary lies along high anticlines with Palaeogene or Cretaceous formations exposed in their cores.*

- *The Foothill zone has the **deepest Precambrian basement** in Iraq (-13 km) and very thick Miocene-Pliocene molasse sediments (-3000 m thick).*
- ***The zone comprises two longitudinal units:-***

A- The Makhul-Hemrin Subzone in the SW.

B- The Butmah- Chemchemal Subzone in the NE.

Fig. 6-2: Cross section through central Iraq passing through the Stable Shelf, the Foothill and High Folded zones showing the deepest basement in Iraq in the Foothill Zone



The Foothill Zone contains four transversal basement blocks:-

***A**-The NW transversal block of the Foothill Zone (**Sinjar Block**) lies to the N of the Sinjar-Herki Fault and covers the Sinjar area (Fig. 6-1).*
Top basement is usually at 8-10 k m but ranges from 5-11 km.

***b**-The transversal block that lies between the Sinjar-Herki Fault in the NW and the Hadhar-Bakhme Fault in the SE is referred to as the (**Mosul High**).*

-It forms an important palaeogeographic and structural divide across the fore deep of Iraq, including the Foothill Zone.

- It overlies shallow Precambrian basement at 6-9 k m.

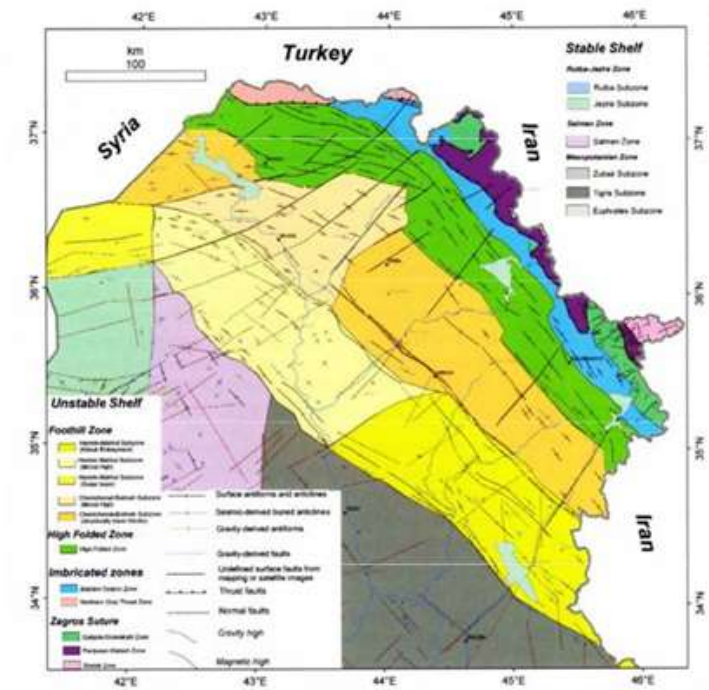


Fig. 6-1: Tectonic zones and structur elements of the Unstable Shelf unit (modified form Buday and Jassim 1984)

__C__-The third transversal block lies between the Hadhar-Bakhme Fault in the NW and Anah-Qalat Dizeh Faults in the SE.

__D__-The largest transversal block is the __Kirkuk Embayment__ which lies between the Anah-Qalat Dizeh Fault in the NW and the Sirwan Fault in the SE.

- *It has the deepest Precambrian basement within the Foothill Zone at 10-14 km but locally rising.*

1.1 Hemrin-Makhul Subzone

- *is the structurally deepest part of the Foothill Zone.*
- *The subzone was the depocentre of __the Neogene molasse__ but has been a subsiding unit throughout the Mesozoic and Tertiary.*
- *The Makhul-Hemrin Subzone comprises long prominent NW-SE (or E-W) trending anticlines with decollement thrust faults .*
- *The anticlines of the Hemrin-Makhul Subzone are over 100 km long.*
- *The anticlines are also segmented into doubly plunging domes; the segmentation usually occurs at intersections with transversal faults where the axes of the anticlines are bent.*

- *Within **the Sinjar block**, the subzone is restricted to a relatively narrow belt which is the eastern continuation of folded zone of Syria.*
- *The most prominent feature of this part of the subzone is the Sinjar line (Fig. 6-3 A and Fig. 6-5 A).*
- *It is a box-shaped line flanked in the subsurface by faults.*
- *It is the structurally the highest anticline in the Foothill Zone.*
- *It formed by inversion of a deep rift basin during Late Tertiary time.*

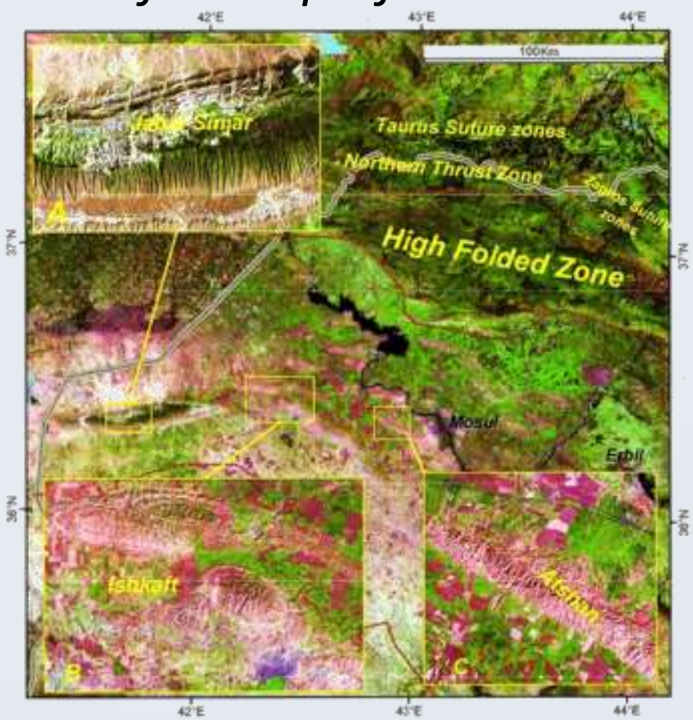


Fig. 6-4: Satellite image of the NW part of the Foothill Zone with insets showing close-up of three anticlines

- *The anticlines of the **Mosul Uplift** are generally dense and short (10-15 km) long, but increase in length towards the SE.*

They usually trend NW-SE except in the NW near Tel Afar (Fig. 6-3 B and C) where they trend E-W.

- *Some shorter anticlines, mainly on the Mosul High, such as Adaiyah and Hibbarah are also accompanied by deep faults evident on seismic maps.*
- *Prominent synclines are not common on the Mosul High.*
- *The anticlines in this relatively uplifted part of the subzone are Ishkaft, Atshan, Mishraq, Qalian, Qara Chauq-Makhmur (>1000 m amplitude), Sasan, Ibrahim, Adaiyah, Jawan, Najmah, Qaiyarah, Hibbarah and Khanuqa.*

Fig. 6-3: Satellite image of the SE part of the Foothill Zone with insets showing close-up of three anticlines

- *The **Kirkuk Block (Embayment**) portion of the subzone contains the long anticlines of Hemrin (Fig. 6-5 B) that form the SW border of the subzone, and the Bai Hassan and Jambur anticlines that form the NE border.*
- *These anticlines are 130-200 km long, with several doubly-plunging domes (Fig. 6-3),*

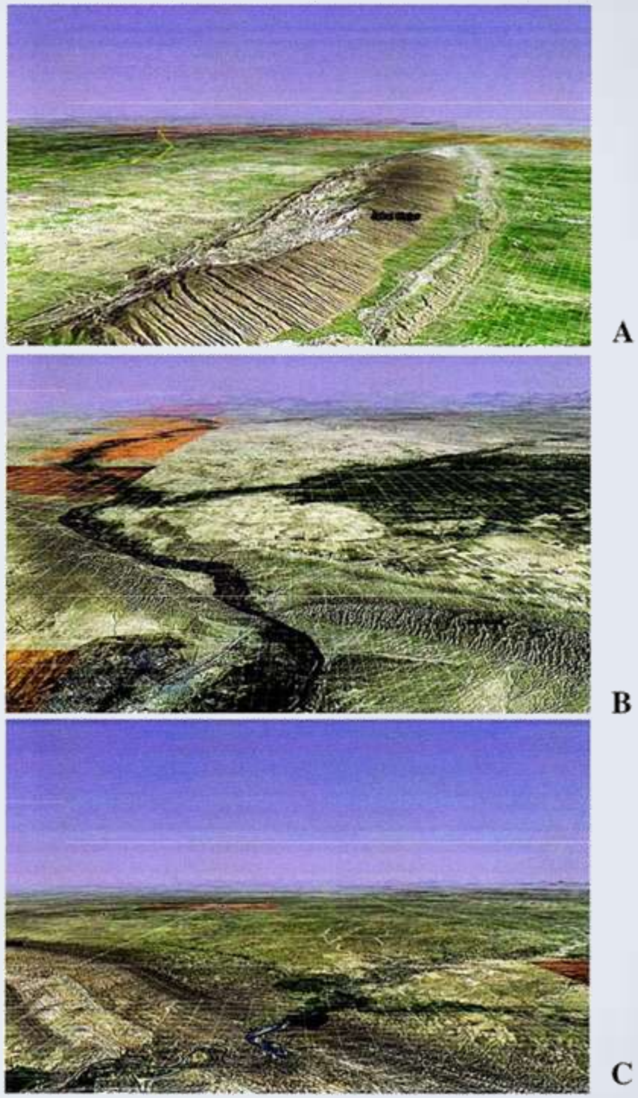


Fig. 6-5: Inclined views of some anticlines of the Foothill Zone: A) Looking east to the Sinjar anticline with Palaeogene whale back and incised northern limb with Cretaceous marls; located 100 km W of Mosul. B) The Al Fatha Col between Hemrin anticline (right) and Makhul anticline (left) with the Tigris River passing through it (220 km N of Baghdad). C) Kirkuk anticline with the Dibis col between the Avanah dome (right) and the Khurmala dome (left) (40 km NW of Kirkuk). All photos have 3× vertical exaggeration. Views are derived from Google Earth

1.2- Butmah-Chemchemal Subzone

- *The **Butmah-Chemchemal** Subzone is the NE unit of the Foothill Zone.*
- *It is the structurally highest part of the Zone.*
- *The Mesozoic-Tertiary sequence is up to 1.5 km thick.*
- *The subzone was intermittently uplifted during the Jurassic and Cretaceous, usually forming either a submerged or exposed ridge often associated with a carbonate platform (the Chemchemal- Taq Taq palaeoridge).*
- *In the latest Miocene-Pliocene the subzone became part of the Foothill Trough and was filled in by coarse molasse sediments.*
- *The transversal Mosul Uplift affected the subzone, but to a lesser extent than in the Makhul-Hemrin Subzone.*
- *The anticlines are medium-sized, NW-SE trending in the SE and E-W trending in the NW.*

- *The **Butmah-Chemchemal Subzone**, however, has very conspicuous long and deep synclines with thick Pliocene molasse dominated by conglomerate.*
- *The prominent features of the subzone are long anticlines often not associated with longitudinal faults with the exception of the Kirkuk structure.*
- *-Broad and deep synclines are a feature of the subzone.*
- *- The three transversal blocks of **Sinjar**, **Mosul** and **Kirkuk** have also influenced the structure of the subzone but to a lesser degree than in the Makhul-Hemrin Subzone.*

2- The High Folded Zone

- *The **High Folded Zone** is located between the Zakho area, on the Turkish border in the NW and the Derbendikhan Halabja area near the Iranian border in the SE.*
- *The width of zone varies from 25 to 50 km.*
- *It i s also affected by transversal blocks.*
- *The zone was intermittently uplifted in Cretaceous and Palaeogene time and strongly deformed in e Late Tertiary.*
- *The zone was the marginal part of the Palaeogene molasse basin.*
- *The High Folded Zone covers most of the Iraqi Kurdistan region.*
- *It comprises harmonic folds with Mesozoic limestone in their cores and Palaeogene and Neogene limestone and clastics on their flanks.*
- *The anticlines of the High Folded zone generally trend NW-SE in NE Iraq and E-W in N Iraq.*

- *The **High Folded Zone** has an elevated basement (-8 km) compared to the neighbouring Foothill Zone (-13 km) and the Balambo- Tanjero Zone (-10 km).*
- *The zone was a molasse basin during the Palaeogene and was elevated (forming the Qamchuqa ridge) during Cretaceous and early Palaeogene time.*
- *The High Folded Zone comprises whale-back anticlines (Fig. 6-7 top inset) with Palaeogene carbonates in their cores and Neogene clastics on their flanks in the SW part of the zone.*
- *In the NE Cretaceous or older Mesozoic carbonates form the cores of the anticlines and Palaeogene rocks form the flanks with carbonate units forming resistant ridges (Fig. 6-8 both insets).*

- ***Narrow synclines are characteristic features of the High Folded Zone; the broad syncline near Zakho is an exception***.

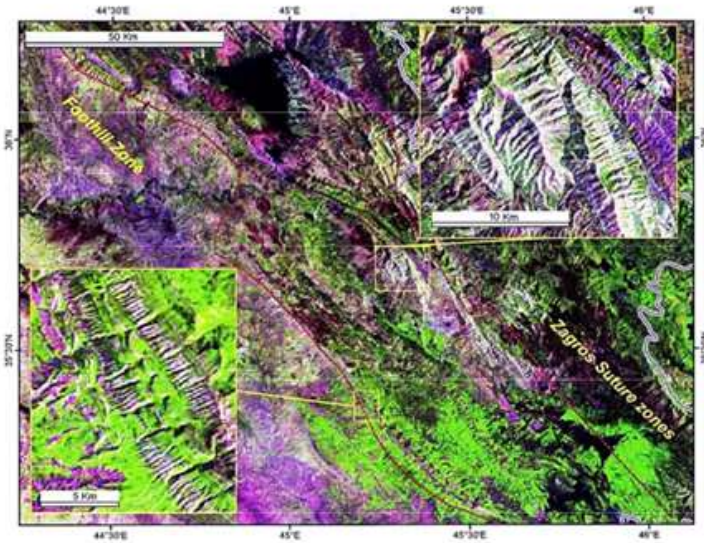


Fig. 6-7: Satellite image of the SE part of the High Folded Zone with two insets showing details of two anticlines

Fig. 6-8: Satellite image of the NW part of the High Folded Zone with insets showing details of two anticlines

Wale back:- *is a rock formation created by the passing of a glacier. The passage of glacier ice over underlying bedrock often results in asymmetric erosional forms as a result of abrasion on the "stoss" (upstream) side of the rock and plucking on the "lee" (downstream) side.*

3- The Imbricated Zones

3.1- The Balambo-Tanjero Zone

*The **Balambo- Tanjero** zone was a trough that developed along the plate boundary during the opening of the Southern Neo Tethys from Late Jurassic time.*

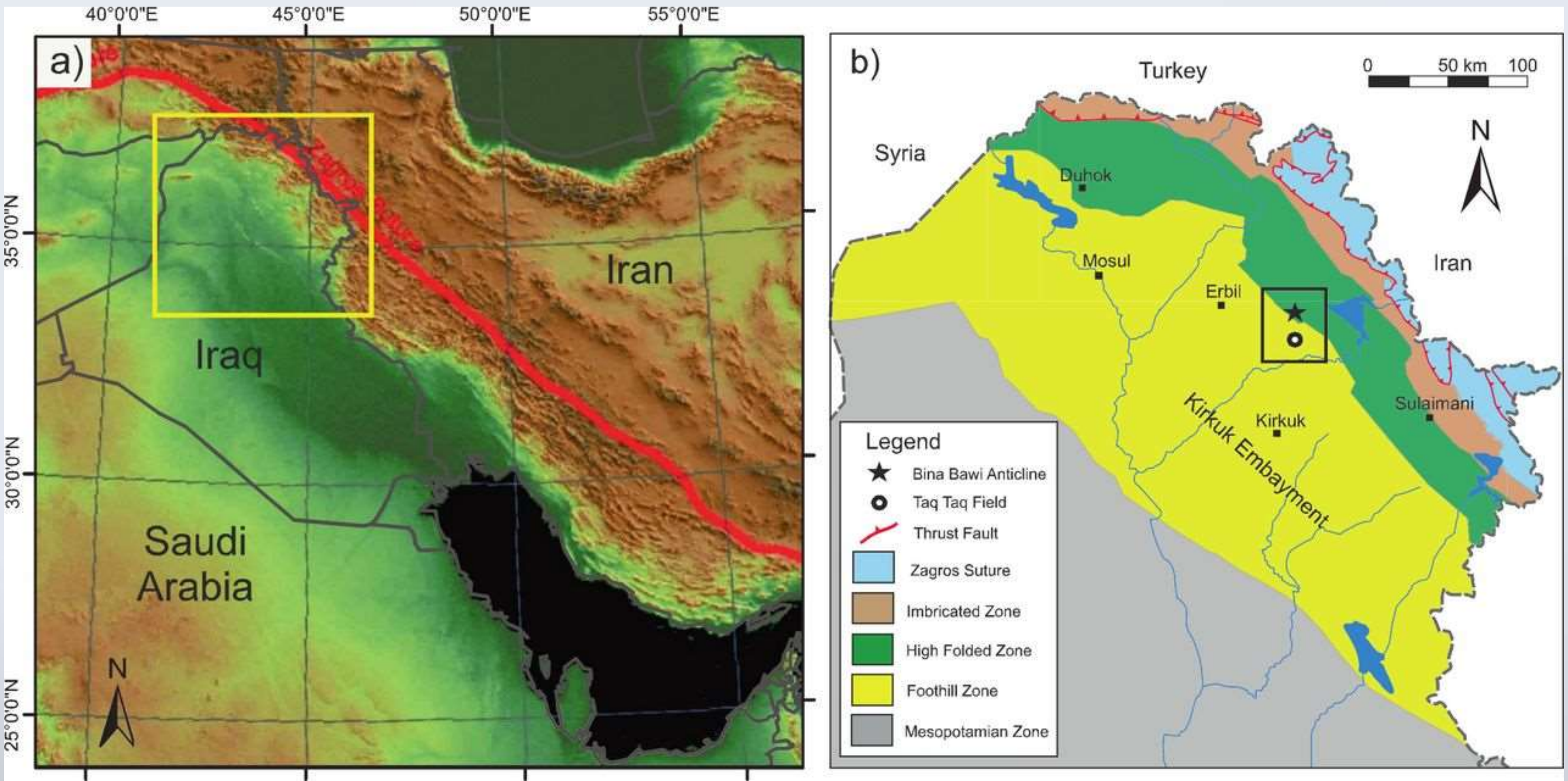
- *It is a narrow belt (up to 25 km wide) trending NW-SE.*
- *It extends from the Iranian border in the SE to the Turkish border in the NW.*
- *The zone may be completely over-ridden by the Northern 'Thrust Zone in N Iraq and partly by units of the Zagros Suture in NE Iraq.*
- *The **Mesozoic sedimentary section** of the zone consists of pre-Tithonian platform carbonates, Tithonian-Lower Campanian marine basinal sediments of the Balambo and Shiranish formations, and the Tanjero flysch of Late Campanian-Early Maastrichtian age.*
-

- *The Palaeogene Neogene section consists of thick molasse deposited in an intermountane basin between the High Folded Zone and the suture zone.*
- ***The Balambo- Tanjero Zone** is intensely folded and faulted throughout.*
- *Folded pre- Tithonian sediments have a structural style similar to the High Folded Zone; Cretaceous strata are isoclinally folded.*
- *Both Cretaceous and earlier units are traversed by reverse faults dislocating the anticlines into imbricates; the anticlines often over-ride the synclines..*

Longitudinally, the Balambo- Tanjero Zone can be subdivided into two belts.:-

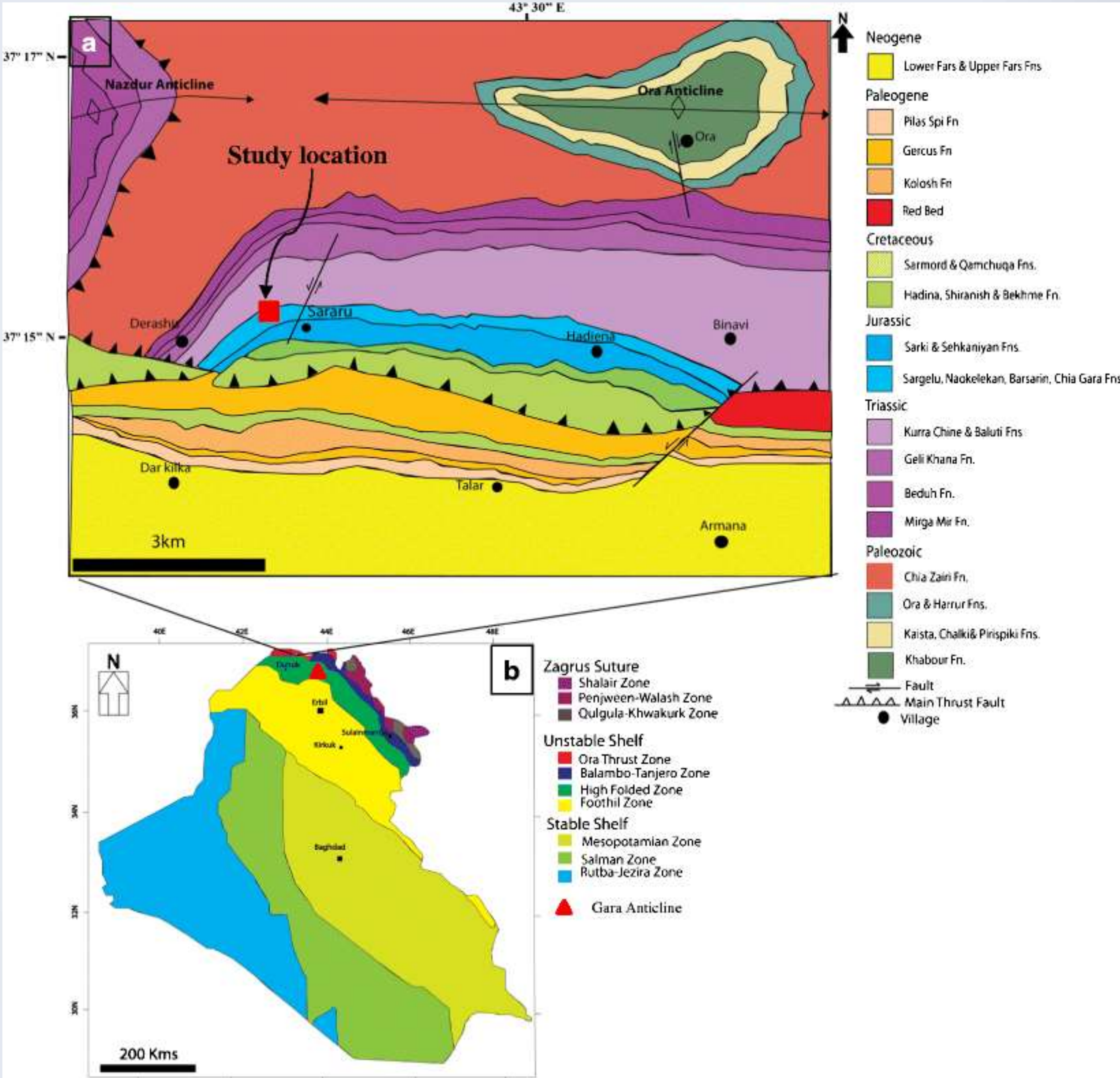
A-*The NE belt is a depression with Tertiary clastics and forms a monocline dipping to the NE below the thrust sheets of the Zagros Suture.*

B- *The SW part (where Tertiary clastics are absent) is characterized by closely packed folds with several parallel or often obliquely (NNW-SSE) trending reverse faults or minor thrusts*



3.2- The Northern (Ora) Thrust Zone

- *The Northern Thrust Zone (15 Ian at its widest in Iraq) is located along the **Turkey-Iraq border**.*
- *It is an E-W trending narrow belt between the Hazil Su valleys in the W and the Dirri area in the E, running along the Turkish frontier.*
- *It contains Mesozoiac and Palaeozoic formations, thrust over units of the High Folded Zone, usually with underlying Palaeogene and Neogene clastics and carbonates .*
- *Lower Palaeozoic clastics form the soft cores of the two major domes (**Ora to E and Kaista to the W**),*
- *The zone is widest in the W with three domal culminations (**Sinat**, **Kaista** and **Ora**).*
- *The domes are asymmetrical .*


43° 30'' E
37° 17'' N
37° 15'' N
a
Nazdur Anticline
Ora Anticline
Ora
Study location
Derashi
Sararu
Hadiena
Binavi
Dar kilka
Talar
Armana
3km
N
Neogene
Lower Fars & Upper Fars Fns
Paleogene
Pilas Spi Fn
Gercus Fn
Kolosh Fn
Red Bed
Cretaceous
Sarmord & Qamchuqa Fns.
Hadina, Shiranish & Bekhme Fn.
Jurassic
Sarki & Sehkaniyan Fns.
Sargelu, Naokelekan, Barsarin, Chia Gara Fns.
Triassic
Kurra Chine & Baluti Fns
Geli Khana Fn.
Beduh Fn.
Mirga Mir Fn.
Paleozoic
Chia Zairi Fn.
Ora & Harrur Fns.
Kaista, Chalki& Pirispiki Fns.
Khabour Fn.
Fault
Main Thrust Fault
Village
b
N
Zagrus Suture
Shalair Zone
Penjween-Walash Zone
Qulgula-Khwakurk Zone
Unstable Shelf
Ora Thrust Zone
Balambo-Tanjero Zone
High Folded Zone
Foothil Zone
Stable Shelf
Mesopotamian Zone
Salman Zone
Rutba-Jezira Zone
Gara Anticline
200 Kms

2- Units of the Zagros Suture

- *The Zagros Suture units formed within the Neo- Tethys.*
- *They were thrust over the Arabian Plate during two distinct phases:- 1-of **obduction** and*

  *2- **collision**, during the Late Cretaceous and Mio-Pliocene.*

Q. What is Obduction & what is collision?

Three tectonic zones are identified within Iraq and comprise from the SW:

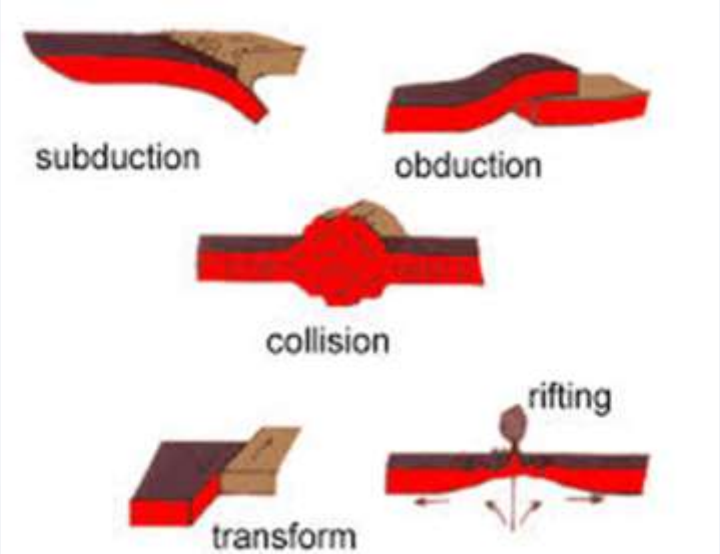
1-The Qulqula-Khwakurk Zone

2-The Penjween- Walash Zone

3- The Shalair Zone

Definitions

- ***Obduction*** *mean the overthrusting of oceanic lithosphere onto continental lithosphere at a convergent plate boundary where continental lithosphere is being subducted beneath oceanic lithosphere.*
- ***Subduction*** *is a geological process that takes place at convergent boundaries of tectonic plates where one plate moves under another and is forced or sinks due to gravity into the mantle.*
- ***collision*** *is an event in which two or more bodies exert forces on each other for a relatively short time.*



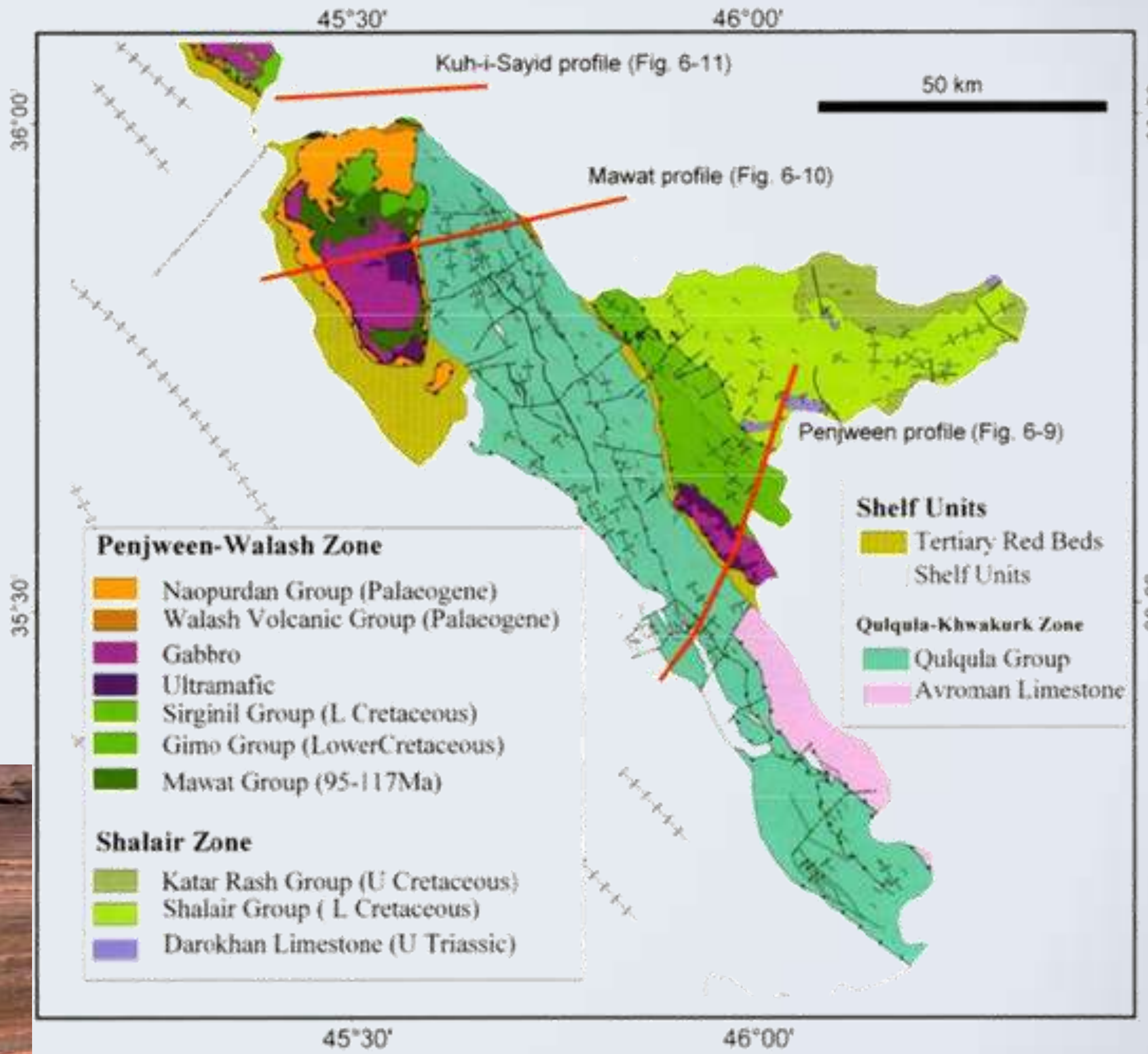
2.1- Qulqula-Khwakurk Zone

- *The* ***Qulqula-Khwakurk Zone*** *forms the units of the Southern Neo-Tethys that were folded, obducted and sutured to the Arabian Plate during the Late Cretaceous (Campanian-Maastrichtian).*

-It contains Upper Tithonian Cenomanian sediments of deep water facies (radiolarian chert, mudstones, and limestone) with increasing proportions of basic volcanics to the NE and with conglomerates in the upper parts.

- *The zone is strongly isoclinally folded and cut by reverse faults.*
- *The main structural features are isoclinal and recumbent folds, reverse faults and thrusts.*

A ***thrust fault*** *is a type of fault, or break in the Earth's crust across which there has been relative movement, in which rocks of lower stratigraphic position are pushed up and over higher strata. They are often recognized because they place older rocks above younger. Thrust faults are the result of compressional forces.*



3: Geological map of the SE part of the Zagros Suture

2.2- Penjween- Walash Zone

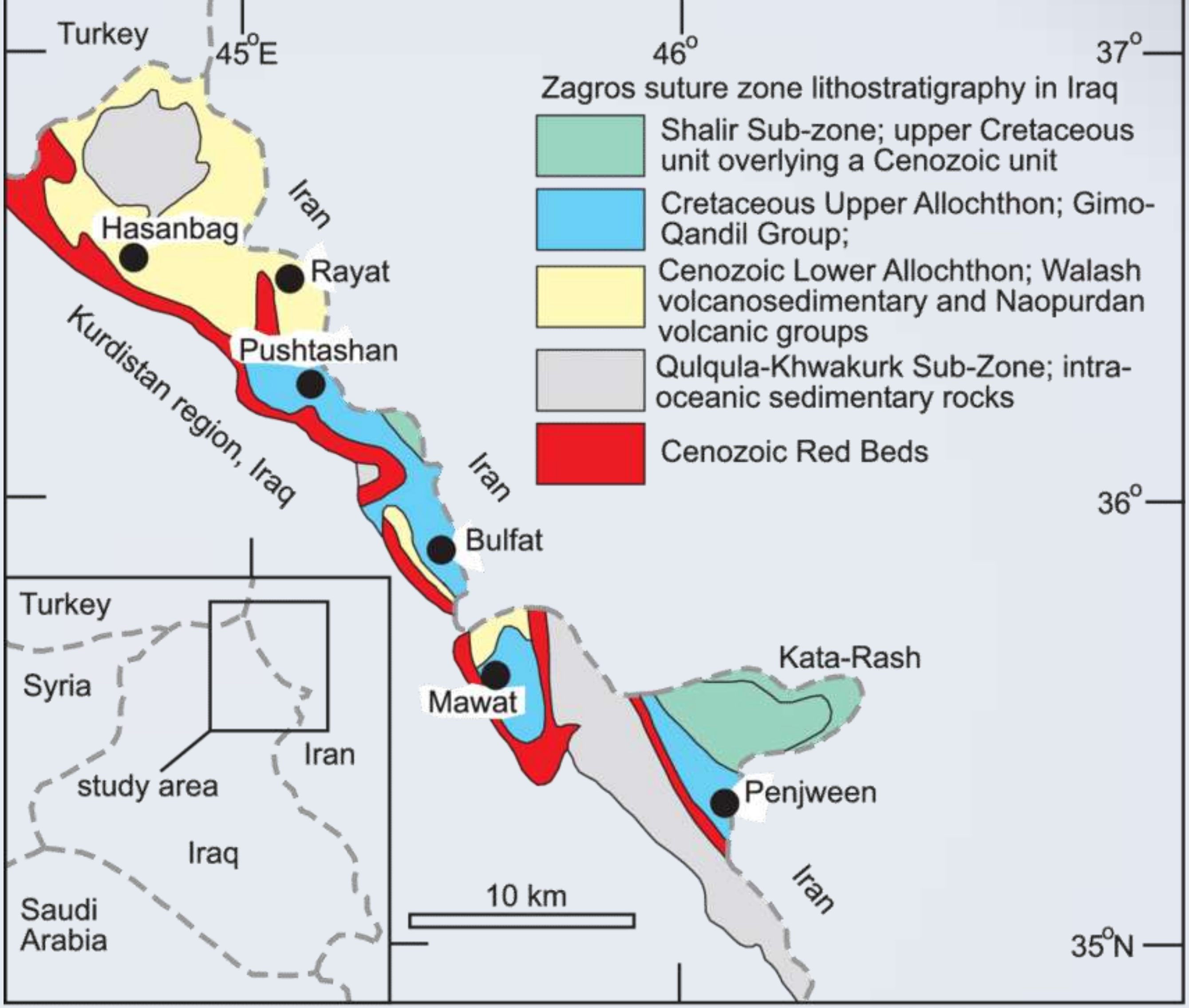
- *The Penjween-Walash Zone is a unit of the main (Central) Neo-Tethys.*
- *It comprises volcanosedimentary sequences formed during Cretaceous ocean spreading in the NeoTethys, and Palaeogene arc volcanics and syn-tectonic basic intrusions formed during the final closure of this ocean.*
- *The zone is thus a remnant of the Neo- Tethys which was thrust over the Arabian Plate during Miocene-Pliocene time.*
- *The Penjween- Walash Zone forms an almost continuous belt along the Iraq-Iran border (Fig. 6-1).*
- *The zone is thrust over the Qulqula-Khwakurk Zone or the Balambo-Tanjero Zone.*
- *The Mesozoic sequences are mostly of Cretaceous age.*
- *They comprise alternating pelitic and carbonate beds with volcanics and pyroclastics that were metamorphosed during Late Cretaceous deformation; occasionally strong contact metamorphism can be seen near gabbro bodies such as Bulfat.*
- *The main structural features of the zone are thrust sheets sometimes dislocated by reverse faults.*

- ***The Penjween- Walash Zone consists of three thrust sheets:***

1-The structurally lowest Naopurdan,

2-The middle Walash

3-The upper Qandil (structurally highest).



Upper + Lower Allochthons = Penjween Walash Sub-Zone

an allochthon, or ***an allochthonous*** *block, is a large block of rock which has been moved from its original site of formation, usually by low angle thrust faulting.*

2.3- Shalair (Sanandaj-Sirjan) Zone

- *The **Shalair Zone** comprises pre-Upper Permian metamorphosed rocks overlain, in Iraq, by ?Jurassic and Lower Cretaceous fore-arc metasediments and upper Cretaceous andesite arc volcanics with imbricates of Upper Triassic deep water carbonates .*
- *The zone is the innermost metamorphosed unit, **forming the structurally higher thrust sheets in Iraq.***
- *The zone outcrops in the Shalair valley NE of Penjween Town; smaller, isolated outcrops comprise thrust sheets along the Iranian border in Jabal Qandil NE of Qalat Dizeh.*
- *The Cretaceous rocks of the zone were affected by low grade metamorphism in Cretaceous time.*
- *Palaeozoic rocks were metamorphosed during the Late Carboniferous.*
- *In the eastern most part of the Shalair valley syn-Hercynian Upper Carboniferous granite bodies occur.*

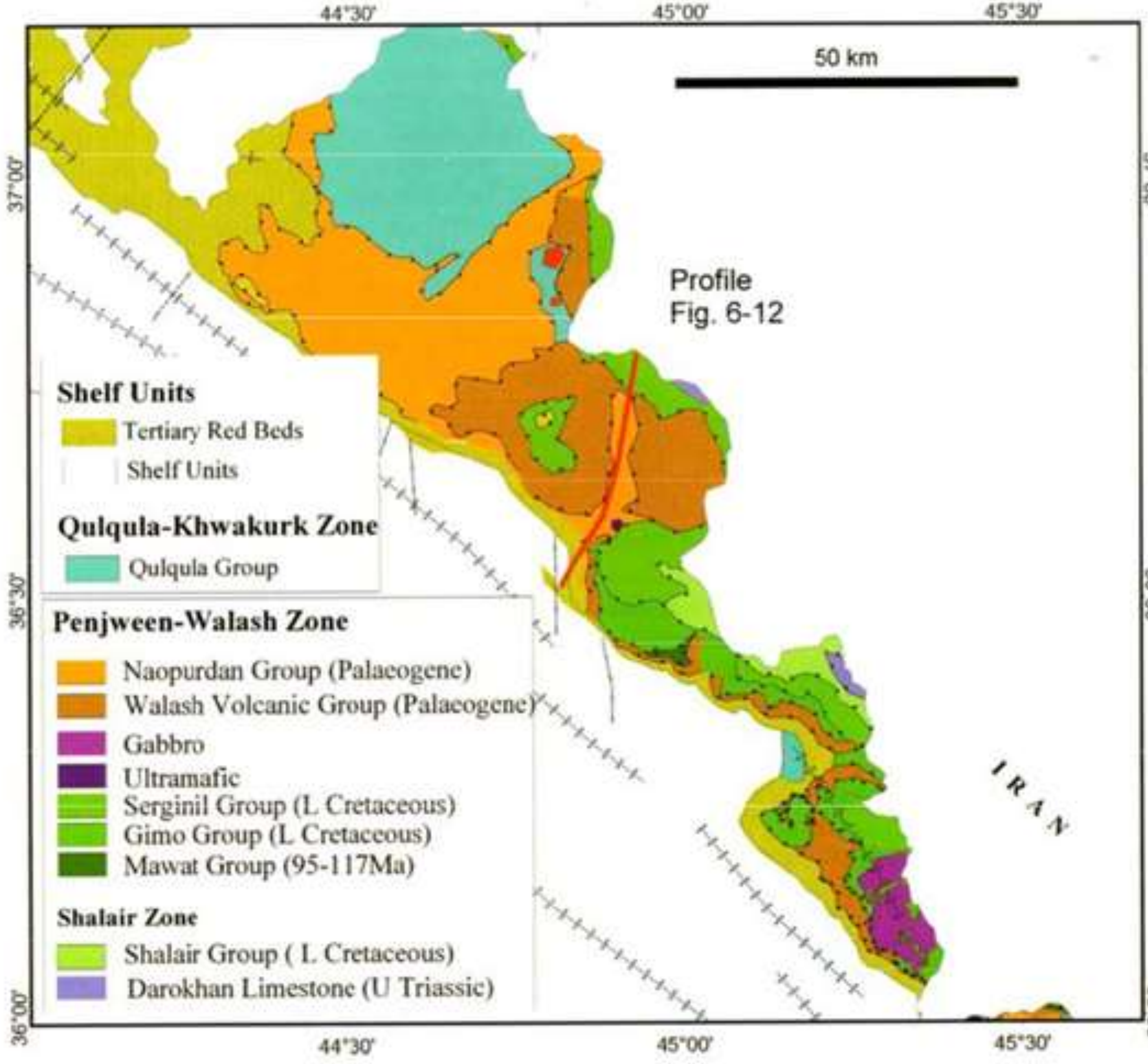
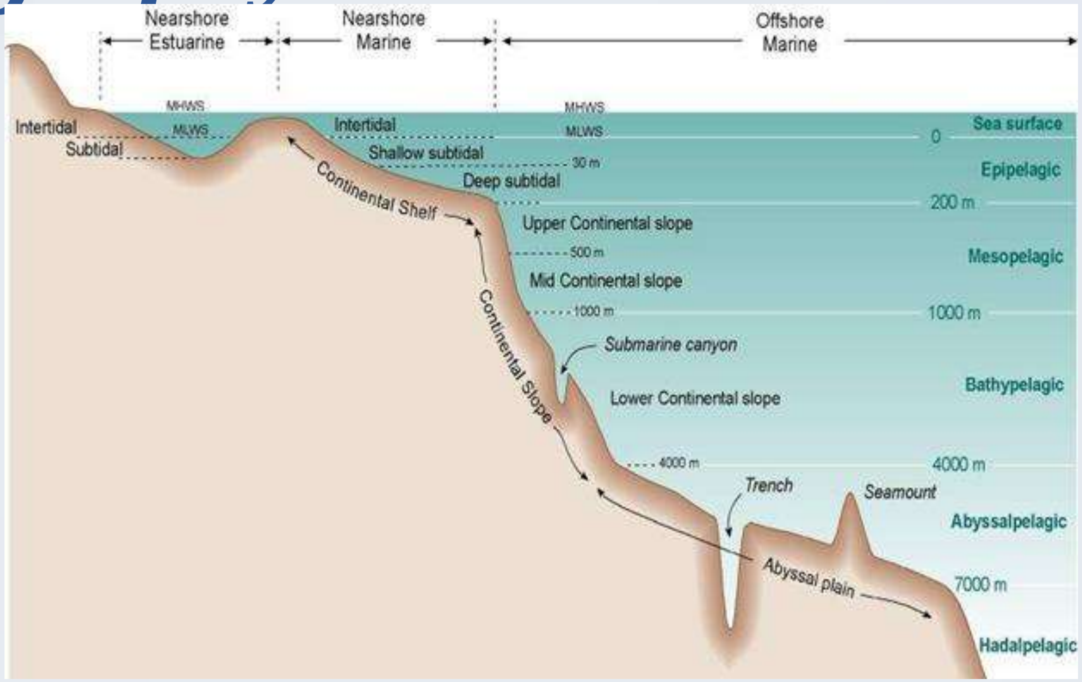
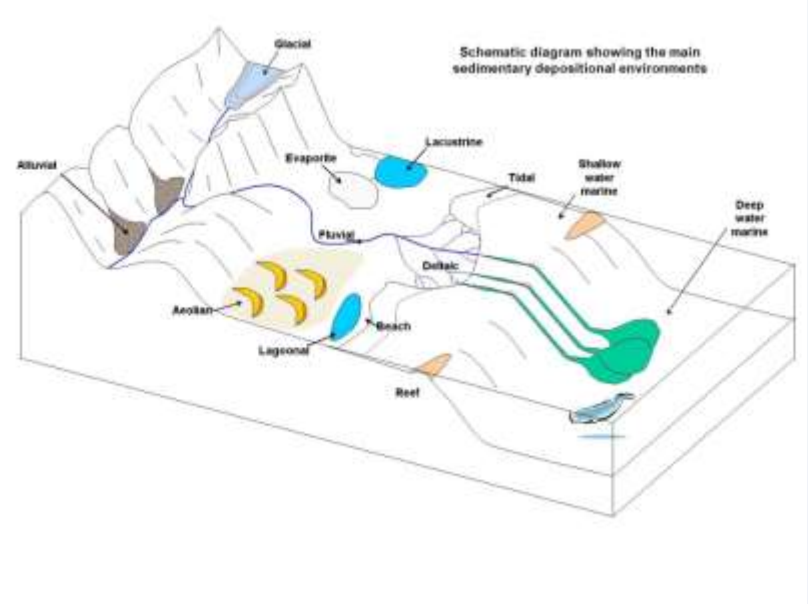


Fig. 6-14: Geological map of the NW part of the Zagros Suture

Stratigraphy & Paleoenvironments

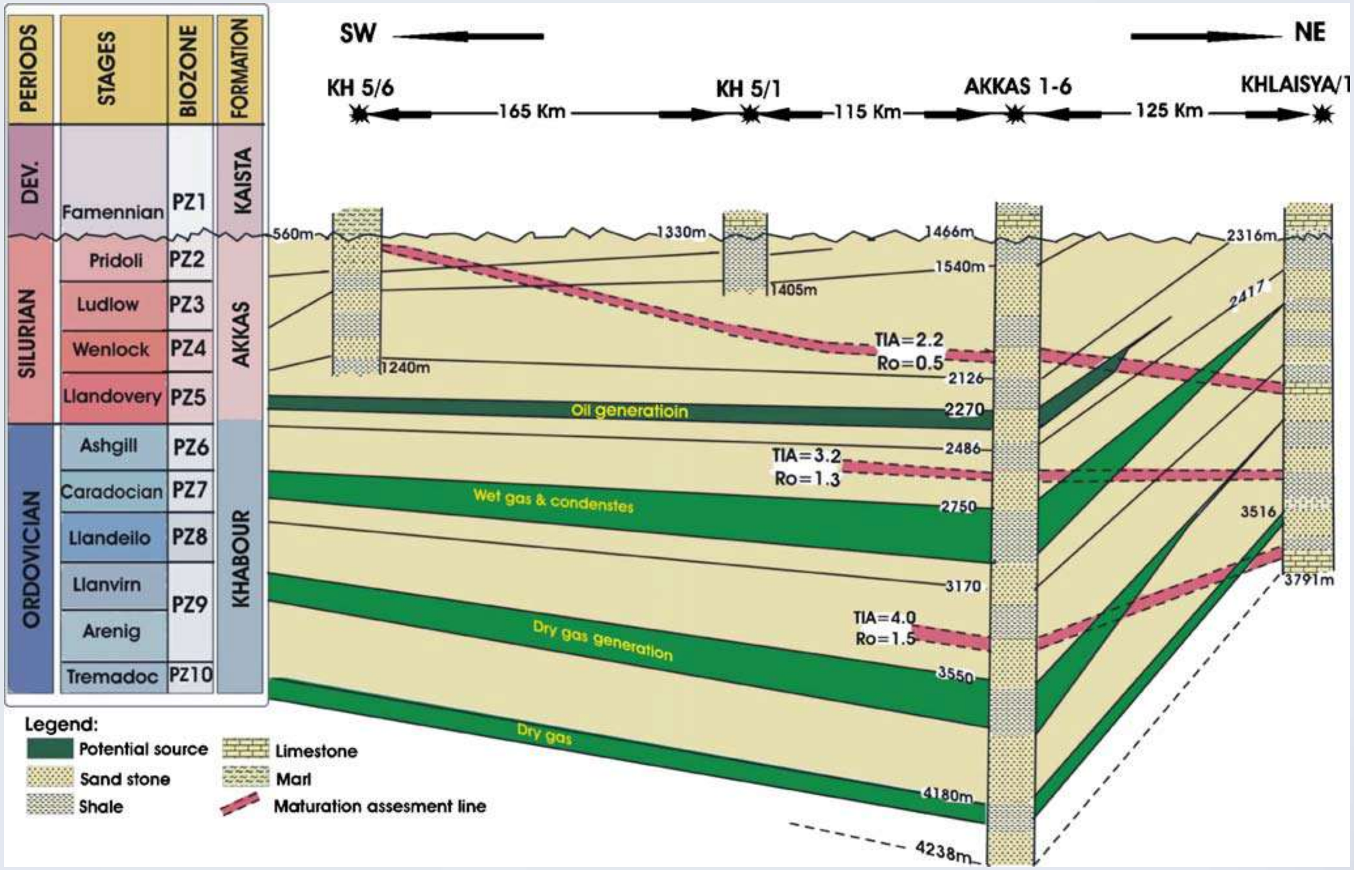




Marine Environments

Late Cambrian-Early Ordovician Sequence

- This sequence does not outcrop in Iraq but may be penetrated in well Akkas-l in W Iraq as part of the Khabour Formation, probably comprising the lower 1170 m of the drilled section.



Mid-Late Ordovician Sequence

The sequence is represented by the Khabour Formation in Iraq.

1- Khabour Formation

- *an 800 m section exposed in the Khabour valley within the Ora Zone of N Iraq (cores of Ora and Kaista anticlines).*

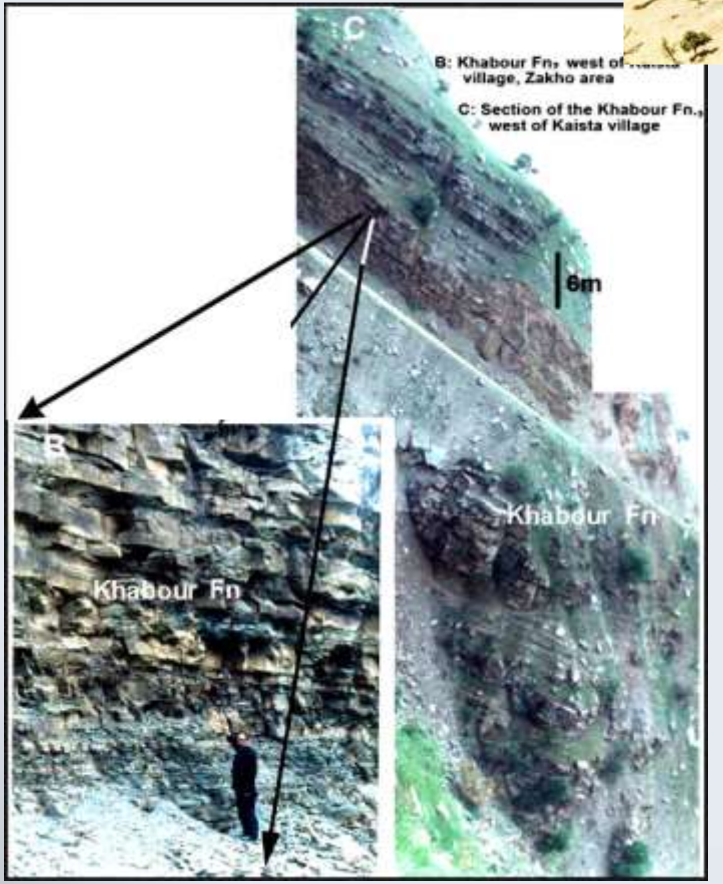
Lithology:- *It comprises beds of thin-bedded, fine-grained quartzite, siltstone and micaceous shale.*

L. Contact:- *The base of the formation is not exposed.*

Environment:- *The formation passes from* ***littoral facies in the Ora anticline*** *into a* ***deeper marine turbidite facies in the Kaista anticline*** *(20 km to the west) (Seilacher, 1963).*

- *The formation has been penetrated in wells Khlesia-I in the Jezira subzone and Akkas-l in the Rutba subzone (comprises beds of sandstone and shale).*


Bekhme/ Aqra Formation
Khabour River
Khabour Quartzite Shale Formation


C
B: Khabour Fn, west of
village, Zakho area
C: Section of the Khabour Fn.,
west of Kaista village
6m
B
Khabour Fn
Khabour Fn

2- Silurian Sequence

2.1- Akkas Formation

The Akkas Formation was introduced by Habba et al. (1994) from well Akkas-l in W Iraq between 1451 m and 2316 m depths .

-consist as of black shale with occasional thin layers of sandstone.

- *The sequence in general has high TOC.*

The Caledonian orogeny encompasses events that occurred from the Ordovician to Early Devonian, roughly 490–390 million years ago (Ma).

Late Devonian- Early Carboniferous Sequence

1-Pirispiki Formation (including Chalki Volcanics)

Age:- *Late Devonian-Early Carboniferous .*

Lithology:- *fine-grained soft sandstone , of red marly sandstone with subordinate dolomite , with occasional beds of conglomerate with pebbles of green basalt, quartzite and sandstone and green , occasionally purplish siltstone and silty shale with occasional beds of cross-bedded quartzite (formerly assigned to the Kaista Formation).*

The Chalki Volcanics comprise altered olivine basalt flows (Bellen et al., 1959) with beds of tuff, ash, shale and siltstone.

Environment:- *continental to marginal marine.*

Fig. 8-8: Late Devonian to Early Carboniferous Palaeogeography

2-Ora Formation

Lithology:- *The formation comprises black micaceous and calcareous shale with olive green silty marl and lenses of detrital limestone.*

Fine-grained sandstone beds occur intermittently throughout the formation.

Age:- *Late Devonian – Early Carboniferous.*

Contacts:- *The Ora Formation is overlain by* ***Harur*** *Formation with conformable and gradational contact.*

The ***Kaista*** *Formation underlies the Ora Formation with conformable and gradational contact*

3- Harur Formation

The formation has been penetrated in wells Khlesia-l, Akkas -I and water well K5-1 and reached in well Jabal K and-l.

Lithology:- *In the type area the formation consists of 62 m of thick-bedded detrital limestone with thin inter beds of black calcareous micaceous shale.*

Environment:- *deposited as a marine neritic facies (mostly reef and* ***fore reef).***

Contact:- *The Harur Formation conformably and abruptly overlies the* ***Ora*** *Formation in the type area.*

Age:- *Rich fossil assemblages in the type section and in well Khlesia-1 indicate an Early Carboniferous (Tournasian) age.*

Late Carboniferouse - Early Permian

1- Bir - ElRah Formation

Lithology:- *limnic claystone and shale with thin beds of cross-laminated sandstone with o ccasional immature clayey coal horizons at 360-856 m (496 m thick) in water well K5-1, 5 km west of Bir El Rah village in the Ga'ara depression*

Age:- *The age of the formation in well KS-2 thus probably ranges from Late Carboniferous to Early Permian .*

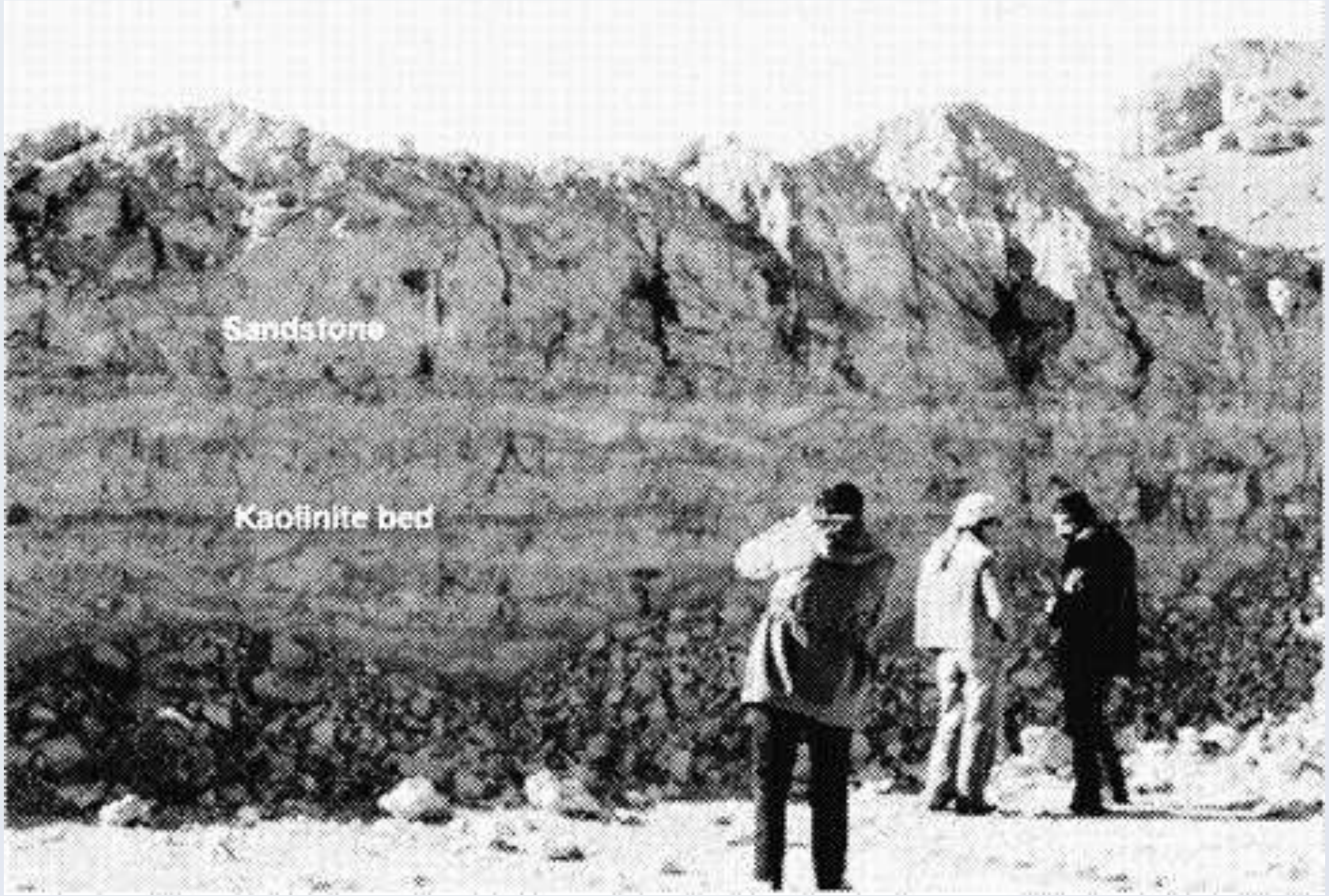
Environment:- *The richness in plants and reducing conditions of the sediments indicate that the formation was deposited in a fluvio-lacustrine swampy environment.*

Contacts:- *In well K5 -1 the formation lies below an interval of thick red and green mudstones; the contct is gradational taken at base of a*

dark red mudstone layer.

The lower contact with the underlying marine shales and thin limestone beds of the ***Harur*** *Formation is disconformable and taken at the base of an interval of sandstone and shales*

Gaara Fn.

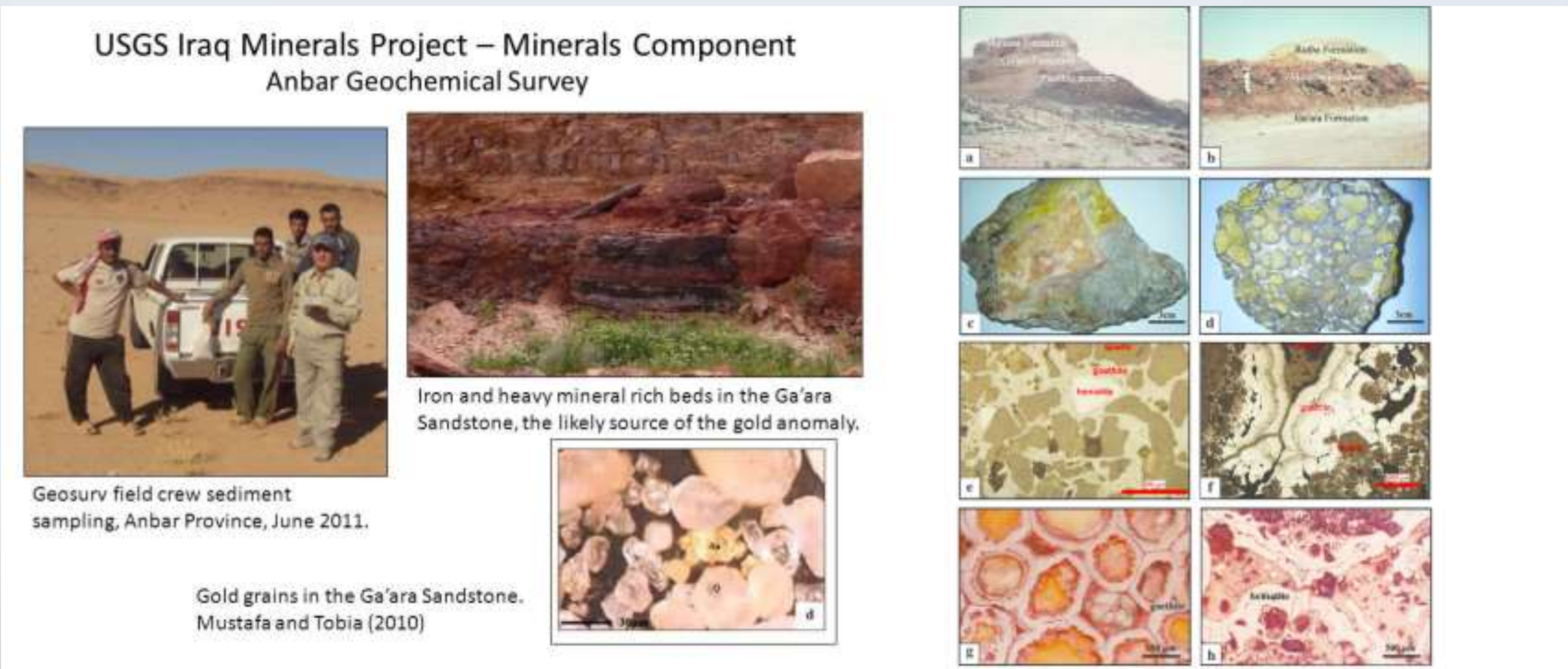


2- Ga'ara Formation *(Early Permian-early Late Permian)*

Lithology:- *contains stacked sandstone channels (often with channel lags of ironstone pebbles) passing upwards into siltstone, green kaolinitic mudstone and mottled red-green mudstones, overlain by purple to red (locally pisolitic) ironstone.*

Environment:- *The Ga'ara Formation was deposited by large river systems.*

The abundance of red claystone and ironstones suggest frequent long periods of drought occurred*.*



Late Permian-Mid Triassic Sequence

*Following the **Hercynian** uplift during the Late Carboniferous and early Permian major changes' in basin' geometry occurred late' Permian time in Iraq .*

*-The previously subsiding area of the' Stable Shelf (Rutba-Jezira Zone) was **uplifted** initiating the Rutba uplift, whereas the previously elevated Salman and the Mesopotamian zones **subsided**.*

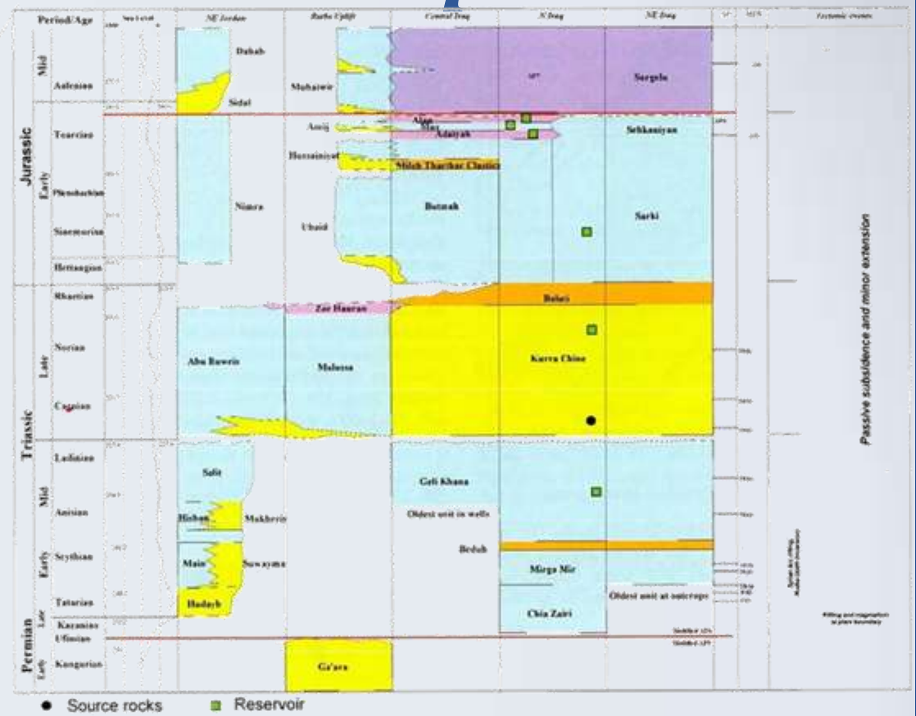


Fig. 9-1: Stratigraphic correlation of the Late Permian-Liassic Megasequence (AP6)

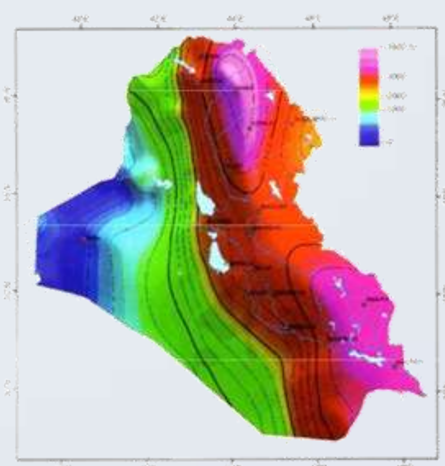


Fig. 9-2: Thickness of the Late Permian-Liassic Megasequence AP6

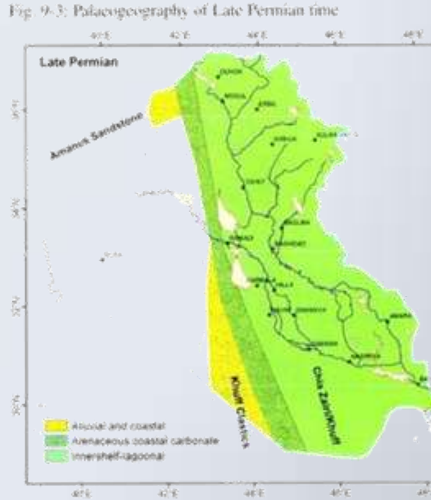


Fig. 9-3: Palaeogeography of Late Permian time

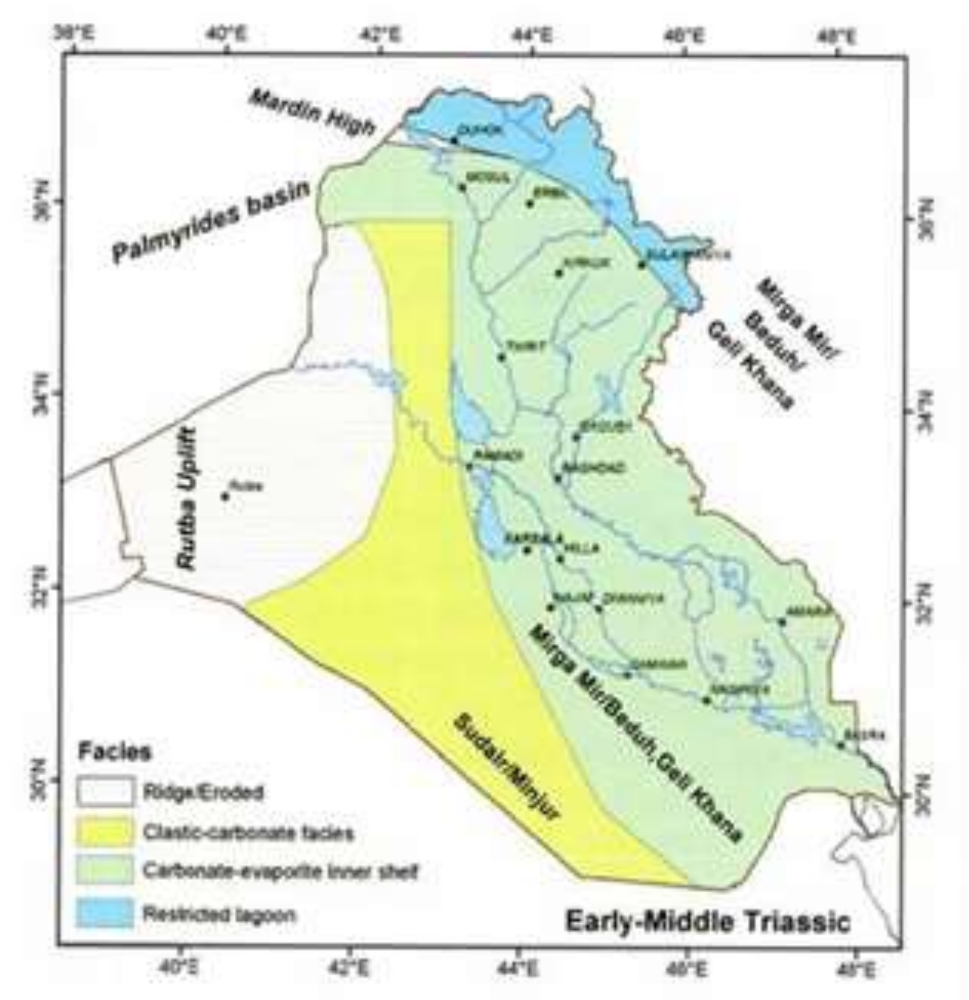


Fig. 9-4: Palaeogeography of Early-Mid Triassic times

1- Chia Zairi Formation

Lithology:- *Consist of alternating thin bedded organic detrital Limestone, dark blue Limestone and massive cliff forming silicified L.st.,with black shale at the base.*

Environment:- *The Chia Zairi Formation was deposited in a transgressive neritic sea on a broad carbonate platform with locally developed lagoonal conditions and sabkhas.*

Age:- *Mid"-Late Permian age*

2-Mirga Mir Formation

The Mirga Mir Formation was first described by Wetzel in 1950 from the Ora region of the Northern Thrust Zone.

Lithology:- *It comprises 200 m of thin bedded grey and yellow argillaceous limestone and shale with some recrystallized breccias.*

Contacts:- *The formation is always underlain by the Chia Zairi Formation and overlain by the Beduh Formation; both contacts are gradational .*

Age:- *an Early Triassic .*

Environment:- *Anhydrites in well Atshan-l and the presence of solution breccias in outcrops also indicate lagoonal conditions.*

Mirga Mir Formation (Lower Triassic), Nazdur area, Northern Thrust Zone

3 - Beduh Formation

Lithology:- *60 m of shale and marl, sometimes silty, with subordinate thin limestone interbeds with sandstone streaks.*

Its red brown-purple colour makes it an excellent marker unit for field mapping.

Contacts:- *The contacts of the formation with the overlying* ***Geli Khana*** *and the underlying* ***Mirga Mir*** *formations are conformable and gradational.*

Environment:- *The formation is of shallow marine origin.*

4- Geli Khana Formation

Lithology:- *comprises dark, massive dolomites overlying thick-bedded limestone with subordinate marl and shale with occasional chert nodules.*

Environment:- *The upper division was deposited in a shallow marine basin while the lower division was deposited in a near shore (locally lagoonal) environment .*

All outcrops in N and NE Iraq are of similar facies and include anhydrite in the lower parts of the formation.

The absence of Middle Triassic deposits in the Rutba-Jezira zone, in the eastern Syria, and in extreme N E Jordan suggests that sedimentation was influence by the mega N-S tending Rutba Uplift.

Beduh Formation (Lower Triassic), Naadur area, Northern Thrust Zone

Geli Khana Formation (Middle Triassic), Ora region, Northern Thrust Zone

2- Late Triassic Sequence

The Late Triassic Sequence is the most widespread Triassic sequence in the Arabian Peninsula.

The sequence is represented by the:-

-***Mulussa & ZorHauran*** *formations in the Rutba Subzone*

- *and by the* ***Kurra Chine & Baluti*** *formations in the rest of Iraq.*
- *The palaeogeography of Late Triassic time differs from that 'of the Middle Triassic only by the extent of the Rutba Uplift.*
- *In W Iraq, most of the Stable Shelf was submerged (Fig. 9-7).*

Fig. 9-7 Thickness of the Late Triassic Sequence

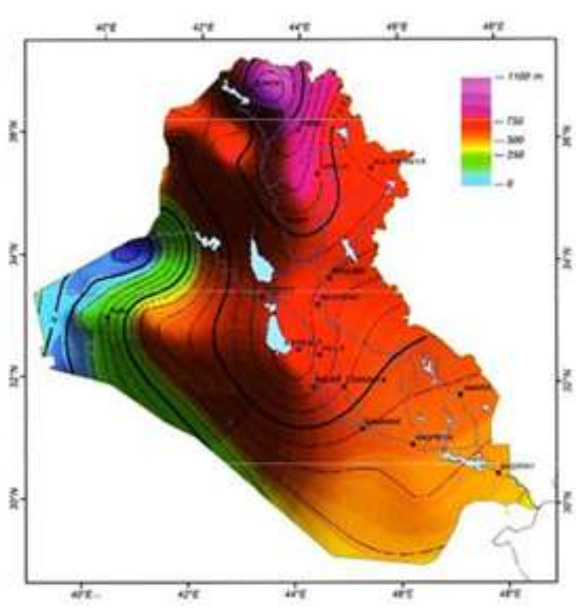
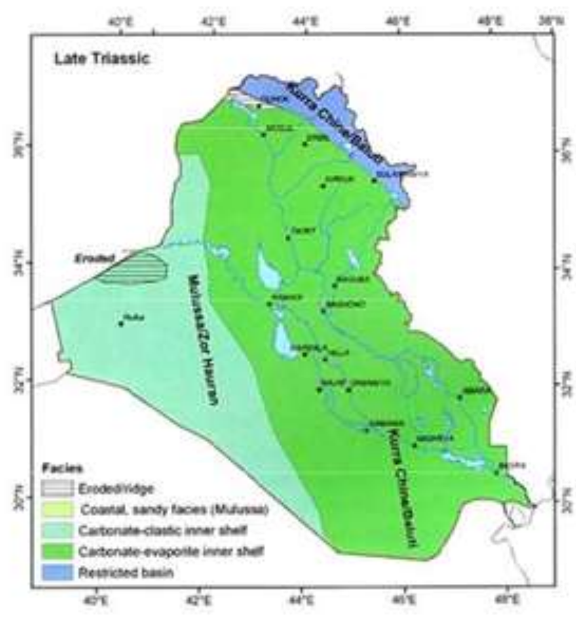


Fig. 9-8: Palaeogeography of Late Triassic time



Three distinct facies are recognized comprising:-

*1- inner shelf carbonates and clastics on the Stable Shelf (**Mulussa** and **ZorHauran** formations),*

2- inner shelf carbonates and evaporates in the Foothill Zone,

*3- and restricted lagoonal facies in the High Folded Zone (**Kurra Chine** and **Baluti** formations) (Fig. 9-8).*

The Late Triassic transgression reached far beyond the Mid Triassic shoreline.

- *The whole Stable Shelf area of Iraq was **submerged** in the Late Triassic; its shoreline was located not far beyond Iraq in Saudi Arabia.*

1- Carbonate-clastic inner shelf

1.1- Mulussa Formation

The Mulussa Formation is exposed in the western parts of Iraq in the Rutba area and is widespread on the Rutba Subzone except in the area between the Ga'ara depression and the Euphrates River (Fig. 9-8) where it may have been <u>eroded</u>.

Lithology:- *The formation consist mainly of limestone some times sandy and oolitic, often dolomitized with yelow marl and marly limestone*.

The thickness of the formation is up to 150 m thick but wedges out by erosion towards the N and NW. It has been completely eroded in the central part of the Ga'ara depression.

Contacts:- ***The lower contact*** *of the Mulussa Formation, according to Bellen et al. (1959), appears conformable.*

- However the recently recognized age gap between the Palaeozoic Ga'ara Formation and the Upper Triassic Mulussa Formation is large.

- The apparent conformity is due to reworking of the clastics of the underlying Ga'ara Formation into the overlying basal units of the Mulussa.
Upper contact:- *The formation passes upwards gradationally into the marly* ***Zor Hauran*** *Formation .*

- *However, around the rim of the Ga'ara depression, the formation is unconformably overlain by Cretaceous and Tertiary formations, (Cenomanian* ***Rutbah*** *Sandstone and late Campanian Hartha Formation along the western rim and by the* ***Eocene Ratga*** *Formation along the SE rim).*

Environment:- *The Mulussa Formation was deposited in tropical to subtropical shallow water and supra-littoral environments.*

-The upper part of the formation is gypsiferous indicating a sabkha depositional environment.

Mullusa Fn.

1.2- Zor Hauran Formation

Lithology:- *yellow and grey gypsiferous marl, interbedded with yellow green marly limestone, oolitic limestone and dolomitized limestone .*

Contacts:- *The lower boundary with the underlying Mulussa Formation is gradational and placed at the base of the first continuous bed of yellowish or yellow-green marl.*

The upper contact with the Ubaid Formation is disconformable.

Environment:- *The oolitic facies was probably deposited in a shelf lagoon.*

-The presence of gypsum and desiccation cracks indicates an evaporitic supratidal environment.

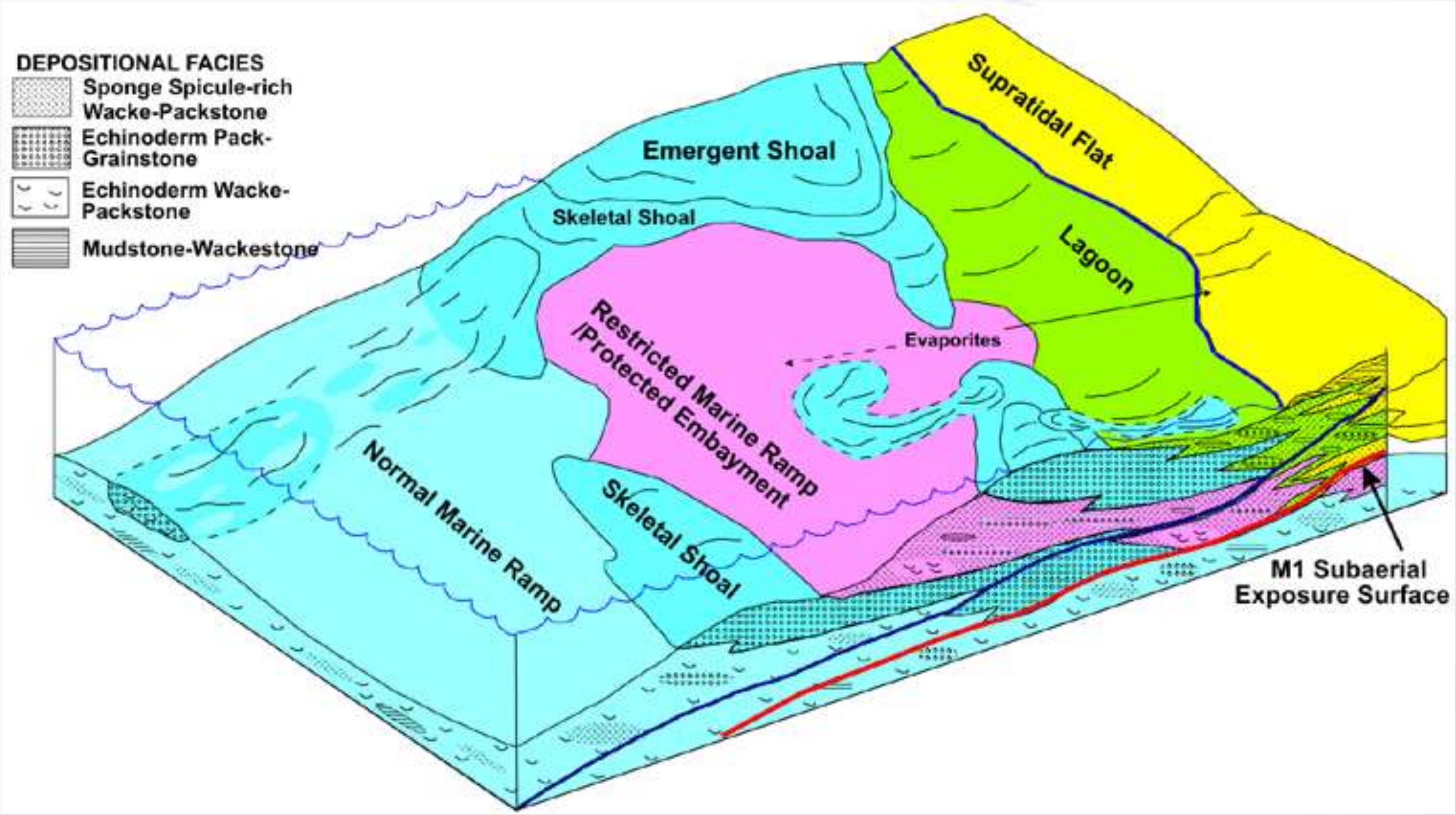
Q.1. What is oolitic facies?

Oolite or oölite (egg stone) is a sedimentary rock formed from ooids, spherical grains composed of concentric layers. Strictly, oolites consist of ooids of diameter 0.25–2 mm; rocks composed of ooids larger than 2 mm are called pisolites.

Modern oolite-Bahama

Q.2. What is inner shelf environmnt?

Inner shelf Environment



2- Carbonate-evaporite inner shelf and restricted

2.1 - Kurra Chine Formation

The Kurra Chine Formation is the most widespread formation of the Late Triassic Sequence.

Lithology:- *it is up to 850 m thick and comprises monotonous dark brown and black limestones, thin and thick-bedded, with occasional beds of thick bedded fetid dolomite with slump structures, and papery shales.*

Recrystallization breccias also occur occasionally.

Remarks:-*The absence of evaporites from the type section may be due to surface dissolution with formation of recrystallization breccias.*

Contacts:- *The* ***lower contact*** *of the formation is marked by an erosional break indicated by haematitization, silicification and leaching of the underlying Geli Khana Formation.*

Upper :- *The contact with the overlying Baluti Formation is conformable and taken at the base of the first green shale bed of the Baluti Shale Formation.*

Age;- *Late Triassic age*

Environment:- *The depositional environment of the Kurra Chine Formation is characterized by lagoonal, sometimes euxinic, conditions in the Foothill and Mesopotamian zones.*

- *Along the western margins of the Mesopotamian Zone (Tharthar and Awasil), terrigenous clastics were derived from the Rutba Uplift to the W-Sw.*
- *The Kurra Chine Formation is correlatable with the Mulussa and probably the Zor Hauran formations of W Iraq*

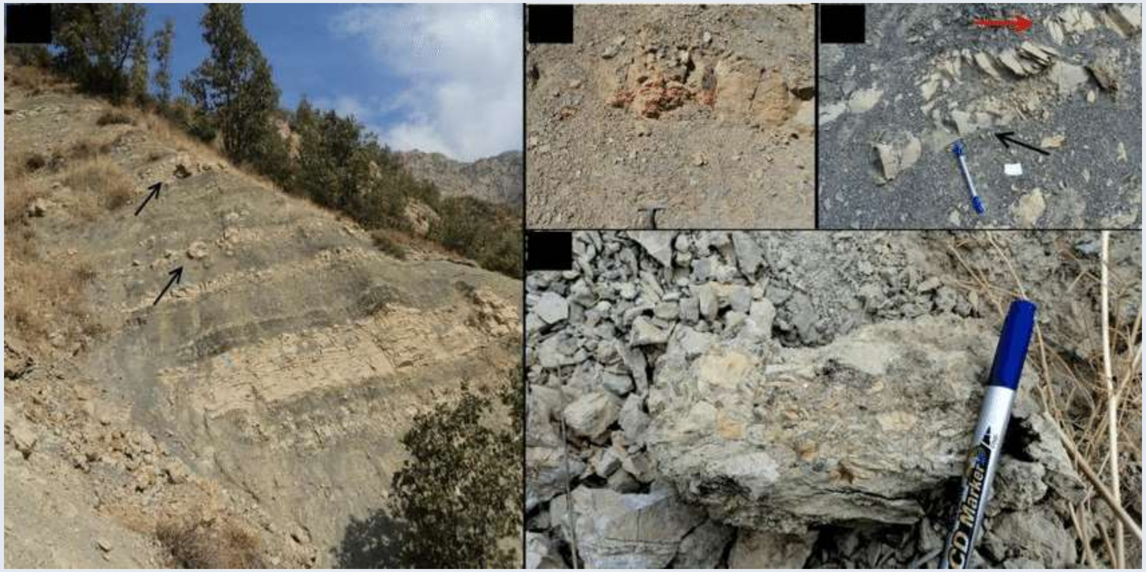
KURRA CHINA FORMATION

2.2- Baluti Formation

Lithology:- *It comprises 60 m of grey green and grey shale with decimeter beds of thin bedded dolomitic, silicified, and oolitic limestone, and recrystallization breccia.*

Contacts:- *Both lower and upper contacts of the formation are reported to be conformable .*

Environment:- *The formation was deposited in lagoonal/evaporitic and estuarine environments.*



3- Liassic Sequence

Early Jurassic epoch of the geologic timescale.

It is now more specifically known that the Lias is Rhaetian to Toarcian in age (over a period of c. 20 million years between 200 to 180 million years ago) and thus also includes a part of the Triassic.

The Liassic Sequence outcrops in numerous anticlines of the High Folded Zone of N and NE Iraq and in the Rutba subzone in W Iraq.

The formations included in this sequence are:-

*1-The clastic-carbonate inner shelf(**Ubaid, Hussainiyat** & **Amij)** formations in W Iraq,*

*2-The carbonate-evaporite inner shelf(**Butmah, Adaiyah, Alan** and **Mus)** formations in well sections of central Iraq and the Foothill Zone,*

*3-The restricted lagoonal (**Sarki** and **Sehkaniyan**)formations in the High Folded and Balambo-Tanjero zones of N and NE Iraq.*

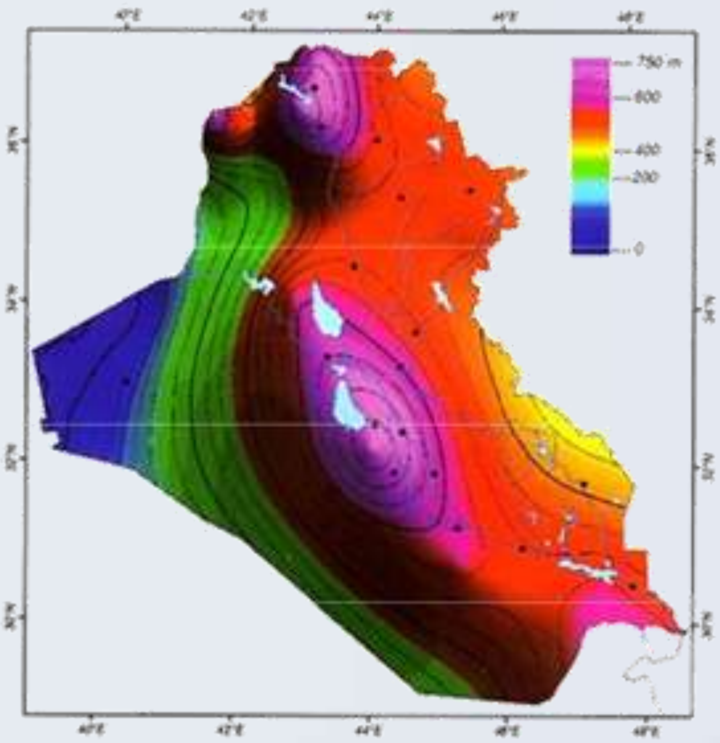
The sequence in W Iraq contains three cycles; each cycle comprises fluvial to fluviomarine clastics overlain by inner shelf to coastal carbonates.

Towards Mesopotamia the cyclicity is defined by alternating inner shelf carbonate and sabkha facies.

The Paleogeography of Late Liassic Time

Fig. 9-9: Palaeogeography of Late Liassic time

Fig. 9-10: Thickness of the Liassic Sequence



1- The Clastic-carbonate inner shelf

1.1- Ubaid Formation

Lithology:- *The Ubaid Formation was later described from Wadi Hauran (Jassim et al. 1984) as a 95 m thick section consisting, from the base upwards, of the following units:*

1) 35 m of sandstone, sometimes pebbly, and red claystone with ironstone beds in the upper part; these clastics thin towards the SE as noted in wells KS-9 where the Ubaid Formation overlies the Zor Hauran Formation with a thin basal bed of green silty marlstone.

2) 40 m of dolomite and recrystallized dolomitic limestone, yellowish to light grey with thick and thin bedded silicified horizons and chert nodules; with yellowish marly limestone in the upper part.

3) 20 m of gypsiferous marl and recrystallized shelly limestone often stained purple to red at the top.

Age:- *The age of the formation was assumed to be Liassic .*

Contacts:- *The **lower contact** with the under lying **Zor Hauran** Formation is variable.*

*The **upper contact** with the newly introduced **Hussainiyat** Formation is a disconformity.*

Remarks:- *The uppermost part of the Ubaid Fn. is highly karstified.*

The karsts are often filled in with laterite, bauxite and clastics.

Environment:- *Al Jumaily (1984; in Jassim et al., 1984) considered the basal clastics were deposited in a fluvial depositional environment. The carbonates were deposited in shallow hypersaline and supratidal ponds and subtidal lagoons .*

The probable equivalent unit in the Unstable Shelf region is the lower part of the Butmah Formation.

1.2- Hussainiyat Formation

The Hussainiyat Formation was introduced by Al Mubarek et al, in 1981 (Jassim et al., 1984) for a sequence of clastics and carbonates that overlie the Ubaid Formation. Dunnington (in Bellen et al., 1959) probably included this unit in the Ubaid Formation.

***Lithology:-** It has a lower clastic unit and an upper carbonate unit, both thinning towards the SW.*

The outcrop of the formation between Rutba and Wadi Hauran is dominated by stacked river channels, the SW Part dominated by highly ferruginous flood plain mudstones truncated by minor channels with basal lags of ironstone pebbles.

The NE part is dominated by deltaic facies with common silicified tree trunks in Wadi Hauran.

Sandstones of the formation also contain silicified plant stems, prints of leaves and layers of Turritellaceae coquinas.

The dolomites contain fragments of pelecypods and gastropods and are highly bioturbated and in places silicified.

The carbonate member comprises heavily bioturbated dolosparites with ghosts of pellets and intraclasts, dolosparites with ghosts of bioclasts (mainly pelecypods and gastropods) and micritic limestone with detrital quartz and lacking fossils.

***Environment:-** The carbonates occasionally contain algal structures and were probably deposited in a lagoonal to supratidal environment.*

The specific character of the Turritellaceae coquinas suggests a partly freshwater deltaic environment with supply of terrigenous organic material (tree trunks).

-The uppermost part of the formation was deposited in the supratidal zone. .

Turritella

Hussaniyat Fn.

1.3- Amij Formation

The formation was probably previously included in the Muhaiwir Formation. The type section in Wadi Amij (50 km ENE of Rutba Town) is 42 m thick.

***Lithology:-** It comprises a lower clastic unit and an upper carbonate unit.*

- *The **lower clastic unit** consists of 20-30 m of cross-bedded and cross-laminated (herring-bone), ripple-marked (oscillation ripples) fine-grained quartzitic sandstone and siltstone with lamination produced by concentration of heavy minerals such as zircon and ilmenite. The sands are associated with red and green mudstone and occasional thin beds of gypsum.*
- *The **upper carbonate unit** is composed of white to yellowish argillaceous dolomite and dolomitic limestone. Laminated and **domal algal stromatolites were also recorded.***

***Contacts:-** The Amij Formation unconformably overlies the Hussainiyat Formation; the contact is taken at the base of a red claystone bed.*

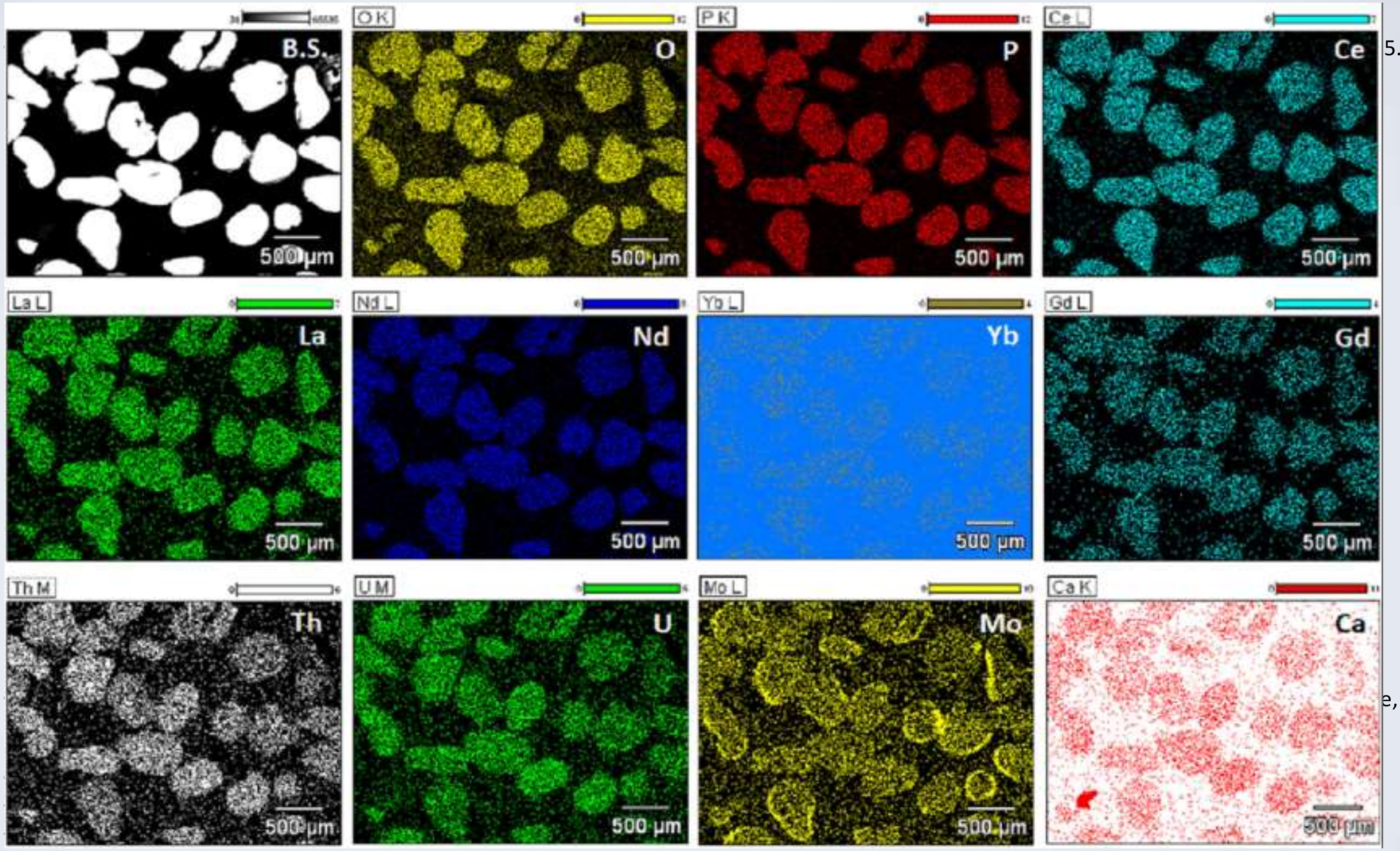
***Environment:-** The The Amij Formation was deposited in a marginal marine, coastal lagoon and marsh environment.*

***Remarks:-** Both the **Mus Limestone** and the overlying **Alan Anhydrite** in central Iraq may be the lateral equivalents of the **Amij** Formation.*

Herringbone cross-stratification :- ***is a type of sedimentary structure formed in tidal areas, where the current periodically flows in the opposite direction.***

These sedimentary structures are not common because they require the current to be equal in both directions, which rarely happens in nature.

Electron microprobe BSE image for a group of monazite grains from Amij



5.0 to

e,

- , *The* ***Monazite*** *is a reddish-brown phosphate mineral containing rare earth metals. It occurs usually in small isolated crystals. It has a hardness of 5.0 to 5.5 on the Mohs scale of mineral hardness and is relatively dense, about 4.6 to 5.7 g/cm3. There are at least four different kinds of monazite, depending on relative elemental composition of the mineral:[3]*

- ***Monazite-(Ce), (Ce, La, Nd, Th)PO4 (the most common member)***
- ***Monazite-(La), (La, Ce, Nd)PO4   Lanthanite-(La)***
- ***Monazite-(Nd), (Nd, La, Ce)PO4***
- ***Monazite-(Sm), (Sm, Gd, Ce, Th)PO4)PO4***

What is stromatolites?

are layered bio-chemical accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains by biofilms (microbial mats) of microorganisms, Fossilized stromatolites provide ancient records of life on Earth by these remains, some of which may date from 3.7 billion years ago.



2- Carbonate-evaporite inner shelf

2.1- Butmah Formation

***The Butmah Formation does not outcrop but is penetrated in wells in the Foothill, Mesopotamian and Salman zones*.**

Lithology:- *The Butmah Formation is lithologically heterogeneous. The upper 200 m in the type section consists of oolitic, pseudooolitic and detrital limestone with beds of argillaceous limestone, shale and anhydrite.*

-The middle part of the formation (180 m) is oolitic and pseudo-oolitic, argillaceous and dolomitic with sandstone and shale beds.

- The lower part (120 m) is composed of limestone with bedded anhydrite.

Environment:- *The lithofacies and faunal assemblages indicate the Butmah Formation was deposited in a shallow water lagoonal and sabkha environment.*

Remarks:- *the upper part of the Butmah Formation might be equivalent to the Hussainiyat Formation and the lower part with the Ubaid Formation.*

2.2- Adaiyah Formation

The Adaiyah Formation is present in the Mesopotamian and Foothill zones and the Anah Graben.

Lithology:- *90 m of bedded anhydrites with subordinate beds of brownish limestones and of black calcareous shales and greenish marls, both with anhydrite nodules. In some wells, such as Makhul-2, salt beds occur .*

Contacts:- *Both lower and upper contacts of the formation are elsewhere gradational and conformable.*

Environment:- *The formation was deposited in sabkha environment in an inner shelf basin.*

2.3- Mus Formation

Lithology:- *It is a 50 m thick limestone consisting, in the upper part of locally recrystallized, occasionally dolomitized, pseudo-oolitic limestone, with some organic detritus, and beds of argillaceous limestone.*

Contacts:- *The formation has conformable and gradational contacts with the underlying **Adaiyah** and overlying **Alan** Formations.*

Environment:- *The formation was deposited in a transgressive marine environment of normal salinity .*

2.4- Alan Formation

The Alan Formation is the uppermost part of the Liassic Sequence in the western parts of the Unstable Shelf and on the Stable Shelf in Iraq.

Lithology:- *87 m of bedded anhydrites with subordinate pseudo-oolitic limestones.*

Contacts:- *It has conformable and gradational contacts with both underlying and overlying formations.*

Environment:- *The formation was deposited in a basin-centred sabkha environment.*

3-Restricted lagoons

3.1 -Sarki Formation

Lithology:- *The formation consists of a lower unit (120 m thick) comprising thin bedded, fine-grained, cherty and dolomitic limestone, alternating with cherty shale, occasional dark sugary dolomites, and bands of shell breccias, oolitic limestones, micro conglomerates and recrystallisation breccias. A dark brown massive-bedded dolomite marks the base of the unit. The upper unit (180 m thick) consists almost entirely of dolomites.*

Contacts:- *The upper and lower contacts of the formation are conformable and gradational.*

The lower contact is at the top of the shales of the **Baluti** *Formation.*

The upper boundary is often obscured by dolomitisation.

Environment:- *The Sarki formation was deposited in a restricted lagoonal environment.*

Age:- *An Early Liassic age has been inferred based on the stratigraphic position of the formation between the well defined underlying Upper Triassic* ***Kurra Chine*** *Formation and the well-defined overlying Mid Jurassic beds of the* ***Sargelu*** *Formation.*

3.2- Sehkaniyan Formation

Lithology:- *a 180 m thick carbonate unit divided into three units.*

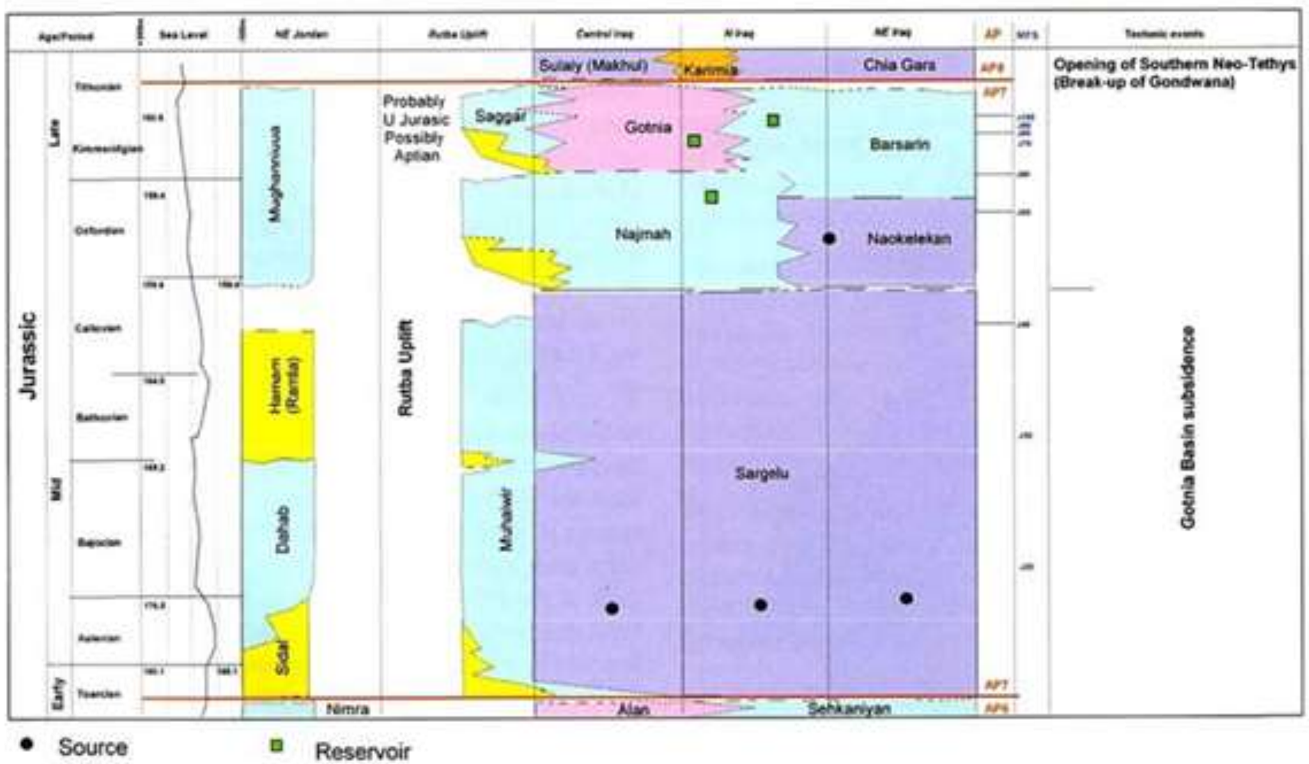
- *The lower unit (85 m) comprises dark saccharoidal dolomites and dolomitic limestones with some solution breccias.*
- *The middle unit (44 m) referred to as the "Lithiotis Limestone", consists of organic and pelletal fossiliferous limestone, often dolomitized with some chert bands that become thicker near the top.*
- *The upper unit (51 m) comprises dark, fetid, sachharoidal dolomites and dolomitic limestones, locally with chert.*

The Sehkaniyan Formation in Surdash anticline -Sargelu Formation (Middle Jurassic, Bajocian – Bathonian)

Late Toarcian-Early Tithonian (Mid-Late Jurassic) Megasequence

The megasequence comprises two second order sequences:
A- the Late Toarcian- Callovian
B-Late Jurassic sequence.

Fig. 10-1: Stratigraphic correlation of Megasequence AP7



A-The Mid- Jurassic (Late Toarcian-Call ovian) Sequence

Late Toarcian time was marked by a transgression that partially covered the evaporitic platform sabkhas basins of the Liassic, creating a more uniform basin with relatively deep water and euxinic sedimentation.

The Mid Jurassic Sequence is represented by;-

*1- The sandy calcareous shallow water **Muhaiwir Formation** in the Rutba Subzone of W Iraq*

*2- and the deeper water euxinic argillaceous-calcareous **Sargelu***

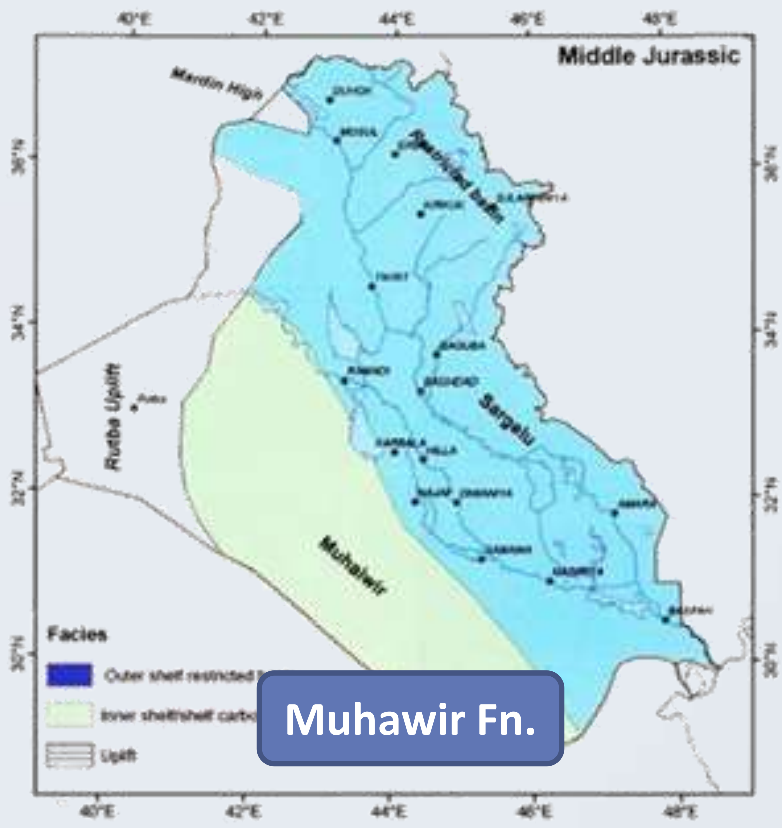
Formation elsewhere.

The boundary between these two facies lies on the W side of the Salman Zone.

What is the meaning of Argillaceous rocks ?

a sedimentary rock formed from clay deposits

Fig. 10-3: Mid Jurassic Palaeogeography



A-1- Inner shelf clastic-carbonate platform

A-1-1 - Muhaiwir Formation

Lithology:- *It comprises two carbonate units, each with a basal clastic layer.*

Contacts:- *The Muhaiwir Formation is overlain by* ***the Saggar*** *Formation throughout the outcrop area except near Wadi Hauran where it is overlain by* ***Najmah*** *Formation. This contact is generally unconformable and is taken at the base of a sandstone layer or reworked lateritic conglomerate.*

The lower contact with the underlying ***Amij*** *Formation is at the base of a conglomeratic or sandy dolomite. The upper carbonates of the Amij Formation are often stained red, indicating a hiatus associated with leaching.*

Environment:- *The lower unit was deposited in a shallow water inner shelf environment comprising tidal flats, sandy shoals and lagoons.*

The carbonates of the upper unit were deposited in an inner shelf marine environment .

Age:- *Middle Jurassic, Bathonian*

A-2 -Restricted outer shelf and basinal
1- Sargelu Formation

*It is present throughout Iraq except in the Rutba Subzone where it passes into the **Muhaiwir** Formation.*

Lithology:- *The Sargelu Formation in its type section comprises 115 m of thin-bedded, black, bituminous and dolomitic limestone, and black papery shale with streaks of thin black chert.*

Age;- *Bajocian-Bathonian age*

Environment:- *The Sargelu Formation was deposited in basinal euxinic marine environment; some beds were deposited in shallower or better aerated water (on the Salman Zone of the Stable Shelf).*

These shallow carbonates represent tongues of the Muhaiwir Formation.

Contacts:- *The **lower contact** in the type area, and in N and NE Iraq, is usually gradational and conformable.*

- *In subsurface sections the boundary is defined by the last occurrence of anhydrite at the top of the **Alan** Formation.*
- *In the Jezira area (in wells Khlesia and Mityaha), the formation has been truncated at the Base Cretaceous unconformity.*

Type locality of Sargelu Fn.

B- Late Jurassic Sequence

The palaeogeography during the Late Jurassic is controlled by the effects of Late Jurassic tectonic activity along the Arabian Plate margin prior to the opening of the Southern Neo- Tethys .

- ***Differential subsidence led to periodic isolation of the intra-shelf basin from the NeoTethys.***

Three distinct facies can be recognised (Fig. 10-5) these are:

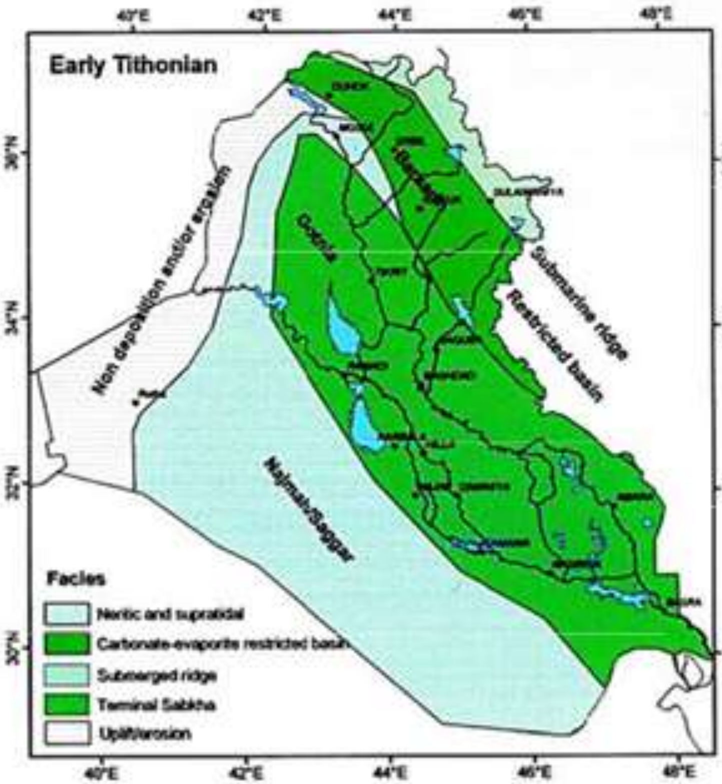
1) A clastic-carbonate inner shelf represented by the(***Najmah*** *and* ***Saggar*** *formations).*

2) A carbonate-evaporite inner shelf represented by the(***Najmah*** *and* ***Gotnia*** *formations).*

*3) A restricted basin represented by the (****Naokelekan, Barsarin*** *and* ***Gotnia*** *formations).*

Remark:-*The area of the High Folded, Balambo- Tanjero and Northern Thrust zones is characterized by a condensed sedimentary succession of euxinic character in the lower part (****Naokelekan Formation****) and lagoonal evaporitic character in the upper part (****Barsarin Formation****) which led Ditmar and the Iraqi-Soviet Team (1971) to assume the presence of a tectonic ridge in N Iraq isolating the basin to the south.*

Fig. 10-5 Palaeogeography of Late Jurassic time (Oxfordian-Early Tithonian)



1- Clastic-carbonate inner shelf

1-1-Najmah Formation

The Najmah Formation represents the calcareous neritic and lagoonal facies of the Late Jurassic Sequence on the Stable Shelf.

The only known outcrop of the formation is in Wadi Hauran, 8 0 km NE of Rutba in W Iraq.

Lithology:- *It comprises, from the base upwards:*

sandstone (base not exposed), 5 m of brown, very hard lithographic limestone with burrows and algal structures, 15 m of white to grey and buff fossiliferous lithographic limestone, 10 m of buff, very hard recrystallised limestone (argillaceous and sandy in part) and 8 m of greyish white to buff, recrystallised limestone with burrows, partly argillaceous and partly oolitic.

Contacts:- *The section is overlain by sandstones of the* ***Saggar*** *Formation (originally included in the Najmah Formation by Al Mubarek, 1978; and Jassim et al., 1984).*

- *The contacts of the formation in the type section and surrounding area are both unconformable.*

The hiatus above the formation occurs below the Gotnia Formation.

Environment:- *The formation was deposited in a neritic environment of oolitic shoals and restricted lagoons.*

Age:- *Late Jurassic*

2 -Saggar Formation

The formation lies between the underlying Callovian Najmah Formation and the overlying Albian Nahr Umr Formation.

Lithology:- *It is 30 m thick and comprises a lower clastic unit and an upper carbonate unit.*

- *The clastic unit consists of red pebbly sandstone with rootlets (sometimes very severely silicified) overlain by gypsiferous sandstone.*
- *The carbonate unit is a very distinctive chocolate-brown sugary dolomite .*

Contacts:*- Saggar Formation unconformably overlies Jurassic and Triassic formations.*

*It overlies the **Najmah** Formation at Wadi Hauran, and the **Muhaiwir** Formation between Wadi Hauran and the Rutba highway.*

*It overlies the **Amij**, **Hussainiya**t, **Ubaid**, and **Zor Hauran** formations near Rutba .*

- *The Saggar Formation is generally overlain by sandstones of the*

***Nahr Umr** Formation .*

Environment:- *The environment of deposition of the Saggar Formation is fluvial in the lower part and lagoonal and supratidal in the upper part.*

2-Evaporite-carbonate lagoons and sabkha

1- Gotnia Formation

Lithology:- *The Gotnia Formation comprises anhydrite with subordinate beds of brown calcareous shales , thin black bituminous shales, and recrystallised oolitic limestones , In SE Iraq, beds of halite are also recorded.*

Contacts:- *contacts o f the formation in the type locality and in other subsurface sections usually appear conformable.*

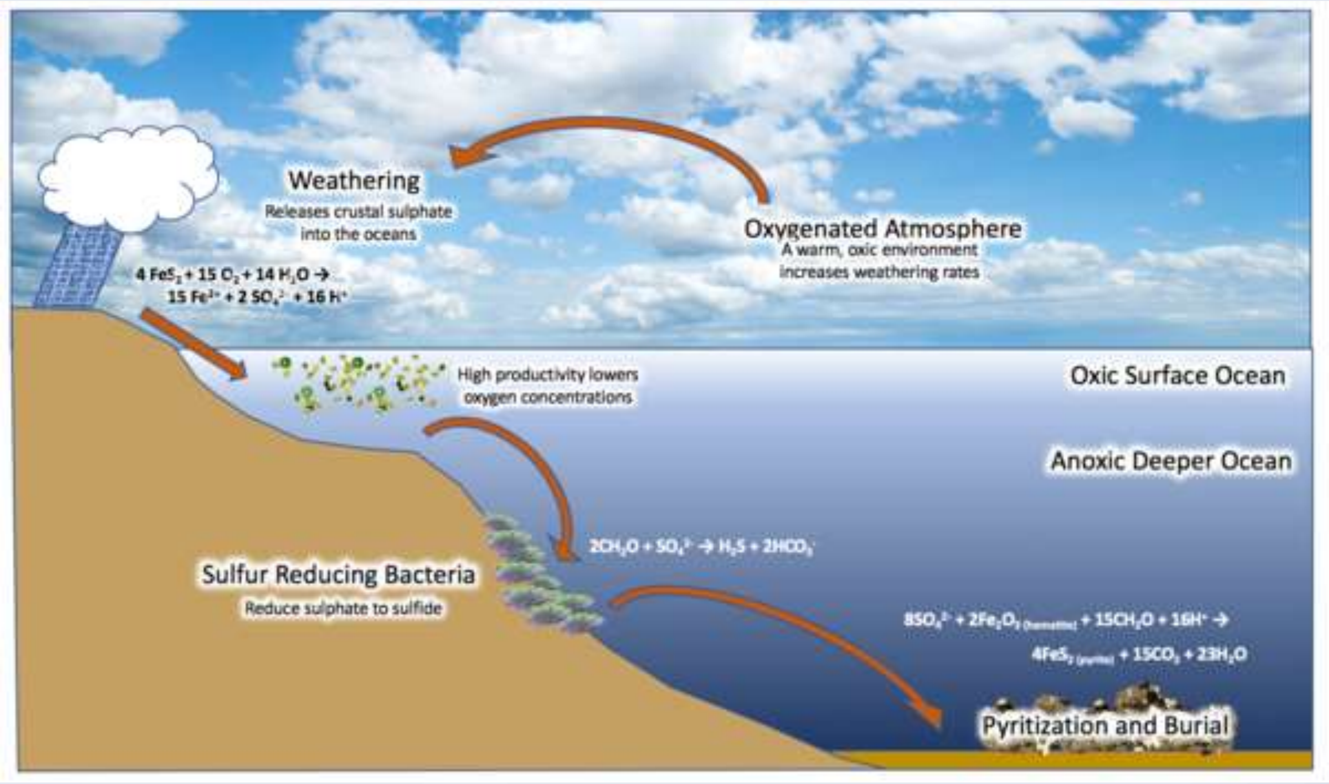
The upper contact with the Makhul Formation is erosional.

3 -Euxinic basin

***Euxinic conditions** occur when water is both anoxic and sulfidic.*

This means that there is no oxygen (O2) and a raised level of free hydrogen sulfide (H2S).

Euxinic bodies of water are frequently strongly stratified, have anoxic, highly productive, thin surface layer, and have anoxic, sulfidic bottom water.



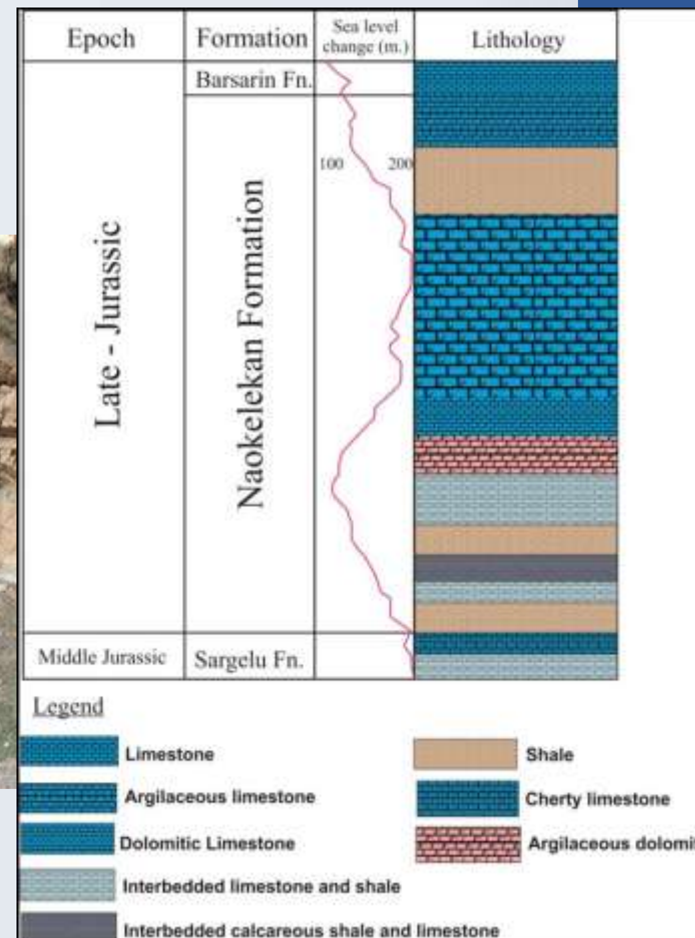
1- Naokelekan Formation

Lithology:- *The 20 m thick formation comprises three units:*

1) *a lower unit of laminated argillaceous bituminous limestone alternating with bituminous shale and fine-grained limestone,*
2) *a middle unit consisting of thin-bedded fossiliferous dolomitic limestone referred to as the "Mottled Beds" and*
3) *an upper unit (mostly obscured in the type section), of thin-bedded, highly bituminous dolomite and limestone with beds of black shale ("coal horizons") in the lower part.*

Environment:- *The formation was deposited in an euxinic environment in a very slightly subsiding or starved basin.*

Photomosaic shows Naokelekan Formation in Hawa Kawn locality, Iraqi Kurdistan.



2- Barsarin Formation

Lithology:- *It is 20 m thick and comprises limestone and dolomitic limestone (laminated, some fluffy textured, locally cherty) and argillaceous, brecciated and contorted beds (Plate 10-2).*

Environment:- *deposited in a lagoonal often evaporitic environment.*

Contacts:- *The contacts of the formation appear conformable in the type area but the base of the formation in the Northern Thrust Z one is marked by a detrital, ferruginous bed.*

The upper boundary is lithologically sharp though no break was identified in the type area.

Plate 10-1: Sargelu Formation along the Rowanduz River at Barsarin village, E of Rowanduz (photo by S. Jassim)

Plate 10-2: Type section of Barsarin Formation, Barsarin village, Rowanduz Valley, E of Rowanduz. Thin bedded sequence to the left belongs to Naokelekan Formation (photo by S. Jassim)

Late Tithonian-Early Turonian Megasequence

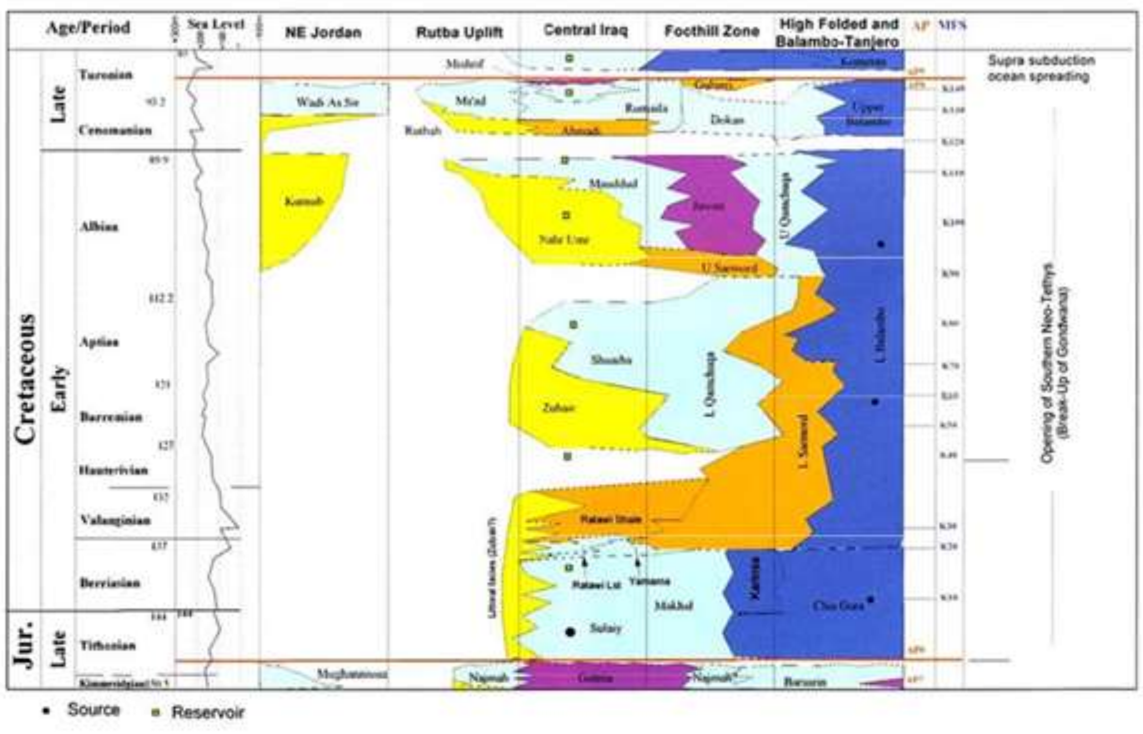
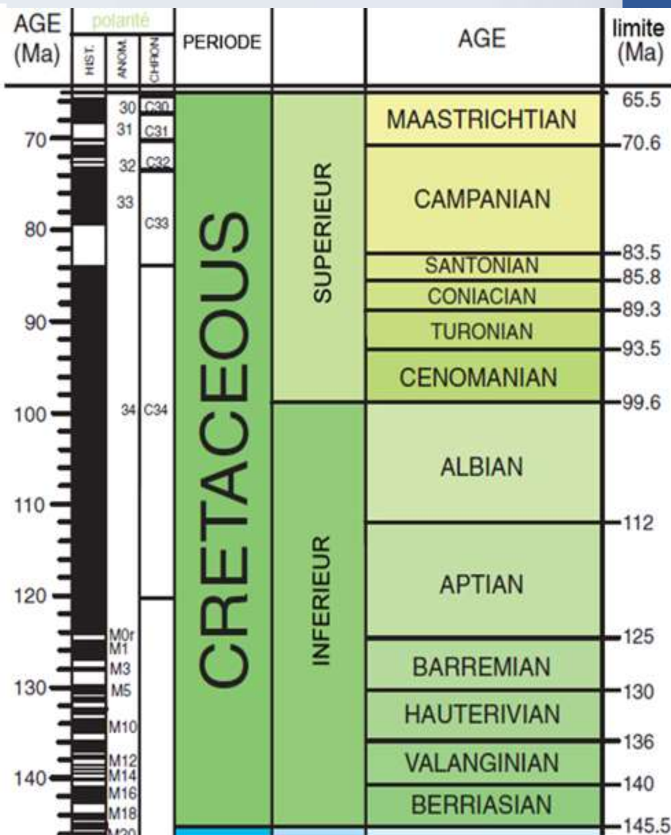


Fig. 11-1: Stratigraphic correlation of formation of Megasequence AP8



1. Late Tithonian-Hauterivian Sequence

*The Late Tithonian- Hauterivian Sequence comprises the (**Sulaiy, Makhul, Chia Gara (including Karimia), Yamama (including Garagu and Zangura), Ratawi and Lower Sarmord formations)**.*

- *Although geologists in Iraq and Kuwalt dropped the Sulaiy Formation in favour of Makhul Formation) the two formations represent two distinct facies,*

- *The **Sulaiy Formation** is an inner shelf facies deposited on the Salman Zone;*
- *The **Makhul Formation** is a deep inner shelf facies deposited in the Mesopotamian Zone.*

1.1 Inner shelf and deep inner shelf facies

1.1.1 Sulaiy and Makhul Formation

Lithology:- *The Sulaiy Formation in subsidiary section in Iraq described by Rabanit (Bellen et al., 1959) in well Ratawi-l in SE Iraq consists of over 331 m (base not reached) of detrital, oolitic limestone and hard recrystallized limestone with rare interbeds of shale.*

Contacts:- *The Sulaiy Formation is conformably overlain by the* ***Ratawi*** *or* ***Yamama*** *Formation except in some parts of the Salman Zone where it is unconformably overlain by the* ***Zubair*** *Formation*

Lithology:- *The* ***Makhul*** *Formation It comprises argillaceous limestones and calcareous mudstones which are sometimes dolomitized with beds of pseudoolitic limestone near the top and base.*

Anhydrite nodules occur in the lower part of the formation in Makhul-1.

In the subsurface the two formations have often not been differentiated.

- ***Towards the E and NE, the Makhul Formation passes laterally into the Chia Gara Formation***

Schematic depositional environments interpreted for Makhul as middle to outer ramp setting for the lower Makhul and outer-middle ramp settings for the upper Makhul

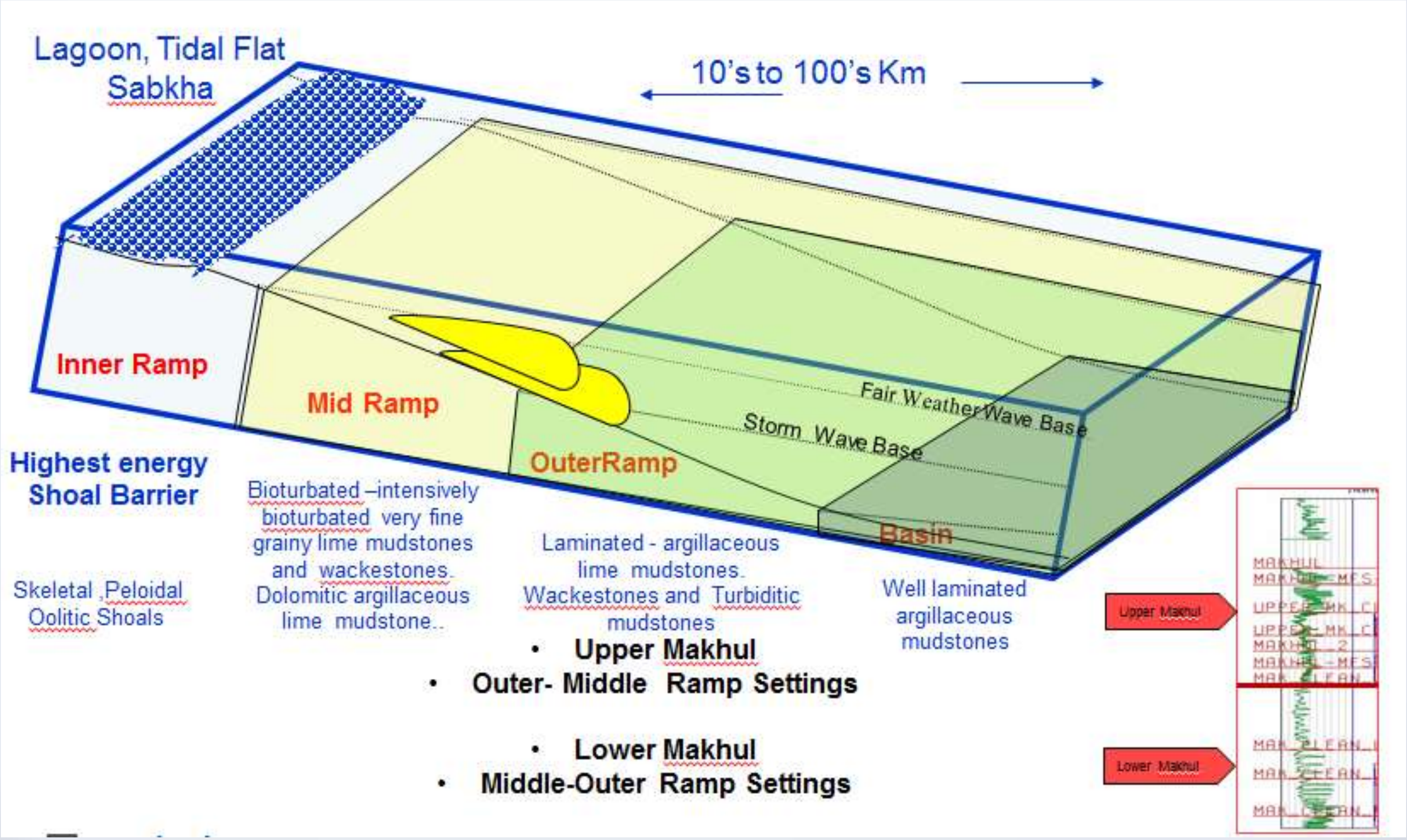


Fig. 11-5: Valanginian Palaeogeography

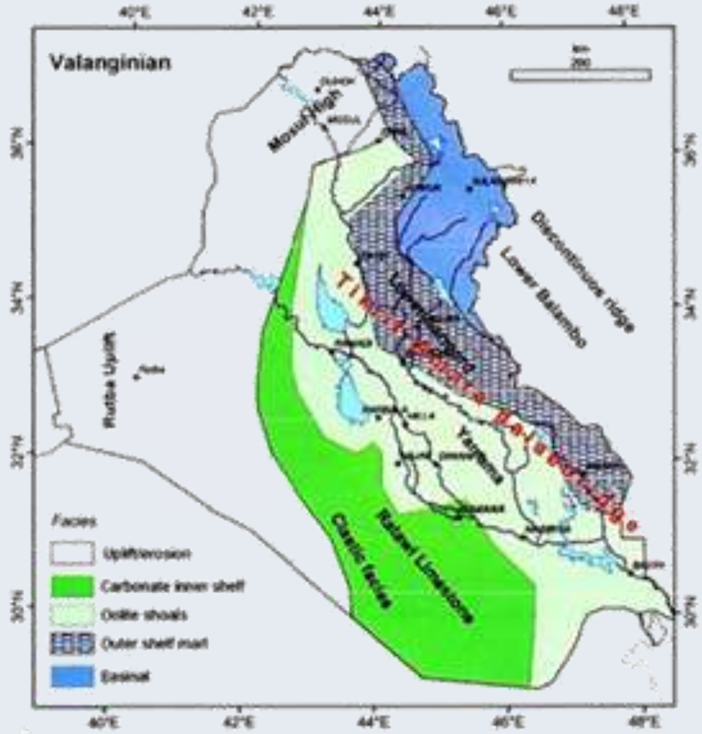
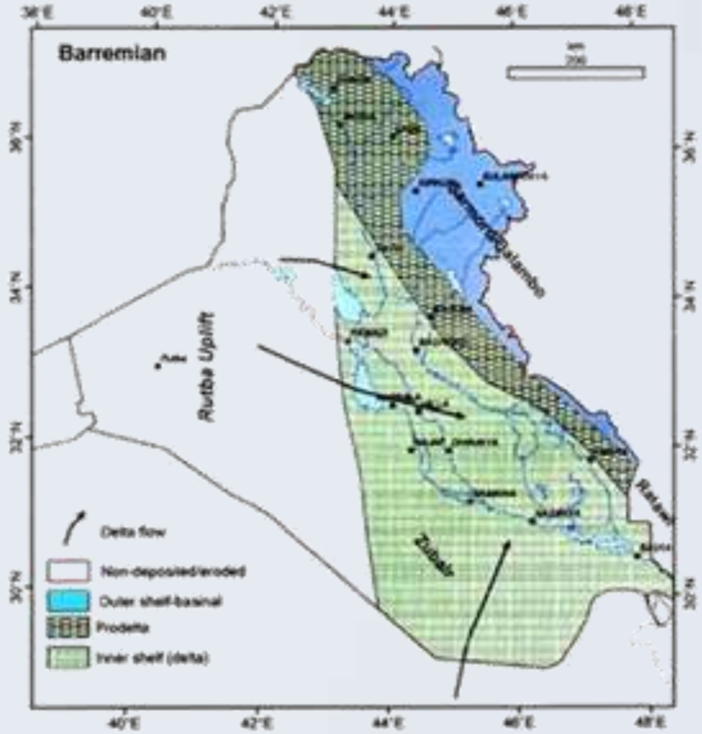


Fig. 11-6: Barremian Palaeogeography



1.2- Yamama Formation (including Garagu and Zangura)

Lithology:- *comprises 12 m of spicular and brown detrital limestone with thin shale beds overlain by 191 m of micritic limestone and oolitic limestone.*

Age:- *The formation is of Berriasian- Valanginian age .*

*Two variants of the **Yamama** Formation (originally described as separate formations) are the "**Garagu**" and "**Zangura**" formations.*

Environment:- *The Yamama Formation was deposited in alternating oolitic shoal and deep inner shelf environments,*

1.3 Ratawi Formation

Lithology:- *The formation comprises dark, slightly pyritic, shales; beds of buff, pyritic, pseudoolitic, detrital fossiliferous limestones are present in the lower part of the formation.*

Ratawi Shale Members; it is recommended that this practise is followed in Iraq.

Environment:- *The lower part of the Ratawi Formation was deposited during a high stand in an inner shelf environment;*

the Upper Ratawi Shale was deposited in a deep inner to middle shelf environment.

Age:- *Vallangenian- Hauterivian*

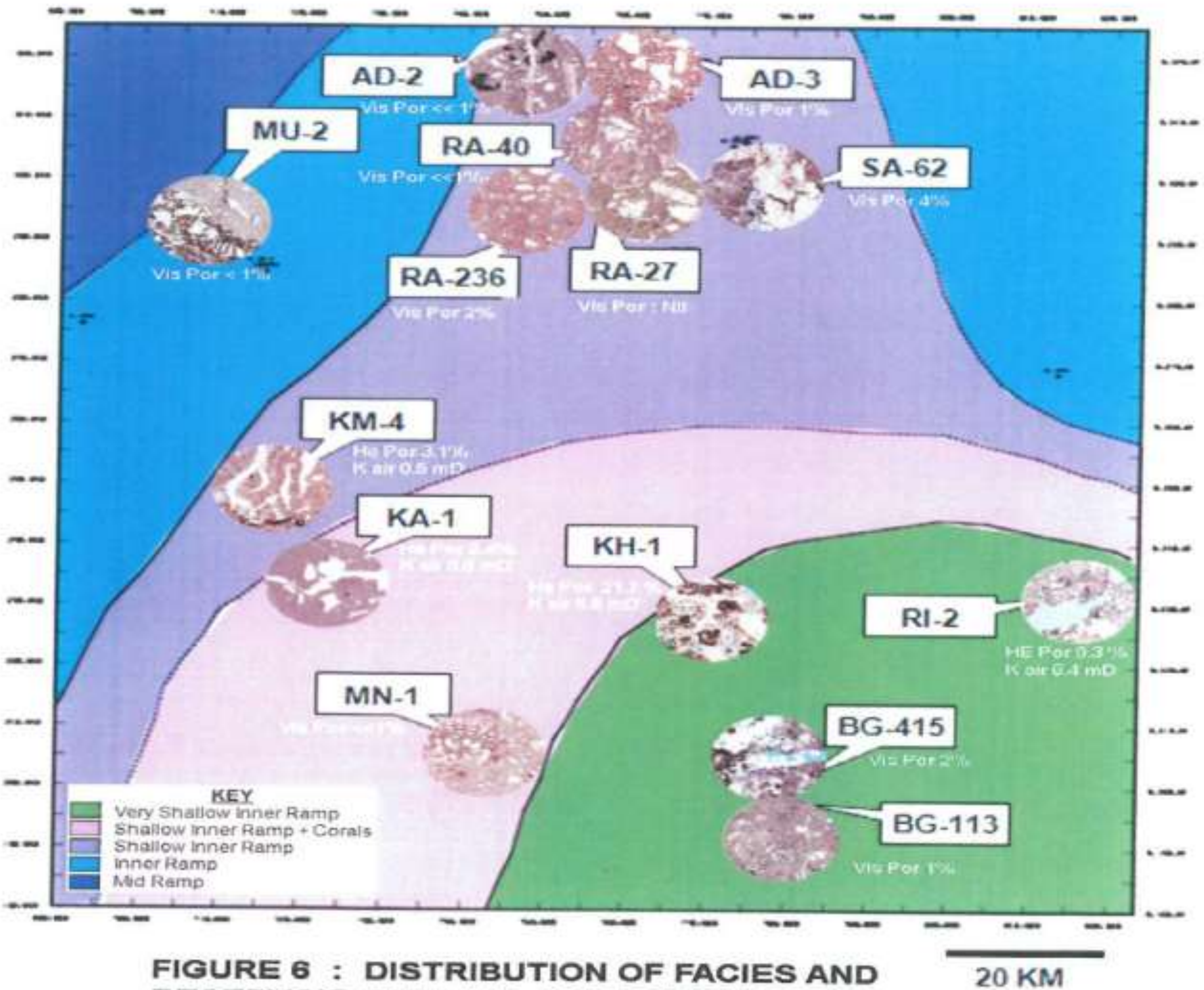


FIGURE 6 : DISTRIBUTION OF FACIES AND RESERVOIR QUALITY - TOP RATAWI CYCLE

2- Outer shelf and basinal

2.1- Chia Gara Formation

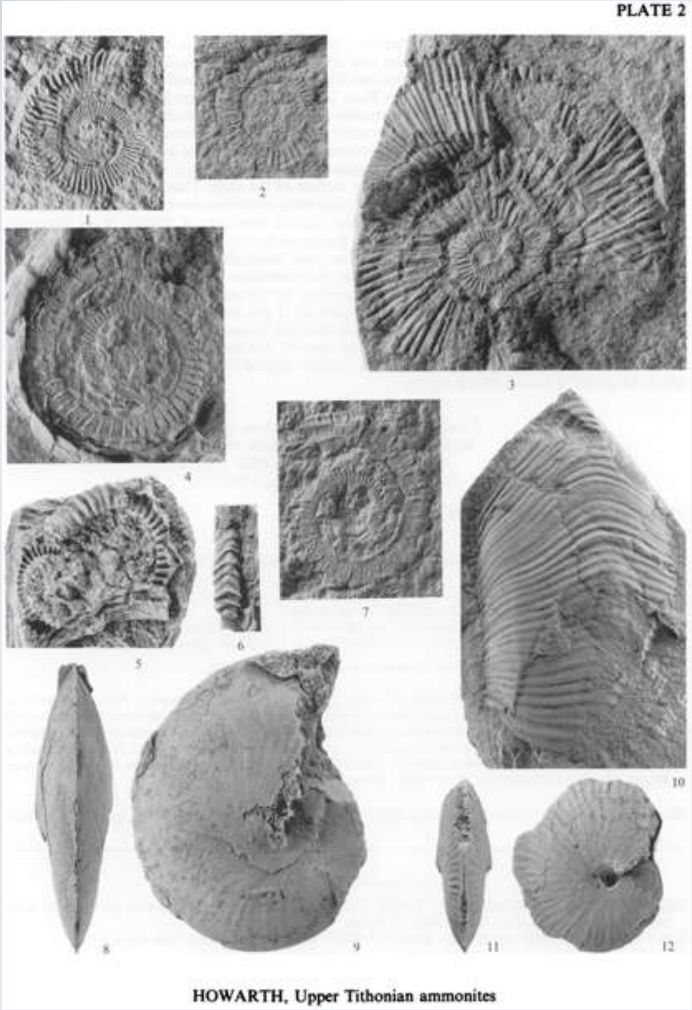
Lithology:- *comprises up to 230 m of thin bedded limestone and calcareous shale, Argillaceous limestone and marl, interbedded with shale prevail in the upper part of the formation (Plate 11-1).*

Contacts:- *The contact with the underlying* ***Barsarin*** *Formation is conformable.*

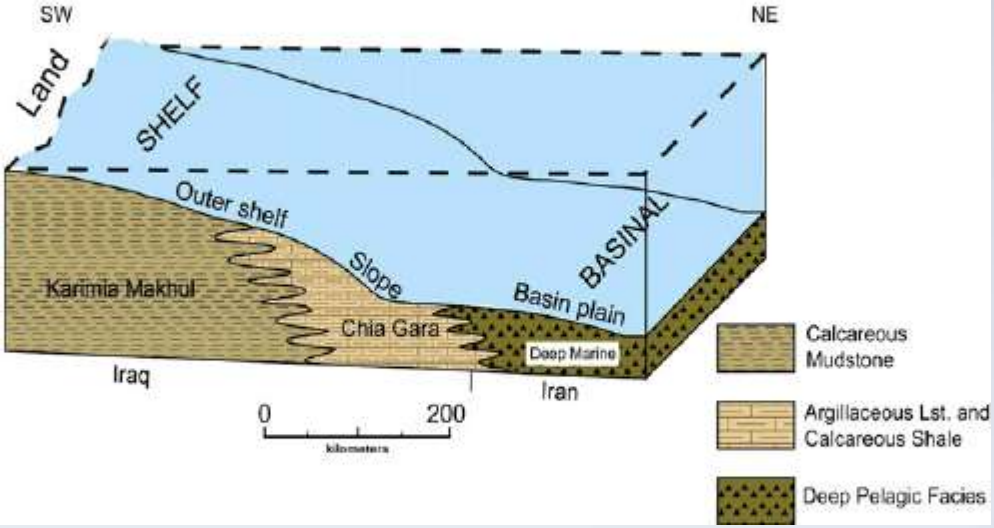
In the type area in N Iraq the formation is conformably overlain by the ***Garagu*** *Formation.*

Age:- *Tithonian age in the lower part and a Berriasian age .*

Environment:- *deposited in a mid-deep shelf environment.*



Tithonian and Berriasian ammonites from the Chia Gara Formation in northern Iraq



Chia Gara- Zako


Qamchuqa Fn
Sehkanian Village
Sehkaniyan fn
Chia Gara Fn
Barsarin and
Naokelekan fns
Sarmord Fn
Sargelu Fn
2011 11 30


Qamchuqa
Sarmord
Chia Gara (Tithonian-Berriasian)
View NW From Barsarin Village, NE of Erbil (<100m in Miran)

2.2- Lower Sarmord Formation

Lithology:- *It comprises 455 m of homogeneous brown and bluish marls, with beds of argillaceous limestones .*

The Upper Sarmord is absent in High Folded Zone of NE Iraq and the Sarmord type section represents the Lower Sarmord only.

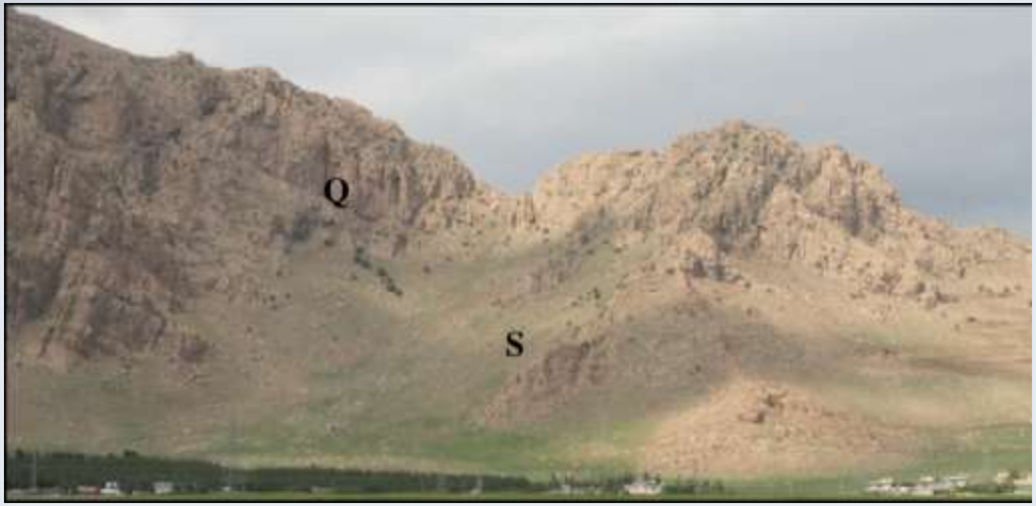
Contacts:- *In the Kirkuk area, the lower boundary of the Lower Sarmord Formation is gradational.*

In the Amadiya area, the basal beds of the formation, of Valanginian age, unconformably overlie the **Chia Gara** *Formation.*

The upper contact with the Albian ***Mauddud*** *(Upper Qamchuqa) Formation is conformable.*

Age:- *Hauterivian at base, Barremian at top.*

Environment:- *The Sarmord Formation with its marl component, echinoid and algae represent quiet marine sedimentation of inner shelf facies (inner neritic – neritic).*



The Sarmord Formation (S) overlain by the Qamchuqa Formation (Q) east of Ranya, along the eastern bank of Dokan Lake 1.3.4. Qamchuqa Formation (Early Aptian – Early Cenomanian) The Qamchuqa Formation is one of the most wide spread formations in Iraq, it forms the carapace of the main mountains; in the High Folded Zone.

Type section of Sarmord Fn.

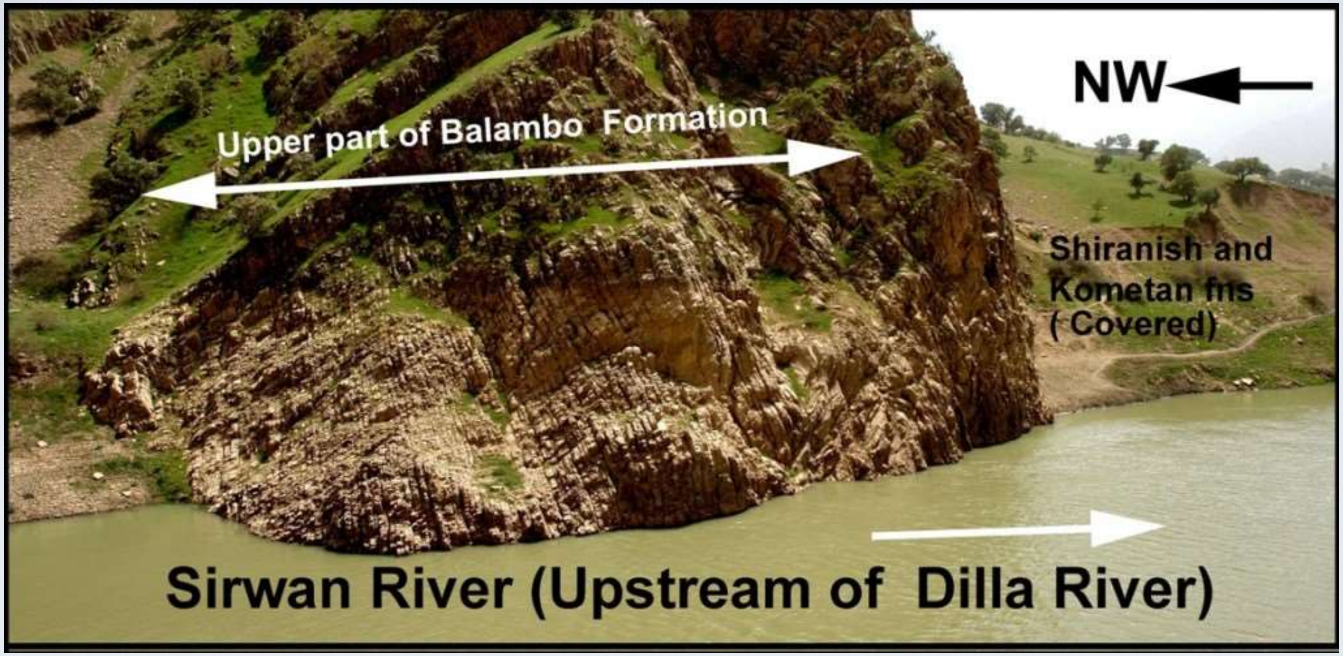
2.3- Lower Balambo Formation

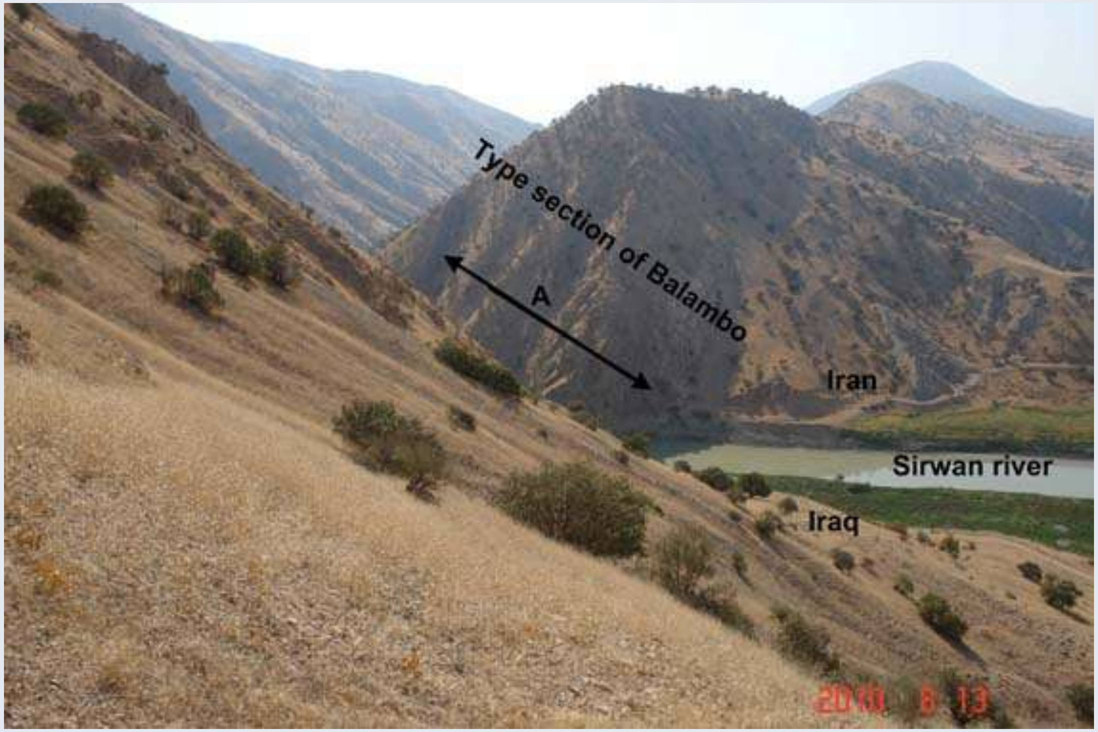
- *The Balambo Formation was first described by Wetzel in 1947 (Bellen et al., 1959) from the Sirwan valley near Halabja in NE Iraq.* ***Age:-*** *It can be divided into two units of Valanginian-Middle Albian and Late Albian-Turonian age, representing the Lower and Upper Balambo respectively.*

Environment:- *The formation as a whole was deposited in a deep water bathyal environment in an outer shelf basin near the margin of the Arabian Plate in NE Iraq.*

Lithology:- *The Lower Balambo Formation comprises 280 m of uniform thin bedded blue ammonite bearing limestone, with beds of olive green marl and dark blue shale .*

Balambo Formation showing well bedded and highly deformed nature (Along Sulaimaniya – Said Sadaq road)


NW
Upper part of Balambo Formation
Shiranish and
Kometan fms
(Covered)
Sirwan River (Upstream of Dilla River)


Type section of Balambo
A
Iran
Sirwan river
Iraq
2010 8 13

2- Barremian-Aptian Sequence

The Barremian-Aptian Sequence comprises the following facies:

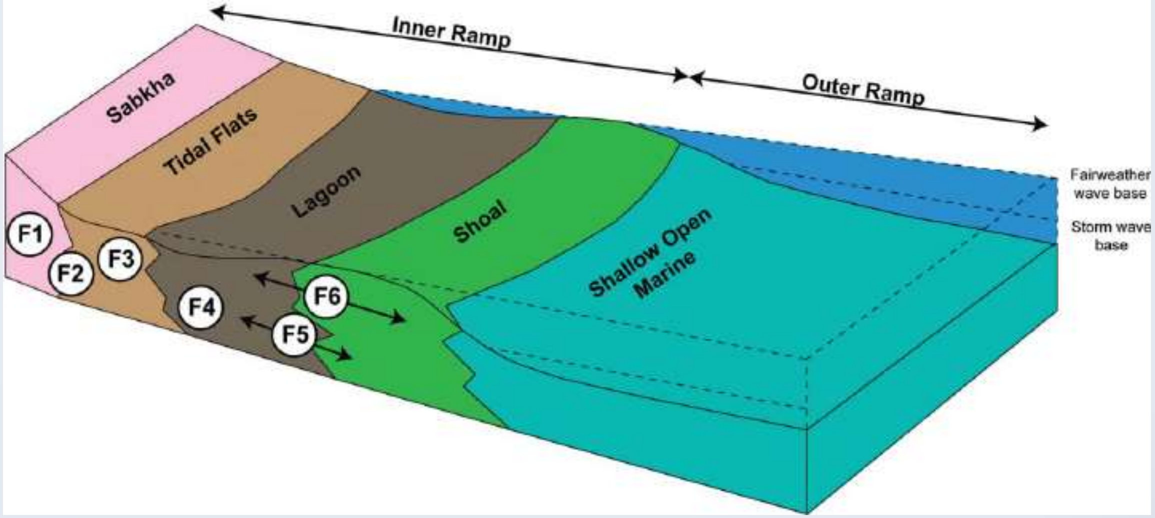
*1) A clastic inner shelf (**Zubair**),*

*2) a carbonate ramp (**Shu'aiba**) over the Tikrit-Amara palaeoridge in S Iraq and the Qamchuqa Ridge in NE Iraq and*

*3) an outer shelf basin facies (**Sarmord** and **Lower Balambo**) in the High Folded and Balambo-Tanjero zones and the Kirkuk Embayment of the Foothill Zone of the Unstable Shelf.*

Remark

Carbonate ramps :- are carbonate platforms which have a very low gradient depositional slope (commonly less than 0.1 ~ from a shallow-water shoreline or lagoon to a basin floor.



2.1 -Clastic-carbonate inner shelf

2.1.1 Zubair Formation

Lithology:- *The formation comprises 380-400 m of alternating shale, siltstone and sandstone. The type section was divided into five informal sand and shale units used for reservoir description in the Zubair oil field.*

Environment:- *The Zubair Formatio n is assumed to represent a prograding delta originating from the Arabian shelf.*

Age:- *Hauterivian to Early Aptian age .*

Contacts:- *The contacts of the formation are gradational and conformable in the central part of the basin.*

Towards the W in the Salman Zone, the lower boundary is un conformable and the ***Zubair*** *Formation represents the lowermost unit of the Thamama Group.*

The upper boundary with the overlying Albian Sequence in the Salman Zone is unconformable.

Fig. 11-8: Aptian Palaeogeography

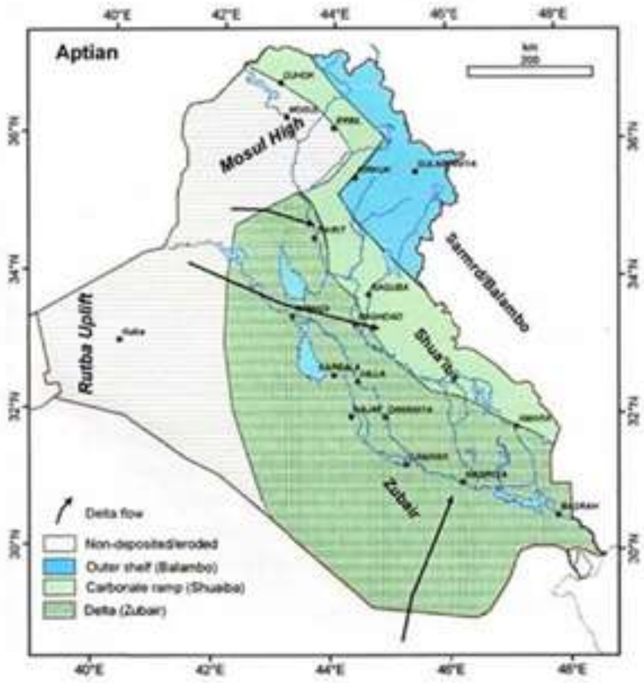
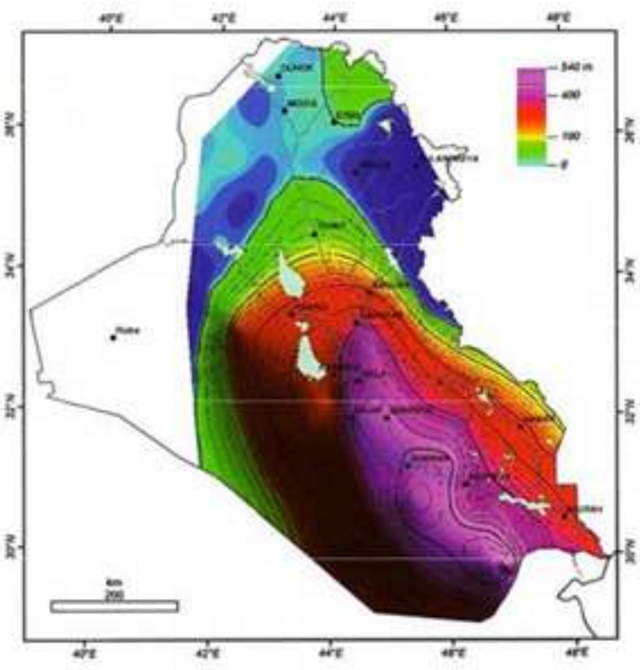


Fig. 11-9: Thickness of the Zubair Formation



2.1.2. Shu'aiba (including Lower Qamchuqa) Formation

Lithology:- *It comprises 62 m of pseudo-oolitic limestone, sometimes sandy, fine- grained organo-detrital limestone grading into chalky limestone & L.st with shale streak near top.*

Contacts:- *The formation overlies and passes laterally into the* ***Zubair*** *formation with a conformable and gradational contact.*

Age:- *Aptian age.*

Qamchuqa Formation

Lithology:- *It comprises thick bedded limestones (often strongly dolomitized)*

Age:- *Hauterivian to Albian age.*

Subsequently, Chatton and Hart (1960) divided the Qamchuqa into :-

A- lower unit of Barremian-Aptian age.

B- upper unit of Albian age.

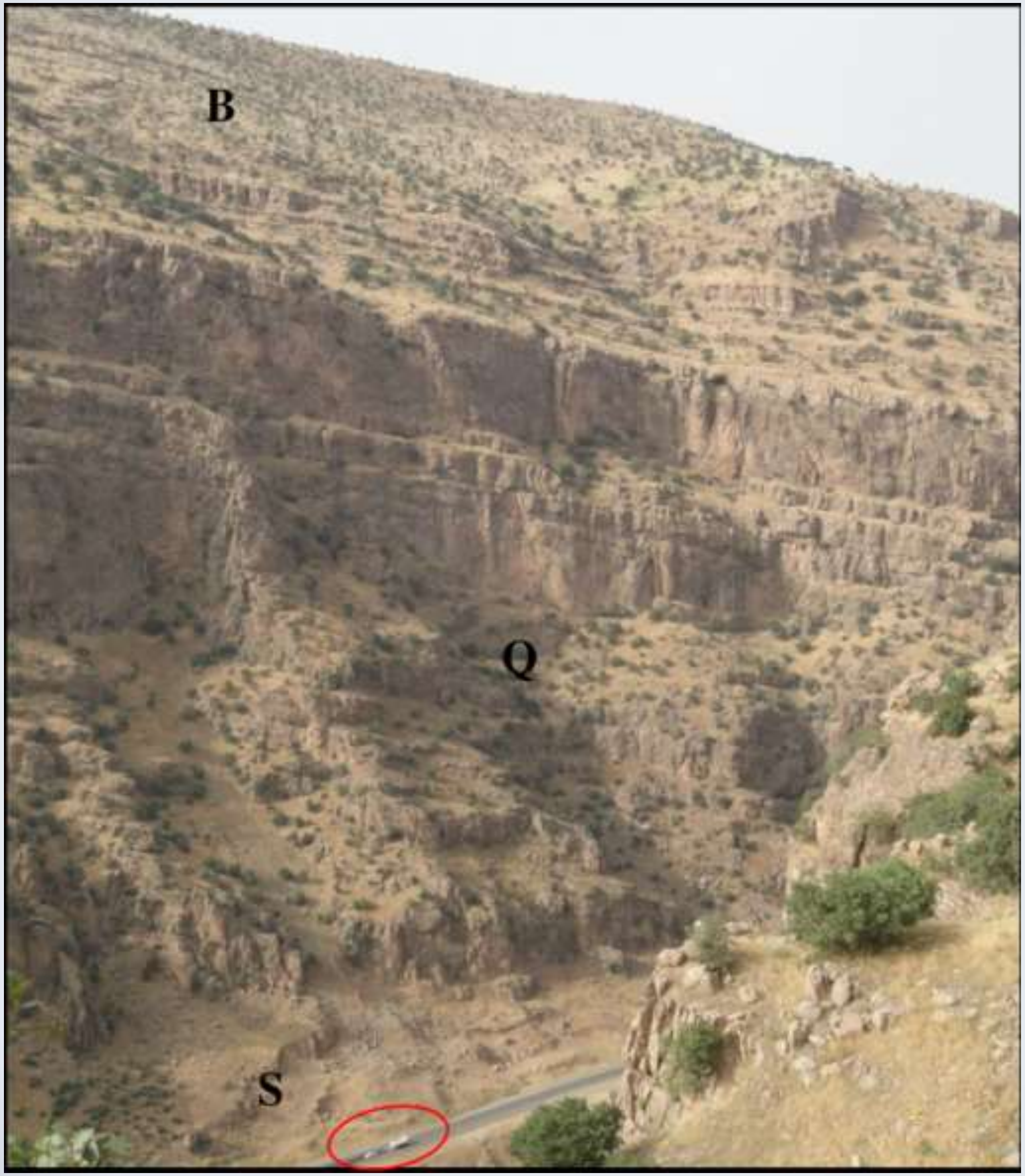
The Shu'aiba and Mauddud formations of S Iraq are laterally extensive tongues of the Lower and Upper Qamchuqa formations respectively. .

In outcrops in NE Iraq where the two units are difficult to differentiate, the term Qamchuqa Formation should be retained.

Contacts:- *The lower contact is conformable except in the W parts of the Northern Thrust Zone near Banik where the "Qamchuqa" Formation unconformably overlies the Garagu Formation. The upper boundary of the formation is usually conformable in N and NE Iraq.*

To the NE the Lower Qamchuqa Formation passes into the Balambo Formation .

Environment:- *The fossils' assemblages within the Qamchuqa Formation indicate warm tropical shelf to inner shelf marine conditions of normal salinity, with neritic environment indicating local changes to basinal; in its uppermost part*



: Massive limestone and dolostone beds in the Qamchuqa Formation (Q) underlain by thinly bedded soft Sarmord Formation (S), and overlain by well thinly bedded Bekhme Formation (B) in Gulley Ali Beg gorge. (Compare the thickness with the size of the two cars)

Chia Gara

Plate 11-1: Chia Gara Formation, Rowanduz River near Barsarin village, W of Rowanduz (photo by S. Jassim)

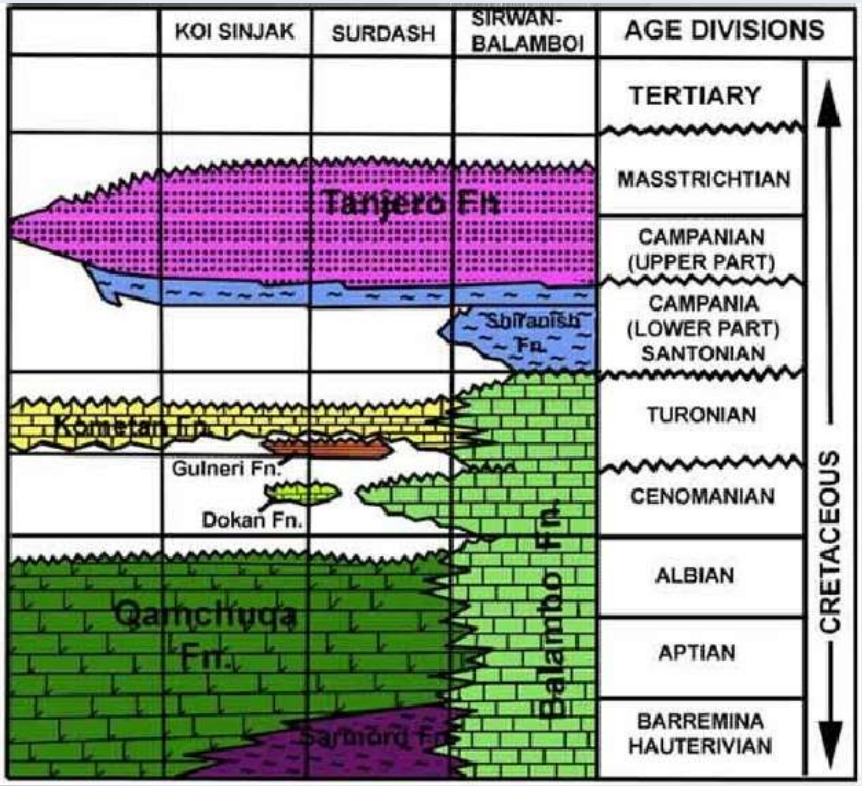
Sarmord

Plate 11-2: Sarmord Formation overlain by terrace gravel along Geli Ali Beg gorge, W of Rowanduz (photo by S. Jassim)

Plate 11-3: The Mauddud (Qamchuqa) Formation exposures along the Geli Ali Beg gorge of the Rowanduz River W of Rowanduz (photo by S. Jassim)

Qamchuga
(Mauddud)

Conformable boundary between Qamchuqa and Aqra-Bekhme formation



2.2. Outer shelf and Basinal

*The outer shelf and basinal sediments of this sequence shelf are part of the **Lower Sarmord Formation** in the High Folded Zone area and the **Lower Balambo Formation in** the Balambo-Tanjero Zone.*

These two formations were discussed before.

2 -Albian-Early Turonian Sequence

- *It can be divided into two sequences:*

1-The Albian

2- The Cenomanian-Early Turonian sequences.

1 -The Albian Sequence

The Albian sequence is separated from the underlying Aptian sequence by a major sequence boundary with a 6 Ma break in Kuwalt

This break is also evident throughout the Stable Shelf of Iraq but not within the Unstable Shelf area.

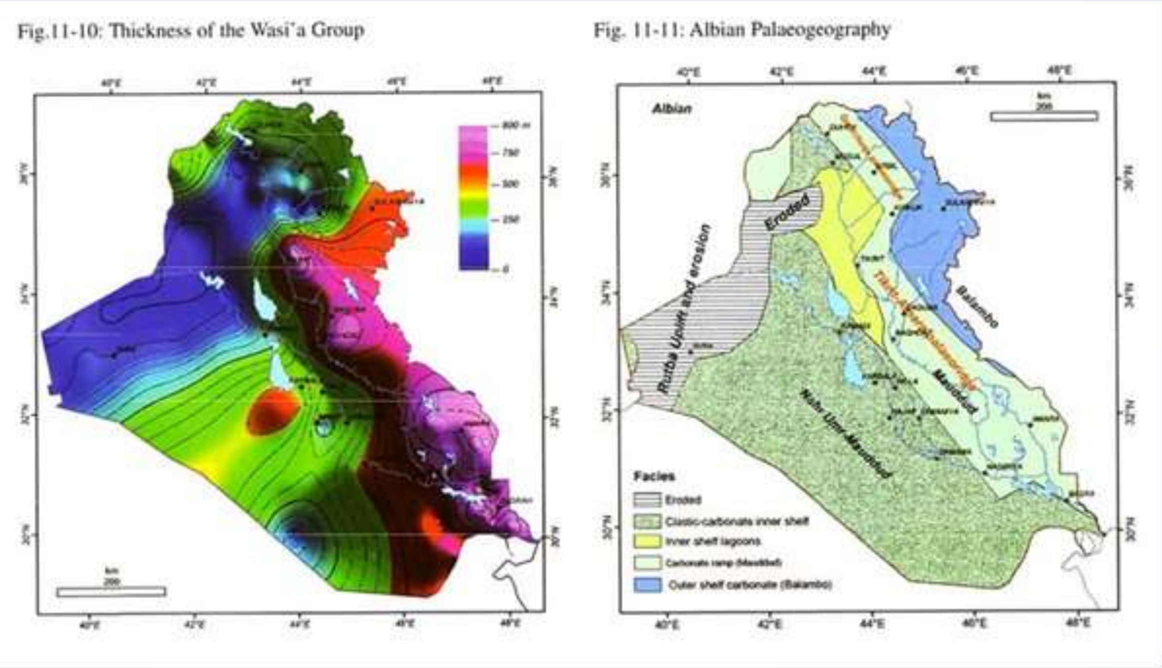


Fig.11-10: Thickness of the Wasi'a Group

Fig. 11-11: Albian Palaeogeography

1.1 Clastic-carbonate inner shelf

(Nahr Umr Formation, including Rim Siltstone)

***Lithology:-** In the type locality, Bellen et al. (1959) described it as black shales interbedded with medium and fine-grained sands and sandstones with lignite, amber and pyrite. Al-Mubarak and Amin(1983) divided it NW of Kilo 160 vicinity into two parts:*

A lower part that consists of white, yellow, greenish grey, pink and brown sandstone, occasionally pebbly.

An upper part, which consists of yellow and pale green, fossiliferous marl inter bedded with (2 – 3) horizons(1 – 1.5 m, each) of fossiliferous, yellow and brown limestones, which include geodes and ferruginous concretions.

***Environment:** - Shallow coastal marine, for the clastic unit.*

Contacts:- The Nahr Umr Formation overlies unconformably all Jurassic formations.

*In all cases the contact is based on the bottom of the first clastic horizon that overlies the last carbonate horizon of **Ubaid**, **Hussainiyat**, **Amij**, **Muhaiwir** and **Najmah** formations.*

The upper contact is generally conformable.

1.2 Carbonate ramp (Mauddud Formation, including U. Qamchuqa

The Mauddud Formation includes the Upper Qamchuqa and is the most widespread Lower Cretaceous formation in Iraq.

Its thickness varies due to lateral facies changes and erosional truncation .

Lithology:- *Al-Mubarak and Amin (1983) described Mauddud Formation NW of Kilo 160 vicinity as alternation of thick horizons of fossiliferous marl to marly limestone with thin horizons of fossiliferous limestone.*

Both of them have common yellow color.

- *While the Qamchuqa Formation to the north comprises organodetrital and detrital and locally argillaceous limestones with variable degrees of dolomitisation .*

Environment:- *Marine, tropical to subtropical, central shelf – innershelf*

- *(50 – 100) m depth, reef – backreef facies with normal salinity .*

Contacts:- *The lower contact of the Mauddud ("Upper Qamchuqa") Formation is conformable and gradational with the* ***Nahr Umr****, Lower* ***Balambo*** *or* ***Lower Sarmord*** *formations.*

- *The upper contact is marked by a break and is either non sequential or unconformable;*

1.3- Inner shelf lagoons

1.3.1-Upper Sarmord Formation

The Upper Sarmord Formation occurs in the subsurface between Kirkuk in the E and Mosul in the W.

- *This area was separated from the Balambo basin by the Qamchuq*
- *a carbonate ramp situated on the High Folded Zone.*

The Sarmord Formation, at its type locality, does not include Albian sediments.

*- In the SE part of the Footh ill Zone and the Mesopotamian Zone the Upper Sarmord passes into the **Nahr Umr** Formation.*

***Lithology:-** The Upper Sarmord Formation in the Foothill Zone comprises marls with neritic limestone beds.*

***Environment:-** The association o f the formation with the partly evaporitic **Jawan** Formation suggests that it was deposited in a lagoon developed to the SW of the Qamchuqa Ridge.*

***Contacts:-** The lower contact of the formation in the E is gradational and conformable. In the W, the Upper Sarmord Formation unconformably overlies the **Najmah** or **Sargelu** formations.*

*The upper contact with the **Mauddud** Formation is usually conformable and gradational.*

1.3.2 Jawan Formation

Lithology:- *It comprises > 176 m of pseudoolitic, argillaceous and recrystallized limestone, argillaceous dolomite and anhydrite .*

Contacts:- *The Jawan Formation unconformably overlies the* ***Najmah*** *Formation in well Qalian-l but in many wells SW of the Mosul High it unconformably overlies the* ***Shu'aiba*** *Formation. Near Kirkuk the formation conformably overlies the* ***Upper Sarmord*** *Formation.*

The upper contact is gradational and conformable in areas where the formation occurs as a tongue within other Albian formations at Qara Chauq and Makhul .

In all other areas the formation is unconformably overlain by the Turonian ***Kometan*** *Formation.*

Environment:- *deposited in a restricted lagoonal environment.*

2.2 The Cenomanian-Early Turonian Sequence

- *Deformation along the NE Tethyan margin of the Arabian Plate in Cenomanian-Early Turonian time led to the reactivation of longitudinal ridges and transversal blocks such as the Mosul High and the Kirkuk Embayment.*
- *The Cenomanian Sea transgressed onto the Rutba and Mosul Highs, which re-emerged during the Early Turonian.*
- *Deposition of the pelagic Balambo Formation (of globigerinal and partly oligosteginal facies) continued in the Balambo- Tanjero Zone.*

Major facies belts of the Cenomanian-Early Turonian Sequence comprise:

*1) A western clastic-carbonate inner shelf on which clastics of the **Rutba** Formation, followed by coastal and supratidal carbonates of the **M'sad** Formation were deposited.*

*2) A deep inner-middle shelf sea in which deeper water limestone and marls of the **Rumaila** Formation were deposited.*

*3) A belt of shoals and rudist patch reefs of the **Mishrif** Formation which formed above actively growing structures within the Rumaila basin.*

*4) A deep water basin developed along the plate margin (Balambo- Tanjero Zone) in which the basinal limestones of the **Upper Balambo Formation** were deposited. This basin shifted towards the SW and encroached on the Foothill Zone in the Kirkuk Embayment..*

5) An isolated deep basin, which formed between the Balambo basin in the NE and the Rumaila basin in the Sw.

*It occupied the area of the Foothill Zone, especially the Kirkuk Embayment, in which the euxinic shales of the **Gulneri** Formation and the basinal oligosteginal limestones of the **Dokan** Formation were deposited).*

*6) The lagoonal inner shelf desiccation basin of the **Kifl** Formation which is the youngest unit of the sequence developed in the Mesopotamian Zone; it is not shown on the palaeogeographic map of Fig. 11-15.*

- *In NW Iraq a relatively small basin (mainly in the Sinjar area) developed in which carbonates of the **Gir Bir** and **Mergi** formations were deposited; these facies are now included in the **Mishrif** Formation*

2.2.1-Clastic-carbonate inner shelf facies

2.2.1.1 - Rutbah Formation

The Rutbah Sandstone (as originally named) was deposited following the Cenomanian transgression on the Stable Shelf in Iraq.

Lithology:- *It comprises 30-40 m of white to varicoloured fine to coarse grained, cross-bedded quartz sands (sometimes ferruginous) which are locally calcareous or argillaceous.*

Age:- *Cenomanian – Turonian*

Contact:- *The lower contact of the formation is unconformable. In the type area the underlying formation is the Upper Triassic Mulussa Formation;*

Environment:- *continental depostioinal environment with marine influence.(Fluvio-Lacustrine)*

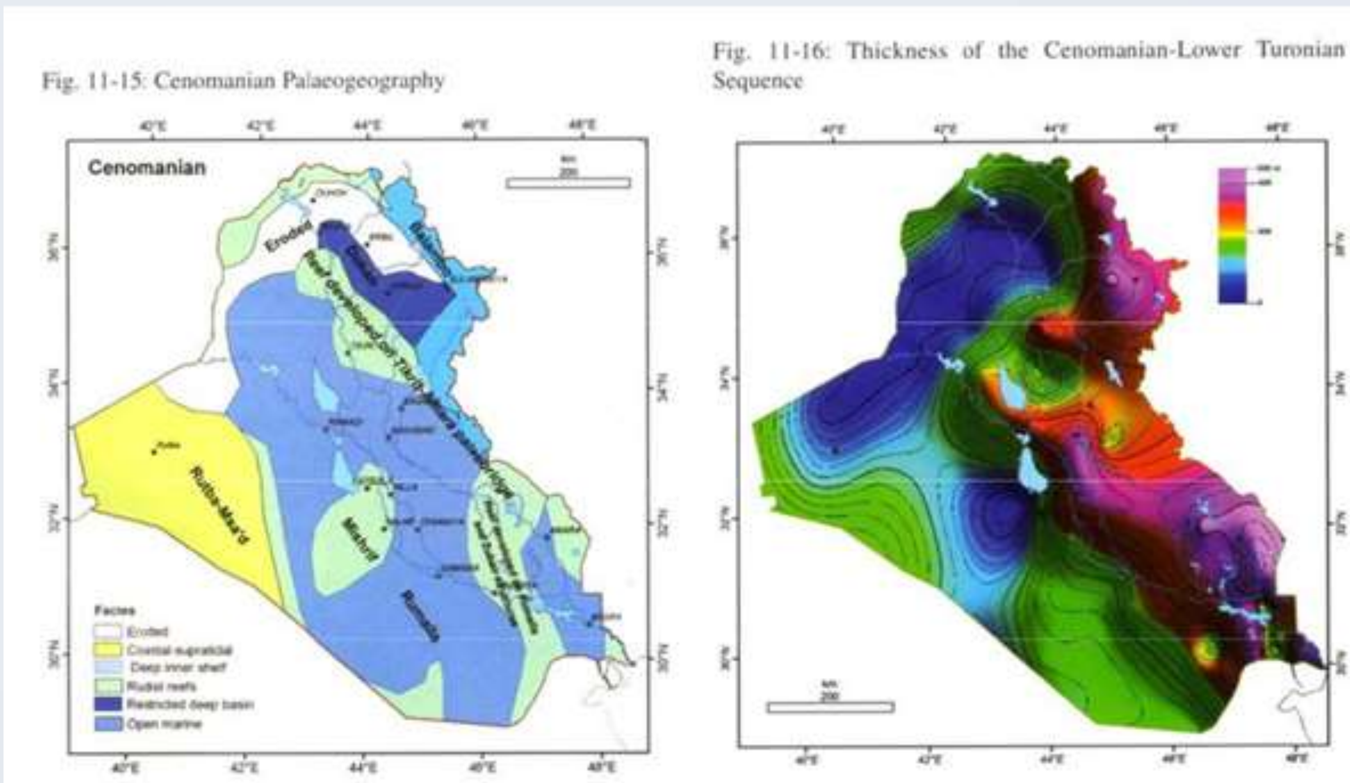
2.2.1.2 M'sad Formation

Age:- *Cenomanian – Turonian*

Lithology:- *In the type locality it consists of alternating of shallow marine limestone, reef limestone, shell breccia, white and pink marls, sandy marls and sands, with a thin sandstone tongues near theBase.*

Enironment:- *Eshallow marine, reef –back reef (Al-Mubarak and Amin, 1983); reef near shore, in the west of Rutbah it is nearshore, inner shelf facies,*

Contact:- *the Ms`ad Formation overlies Rutbah Formation, gradationally and conformably*



2.2.1.3 Ahmadi Formation

Lithology:- *comprises from the base upwards: grey detrital spicular limestone, unfossiliferous micritic limestone, and black silty shale*

(Bellen et al. , 1959).

Environment:- *The Ahmadi Formation was deposited in a shallow marine basin with fine clastic sediment supply from the south.*

Age:- *Cenomanian*

Contacts:- *In Iraq the Ahmadi Formation unconformably overlies the Mauddud Formation.*

The formation is usually overlain conformably and gradationally y the ***Rumaila*** *Formation.*

2.2.2 Deep inner shelf facies
Rumaila Formation

- *The Rumaila Formation is the most widespread Cenomanian formation in Sand SW Iraq and extends as far north as the Makhul area in the N.*

Lithology:- *In the type area the formation comprises fine-grained, marly, oligosteginal limestones with marls passing down into fine-grained, chalky limestones. Beds of dolomite, dolomitic limestone and subordinate shale occur in some wells.*

Environment:- *The Rumaila formation was deposited in a relatively deeper basin which was locally restricted in the north (indicated by the dwarfed character of the fauna).*

Age:- *The age of Rumaila Formation ranges from Cenomanian to Early Turonian .*

Contacts:- *In the type area and in S Iraq in general, the lower boundary of the formation with the* ***Ahmadi*** *Formation is conformable and gradational.*

- *In the S, the formation is conformably overlain by the* ***Mishrif*** *or* ***Kifl*** *formations.*
- *In N part of the Mesopotamian Zone the formation is unconformably overlain by the Turonian (****Kometan****) or Senonian* ***Sa'di*** *formations.*

2.2.3 Rudist reefs
Mishrif Formation, including Gir Bir

Lithology:- *The Mishrif Formation in its type area is composed of grey-white, dense, algal limestones with gastropods and shell fragments above, and of brown, detrital, porous, partly very shelly and foraminiferal limestone, with limestone with rudist debris below .*

- *Chatton and Hart (19 61 and 19 62) include d all the organic detrital neritic limestone units of Cenomanian-Early Turonian age, such as the M'sad, Gir Bir, and Mergi formations in the Mishrif Formation.*

Age:- *Cenom anian-Early Turonian age.*

Environment:- *The formation was deposited as rudist shoals and pate reefs over growing subtle structural highs developing in an otherwise relatively deeper shelf on which open marine sediments of the Rumaila Formation were deposited.*

Contacts:- *The **lower contact** of the formation is usually conformable.*

The underlying unit is usually the Rumaila Formation in the S, and the M'sad Formation in the W. In the northern most area where the Mergi and Gir Bir facies occur, the lower boundary is unconformable and those units overly the Albian Mauddud (Upper Qamchuqa) Formation. and Mergi occurrences).

- ***The upper boundary** is unconformable in the Awasil-Samarra area of central Iraq and in the Foothill and High Folded zones (Gir Bir basin roughly to the west of the Musalyib-Nahr Umr palaeoridge) the upper contact is conformable. Where the Kifl is absent the top of the Mishrif Formation is marked by an unconformity.*
- ***The Mishrif Formation passes into the M'sad Formation towards the Rutba Subzone.***

- ***Rudists** are a group of box-, tube-, or ring-shaped marine heterodont bivalves that arose during the Late Jurassic and became so diverse during the Cretaceous that they were major reef-building organisms in the Tethys Ocean.*

2.2.4 Evaporitic inner shelf lagoonal facies

Kifl Formation

- *Previously it was included in the Rumaila, Mishrif Formatons*.

Lithology:- *It comprises anhydrit e and oolitic and pseudo-oolitic limestone.*

Age:- *Turonian age was assumed based on its stratigraphic position.*

Environment:- *The formation is probably equivalent to the supratidal upper part of the M'sad Formation in W Iraq.*

2.2.5 Restricted deep basin facies

1- Dokan formations

The Dokan Limestone was formerly included in the Kometan Formation.

Lithology:- *It comprises 4 m of light coloured grey and white oligosteginal limestone, locally rubbly, with glauconitic coatings of the pebble-like masses .*

Environment:- *The presence of ammonites indicates the formation was deposited in an open marine environment.*

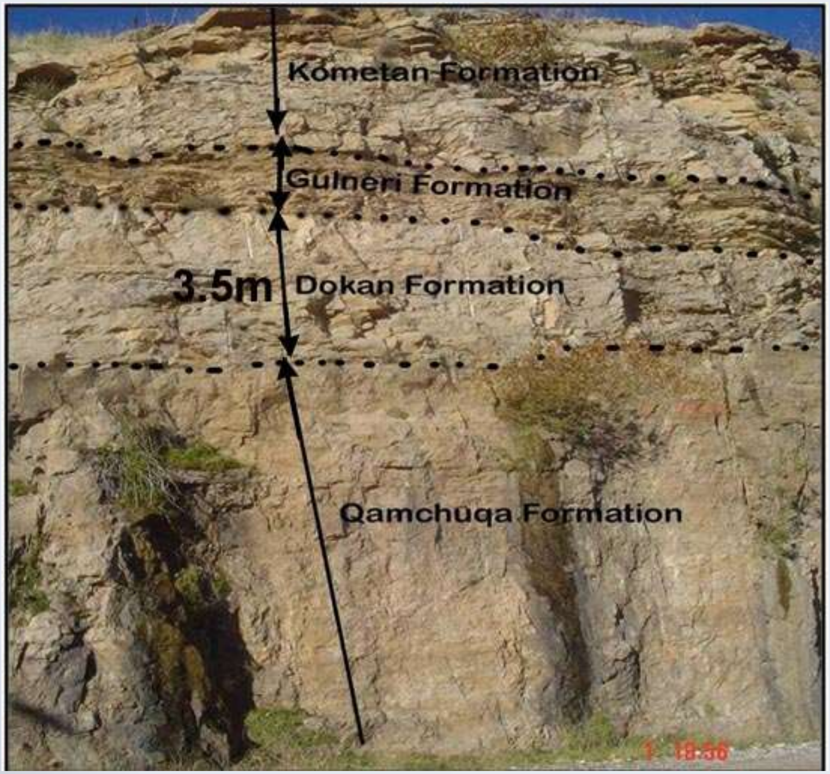
Age:- *The fauna in the type locality and in Bai Hassan (Ditmar and the Iraqi-Soviet Team, 1971) confirm the formation is of Cenomanian age.*

Contacts:- *Both the lower and upper contacts of the formation in the type area are unconformable. In the type locality, the Dokan Formation is underlain by* ***Qamchuqa*** *Formation; the contact is an erosional unconformity*

The overlying formations are of Turonian age, mostly represented by the ***Kometan*** *Formation.*

- ***Ammonoids*** *are an extinct group of marine mollusc animals in the subclass Ammonoidea of the class Cephalopoda.*
- *The earliest ammonites appear during the Devonian, and the last species died out during the Cretaceous–Paleogene extinction event.*


Gulneri Formation


Kometan Formation
Gulneri Formation
3.5m
Dokan Formation
Qamchuqa Formation

Dokan Fn.


DC
K
S


DC

Dokan Conglomerate overlying the Kometan, Shiranish and Tanjero formation,

2-Gulneri Formation

The Gulneri Shale Formation is a thin, highly condensed, unit which is locally preserved at the top of the Cenomanian-Early Turonian Sequence. Stratigraphic breaks occur at the base and top of the formation.

Lithology:- *it consists of about 2 m of black, bituminous, finely laminated, calcareous, shale with some glauconite and collophane in the lower part (Bellen et al., 1959).*

Environment:- *The high bitumen content and dwarfed fossils indicate the formation was deposited in an euxinic environment.*

Age:- *Early-Mid Turonian age*

Contacts:- *The formation is separated by unconformities from both the underlying Dokan and the overlying Kometan formations.*

2.2.6 Open Marine Facies

Upper Balambo Formation

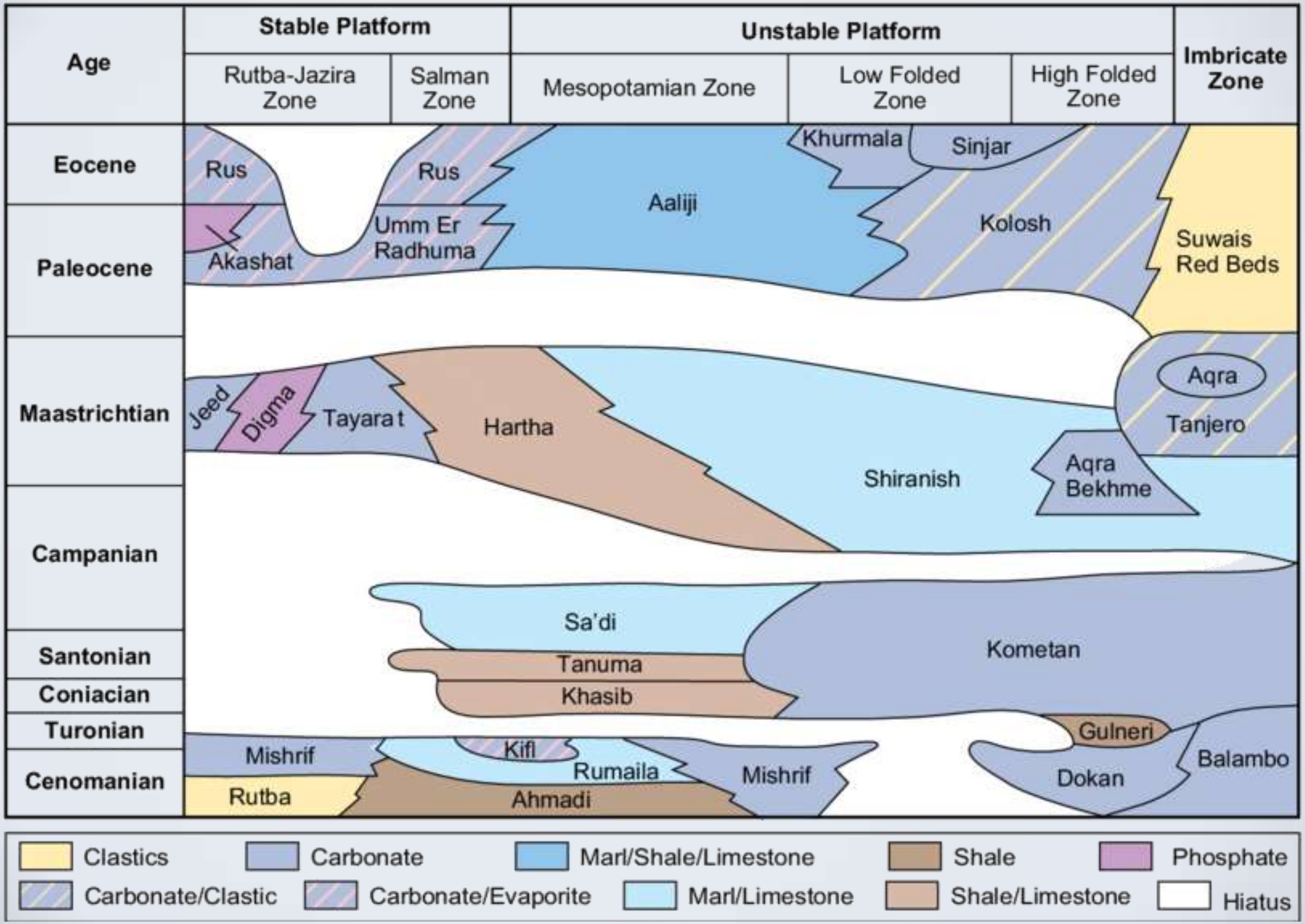
Age:- *The Balambo Formation of Valanginian- Turonian age is divided into the Lower Balambo Formation of Valanginian Albian age and Upper Balambo Formation of Cenomanian Turonian age.*

Lithology:- *In the type area between the Sirwan and Rowanduz rivers the Upper Balambo Formation comprises mostly thin bedded, (rarely thick bedded) light coloured limestones with a pelagic globigerinal -radiolaria oligosteginal fauna.*

Environment:- *The Upper Balambo Formation was deposited in an outer shelf to bathyal environment.*

Contacts:- *The formation is overlain by the Upper Campanian Shiranish Formation (Bellen et al., 1959) or the Upper Turonian Kometan Formation (Bolton, 1958d).*

In the High Folded Zone, the formation passes laterally into the Kometan, Gulneri, and Dokan formations.


Age
Stable Platform
Rutba-Jazira Zone
Salman Zone
Unstable Platform
Mesopotamian Zone
Low Folded Zone
High Folded Zone
Imbricate Zone
Eocene
Paleocene
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Rus
Rus
Akashat
Umm Er Radhuma
Aaliji
Khurmala
Sinjar
Kolosh
Suwais Red Beds
Jeed
Digma
Tayarat
Hartha
Shiranish
Aqra
Tanjero
Aqra Bekhme
Sa'di
Kometan
Tanuma
Khasib
Gulneri
Mishrif
Kifl
Rumaila
Mishrif
Dokan
Balambo
Rutba
Ahmadi
Clastics
Carbonate
Marl/Shale/Limestone
Shale
Phosphate
Carbonate/Clastic
Carbonate/Evaporite
Marl/Limestone
Shale/Limestone
Hiatus

Late Turonian-Danian Megasequence

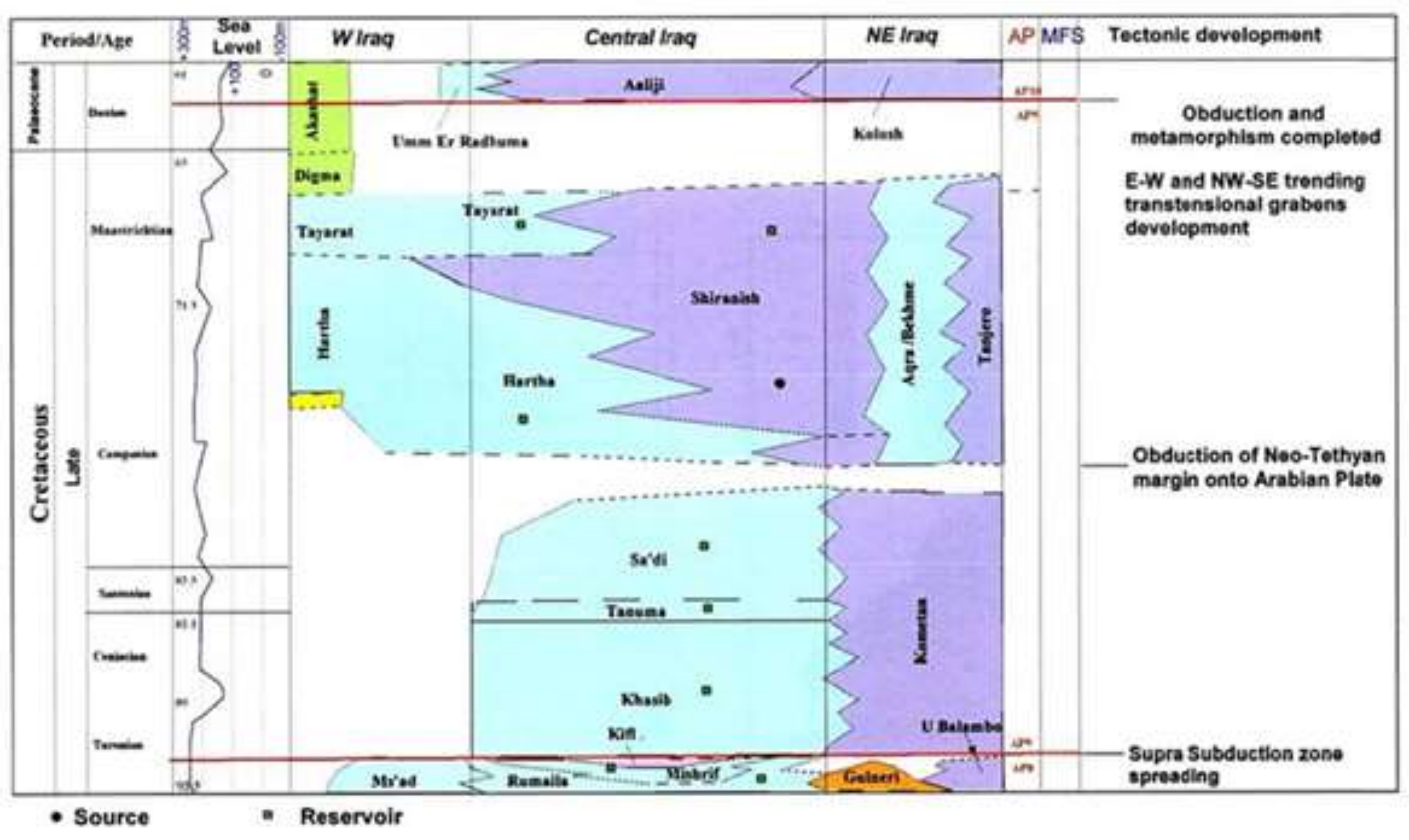


Fig. 12-1: Stratigraphic correlation of formations of the Late Early Turonian-Danian Megasequence

Late 'Turonian-Early Campanian Sequence

- *The Late Turonian-Early Campanian Sequence was **deposited** in a relatively narrow seaway occupying the area of the Salman, Mesopotamian, Foothill and High Folded zones. The Rutba-Jezira Zone of the Stable Shelf was emergent. In the Northern Thrust Zone, Turonian sediments are absent suggesting that this zone was part of a ridge separating the Southern Neo- Tethys from the Balambo Tanjero Zone (Fig. 12-3). Turonian sediments were fully deposited in the Balambo-Tanjero Zone.*
- *The sequence is represented by the **Khasib, Tanuma, Sa'di and Kometan formations.***

The sequence comprises two main facies,

*- the deep inner shelf and lagoonal (**Khasib, Tanuma and Sa'di** formations,*

*- and the outer shelf and basinal facies of the **Kometan** Formation.*

Fig. 12-2: Thickness of the Late Turonian-Danian Sequence in meters

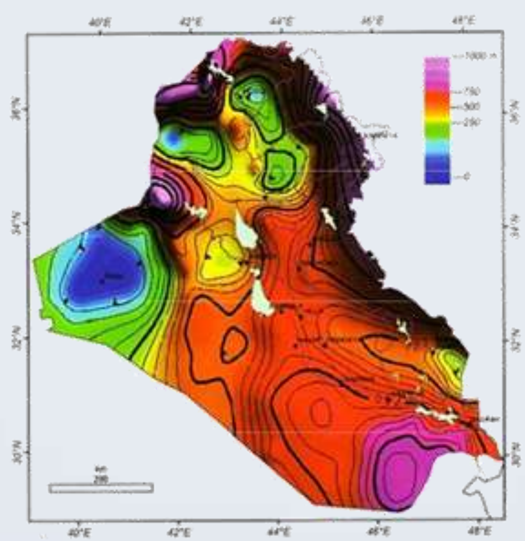
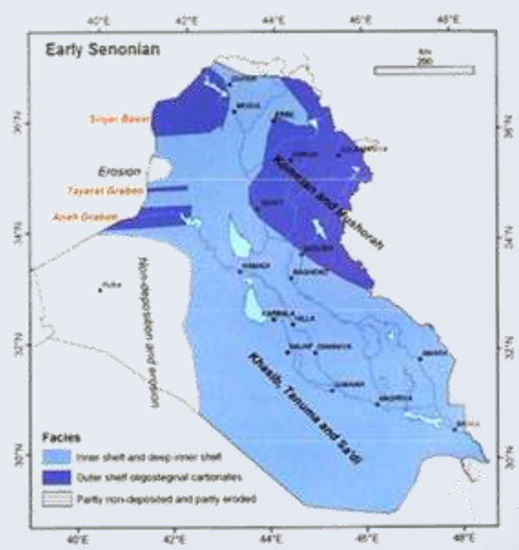


Fig. 12-3: Late Turonian-Early Campanian palaeogeography



2.1 Deep inner shelf and lagoons

2.1.1 Khasib Formation

Lithology:- *The lower part (20 m) of the formation consists of dark grey and greenish grey shales, and grey, fine grained , argillaceous limestone. The upper part (30 m) comprises grey, fine grained argillaceousL.st.*

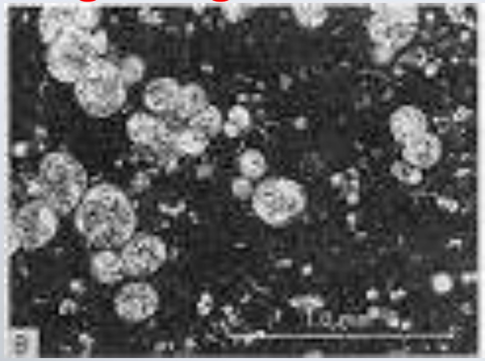
Environment:- *The oligosteginal fauna and the dwarfed character of the fossils indicate the Khasib Formation was deposited in a restricted basin. Open marine Globotruncan a assemblages are also present.*

Contacts:- *According to Bellen et al. the lower boundary of the formation is disconformable.*

- *The upper boundary with the **Tanuma** Formation is gradational.*

Age:- *Turonian-Early Campanian age.*

Oligostegina :- Microfossil of uncertain effinities •



2.1.2 Tanuma Formation

Lithology:- *It comprises 30 m of black, fissile (locally pyritic) shale with streaks of grey, macrocrystalline, argillaceous and detrital limestone (sometimes glauconitic), with an oolitic limestone layer at the top.*

Environment:- *The Tanuma Formation was deposited in a restricted shallow basin , in partly euxinic environment.*

Age:- *Turonian- Early Cam panian age.*

Contacts:- *The Tanuma Formation usually conformably overlies the* ***Khasib*** *Formation.*

2.1.3 Sa'di Formation

- *The Sa'di Formation is the youngest, thickest, and most widespread formation of the Late Turonian-Early Campanian Sequence.*

Lithology:- *The formation comprises 300 m of white, chalky, argillaceous and globigerinal limestones with a well-developed 60 m thick marl bed at the top.*

Age:- *Santonian-Early Campanian age.*

Contacts:- *The Formation is transgressive unit; its lower contact is conformable and gradational only where it is in contact with the* ***Tanuma*** *Formation.*

Elsewhere it unconformably overlies different units, especially in uplifted areas towards the Rutba-Jezira Zone.

The upper boundary of the Sa'di Formation is usually unconformable and overlain by ***Hartha*** *Formation.*

2.2 Outer shelf and basinal

Kometan Formation

Lithology:- *The formation comprises 120 m of light grey, thin bedded, globigerinal-oligosteginal limestone, locally silicified (with chert concretions in some beds), with a glauconitic bed at the base* **.**

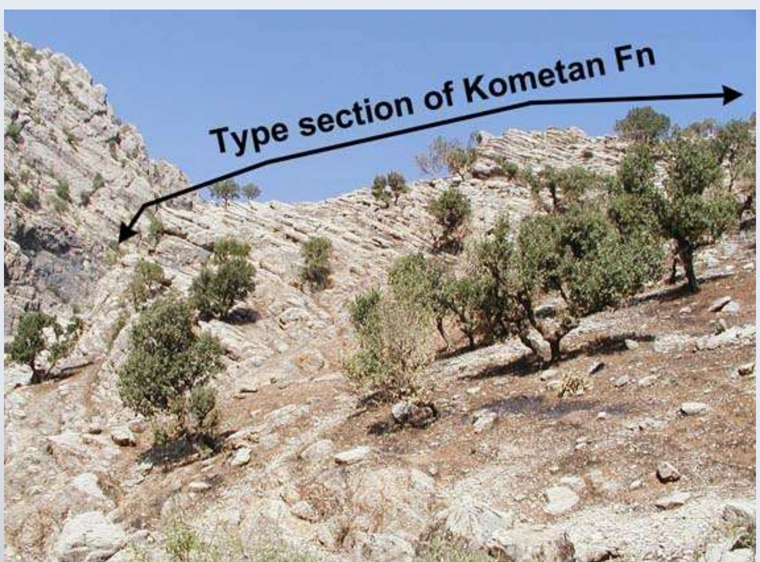
Age:- *Turonian to Late Campanian*

Environment:- *The Kometan Formation represents a typical basinal marine environment of bathyal depth.*

Contacts:- *In the type locality the Kometan Formation is underlain by the Balambo Formation, the contact is unconformable, faunal break and intense glauconitization at the base of the formation indicate depositional hiatus, with probable erosion (Bellen et al., 1959).*

The Kometan Formation passes laterally into the uppermost part of Balambo Formation.


Kometan
Formation(Turonian) in SW
limb of Pira Magrun.
Reaches 160m in Miran-1


Type section of Kometan Fn

3- Late Campanian-Maastrichtian Sequence

- *The climax of the obduction and closure of the Southern Neo- Tethys occurred during the Late Campanian and Maastrichtian. This contributed to a major transgression across the whole of Iraq.*

The following formations are recognized in the Late Campanian-Maastrichtian Sequence:

*1) The Upper Campanian-Lower Maastrichtian **Hartha Formation** deposited in an inner shelf to lagoonal environment*

*2) The Middle-Upper Maastrichtian inner shelf and shoal **Tayarat Formation** deposited in a inner shelf and shoal environment.*

*3) The Middle-Upper Maastrichtian phosphatic **Digma Formation** deposited in a lagoonal-outer shelf and basinal environment in the Rutba basin.*

*4) The Upper Campanian-Maastrichtian outer shelf to basinal marls and limestones of the **Shiranish Formation**.*

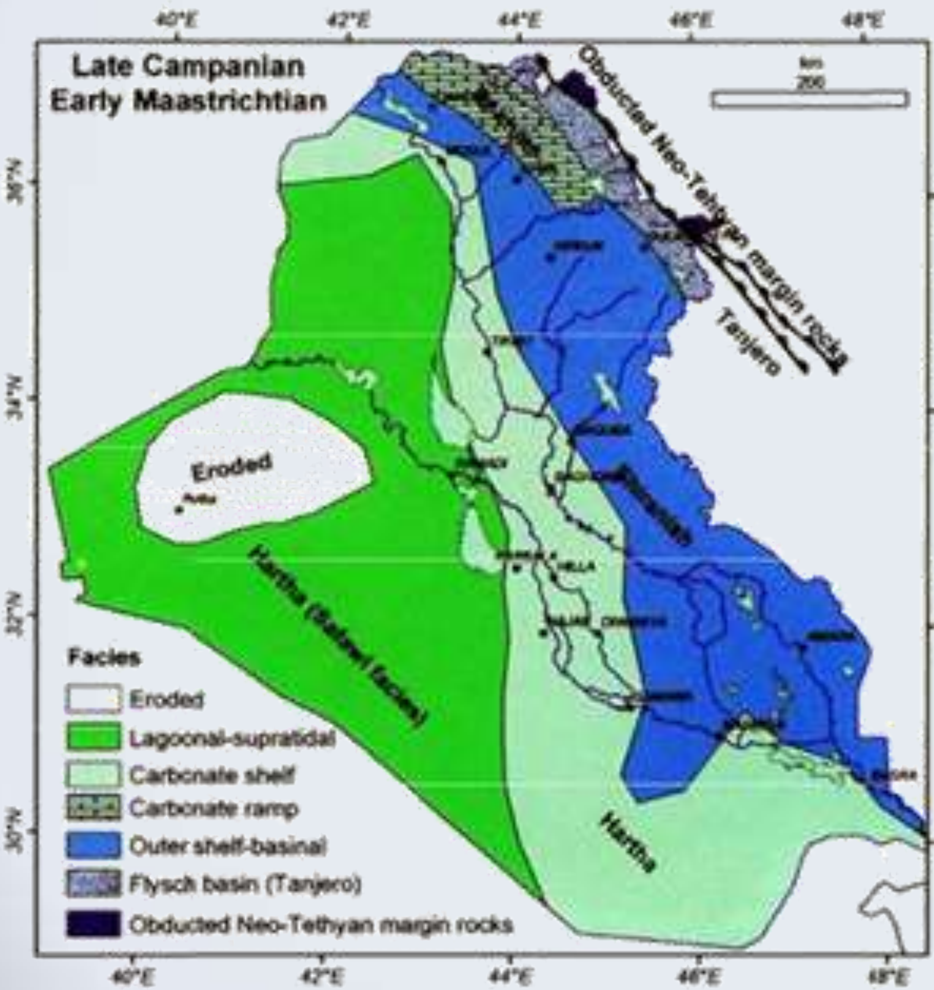
*5) The Upper-Campanian-Maastrichtian ramp carbonates of the **Bekhme Formation** deposited on the Qamchuqa Ridge**.***

*6) The Maastrichtian ramp carbonates of **the Aqra Formation** deposited on the Qamchuqa Ridge.*

*7) The Upper Campanian-? Maastrichtian sediments of the **Hadiena Formation** deposited on the Ora Ridge.*

*8) The Upper Campanian-Maastrichtian flysch of the **Tanjero** Formation.*

Fig. 12-5: Late Campanian-Early Maastrichtian palaeogeography



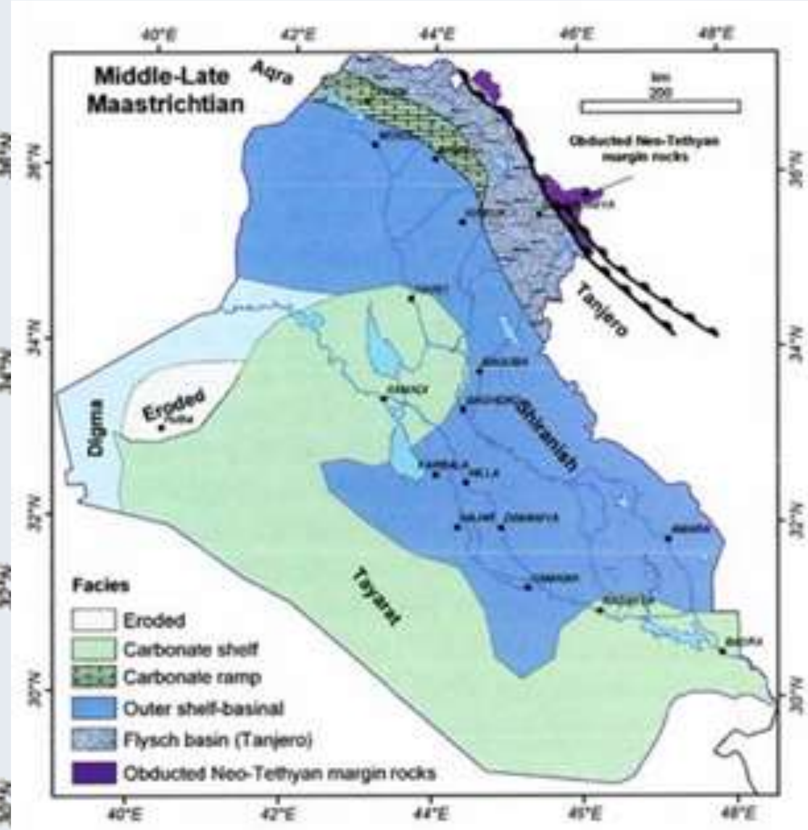


Fig. 12-6: Mid-Late Maastrichtian palaeogeography

3.1 Carbonate inner shelf

3.1.1 Hartha Formation

Lithology:- *It comprises organic detrital and glauconitic limestones with beds of grey and green shale; the limest ones are locally strongly dolomitized. Beds of chalky limestone occur frequently.*

Anhydrite and oolitic limestone beds and lenses are recorded in the Hartha Formation between Ramadi and Makhul.

-In the Rut ba area, in W Iraq, the Hartha Formation consists of beds of marl and dolomite wit h well developed fenestral porosity and "Birds Eye" texture indicating a supratidal subtidal depositional environment..

Environment:- *The Hartha Formation was deposited in forereef to shoal environment. Locally lagoonal back reef facies occur around the margins of the Stable Shelf.*

Contacts:- *The lower contact of the formation is usually an unconformity, often marked by a basal conglomerate.*

The upper boundary in S Iraq is conformable and the formation is often overlain by pelagic sediments of the ***Shiranish*** *Formation.*

3.1.2 Tayarat Formation

Lithology:- *It comprises 48 m of rubbly, porous, chalky limestone which is locally dolomitised and sandy rich in **Loftusia** . The upper part of Tayarat Formation to the W of the type section is replaced by the phosphatic Digma Formation.*

- *Geodes and chert concretions are common in the carbonates of the upper unit.*
- *The clastics in the lower unit pass into carbonates to the east.*

The type section of the Tayarat Formation includes some phosphatic beds.

Contacts:- *The formation overlies the Shiranish Formation in S and SW Iraq and the **Hartha** Formation in all other areas. The upper contact with the **Umm Er Radhuma** Formation in S and SW Iraq is disconformable; Danian beds are absent. W of Rutba, the Tayarat Formation is conformably overlain by the **Digma** Formation.*

Age:- *Maastrichtian*

Environment:- *marine, warm, inner shelf env.*

Geode*;- are geological secondary structures which occur in certain sedimentary and volcanic rocks. They are themselves of sedimentary origin formed by chemical precipitation. Geodes are essentially hollow, vaguely spheroid to oblate masses of mineral matter that form via either of two processe.*



3.2 Phosphatic inner and outer shelf

Digma Formation

Lithology:- *It comprises 50 m of phosphatic, glauconitic, locally silicified marls.*

- *This phosphatic sequence lies conformably on Loftusia limestones of the Tayarat Formation.*
- *It is overlain conformably by Danian shale.*

Lithology:- *Al-Bassam et al. (1990) described the Digma Formation, which they called it as "**Safra Beds**" as white to creamy limestone, dolostone with phosphorite horizonand green to ocher pappery shale, with oyster shell horizon.*

Environment:- *shallow marine*

Contacts:- *The Digma Formation is underlain unconformably by **Ms`ad** Formation*

- *(Buday and Hak, 1980). It is underlain conformably by the **Tayarat** Formation.*
- *The upper contact with the A kashat Formation is apparently conformable but is probably associated with a slight break in sedimentation .*

Age:- *Maastrichtian age.*

Remark:- Phosphorite, phosphate rock or rock phosphate:- *is a non-detrital sedimentary rock which contains high amounts of phosphate minerals. The phosphate content of phosphorite (or grade of phosphate rock) varies strongly, from 4%[1] to 20% phosphorus pentoxide (P2O5). Marketed phosphate rock is enriched ("beneficiated") to at least 28%, often more than 30% P2O5.*

Plate 12-1: Radhuma Safra butte, north of the Ga'ara depression, showing Lopha-bearing limestone overlying the yellow marls of the Digma Formation (photo by Jiří Rudolský)

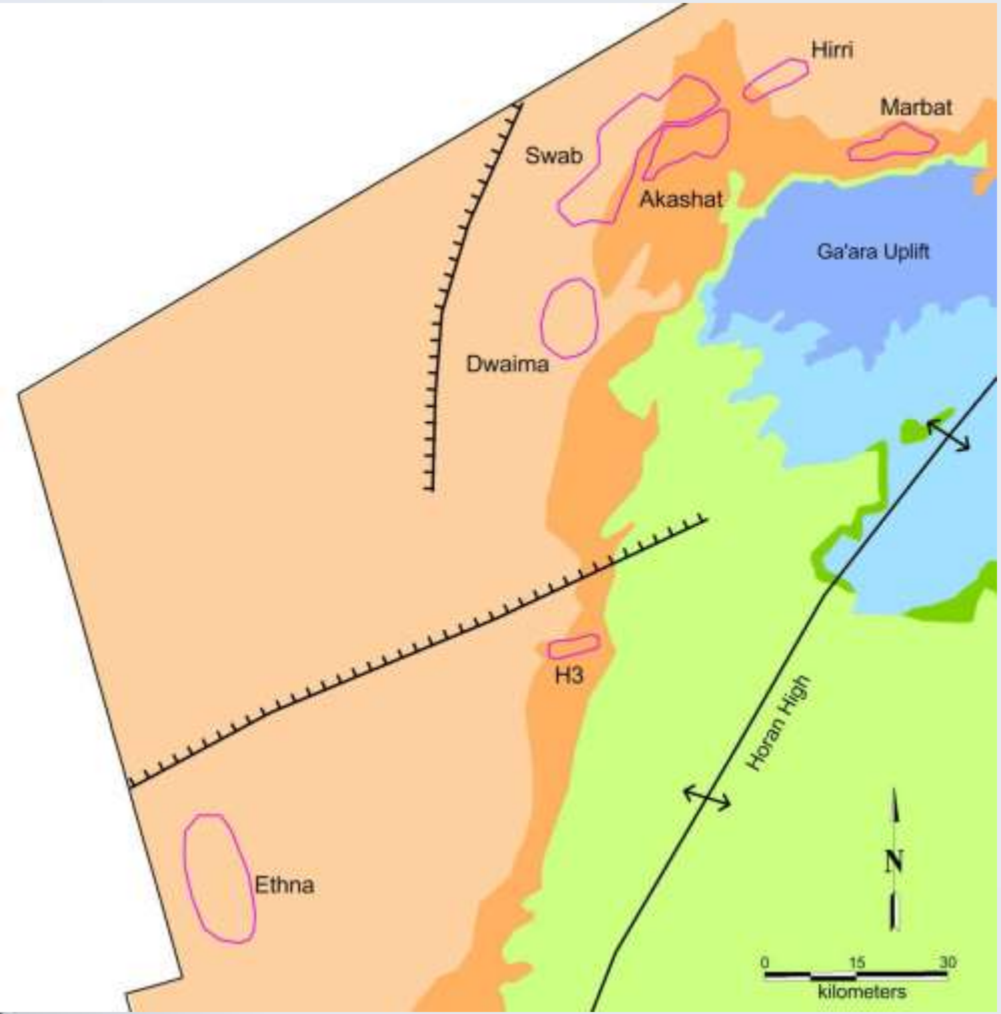
Plate 12-2: Bekhme Formation in core of the Harir Dagh anticline, 10 km NE of Shaqlawa Town in NE Iraq (photo by S. Jassim)

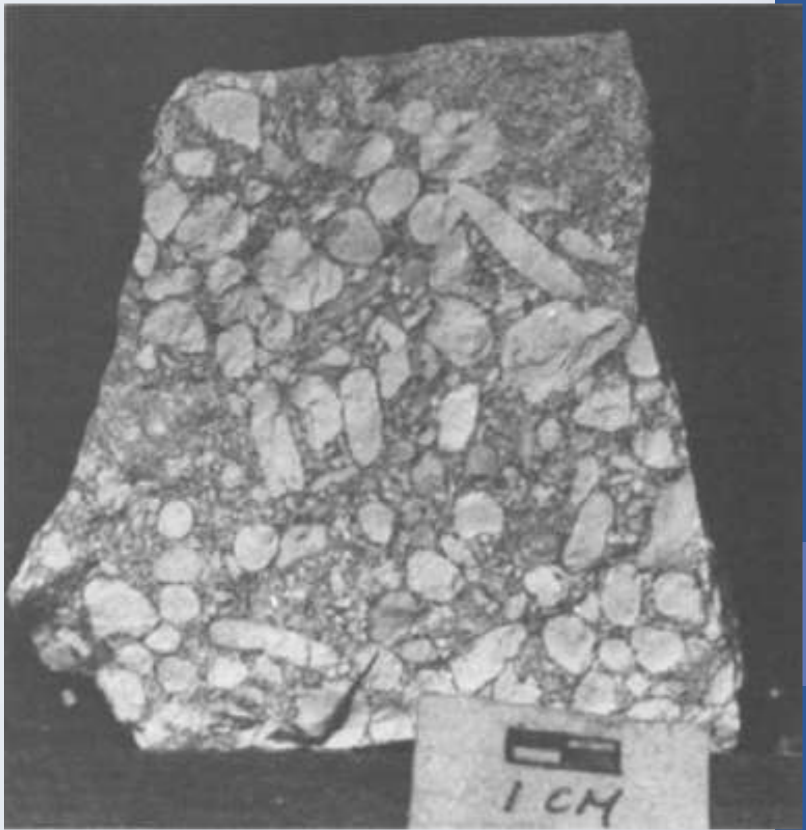
Remarks:_Phosphate Deposits of Iraq

- *Phosphate deposits are developed in rocks ranging from Upper Cretaceous to Eocene.*
- *The majority of the deposits are of Paleocene age.*
- *The phosphate minerals are granular and are mostly composed of coated grains (ooids, peloids, cortoids, etc.).*
- *Coprolites, intraclasts and fish bones are common, especially in the Late Cretaceous and Eocene deposits.*
- *The Paleocene deposits are cemented with calcite with little terrigenous material.*
- *Silica cement is more common in the Eocene deposits.*
- *The Late Cretaceous deposits contain clastic material consisting of clay and sand.*
- *The host rocks are typically limestone, lime mudstone, shale and porcellanite which may contain chert beds, chert nodules and quartz geodes.*

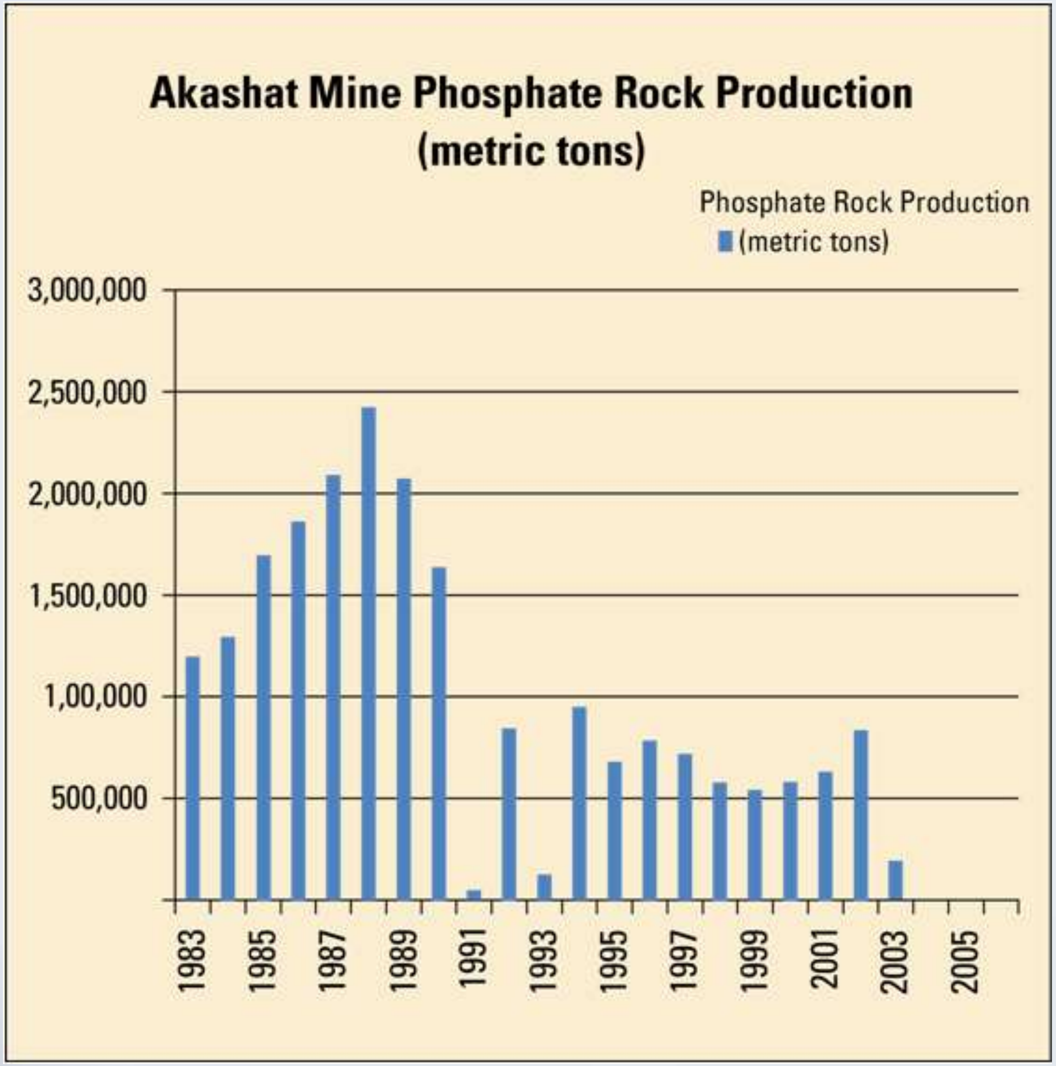
***A coprolite** :- is fossilized feces. Coprolites are classified as trace fossils as opposed to body fossils, as they give evidence for the animal's behaviour (in this case, diet) rather than morphology. (روث الحيوانات المنقرضة)*

Outcrop of Paleocene Phosphorite Akashat Mine

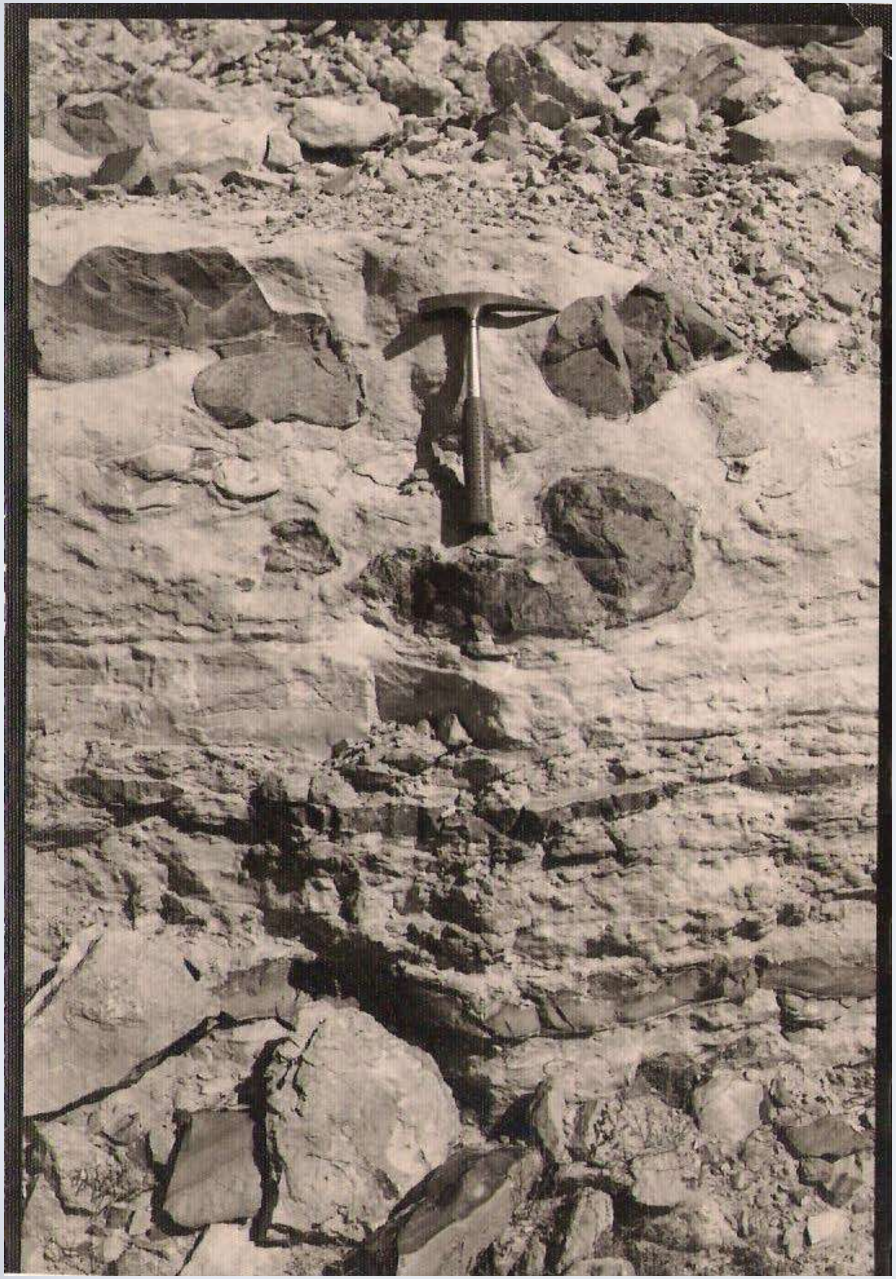




Akashat Phosphate Mine



Year	Phosphate Rock Production (metric tons)
1983	1,199,343
1984	1,292,172
1985	1,692,168
1986	1,859,223
1987	2,094,780
1988	2,423,550
1989	2,073,557
1990	1,635,283
1991	47,940
1992	841,495
1993	124,825
1994	950,235
1995	676,210
1996	785,290
1997	719,518
1998	576,381
1999	543,635
2000	581,245
2001	630,355
2002	835,285
2003	192,940
2004	—
2005	2,090
2006	500
Total production	21,778,020



Paleocene posphate

Coprolite

3.3 Carbonate ramp

Bekhme -Aqra Formation

Lithology:- The Aqra and Bekhme *formations comprise reef limestones, forereef and shoal limestones, and associated facies (Bellen et al., Op. Cit.).*

It is difficult to separate the two formations where an intervening tongue of the Shiranish or Tanjero formations is absent.

- *The name Aqra-Bekhme has been suggested by Buday (1980) where these intervening formations are absent.*
- *Both formations were deposited over the Qamchuqa ridge of the High Folded Zone.*

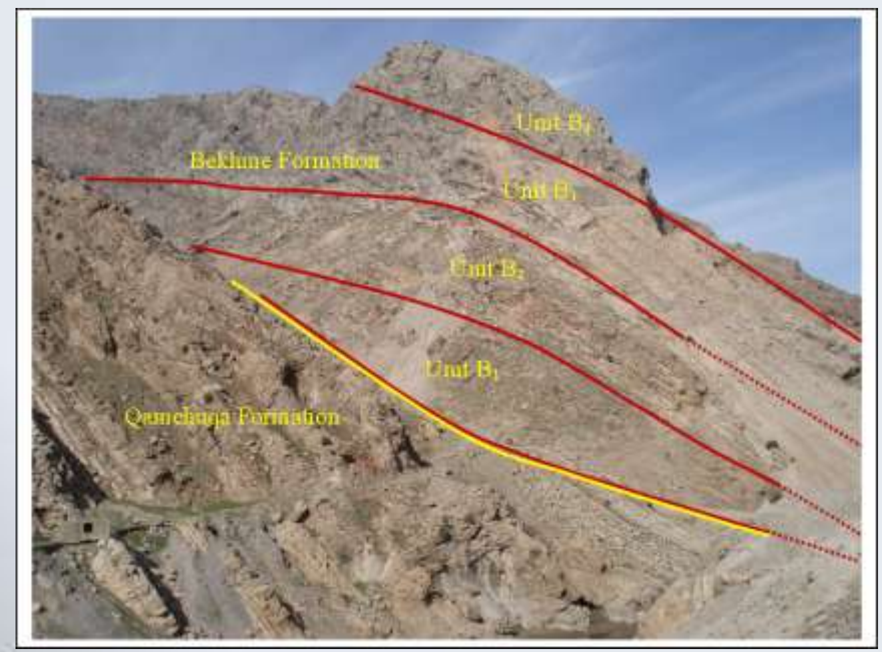
Environment:- *The formations were deposited mostly in a reef-forereef environment.*

The Aqra Formation also transgressively overlies the Tanjero Formation.

Age:- *Abundant fossils confirm a Late Campanian age for the Bekhme Formation and a Maastrichtian age for the Aqra Formation.(L.Camp- L. Maastr.).*

Contcts:- *The Bekhme Formation unconformably overlies the Mauddud (Qamchuqa) Formation with a basal conglomerate.*

- *The upper contact of the Aqra Formation is marked by an erosional break at the Cretaceous-Tertiary boundary.*



***Glauconite** is an iron potassium phyllosilicate (mica group) mineral of characteristic green color with very low weathering resistance and very friable. Normally, glauconite is considered a diagnostic mineral indicative of continental shelf marine depositional environmGlauconite particles are one of the main components of greensand and glauconitic sandstone, ents with slow rates of accumulation*

3.4 Outer shelf-basinal

Shiranish Formation

Lithology:- *The Shiranish Formation, in its type area, comprises thin bedded argillaceous limestone (locally dolomitic) overlain by blue pelagic marl **.***

The formation gradually passes into the Tanjero Formation to the NE.

*Fossils are very abundant in the Shiranish Formation and its Qurna tongue(in South) but rare in the Jib'ab facies(in Anah graben)**.***

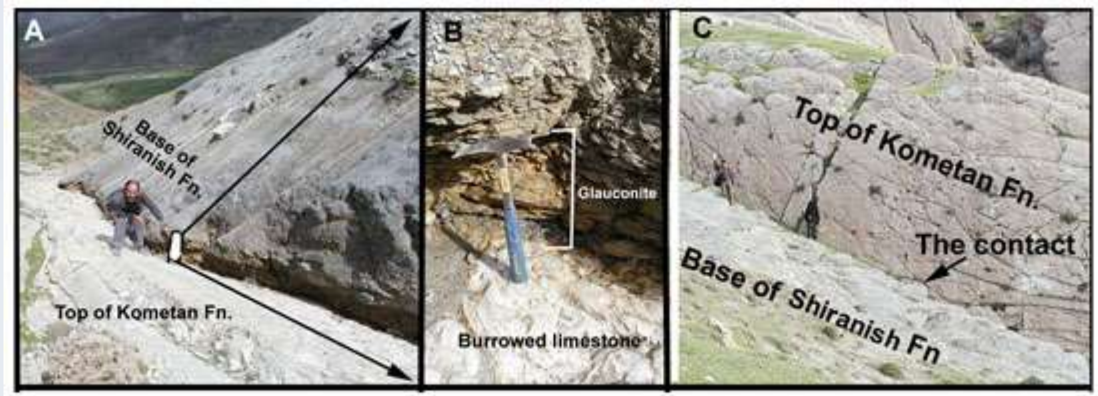
Age:- *Late Campanian-Maastrichtian age.*

Contacts:- *In the type section the Shiranish Formation conformably overlies the **Bekhme** Formation.*

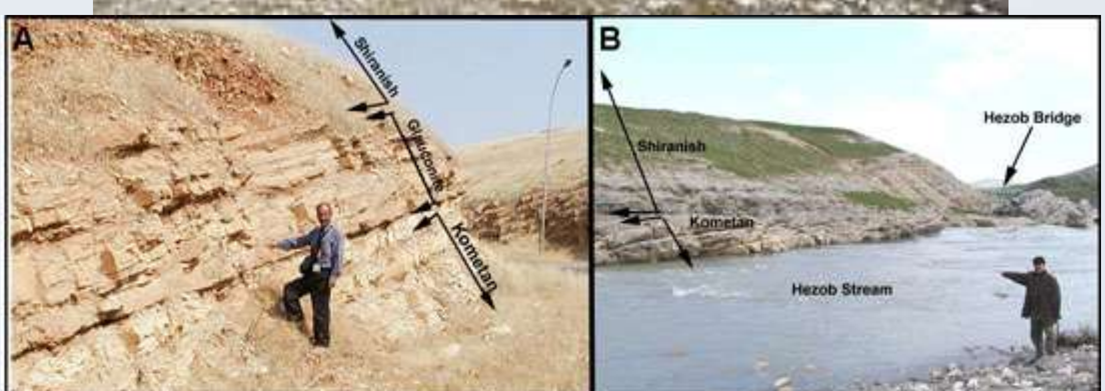
Elsewhere the Shiranish unconformably overlies older Cretaceous formations.

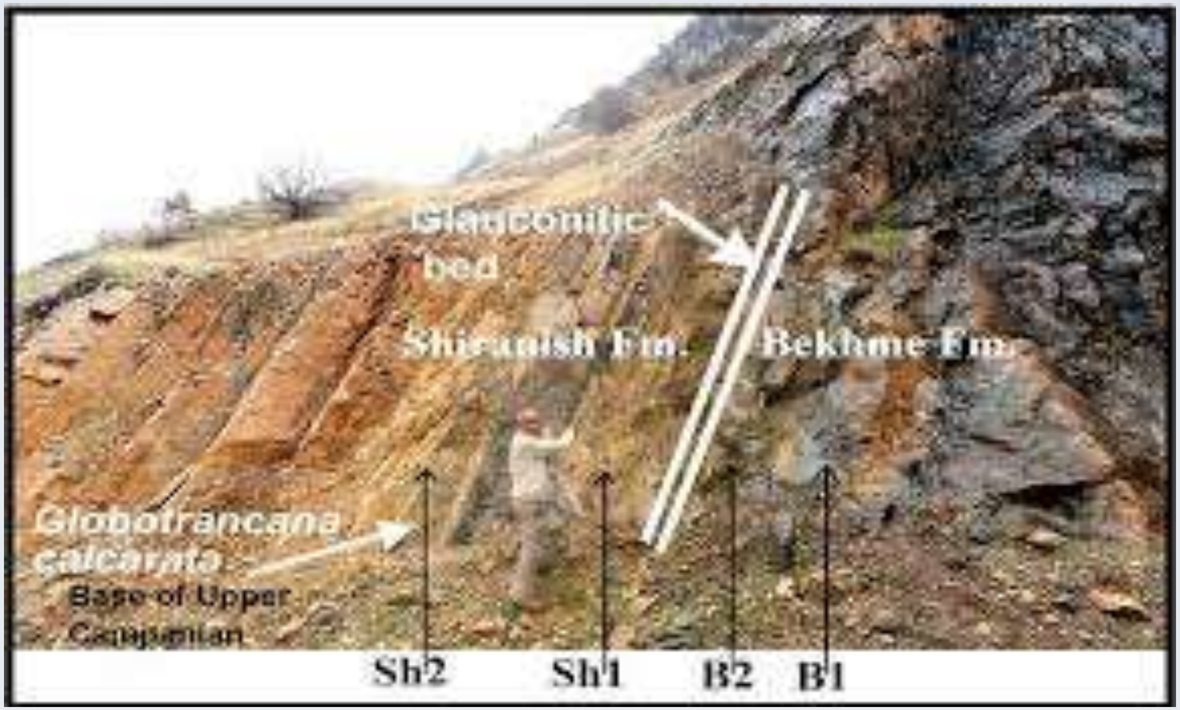
The upper boundary is erosional or nonsequential where the Shiranish Formation is overlain by Palaeogene sediments.

The Anah Graben *is a remarkable tectonic element which contains over 2000 m of Shiranish Formation; thin carbonate turbidite beds are probably present derived from erosion of the adjacent platform areas.*


A
Base of Shiranish Fn.
Top of Kometan Fn.
B
Glauconite
Burrowed limestone
C
Top of Kometan Fn.
The contact
Base of Shiranish Fn


Shiranish Fn.
Transition Zone
Kometan Fn.


A
Shiranish
Glauconite
Kometan
B
Hezob Bridge
Shiranish
Kometan
Hezob Stream


Glauconitic
bed
Shiranish Fm.
Bekhme Fm.
Globotrancana
calcarata
Base of Upper
Campanian
Sh2
Sh1
B2
B1


Shiranish Fn.
Transition Zone
Kometan Fn.

3.5 Isolated basin of the Balambo-Tanjero Zone

Tanjero Formation

- *The type section of the formation in the Sirwan valley (SE of Sulalmaniya comprises two divisions.*

Lithology:- *The lower division comprises pelagic marl, and occasional beds of argillaceous limestone with siltstone beds in the upper part.*

- *The upper division comprises silty marl, sandstone conglomerates, and sandy or silty organic detrital limestones; it interfingers with the* ***Aqra Limestone****.*
- *The sandstones are composed predominantly of grains of chert and green igneous and metamorphic rocks.*
- *The conglomerates contain pebbles of Mesozoic limestones, dolomites, recrystallised limestones, and radiolarian chert.*

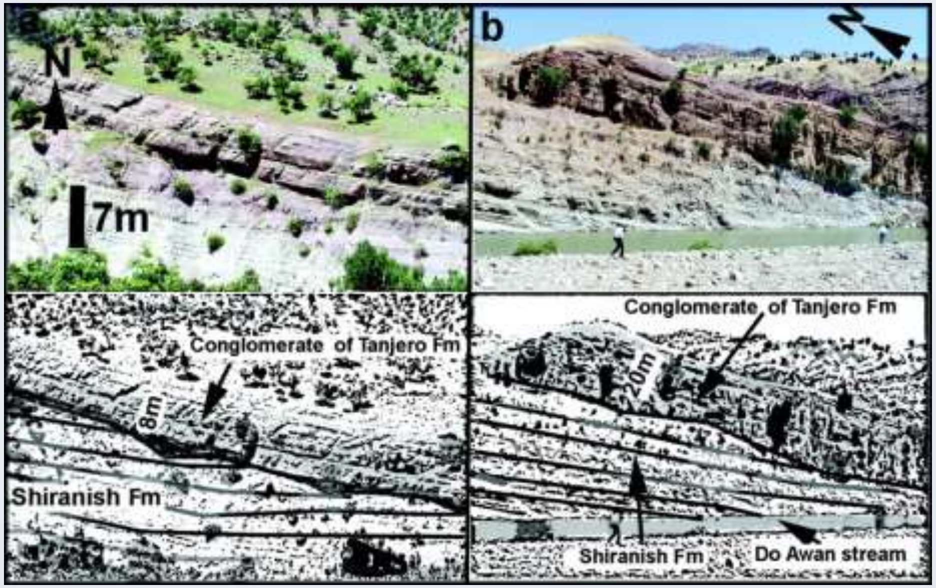
Environment:- *The formation was deposited as flysch in a rapidly subsiding foredeep basin immediately in front of the thrust sheets of the obducted margin of the Southern Neo- Tethys.*

Age:- *Fossils (mostly planktonic fauna) are abundant in the Tanjero Formation and indicate a Late Campanian Maastrichtian age.*

Contacts:- *The formation usually conformably and gradationally overlies the Shiranish Formation.*

- *The formation is usually unconformably overlain by Palaeogene formations except where it passes into the* ***Shiranish*** *Formation or is overlain by the* ***Aqra*** *Formation.*


Balambo mountain
Sirwan stream
Balambo Fn
Ko
Sh
Tanjero Fn type section
Sinjar
Kolo


N
7m
b
Conglomerate of Tanjero Fm
8m
Shiranish Fm
Conglomerate of Tanjero Fm
20m
Shiranish Fm
Do Awan stream

Bekma fn.

Plate 12-3: Bekhme Formation (massive limestone in top view) overlying the thick bedded Mauddud (Qamchuqa) Formation, Gali Ali Beg gorge, W of Rowanduz (photo by S. Jassim)

Tanjero Fn.

Plate 12-4: Tanjero Formation overlying Shiranish Formation along the NE flank of Azmer anticline, E of Sulaimaniya (photo by Jiří Radolský)

3.6 Isolated basin of the Northern Thrust Zone

Hadiena Formation

Lithology:- *The formation (750 m thick) comprises three divisions: - The lower division comprises dolomitised limestone.*

-The middle division consists of silty marl, and argillaceous, sandy limestone with detrital hematite, phosphatic and chert grains, and thin beds of conglomerate and breccias.

-The upper division comprises conglomerates and breccias with angular fragments of hematite set in a matrix of ferruginous limestone and terrigenous quartz grains.

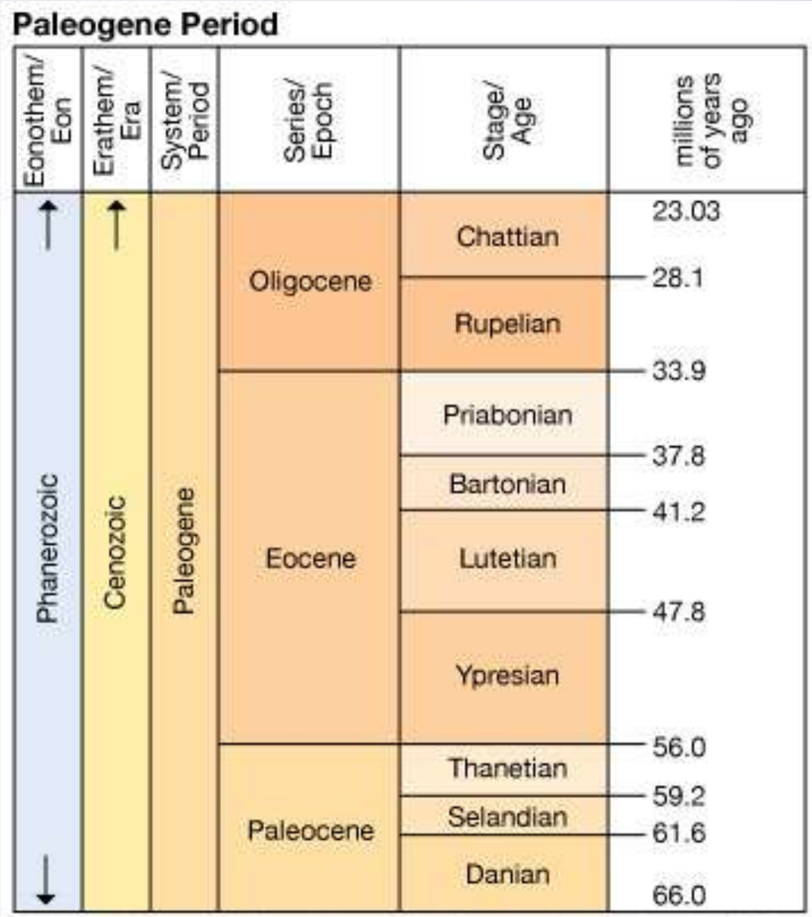
Environment:- *The lithology of the formation suggests it was deposited on a platform that was periodically exposed.*

Age:- *An abundant planktonic and benthonic fauna in the middle and upper divisions is of Late Campanian age.*

Contacts:- *The lower contact of the formation is an unconformity. The formation usually overlies the **Chia Gara, Barsarin or Naokelekan** formations. The upper contact of the formation is conformable; the formation is gradationally overlain by a unit of limestone and dolomitic limestone unit assumed to be the **Aqra Formation**,confirmed by the discovery of rudist reefs.*

4- Danian sequence

- ***The Danian is the oldest age or lowermost stage of the Paleocene epoch or series,***



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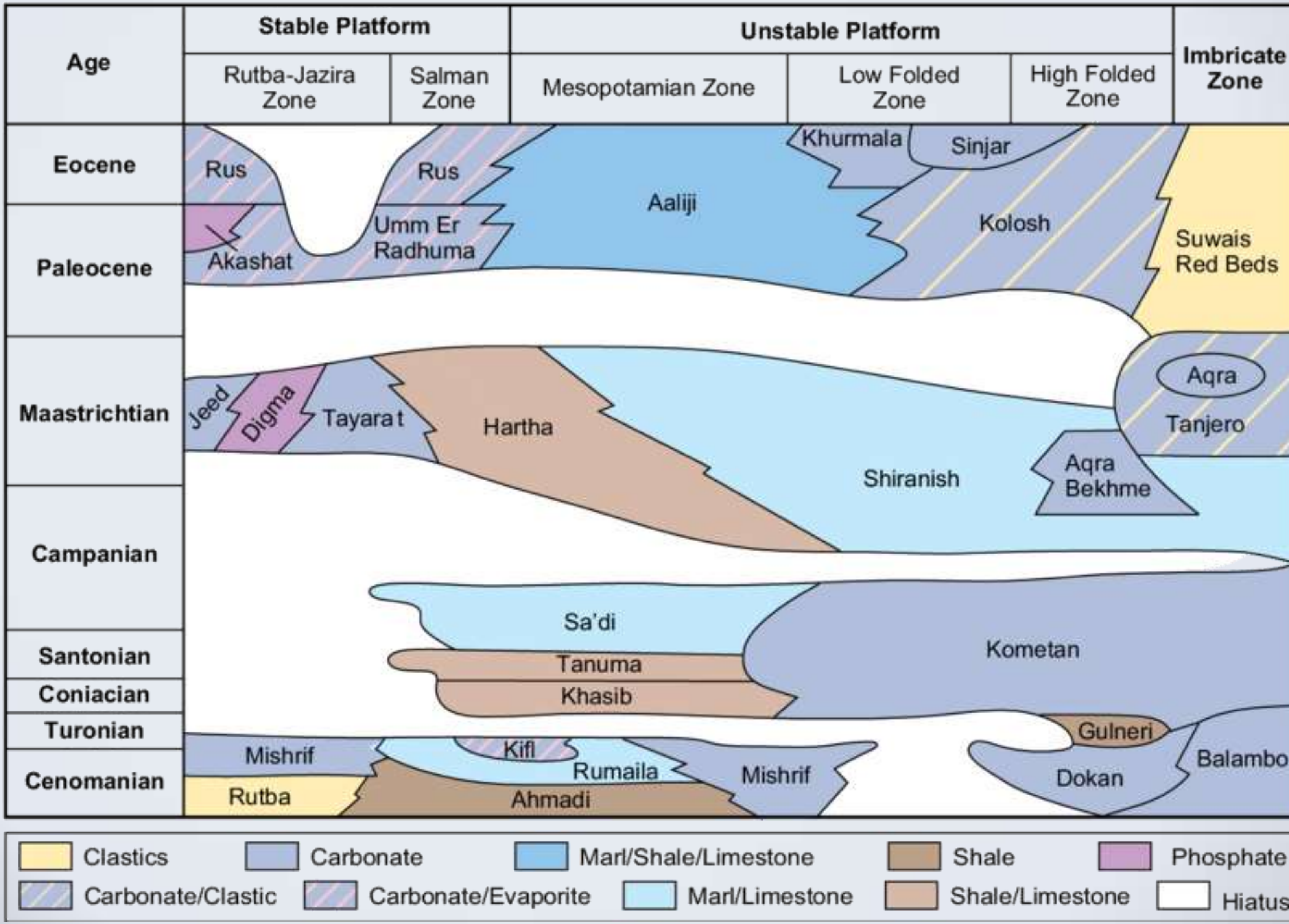
Source: 2015 International Chronostratigraphic Chart produced by the ICS.

The presence of Danian sediments is confirmed locally in Syria (Ponikarov et al., 1967) and in N Iraq (in wells Ain Zalah and Butmah; Dr Farouq AlOmari- oral communication).

Jassim et al. (1984) and Jassim and Karim (1986) confirmed the presence of Danian strata in W Iraq (in the lower part of the Palaeocene Akashat Formation exposed W and NW of Rutba Town).

Kassab (1972, 1975b, 1976) had earlier considered that Danian sediments were absent in Iraq.



Age
Stable Platform
Unstable Platform
Imbricate Zone
Rutba-Jazira Zone
Salman Zone
Mesopotamian Zone
Low Folded Zone
High Folded Zone
Eocene
Paleocene
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Rus
Rus
Akashat
Umm Er Radhuma
Aaliji
Khurmala
Sinjar
Kolosh
Suwais Red Beds
Jeed
Digma
Tayarat
Hartha
Shiranish
Aqra
Tanjero
Aqra Bekhme
Sa'di
Tanuma
Khasib
Kometan
Gulneri
Mishrif
Kifl
Rumaila
Mishrif
Dokan
Balambo
Rutba
Ahmadi
Clastics
Carbonate
Marl/Shale/Limestone
Shale
Phosphate
Carbonate/Clastic
Carbonate/Evaporite
Marl/Limestone
Shale/Limestone
Hiatus

4.1- Phosphatic outer shelf

Tarfawi Member of Akashat Formation

Danian sediments occur to the west of Rutba in W Iraq.

They are included in the Palaeocene Akashat Formation (Jassim et al., 1984). Five outcrop sections were investigated to the SW, Wand NW of Rutba Town (Karim and Jassim, 1986).

Lithology:- *The lowest unit of the formation comprises 7 m of buff to grey shale and white chalk. The shale contalns ribs of intraclastic and bone bearing phosphates; The shales contain montmorillonite and palygorskite*

-The middle unit of the formation consists of 7 m of sandstone which outcrops locally S of the Rutba-Amman highway. It is yellowish, quartzitic and often phosphatic with occasional beds of silicified shelly limestone.

-The upper unit consists of micrite limestone and chert (II m thick).

bathyal to outer shelf environment

Middle Palaeocene-Eocene Megasequence

- *The Middle Palaeocene-Eocene Megasequence was deposited during a period of renewed subduction and volcanic arc activity associated with final closure of the Neo-Tethys.*
- *This led to uplift along the NE margin of the Arabian Plate with the formation of ridges and basins, generally of NW-SE trend in N and Central Iraq and E- W trend in W Iraq.*
- *Significant lateral facies changes occurred across these tectonic features. Uplift of the E margin of the Arabian Plate during the Early Palaeocene explains the absence of the Danian from most of the High Folded Zone and the Foothill Zone.*
- *The Middle Palaeocene-Eocene Megasequence is divided into two sequences:*

1-The Palaeocene-Early Eocene sequence

2- Middle-Late Eocene sequence.

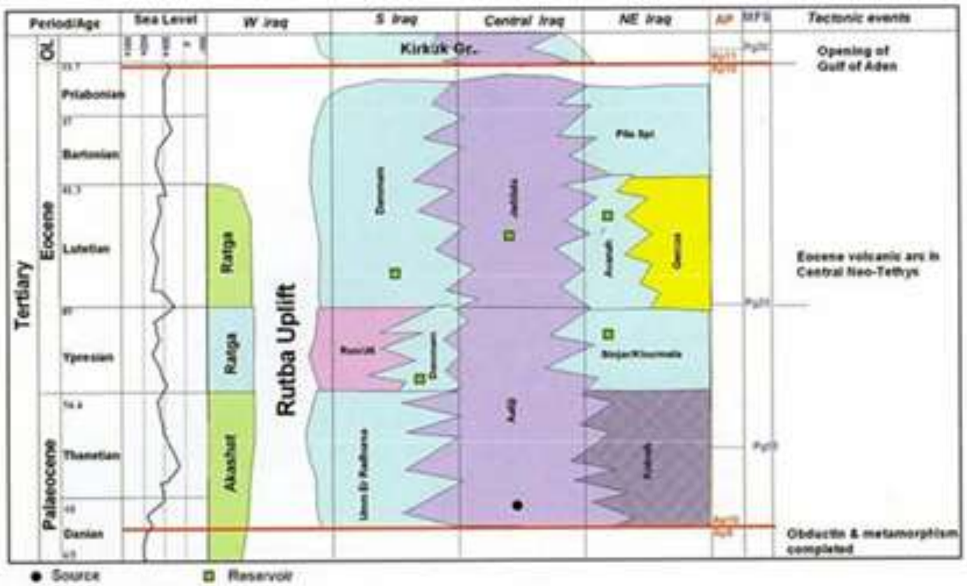


Fig. 13-1: Stratigraphic correlation of the formations of Megasequence AP10

Fig. 13-2: Thickness of the Palaeocene-Eocene Megasequence

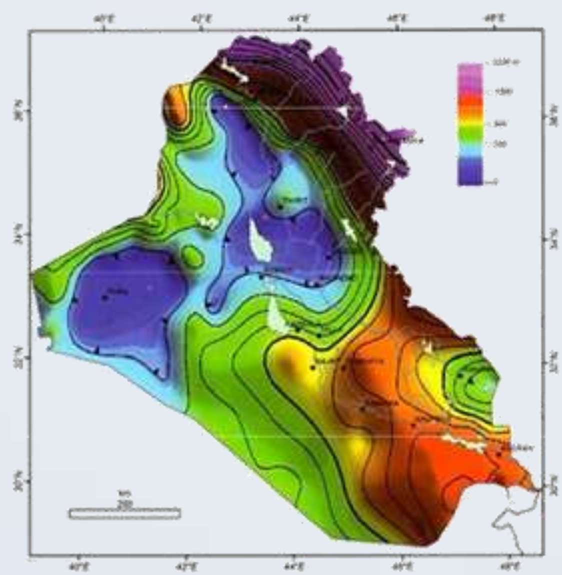
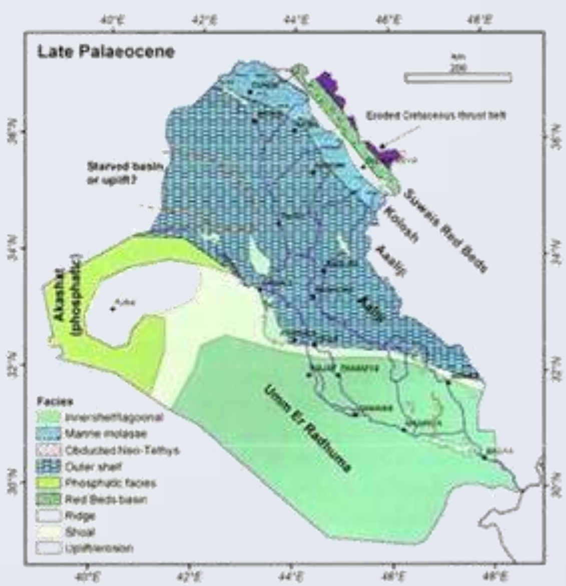


Fig. 13-3: Late Palaeocene Palaeogeography



1- Mid. Palaeocene -Early Eoce ne Sequence

- *Within the Unstable Shelf area two separate longitudinal basins developed in Mid Palaeocene time.*
- *An inter mountane basin (Red beds basin) flanked the SW and NE sides of the eroded thrust belt that has formed in Late Campanian Maastrichtian time.*
- *The Kolosh basin which occupied the area of the High Folded Zone was partly isolated from the Red Beds basin in NE by a ridge along the Balambo- Tanjero Zone from Amadiya in the NW through Rowanduz and Ranya towards Halabja in the SE .*
- *Further to the SW, the Kolosh trough passed into a basin that covered most of the Foothill and the NE parts of the Mesopotamian zone where open marine marls of the Aaliji Formation were deposited.*
- *A facies change occurred along a possible ridge between Falluja in the NW and Amara in the SE. To the SW of this ridge, the Aaliji Formation of SE and central Iraq was replaced by the neritic-shoal facies of the Umm Er Radhuma Formation, followed during the Early Eocene by the evaporites of Rus Formation.*

- *In Early Eocene time a local NW-SE trending basin developed within the Umm Er Radhuma belt extending from Kifl in the NW to the Dammam structure in eastern Saudi Arabia in the S.*
- *This basin was filled by lagoonal evaporitic sediments of the Rus Formation (Fig. 13-4).*
- *To the east, these evaporitic sediments passed into nummulitic shoals which in turn passed into the open marine Pabdeh marls.*
- *The nummulitic shoals were probably formed on the Ramadi-Musalyib palaeoridge.*

Fig. 13-4: Early Eocene Palaeogeography

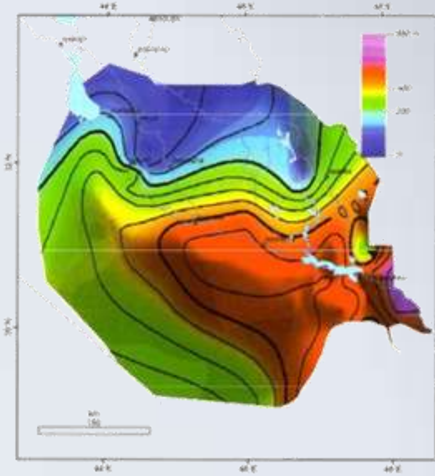
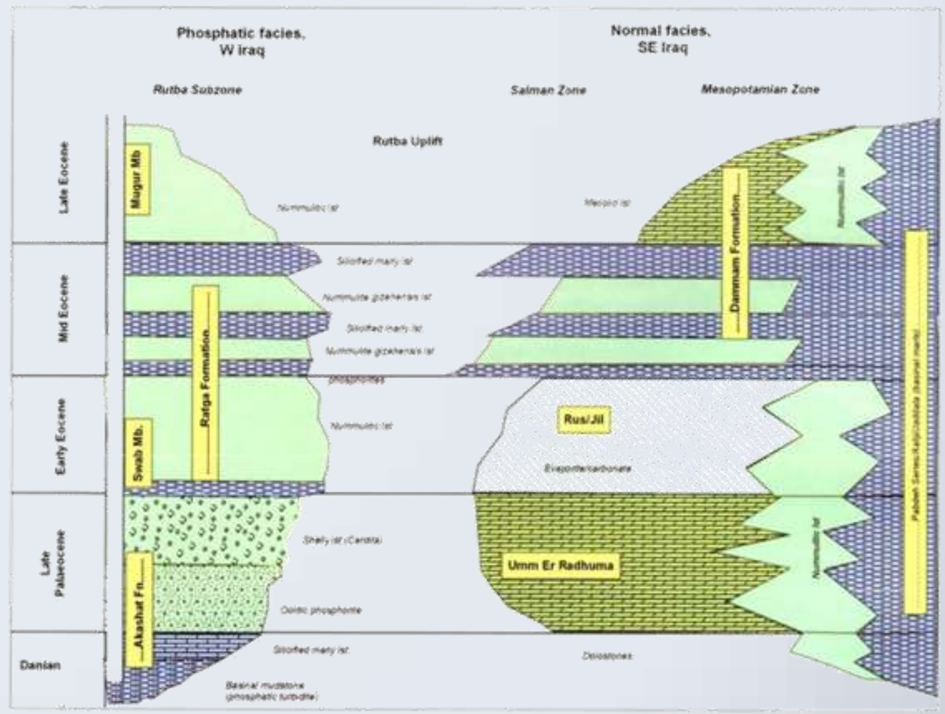


Fig. 13-6: Thickness of the Umm Er Radhuma Formation

Fig. 13-5: Stratigraphic correlation of the phosphatic and non-phosphatic units of Megasequence AP10 in W and SE Iraq



1.1 Carbonate-Evaporite inner shelf

1.1.1 Umm Er Radhuma Formation

Lithology:- *In the supplementary type section, the Umm Er Radhuma Formation consists of anhydritic and dolomitic limestones, mostly dull, white or buff, microcrystalline and porous.Chert occurs in the higher part of the formation.*

(Al-Mubarak and Amin,1983) divided it in the eastern part into two members: ***(1) Lower Member*** *is divided into two lithological rock units, these are:*

(a) Lower Chalky Unit

(b) Lower Shelly Unit

(2) Upper Member

A- Shelly – Chalky Unit

(b) Upper Chalky Unit

(c) Upper Shelly Unit

(Middle – Late Paleocene)

Environment:- *The studied authors agreed for inner shelf hypersaline marine to very shallow marine environment (**a supratidal sabkha environment**).*

Lower Contact: *The Lower contact of the Umm Er Radhuma Formation, with the underlying Tayarat Formation is unconformable.*

The contact is based at the bottom of the first appearance of black and brown chert or the last Loftusia bearing limestone horizon.

Remark: *According to Al-Mubarak and Amin (1983) the lower part of the Umm Er Radhuma Formation is included within the Tayarat Formation (South of Ga`ara) by Buday and Hak (1980). Therefore, conformable contact is considered with the underlying Tayarat Formation.*

1.1.2- Rus (Jil) Formation

Lithology:- *consists predominantly of anhydrite with some unfossiliferous limestone, blue shale, and marl. In some areas the formation has been combined with the Umm Er Radhuma Formation,*

- *The formation is well defined in a very restricted area in Iraq in the southern Salman and Mesopotamian zones especially between the transversal Kut-Dezful and AL Batin Faults (Fig. 13-7).*
- *Outcrops along the Saudi-Iraq border lack anhydrite (due to dissolution). Jassim et al. (1984) suggested the use of the name Jil Formation for the Rus equivalent at outcrop where the anhydrite has been dissolved.*
- *The Jil Formation corresponds to beds previously assigned to the Dammam Formation (the Wagsa, Sharaf, Schbicha Members and the lower chalky part of Huweimi beds introduced by Owen and Nasr.*

Age:- *Early Eocene (Ypresian) age*

Contact:- *The lower contact of the formation is conformable in Iraq and Saudi Arabia. The upper contact is disconformable, marked by a breccia.*

Environment:- *The formation was deposited in a lagoonal-sabkha environment on the Stable Shelf.*

1.2. Phosphatic inner shelf

1.2.1 Akashat Formation (M- U Palaeocene part only)

Phosphorites are restricted to the N, W and S flanks of the Hauran anticlinorium.

They outcrop in W Iraq in a narrow belt near Rutba, extending from the Iraq-Saudi border to the Ga'ara depression in the N. They were deposited in shoreline, shoal and open marine environments.

***Lithology:-** consists of alternation of grey phosphorites and limestones it onsists of phosphatic conglomerate or breccia, followed by oyster bed (biolitite), overlain by a sequence of calcareous siltstone,*

with layers of silty limestone and calcareous mudstone, locally phosphatic.

***Contacts:-** The Akashat Formation overlies the **phosphatic Digma** Fn.(Maastrichtian age), disconformably or gradationally with a short hiatus*

*overlain by the **phosphatic Ratga** Formation of Eocene age . conformably (Lower Eocene nummulitic limestones).*

The Akashat Formation is divided into three members by Al-Bassam et al. (1990):

(1) Traifawi Member

(2) Hirri Member

(3) Dwaima Member

1.2.2. Ratga Formation (Swab Member)

The Ratga Formation was introduced for the phosphatic facies representing the whole of the Eocene in W Iraq (Jassim et al., 1984).

Lithology:- *The formation comprises open marine chalk, nummulitic limestone and phosphorites.*

- ***It was divided into:-***
- ***Lower Eocene Swab Member.***
- ***Middle Eocene Damlouk Member.***
- ***Upper Eocene Mugur Member.***

Age:- *Early-Mid Eocene*

Environment:- *The Swab Member was deposited as a belt of nummulite shoals along the margin of the Rutba Uplift, between the near-shore and shoreline deposits of the Rutba uplift and the outer shelf which lay to the N and W of the Ga'ara anticline and Hauran anticlinorium.*

- ***A nummulite is a large lenticular fossil (single-celled organisms), characterized by its numerous coils subdivided by septa into chambers.***

1.3. Outer shelf-basinal

1.3.1 Aaliji Formation

The Aliji Formation is widespread in the Foothill Mesopotamian zones (Fig. 13-4).

Lithology:- *comprises grey and light brown argillaceous marl, argillaceous limestone, and shale with occasional microscopic fragments of chert and rare scattered glauconite.*

*Silty and sandy beds occur towards the N and NE where the formation gradually passes into the **clastic Kolosh** Formation. Towards the SE and W, the formation is composed predominantly of limy globigerinal mud. Chalky and argillaceous limestone beds occur where the formation passes laterally into the **Umm ErRadhuma** Formation.*

Environment:- *The formation was deposited in an off-shore, open marine environment lying between two belts of platform margin carbonate shoals in the SW and NE.*

Age:- *Early Palaeocene- Early-Mid Eocene*

Contacts:- *The lower contact of the formation in the type area is unconformable except where the Aaliji occurs as tongues within the Kolosh Formation. The upper boundary in the type area is also unconformable.*

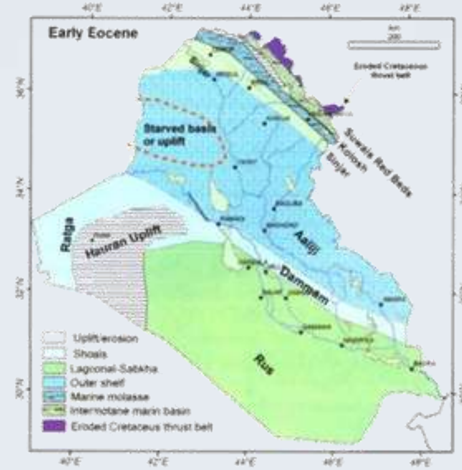


Fig. 13-4: Early Eocene Palaeogeography

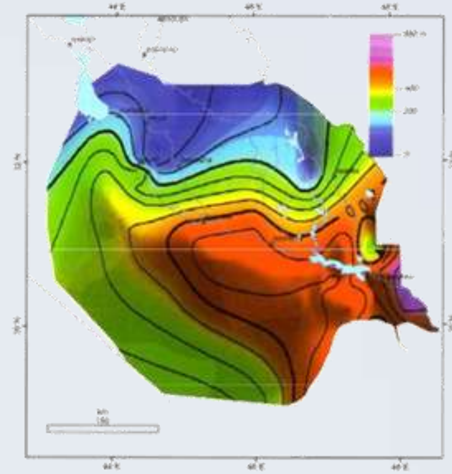
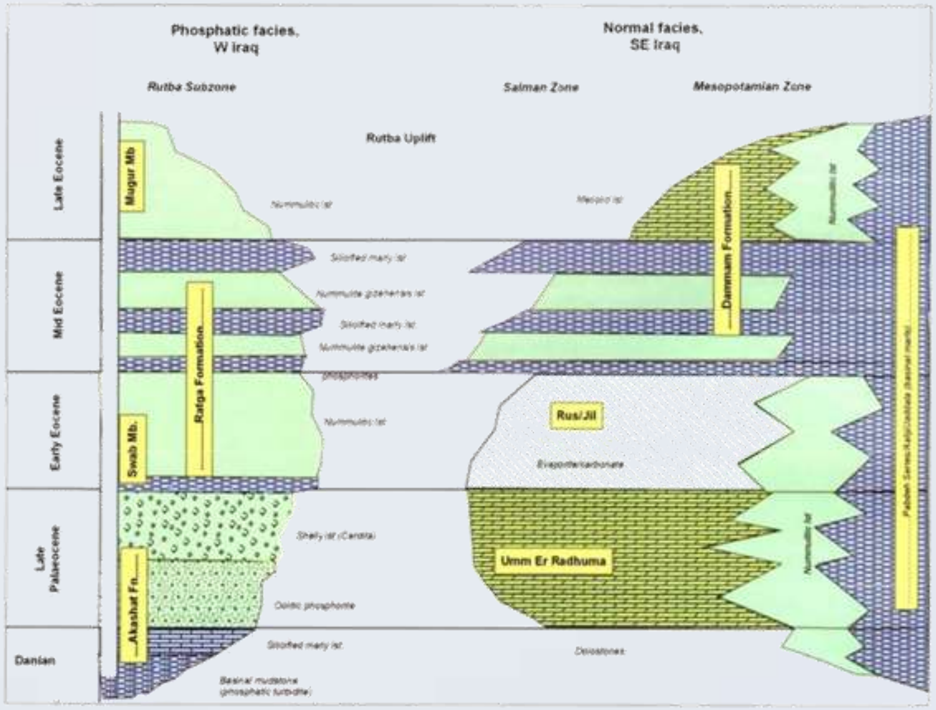


Fig. 13-6: Thickness of the Umm Er Radhuma Formation

Fig. 13-5: Stratigraphic correlation of the phosphatic and non-phosphatic units of Megasequence AP10 in W and SE Iraq



1.3.2. Kolosh Formation

Age:- *Late Paleocene – Early Eocene*

Lithology:- *In the type locality, the Kolosh Formation is composed of "Shale and fine sandstone, composed of fragments of various grain size of green-rock, chert, and radiolarite. Inter fingering occurs with Sinjar limestone, especially in the higher parts.*

Environment:- *The rhythmic sandstone and shale in major parts of the Kolosh Formation with graded bedding is accepted to be of turbidite origin.*

- *The upper part with inter fingering limestone sandstone and shale represents the terminal uplift of the basin in the Upper Paleocene and hence of shallow water shelf, or inner type with abundant terrigenous influx (Jassim et al., 1984).*

Cotacts:- *The formation unconformably overlies Upper Cretaceous beds. In the type area it overlies the Tanjero Clastic Formation; elsewhere it overlies the Shiranish Formation or Upper Cretaceous limestones.*

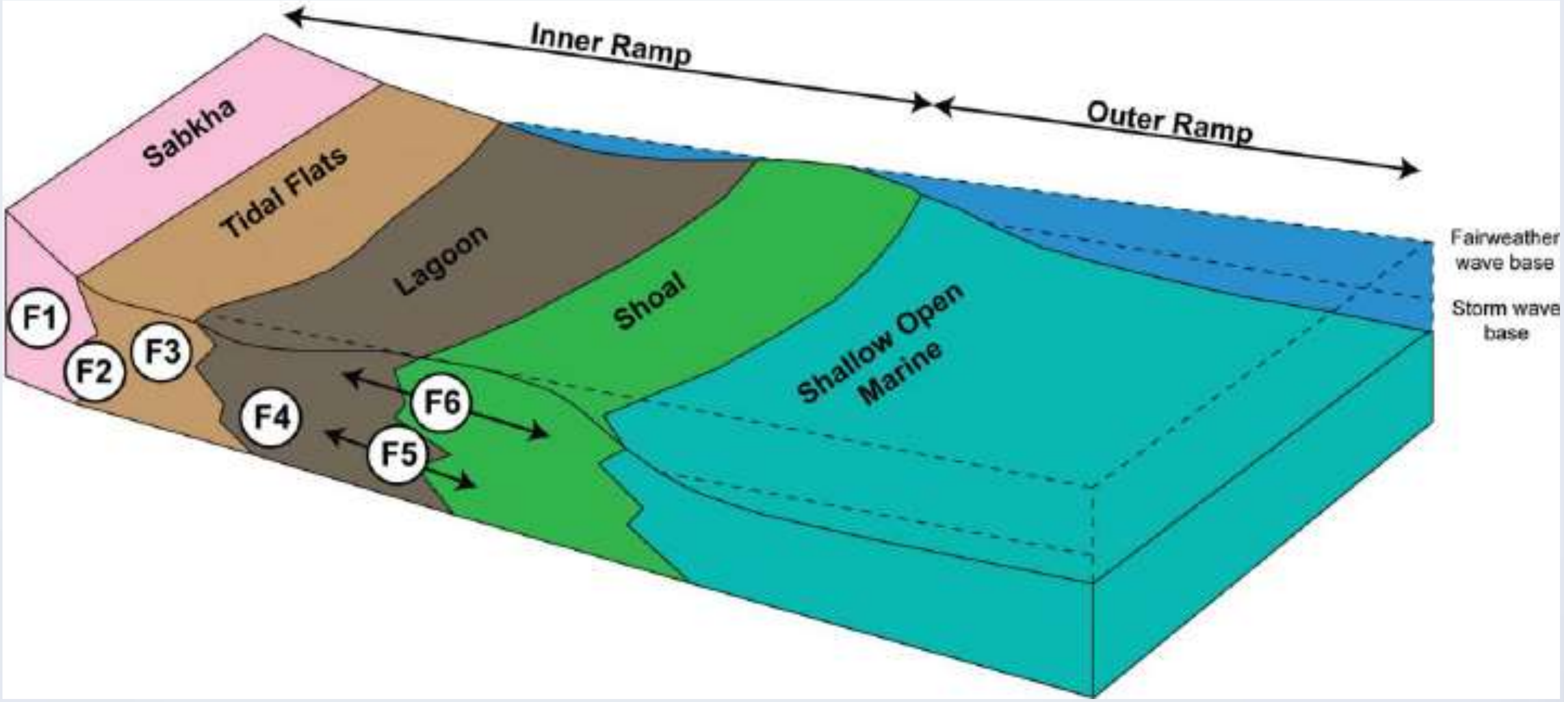
The clastics of the Kolosh were derived from erosion of the Tanjero, Qulqula and other Cretaceous-Jurassic formations. Bellen et al. (1959) suggested that the upper boundary of the Kolosh Formation was unconformable. ***However, where the Kolosh is overlain by Palaeocene-Lower Eocene limestones (as in the type section) the upper boundary is conformable and gradational.***

close up view for the fine conglomerate of Kolosh Fn.

The Kolosh Formation near Debendi Khan Lake

1.4. Carbonate ramp

- ***Carbonate ramps*** *are carbonate platforms which have a very low gradient depositional slope (commonly less than 0.1 ~ from a shallow-water shoreline or lagoon to a basin floor.*



Sinjar Formation

Age:- *Late Paleocene – Early Eocene*

Lithology:- *In the type section, the Sinjar Formation consists of "Limestone showing elements of algal reef facies, lagoonal miliolid facies, and shoal nummulitic facies, usually recrystallized and yellowish of colour"*

(The Sinjar Formation inter fingers with the Kolosh Formation).

Environment:- *algal reef facies, lagoonal miliolids facies and shoal nummulitic facies.*

Contacts:- *In the type section, the lower contact of Sinjar Formation, with the underlying Shiranish Formation is unconformable,*

- *In Darbandi Bazian, Darbandi Khan, Bammu, the Sijnar Formation is underlain by Kolosh Formation conformably, locally they interfinger to each other, especially its lower part.*
- ***The contact is sharp and very clear, due to the lithological change from black clastics of the Kolosh Formation to limestones of the Sinjar Fn.***
- *It is conformably overlain by (or passes laterally) into the* ***Khurmala*** *Formation.*
- *It is locally unconformably overlain by the* ***Jaddala*** *Formation .*

The ***Sinjar*** Formation underlain by the Kolosh Formation in Qara Dagh anticline

1.5 Carbonate inner shelf

Khurmala Formation

Age:- *Late Paleocene – Early Eocene*

Lithology:- *it is 185 m thick and comprises dolomite (pseudoolitic in parts) and finely recrystallized limestone. The calcareous beds inter finger with clastics of the* ***Kolosh*** *Formation. It is locally anhydritic.*

Environment:- *The facies of the carbonates, the high pyrite content, and the presence of beds of gypsum and anhydrite indicate the formation was deposited in a restricted lagoonal environment. Fossils, mostly dwarfed .*

Contacts:- *The lower contact of the formation is usually gradational; the underlying formation is usually the* ***Kolosh*** *Formation, with which the formation inter fingers.*

However, in well Jabal Kand-l the formation disconformably overlies the Upper Cretaceous ***Shiranish*** *Formation.*

Limestone of the Khurmala Formation overlying Kolosh and Tanjero formations

2- Mid-Late Eocene Sequence

The Mid- Late Eocene sequence i s represented by the Dammam, Ratga, Avanah, Jaddala Pila Spi and Gercus formations.
The Neo-Tethys was narrowed and closed during the final phase of subduction.

Fig. 13-9: Mid Eocene Palaeogeography

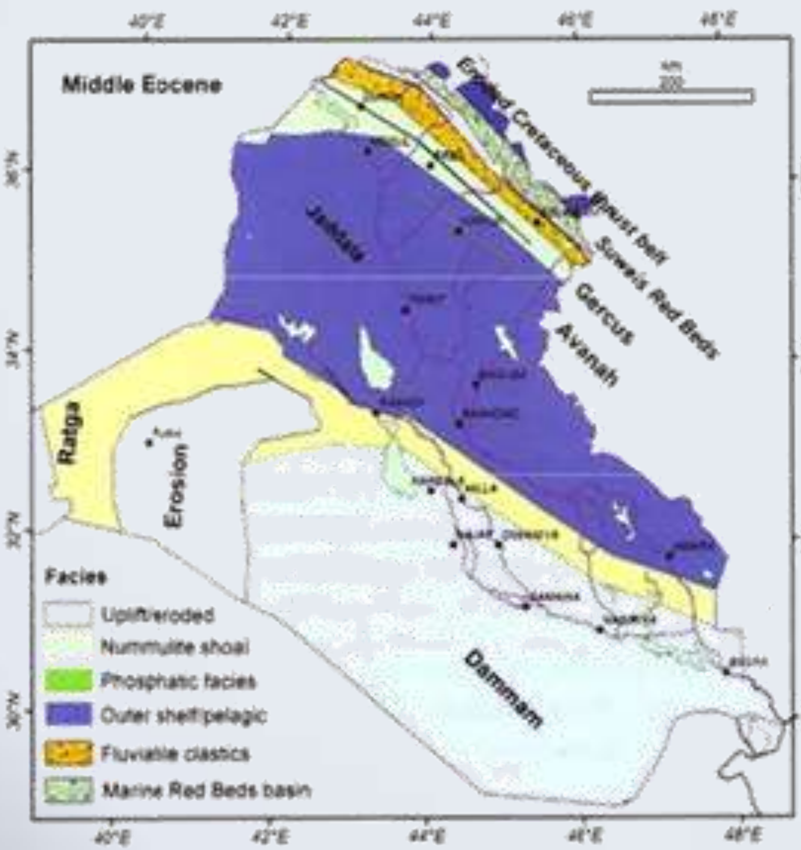
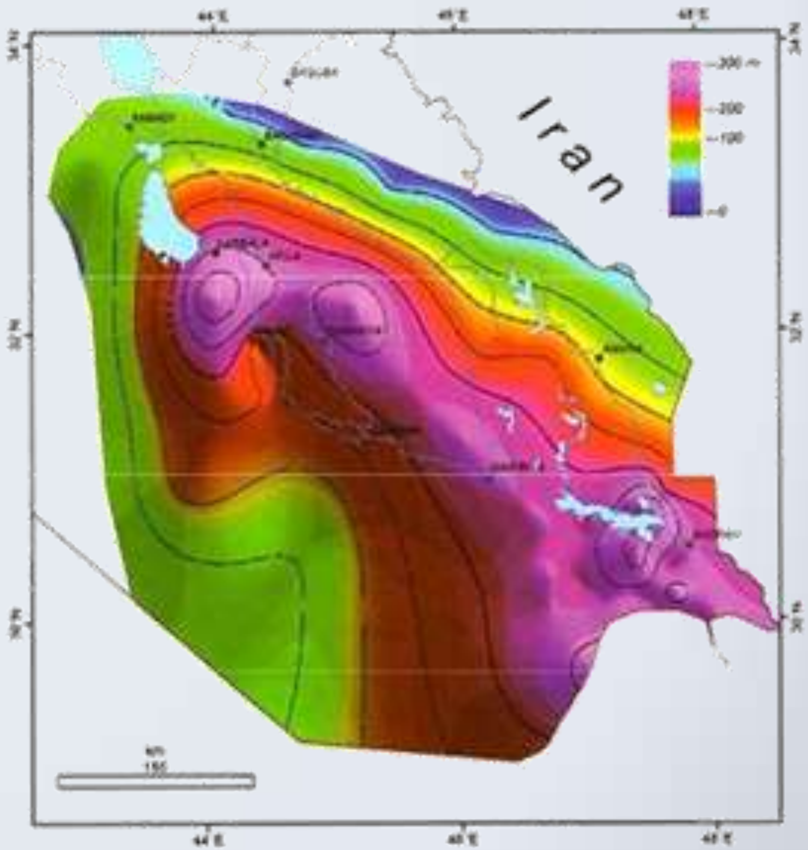


Fig. 13-10: Thickness of the Dammam Formation (not including the Nummulitic limestones of W Iraq)



2.1 Carbonate inner shelf lagoons and shoals

2.1.1 Dammam Formation

Remark: *It is worth to mention that the exposures of the Dammam Formation, west of Rutbah Uplift, i.e. western part of the Iraqi Western Desert, are excluded from Dammam Formation and included within the recently announced* ***Ratga*** *Formation.*

Age:- *Middle – Late Eocene*

Lithology:- *Al-Mubarak and Amin (1983) divided the Dammam Formation into three members, however only two members are exposed in the eastern part of the Western Desert:*

(1) Lower Member*,*

which is divided into two units:

(a) Ubaiyidh Unit, consists of basal conglomerate, overlain by whitish grey fossiliferous (nummulites) limestone.

(b) (b) Thumaily Unit consists of yellowish and greenish grey limestone, alternated with grey, phosphatic imestone, with shark teeth. The upper part consists of yellowish grey limestone, with chert nodules.

(2) Middle Member

It is named as ***Al-Faj Unit****, it consists of yellow and yellowish grey, friable sandy marl, dark brown ferrigenous quartzitic or silicified sandstone, with abundant plant remains.*

Followed, upwards by yellow to creamy massive nummulitic (gizehensis) limestone, with oyster. In the eastern and southern parts,

Environment:- *The Dammam Formation is deposited mostly in shallow neriticenvironment (Buday, 1980); the nummulites indicate a shoale facies of tropical –subtropical quite marine environments depth not more than 100 m*

Lower Contact: *In majority parts of the Western Desert, the Dammam Formation is underlain by* ***Umm ErRadhuma*** *Formation; in remaining parts the base is not exposed.*

In the vicinity of wadi Amij and south of Wadi Hauran, the Middle Member of the Dammam Formation is underlain unconformably by the ***Nahr Umr, Mauddud, Rutbah and Ms`ad*** *formations; in wadi Hauran, south of H1 is underlain unconformably by* ***Rutbah*** *Formation.*

2.1.2 Avanah Formation

Age:- *Early – Late Eocene*

Lithology:- *in the type sections consists of "Limestones, generally dolomitized and recrystallized, of shoal facies, with occasional intercalations of lagoonal limestones, which are treated as Pila Spi limestone tongues.*

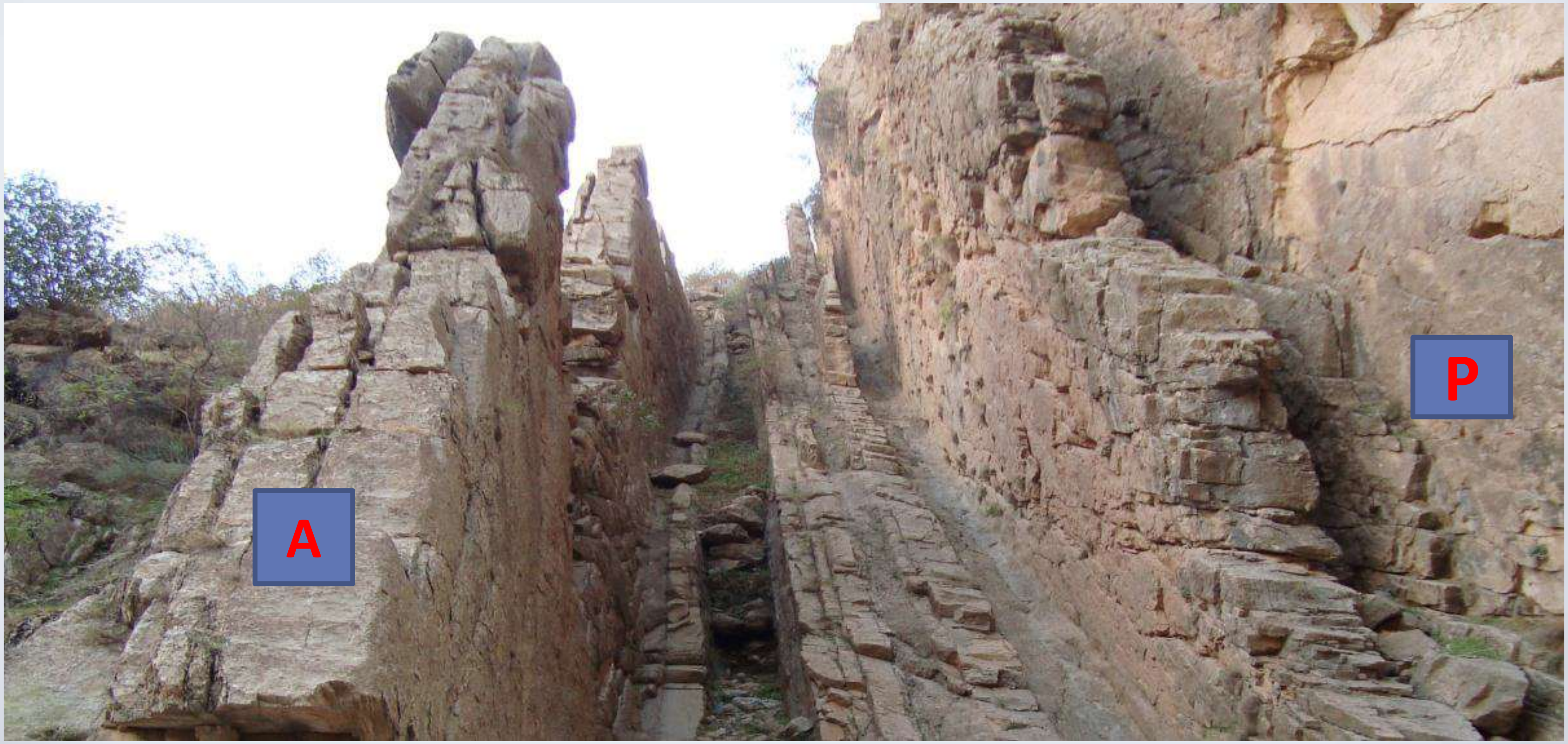
Environment:- *The Avanah Formation was deposited as an isolated carbonate shoal associated with a palaeoridge along the NE shoreline of the basin during a high stand of sea level. This barrier separated the molasse basin of the* ***Gercus*** *Formation in the N and NE from the open sea basin of the* ***Jaddala*** *Formation to the Sand SW.*

Contacts:- *The lower contact of the formation is probably unconformable.*

The abrupt change from the lagoonal facies of the ***Khurmala*** *Formation to the shoal facies of the* ***Avanah*** *Formation is probably associated with a transgression .*

- *Middle Miocene sediments usually unconformably overlie the Avanah Formation, except where Oligocene or Lower Miocene sediments are locally preserved.*

The Avanah Formation (A) underlying the Pila Spi Formation (P) in Sartaq Bammu area, South of Darbendi Khan



2.1.3 Pila Spi Formation

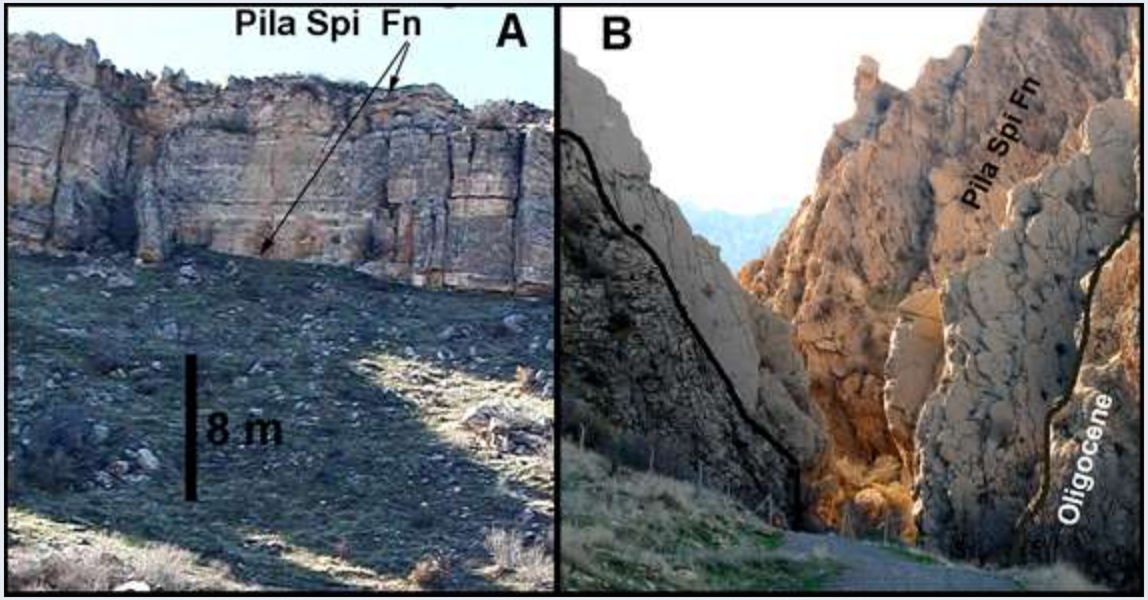
Age:- *Middle – Late Eocene*

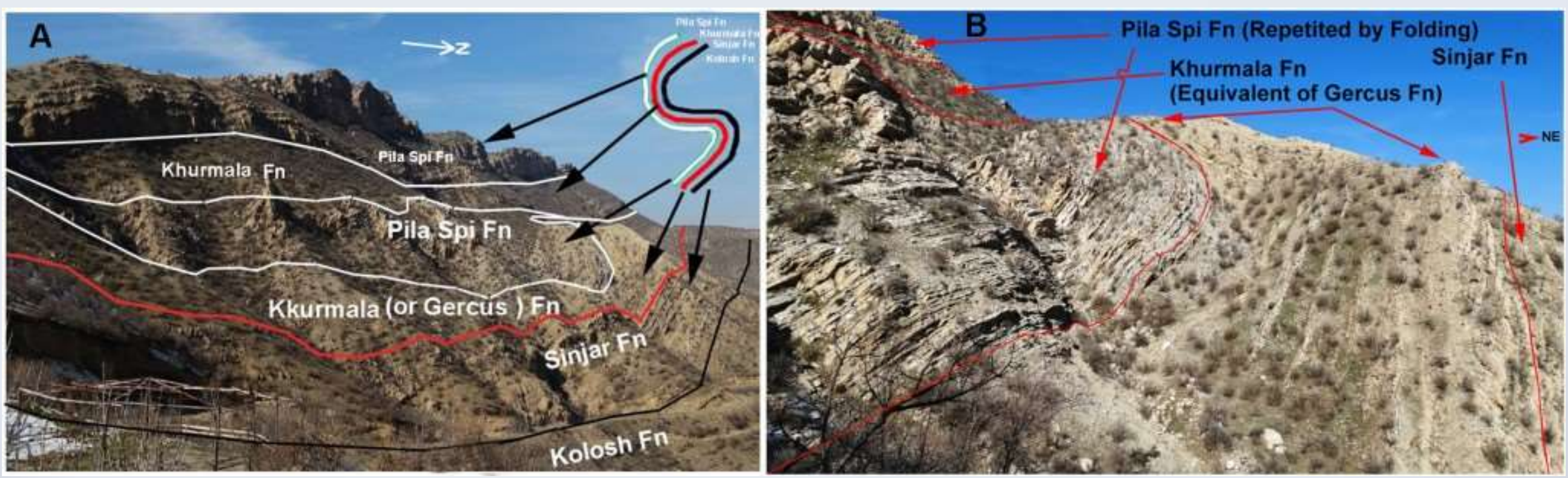
Lithology:- *The Pila Spi Formation, in the type section consists of two parts: "The higher part shows well bedded bituminous limestone, weathering white, chalky and crystalline, with bands of pale green marl or chalky marl with buckled bedding planes; bands of buff chert nodules towards the top, traces of fossils; 57 m thick. The lower part shows well bedded limestones, hard though of chalky appearance, porous or vitreous, bituminous or white, poorly fossiliferous, algal and shell sections in calcite, 28 m thick".*

Environment:- *The Pila Spi Formation represents typical restricted to semi- restricted (lagoonal) marine platform facies of hypersaline marine conditions; demonstrated by the occurrences of miliolids, Peneroplids, within its dolomitic limestone rocks.*

Contact:- *In the type locality, the Pila Spi Formation is underlain by the* ***Gercus*** *Formation, the contact is sometimes gradational through interfingering, sometimes appear to be marked by a conglomerate.*

The Upper boundary is unconformable throughout. The overlying sediments are mostly of Miocene age.


Pila Spi Fn
A
8 m
B
Pila Spi Fn
Oligocene


A
Khurmala Fn
Pila Spi Fn
Pila Spi Fn
Kkurmala (or Gercus) Fn
Sinjar Fn
Kolosh Fn
B
Pila Spi Fn (Repetited by Folding)
Khurmala Fn
(Equivalent of Gercus Fn)
Sinjar Fn
NE

2.2. Phosphatic deep inner shelf-inner shelf

Damlouk and Mugur members of Ratga Formation

*The **Damlouk Member** outcrops Wand N of the Ga'ara anticline and along the Iraq-Jordan border.*

***Lithology:-** It comprises 30 m of thin-bedded argillaceous limestone with loaf-like chert nodules and laterally continuous chert beds.*

The Damlouk Member passes laterally and vertically into highly phosphatic facies in the direction of the Jordanian border where it consists of alternation of three phosphatic horizons (2-4 m thick) and thick- and thin bedded limestone. The phosphorites are very coarse grained, pelletal, with large coprolites and shark teeth.

*The **Mugur Member** outcrops in only one area near the Iraq Syrian border NW of Ga'ara in the Wadi Akash-Mugur El Dhib area. It consists of 159 m of alternating fine- to medium-grained nummulitic limestone and white chalky limestone (tongues of Jaddala Formation).*

2.3- Outer shelf-basinal

Jaddala Formation

Age:- *? (Middle Eocene, Early Lutitian)*

Lithology:- *The Jaddala Formation, in the type locality consists of "marly to chalky limestone and marls with occasional thin intercalations of shoal limestone (Avanah limestone tongues)"*

(Bellen et al., 1959). Hagopian (1979) considered the Al-Tinif Unit of the Ratga Formation to be equivalent of the Jaddala Formation.

It consists of thin to medium beds, upwards become pale brown, white to yellow, chalky limestone to dolomitic limestone, with occasional chert nodules, in the uppermost part.

The lower part contains radiolarian chert and it is rich in planktonic and benthonic foraminifera.

The lower part of Damluk "B" shows similarities to the Jaddalah Formation and it consists of chert bearing limestone and phosphorite (Al-Bassam et al., 1990).

Depositional Environment*: The formation represents a typical basinal facies through out, a shelf margin facies.*

The ***lower contact*** *of the formation in the type area is unconformable (Bellen et al., 1959) and is marked by the occurrence of glauconite.*

The ***upper contact*** *of the formation in the type area is unconformable; the overlying sediments are of Miocene age, except in a narrow belt passing through the Qara Chauq structure of the Foothill Zone where the formation is overlain by the Oligocene sediments.*

2.4 Fluvial and fluviomarine

Gercus Formation

The Gercus Formation consists of molasse deposited following Mid Eocene uplift.

Lithology: *The Gercus Formation, in the upplementary type section, consists of "Red and purple shales, mudstones, sandy and gritty marls with or without pebbles. Some soft pebbly sandstones and conglomerates. Lenticles of gypsum, especially towards the top. Rare lignite in a sandstone near the base. Rock salt occurs sporadically. The lower 259 m consists of variegated marls, siltstones, sandstones and conglomerates, still predominantly red in color but Lower – Middle Eocene.*

Depositional Environment: *The Gercus Formation was deposited in a relatively broad sinking molasse trough (foredeep), after the local Van Phase of the Intra Eocene Orogeny (Buday, 1980).*

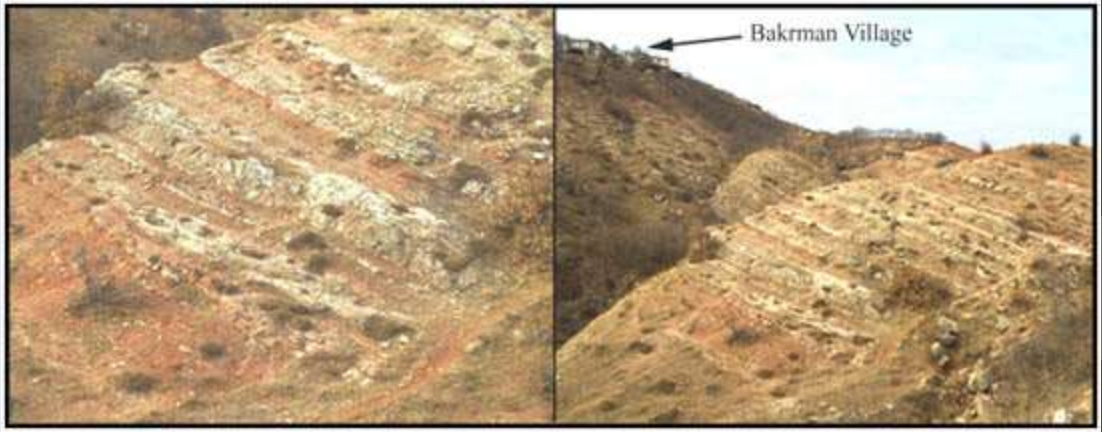
Lower Contact: *The lower contact of the Gercus Formation, in the supplementary type section is with the Kolosh Formation. "The contact appears to be gradational but the two formations are separated by a well marked conglomerate. A color change from predominantly green (Kolosh Formation) to predominantly red (Gercus Formation) may also mark the contact.*

Where the formation is overlain by Miocene deposits, ***the upper boundary*** *is marked by an unconformity; elsewhere it is conformably and gradationally overlain by the Pila Spi Formation (Plate 13-1).*

Red clastics of the Gercus Formation overlain by limestone of the Pila Spi Formation, along the road between Amadiya and Duhok

Varicolored claystone beds at the middle part of the Gercus Formation

General view of outcrop of Gercus formation at northwestern plunge of Sharmin



Latest Eocene-Recent Megasequence

- ***The Lates t Eocene-Recent Megasequence is associated with the collision of Neo-Tethyan terrains along the N and E sides of the Arabian Plate, and the opening of the Gulf of Aden and the Red Sea on the S and W sides of the Plate.***
- ***The opening of the Red Sea and Gulf of Aden was associated with thermal uplift, flood basalt, and rifting.***
- ***The Gulf of Aden opened first in Oligocene time followed by the Red Sea in the Early Miocene.***
- ***The N and NE drift of Arabia and the closure of the Neo- Tethys resulted in folding and thrusting of the Neo- Tethyan terranes along the NE margin of the Arabian Plate.***
- ***It is subdivided into three sequences:-***

1- latest Eocene-Oligocene,

2- Early-Middle Miocene,

3- Late Miocene-Recent age.

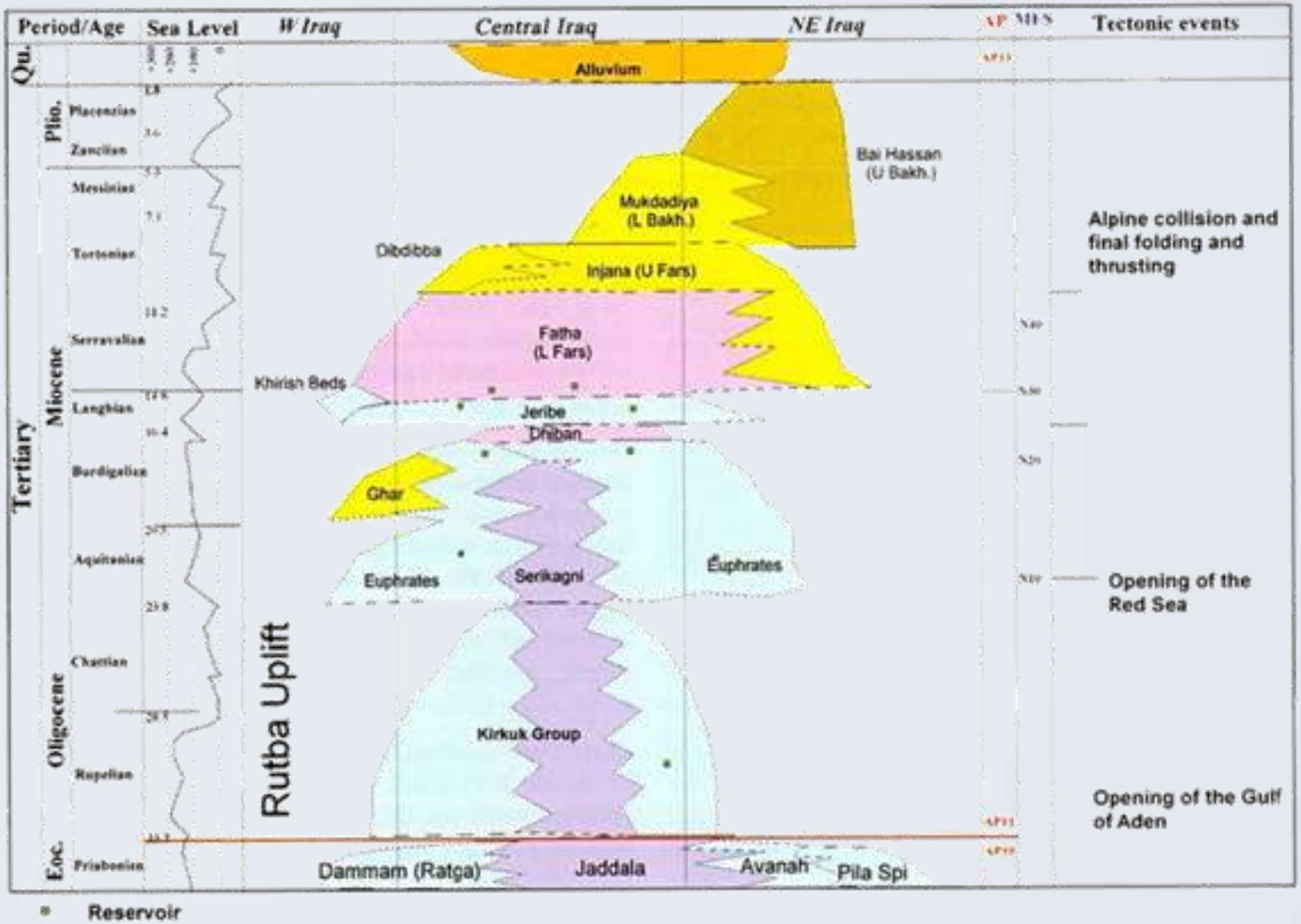


Fig. 14-2: Stratigraphic correlation of formations of Megasequence AP11 (excluding the Quaternary)

1- Latest Eocene-Oligocene Sequence

- *At the end of the Eocene the main intraplate basin became narrower due to-:*

1- the tilting of W Arabia on one side

2-and uplift of the High Folded Zone on the other.

The western shoreline receded towards the area of the present day Euphrates River.

- *The eastern shoreline receded to the SW boundary of the Butmah-Chemchemal Subzone of the Foothill Zone.*
- *The closed Neo-Tethys was a narrow seaway in which clastics and carbonates were deposited.*
- *The remnant Cretaceous thrust belt contained a narrow intermountane molasse basin and was filled with the sediments derived from the Cretaceous thrust zone in the NE and the uplifted High Folded Zone in the Sw.*

-The Oligocene basin was located in the Mesopotamian Zone, in the Makhul-Hemrin Subzone of the Foothill Zone, in the Jezira

Subzone and on the N margin of the Rutba Subzone.

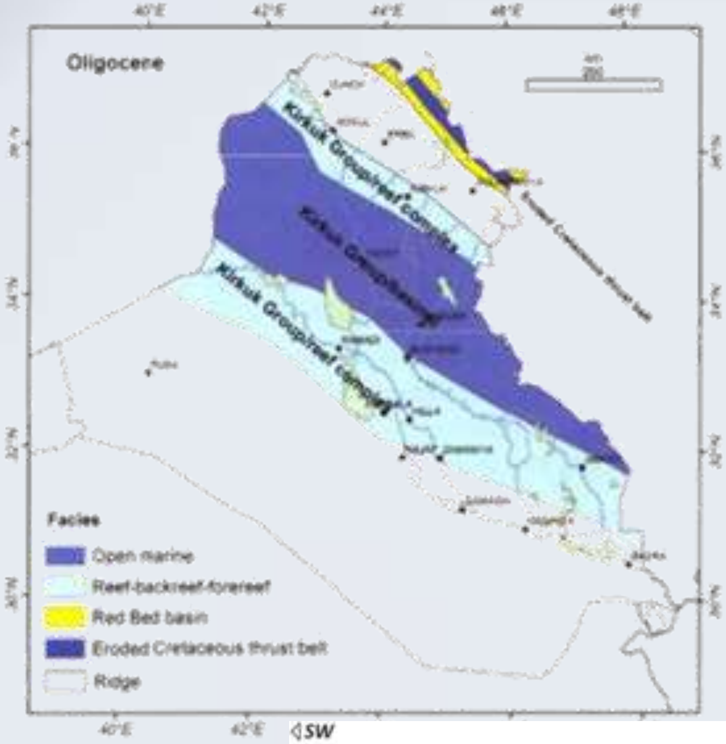
- *The Salman Zone and the Euphrates and Zubair subzones of the Mesopotamian Zone were uplifted in Oligocene time (Fig. 14-3).*
- *The Latest Eocene-Oligocene Sequence is bounded by breaks on both lower and upper contacts.*
- *Outcrops of the Oligocene formations are restricted mainly to the exceptionally elevated Qara Chauq structure of the Foothill Zone and to the Euphrates valley between Haditha and Anah.*

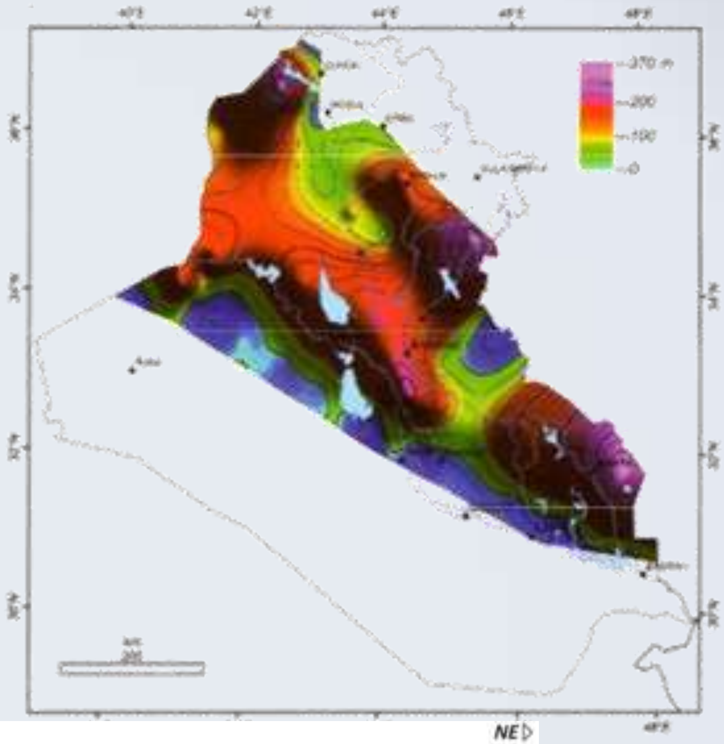
Al Hashimi (1974; in Jassim et al., 1984) recorded the Lower Oligocene ***Sheikh Alas and Shurau*** *formations along the Iraq-Syria border NW of the Ga'ara depression and along Wadi Hauran,*

Following the recom mendations of Ditmar and the Iraq i Soviet Team (1971) the Oligocene is divided in to;-

1- Lower sequence.

2-Upper sequence.





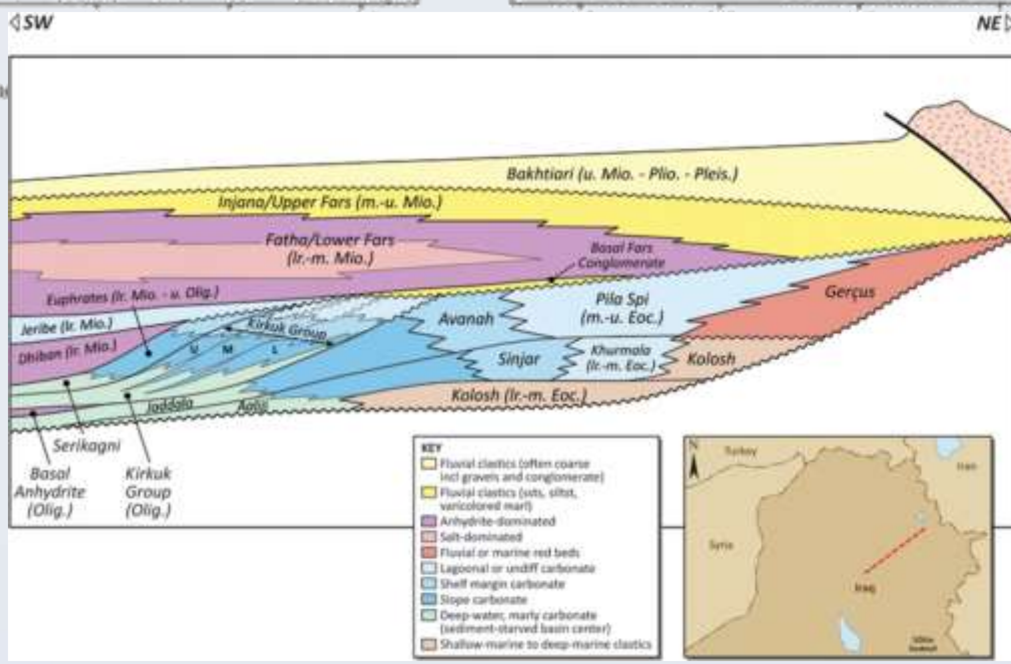
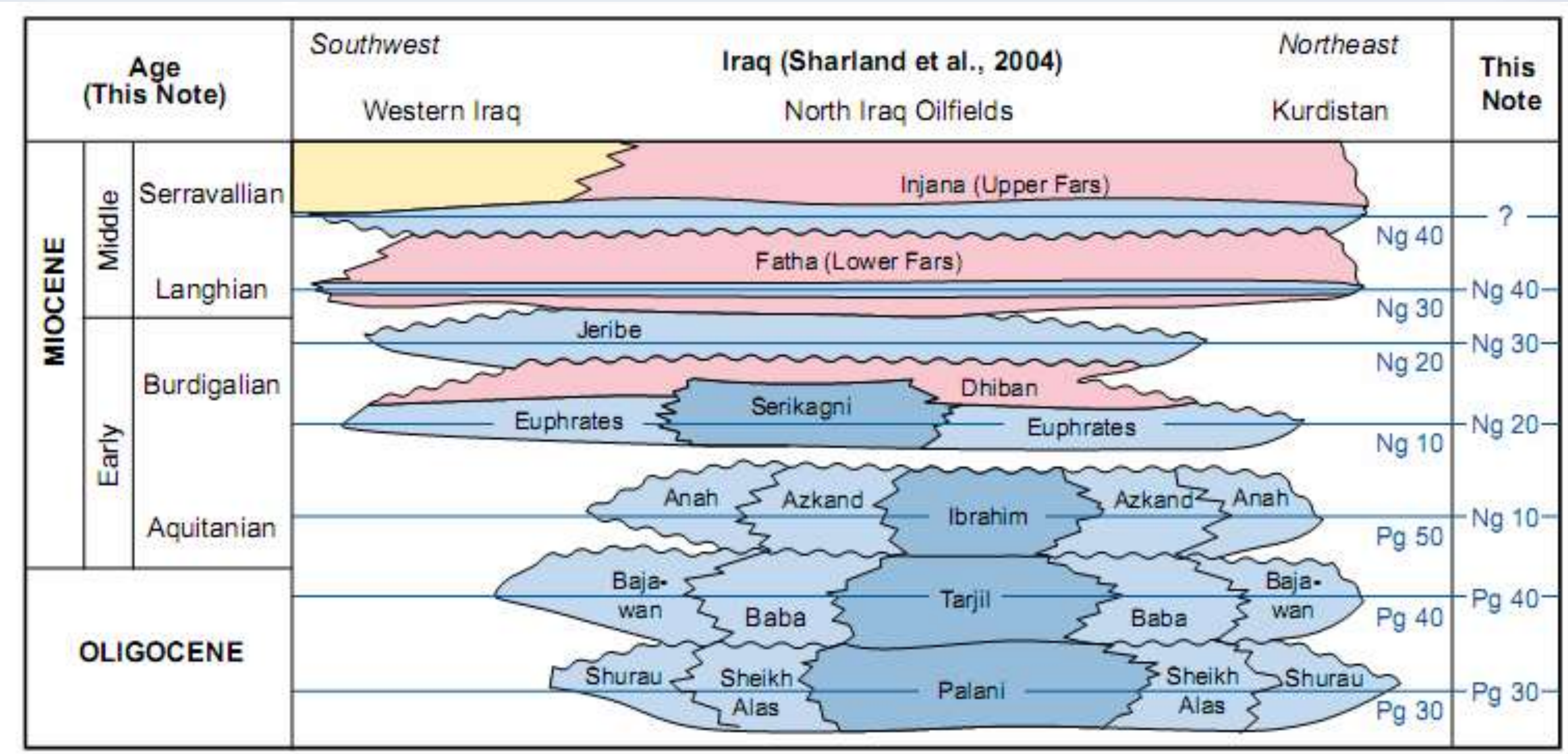


Fig. 14-3: Oligocene Pala… …ene Sequence


Age
(This Note)
Southwest
Iraq (Sharland et al., 2004)
Northeast
This
Note
Western Iraq
North Iraq Oilfields
Kurdistan
MIOCENE
Middle
Early
Serravallian
Langhian
Burdigalian
Aquitanian
OLIGOCENE
Injana (Upper Fars)
Fatha (Lower Fars)
Jeribe
Dhiban
Serikagni
Euphrates
Euphrates
Anah
Azkand
Ibrahim
Azkand
Anah
Baja-
wan
Baba
Tarjil
Baba
Baja-
wan
Shurau
Sheikh
Alas
Palani
Sheikh
Alas
Shurau
Ng 40
Ng 30
Ng 20
Ng 10
Pg 50
Pg 40
Pg 30
?
Ng 40
Ng 30
Ng 20
Ng 10
Pg 40
Pg 30

1.1. Lower Sequence

- ***The Lower Sequence comprises:-***

*- the reefal **Sheikh Alas** & **Shurau** formations .*

- *the basinal **Palani & Tarjil** formations.*

1.1.1 Basinal

1.1.1 Palani Formation

Lithology:- *It consists of 64 m of dolomitized globigerinal limestone .*

Age:- *The age o f the format ion was assumed to be Early Oligocene, based on its stratigraphic position between the underlying Eocene **Jaddala** Formation and the overlying and interfingering Lower Oligocene **Sheikh Alas** Formation.*

Contacts:- *The Palani Formation rests unconformably over the **Jaddala** Formation, & is conformably overlain by the **Sheikh Alas** Fn.*

Environment:- *The globigerinal limestones of the Palani Formation in Kirkuk were deposited in an outer shelf basinal environment passing up into slop environment.*

1.1.1.2 Tarjil Formation

Lithology:- *It consists of 100 m of slightly dolomitized globigerinal marly limestone.*

Environment:- *The fossils indicate the formation was deposited in an outer shelf environment.*

-According to Hamid and Vizer (1986) the lower part of the Tarjil Formation in Kirkuk was deposited in an open marine environment, and the upper part in a shallower toe of slope environment.

Age:- *Nummulites intermedius appears restricted to the Early Oligocene.*

Contacts:- *The Tarjil Formation unconformably overlies the Palani Formation.*

The upper contact with Baba Formation is gradational.

1.1.2 Reef-backreef and forereef

1.1.2.1 Reef-forereef

Sheikh Alas Formation

The Sheikh Alas Formation represents the oldest reef and forereef facies of the Oligocene.

Lithology:- *The formation comprises 26 m of porous, occasionally rubbly dolomitic and recrystallised limestones .*

In outcrops in W Iraq, 6m of limestone were assigned to the Sheikh Alas Formation (Jassim et al., 1984).40 m of limestone exposed in Wadi Swab near the Syrian border were included in this formation .

Contacts:- *The lower contact of the formation in the type area is unconformable; the underlying formation is the Upper Eocene* ***Palani*** *Formation.*

In W Iraq the formation comformably overlies the Upper Eocene ***Mugur*** *Member of the Ratga Formation.*

*The upper contact with the overlying S**hurau** Formation in the type area is conformable.*

In W Iraq the upper contact is either unconformable where the formation is overlain by the Lower Miocene ***Ghar*** *Formation or conformable where it is overlain by the Lower Oligocene* ***Shurau*** *Formation.*

Environment:- *The lower part of the Sheikh Alas Formation was deposited in a fore slope environment, and the upper part in a lagoonal environment .*

It passes vertically and laterally into the reefal facies of the Shurau Formation.


a
Ashdagh mountain
Bajawan Fn.
Breccia bed
Shurau Fn.
A
Sheikh Alas Fn.
Sarchawai Awa spi
Baba Fn.

1.1.2.2- Reef

Shurau Formation

Age:- *Early Oligocene*

Lithology:- *It consists of 18 m of coralline limestone in the lower (thickest) part and grey dense limestones in the upper part.*

Cotacts:- *In W Iraq (Mughr Al Dhib, NW of the Ga'ara depression near the Iraq-Syria border) the formation conformably overlies the* ***Sheikh Alas*** *Formation and comprises 30 m of thick bedded, white and dense limestone.*

The contact of the formation with the underlying ***Sheikh Alas*** *Formation is conformable.*

The upper contact with the ***Baba*** *Formation is unconformable.*

Environment:- *The Shurau Formation of W Iraq was deposited in a reef and partly backreef environment (Jassim et al., 1984).*

In the Kirkuk the lower part of the formation was deposited in a reefal environment, and the upper part in a tidal flat environment.

1.2- Upper Sequence

The Upper Sequence comprises:-

1- The reef complex of Baba, Bajawan, Azkand and Anah formations

2- The basinal Ibrahim and Tarjil formations.

- ***These formations pass both vertically and laterally into each other.***

1- Basinal

1.1-Ibrahim Formation

Lithology:- *It comprises 56 m of globigerinal marly limestones with specks of pyrite and occasional glauconite, and a fauna of planktonic foraminifera.*

Environment:- *It was deposited in a basinal environment*

Age:- *Late Oligocene age.*

Contacts:- *The formation in its type section unconformably overlies the Eocene **Jaddala** Formation, and is unconformably overlain by the Lower Miocene **Euphrates** Formation.*

2- Reef, backreef and forereef

2.1 Reef-forereef (Baba and Azkand Formation)

Lithology:- *It comprises 20 m of porous and dolomitised limestones. At outcrop the limestones are massive and appear chalky. Jassim et al. (1984) described exposures from the Euphrates valley, along Wadi Khazga, Wadi Fuhalmi and Wadi Kheshkhesh near Anah where 20 metres of porous dolomitised limestones were attributed to the Baba Formation.*

Age:- *Mid Oligocene age*

Contacts:- *The Baba Formation unconformably overlies the Lower Oligocene* ***Shurau*** *Formation in the type area.*

In the Anah area, it unconformably overlies the ***Sheikh Alas*** *Formation .*

The formation is conformably overlain by the ***Bajawan*** *Formation in the type area.*

In the Anah area, the Baba Formation is conformably overlain by the ***Anah*** *Fn.*

Environment:- *The Baba formation was deposited in a forereef environment along both the NE and SW margins of the Oligocene basin.*

2.2- Reef- Backreef (Bajawan Formation)

Lithology:- *It comprises 40 m of tight backreef miliolid limestones alternating with porous, partly dolomitized, rotalid-algal reef limestone, with fairly abundant coral fragments and thin argillaceous limestone beds.*

Contacts:- *The Bajawan Formation in its type locality is conformably underlain by the Baba Formation. Towards the shoreline area in the NE and SW the formation transgressively oversteps older pre Oligocene formations. In the type area the formation is unconformably overlain by the Middle Miocene **Fatha** (Lower Fars) Formation.*

Age:- *Late Oligocene age.*

- *Ditmar and the Iraqi-Soviet Team (1971) claimed that there is no age difference between the **Bajawan** and **Baba**, **Anah** and **Azkand** formations and that these four formations belong to one sequence.*

Environment:- *The lower part of the Bajawan Formation was deposited in a reef and partly backreef environment; the upper part was deposited on mud flats.*

2.3.3 Reef-forereef (Azkand Formation)

Lithology:- *It comprises 100 m of thick massive, dolomitic and recrystallized, generally porous limestone .*

Age:- *a Late Oligocene age.*

Cotacts:- *The lower contact of Azkand Formation with the Baba Formation is unconformable in the type area.*

The upper boundary with Anah Formation is conformable and gradational.

Ditmar and the Iraqi-Soviet Team (1971) showed that the Anah-Azkand and Bajawan-Baba formations are partly contemporaneous. Ctyroky and Karim (197la) proved that Baba Formation underlies the Anah Formation.

The contact of the Anah and Baba formations in the Euphrates area is conformable and gradational.

Thus, the unconformity reported from the type locality of the Azkand is probably only locally developed.

2.2.4- Reef (Anah Formation)

- *The Anah Formation was defined by Bellen in 1956 from the Euphrates valley about 15 kms west of Al Nahiyah village near Anah.*

***Lithology:-** The type section comprises grey, brecciated recrystallised, detrital, and coralline limestones.*

***Contacts:-** The lower contact of the formation in the type area is conformable. The upper contact is always unconformable.*

***Age:-** a Late Oligocene age.*

***Environment:-**The formation is mostly a*

- *reef deposit, alternating with*

backreef, milioloid facies.

2- Early-Mid Miocene Sequence

- *The Oligocene-Early Miocene "Savian" movement which affected the Zagros Suture was marked by the uplift of the Balambo- Tanjero Trough.*
- *The palaeogeographic evolution of the shelf during the Early and Middle Miocene is marked by the development of broad but relatively shallow basin.*
- ***The Early-Mid Miocene Sequence can be divided into two second order sequences, each with shallow water carbonates passing up into evaporites**. They are the **Early Miocene** and the **Mid Miocene** sequences.*

Fig. 14-5: Early Miocene Palaeogeography

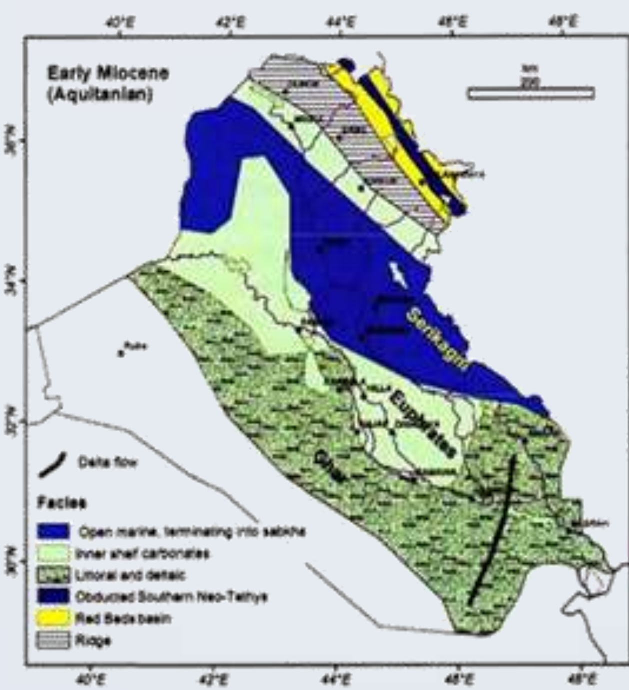
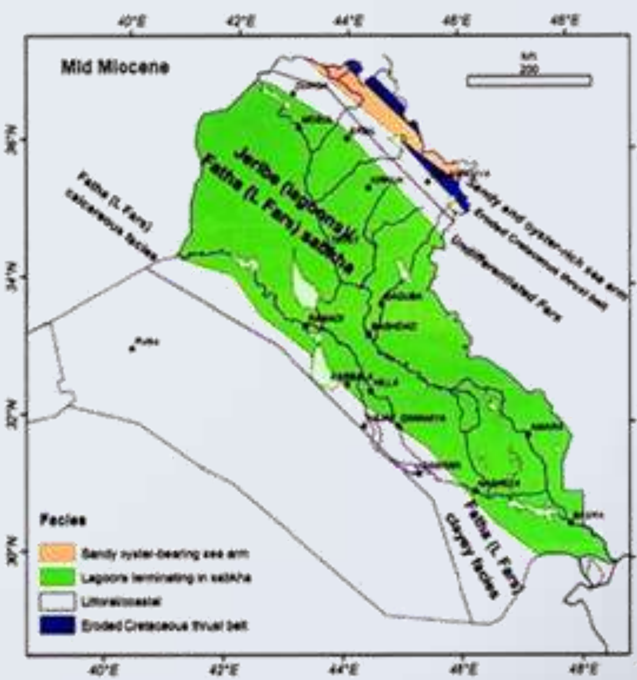


Fig. 14-6: Mid Miocene Palaeogeography



2.1- Early Miocene Sequence

- *The Early Miocene Sequence comprises the **Ghar**, **Euphrates**, S**erikagn**i and **Dhiban** formations. The sequence outcrops in a broad area across the Stable Shelf to the Sand SW of the Euphrates River (Fig. 14-5). It also outcrops in the cores of some anticlines on the Mosul High and along the SW limits of the High Folded Zone.*

2.1.1- Clastic inner shelf (Ghar Formation)

***Lithology:-** It comprises 100-150 m of thick sandstone and conglomerate with rare anhydrite, clay, and sandy limestone beds.*

***Age:-** Early Miocene age*

***Contacts:-** The Ghar Formation unconformably overlies older formations. It overlies the Lower Oligocene **Sheikh Alas** and **Shurau** formations in Wadi Akash near the Syrian border, the **Umm Er Radhuma** Formation in Wadi Ubayidh and the **Dammam** Formation near Busaya.*

*In the Akash area the formation is gradationally overlain by **Euphrates** Formation .In Wadi Ghadaf, the Ghar Formation is overlain by the basal conglomerate of the **Ghadaf Beds**. Near Busaya it is unconformably overlain by the **Dibdibba** Formation.*

*Environ**ment:-** The **Ghar** Formation was deposited in a marginal marine (possibly partly deltaic environment). It passes gradationally into the Euphrates Formation.*

At outcrop the Ghar Formation has been observed to pass laterally into the Euphrates Formation. This stratigraphic relationship indicates the Ghar Formation is of Early Miocene age.

2.1.2 Carbonate inner shelf (Euphrates Formation)

Lithology:- *The type locality near Wadi Fuhalmi near Anah on the Stable Shelf consists mainly of limestons with textures ranging from oolitic to chalky, which locally contain corals and shell coquinas; they are often recrystallized and siliceous. Beds of green marls, argillaceous sandstones, breccias, conglomerates, and conglomeratic limestone also occur.*

Age:- *late Early Miocene*

Contacts:- *The formation usually unconformably overlies Oligocene and Eocene formations.*

- *In the type area the basal beds of the formation comprise conglomerates and residual clays which infill an uneven surface at the top of the Oligocene* ***Anah*** *Formation. In areas where, the underlying unit is the Serikagni Formation, the lower boundary is conformable.*
- *The upper boundary at the type locality is not exposed.*

- *The investigations of GEOSURV revealed, that the upper members of the formation are overlain by a brecciated or conglomeratic horizon above which the Orbulina datum with the index fossil* ***Borelis melo eurdiea*** *of the Middle Miocene* ***Jeribe*** *Formation limestones occurs*
-

Euphrates Fn.

2.1.3 Basinal (Serikagni Formation)

- *The Serikagni Formation represents the basinal facies of the Sequence which has a restricted distribution.*

Lithology:- *it comprises 150 m of globigerinal chalky limestone.*

Environment:- *deposited in a restricted marine environment in the central parts of the latest Early Miocene basin.*

- *Fossils in the Serikagni Formation are abundant and prove a late Early Miocene age .*

Contacts:- *The Serikagni Format ion in the type area unconformably overlies the Eocene* ***Jaddala*** *Formation or basinal Oligocene formations.*

The formation is confor mably overlain by the ***Dhiban*** *Formation*

1.4 Evaporite lagoons (Dhiban Formation)

- *The type area near Dhiban village in the Sinjar area of the Foothill Zone of NW Iraq.*

Lithology:- *The formation comprises 72 m of gypsum, thin beds of marl and brecciated recrystallized limestone, Salt occurs in well Injana-5 .*

Environment:- *The formation was deposited in basin-centred sabkhas and salinas.*

Age:- *The age of the Dhiban Formation has been defined on the basis of stratigraphic relationships with other formations.*

Contacts:- *The* ***Dhiban*** *overlies the* ***Serikagni*** *Formation, interfingers with the* ***Euphrates*** *Formation and is overlain by the* ***Jeribe*** *Formation. Therefore its age has been established as Early Miocene.*

2.2- Middle Miocene Sequence

2.2.1- Carbonate inner shelf and shaols (Jeribe Formation)

Age;- *A Middle Miocene age is indicated by the presence of the Orbulina datum near the base of the Jeribe Formation &* ***Borelis melo curdica*** *.*

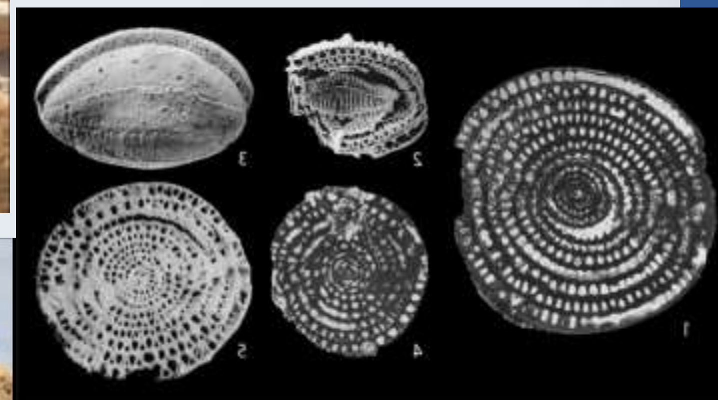
Lithology:- *The Jeribe Formation comprises 70 m of recrystallised, dolomitised, generally massive limestones; in beds 1-2 m thick.*

- *In the Euphrates valley the formation comprises disharmonic ally folded conglomerates, sandy recrystallised limestones, silicified limestones, chalky limestones and some marl (Tyracek and Youbert, 1975).*
- *Unfortunately the Jeribe and Euphrates formation were not differentiated during field mapping when the intervening Dhiban Formation anhydrites are absent.*

Environment:- *Bellen et al. (1959) suggested that the Jeribe Formation was deposited in lagoonal (backreef) and reef environments. Backreef-reef facies are predominant.*

Contacts:- *The lower contact with Serikagni Formation in the type areContacts:-a is unconformable. In many areas conglomeratic beds occur at the base of the Jeribe Formation.*

- *The Jeribe Formation passes gradationally into the overlying Fatha (Lower Fars) Formation.*



2.2.2- Evaporite lagoons (Fatha Lower Farsi Formation)

- *The Fatha (Lower Fars) Formation is one of the most aerially widespread and economically important formations in Iraq.*

Age:- *Middle Miocene*

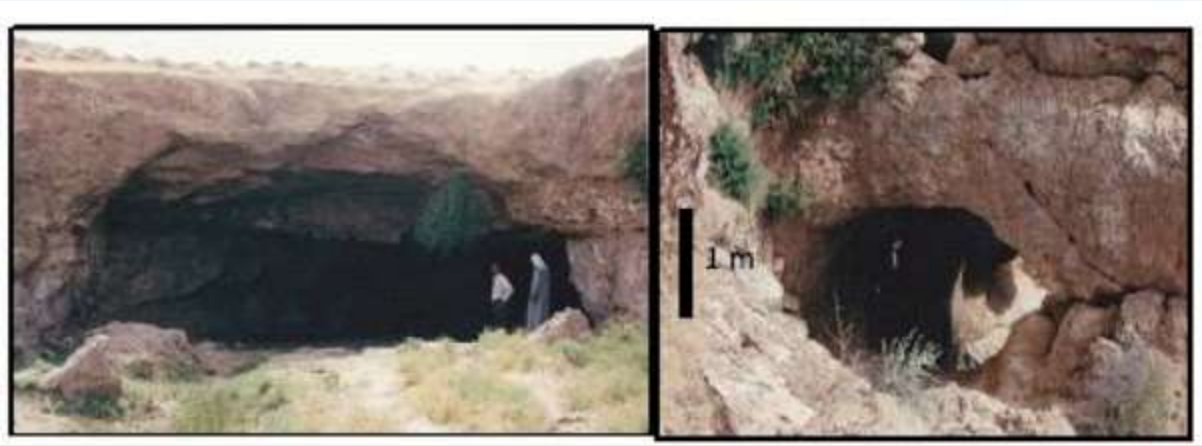
Lithology:- The Fatha Formation in the type section consists of "Cyclic sediments, each ideal cycle consists of green marl, limestone and gypsum, however, in the upper half part of the formation, reddish brown claystone is present over the green marl, moreover, in the uppermost parts; reddish brown clastics are developed within the cycles too.

Environment:- *closed lagoon of hypersaline condition.*

Contacts:- *The lower contact of the Fatha Formation with the underlying Jeribe Formation is conformable.*

- *In some areas, however, the formation overlies older rock units, especially near the shoreline of the basin.*
- *The upper contact with the Injana (Upper Fars) is gradational and diachronous.*

Caves in Gypsum of Fatha Fn.



3- Late Miocene-Pliocene Sequence

- *In Late Miocene-Pliocene time major thrusting occurred during collision of the Neo- Tethyan terranes and the Sanandaj-Sirjan Zone with the Arabian Plate.*
- *This event resulted in the uplift of the High Folded, Northern Thrust zones and the NE parts of the Balambo- Tanjero zones and Mesopotamian zones.*
- *A major foredeep formed in the Foothill Zone. On the SW side of the basin, the whole of the Rutba-Jezira and Salman zones were uplifted (Fig. 14-14).*
- *During the Late Miocene and especially the Pliocene, the High Folded Zone was uplifted with increasing intensity.*
- *The products of erosion were deposited in the nearby molasse basin characterized by the conglomerates of the Bai Hassan (Upper Bakhtiari) Fn. - In the SW the uplifted Stable Shelf was the source of the terrigenous clastics deposited to the NE of the Euphrates Boundary Fault (Dibdibba Formation).*
- *At the end of the Pliocene the Foothill Zone was uplifted and deformed; molasse was deposited in synclines between strongly uplifted long anticlines. Synclines received sediments of polygenetic origin.*
- *The Mesopotamian Zone became the new molasse foredeep.*
- *The Middle Fars Formation is now included in the Injana (Upper Fars)*

Formation.

- *The* ***Bakhtiari*** *Formation comprises two separate formations now referred to as the* ***Mukdadiy****a and* ***Bai Hassan*** *formations*

- *Since the Zahra Formation locally overlies the proved Fatha (Lower Fars) Formation, it is here included i n the Late Miocene-Pliocene Sequence.*
- *Sandstones deposited in a graben 15 km E of Kl60 settlement in the western desert described by Jassim et a l. (1984) are referred to as the Ghadaf Beds.*
- *The following units are included in the Late Miocene Pliocene*

Sequence:

(Dibdibba, Zahra, Injana (Up per Fars), Mukdadiya,

BaiHassan (L and U Bakhtiari) formations and the Ghadaf Beds.

The Merga Group is also included in the sequence).

- *The formations of the sequence are strongly* ***diachronous*** *due to*

facies changes resulting from deposition ***synchronous*** *with folding and thrusting.*

The Zahra Formation clastics of the Salman Zone are not included in Fig. 14-15 due to their patchy distribution.

Remarks

- ***A diachronous deposit*** *in geology is a sedimentary rock formation*
- *in which apparently similar material varies in age from place to place.]*
- *Typically this occurs as a result of a marine transgression or regression, or the progressive development of a delta. As the shoreline advances or retreats, a succession of continuous deposits representing different environments (for example beach, shallow water, deeper water) may be left behind. Although each type of deposit (facies) may be continuous over a wide area, its age varies according to the position of the shoreline through time.*

3.1- Fluvio-lacustrine & karst fill facies

(Zahra Formation)

- *The Zahra Formation occurs locally in the Salman Zone and along the margins of the Rutba Subzone.*

Lithology:- *Fresh water limestone, marl and sandy marl, locally sandstone occure in the base of the formation.*

- *Zahra For mation lies in karst depressions formed on the Rus (Jil) Formation due to dissolution of the anhydrites of the formation .*
- *The **presence of limestone beds similar to those found in the Dibdibba Formation suggests that Zahra Formation may pass laterally in to the Dibdibba Formation.***

Age:- *Late Mio-Pliocene age*

Environment:- *deposited in a fresh water environment.*

3.2 -Alluvial Fans of the Stable Shelf

(Dibdibba Formation)

Lithology:- *It comprises sand and gravel containing pebbles of igneous rocks, (including pink granite) and white quartz, often cemented into a hard grit. Beds of limestone, marl and silt were reported .*

Environment:- *The formation was deposited in a fresh water environment becoming deltaic to the NE.*

Age:- *It is of post Middle Miocene age based on its stratigraphic position.*

Contacts:- *The contact of the formation with the underlying Fatha Formation is conformable in SE Iraq (Bellen et al., 1959).*

At outcrop to the west the formation unconformably overlies Lower Miocene and Palaeogene units.

The formation is often covered by sand sheets or by the alluvial fan sands of Wadi Al Batin.

North Side of Kuwait Bay: Jal Az-Zor Escarpment

- Clastic coastal sabkha

3.3- Fluvial system

3.3.1- 1njana (Upper Fars Formation)

Lithology:- *comprises fine grained pre-molasse sediments deposited initially in coastal areas, and later in a fluvio lacustrine system.*

It is 620 m thick.

The basal unit comprises thin-bedded calcareous sandstone, and red and green mudstones with one thin gypsum bed (20 cm thick) and a purple siltstone horizon with glass shards.

The calcareous sandstones contain miliolids and oscillation ripple marks; they are overlain by fining upwards cycles of sandstone siltstone and red mudstone .

The thickness of individual sandstone beds increase upwards from I m to several metres.

*The formation as a whole **coarsens upwards**.*

Contacts:- *The lower contact of the Injana Formation with the Fatha Formation is gradational.*

The upper contact with the Mukdadiya Formation is gradational marked by appearance of gravely sandstone.

Age:- *Late Miocene.*

Red clastic of Injanah Fn.

Cave Member of Injanah Fn.- Karbala

3.3.2 Mukdadiya and Bai Hassan (Lower and Upper Bakhtiari) formations

Lithology:- *The* ***Mukdadiya (Lower Bakhtiari)*** *Formation comprises up to 2000 m of fining upwards cycles of gravely sandstone, sandstone and red mudstone.*

- *The sandstones are often strongly cross-bedded and associated with channel lags and clay balls.*
- ***in the Injana area the whole formation comprises stacked fining up depositional cycles.***

Environment:- *The Mukdadiya (Lower Bakhtiari) Formation was deposited in fluvial environment in a rapidly subsiding foredeep basin.*

- *It is replaced almost totally by the* ***Bai Hassan (Upper Bakhtiari)*** *conglomeratic facies in the High Folded Zone of NE but not in N Iraq; for instance, in the Derbendikhan area S of Sulalmaniya the Mukdadiya Formation is almost totally replaced by -3000 m of conglomerates of the Bai Hassan Formation (Plate 14-1).*

Environment:- *The conglomeratic Upper Bakhtiari was deposited in alluvial fans originated from the High Folded Zone and the Zagros Suture.*

Conglomerates of the Bai Hassan Formation (B). Note calcrete (C) capping the Mukdadiya Formation (M), south of Derbendi Khan

Mukdadiyah Formation capped by calcrete, Amadiya Plateau