

جيولوجيا الصحراء الغربية

GEOLOGY OF WESTERN IRAQI DESERT

4TH CLASS

APPLIED GEOLOGY DEPARTMENT
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ا.د. عبد صالح فياض

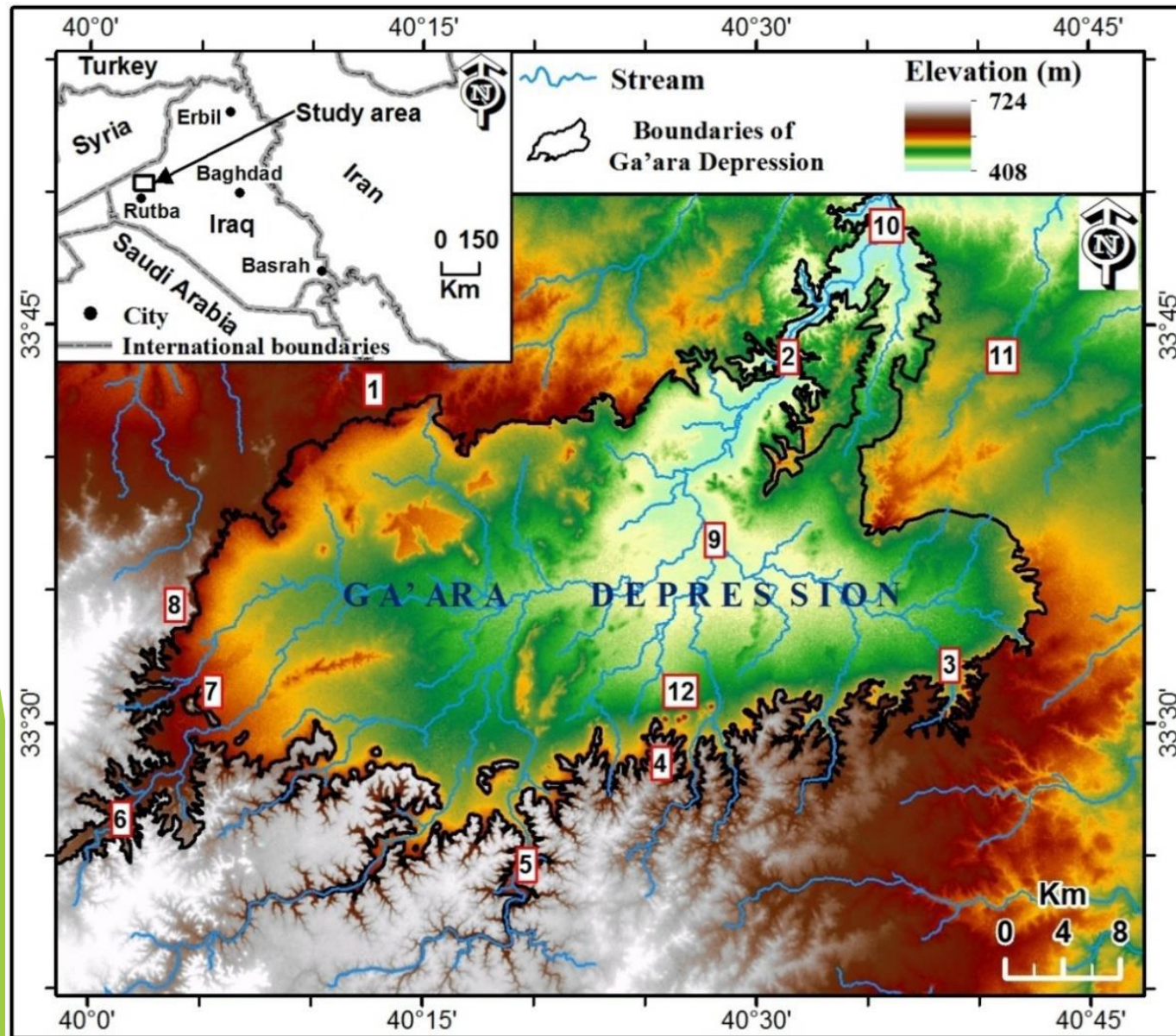
المحاضرة الثالثة

Gaara depression (case study)

The Iraqi Western Desert is characterized by flat and undulated plains; dissected by long valleys, occasionally exhibit canyon type.

Moreover, karst depressions are densely distributed over the flat area.

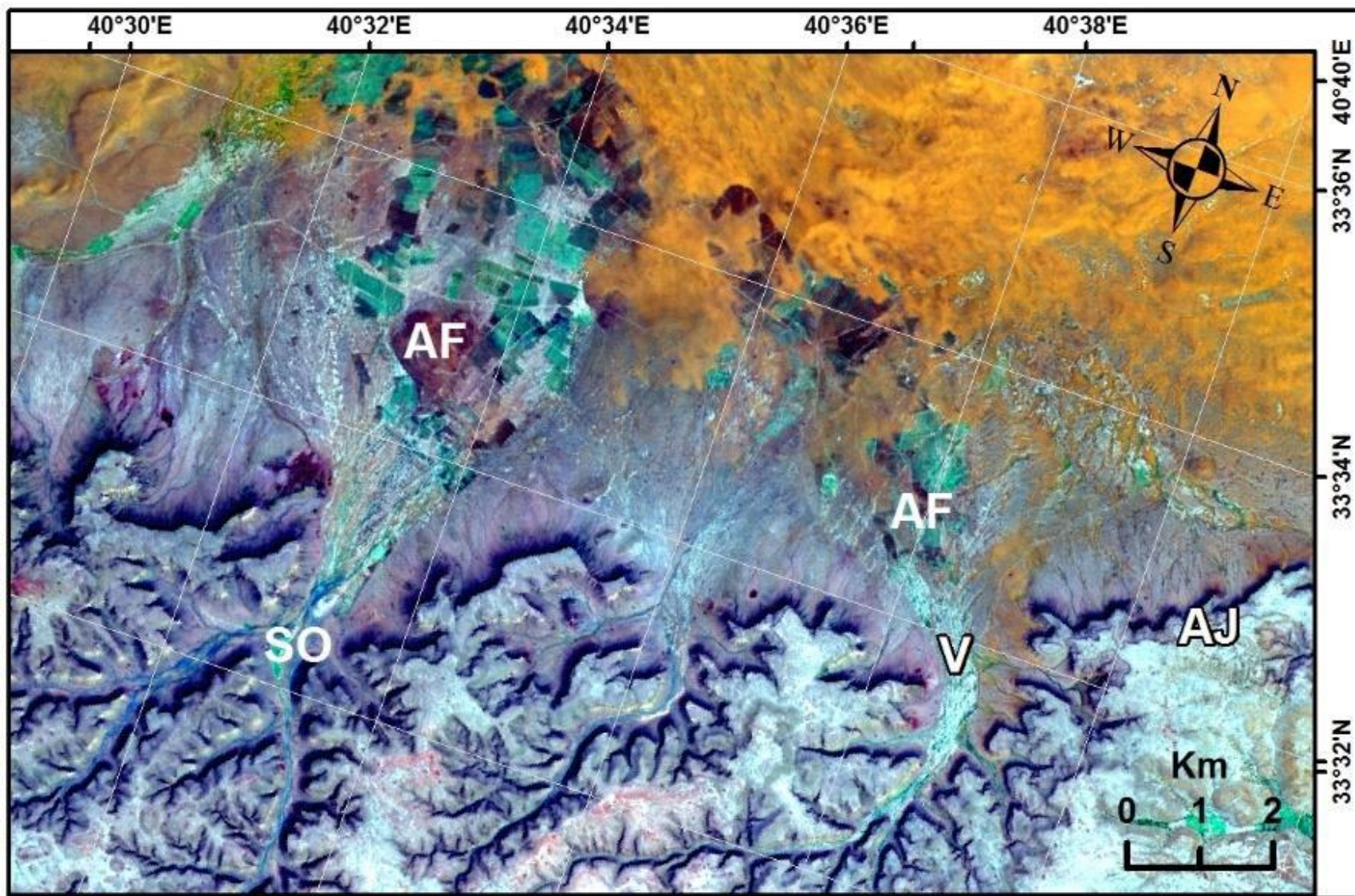
Among the main depressions is the Ga'ara Depression, which is located in the central western part of the Western Desert. It is very large depression; elongated in E – W trend with oblong form exhibiting four distinct rims.



- 1= Marbat El Hsan,
- 2= Al-Halqoom,
- 3= Al-Ujrumiyat,
- 4= Al-Qasir,
- 5= Wadi Al-Ouja
- 6= Wadi Al-Mulussi,
- 7= Chabid Al-Abid,
- 8= Al-Na'jah,
- 9= Al-Rah water well,
- 10= Wadi Ratga,
- 11= Wadi Al-Mani'ai,
- 12= Al-Afayef Hills

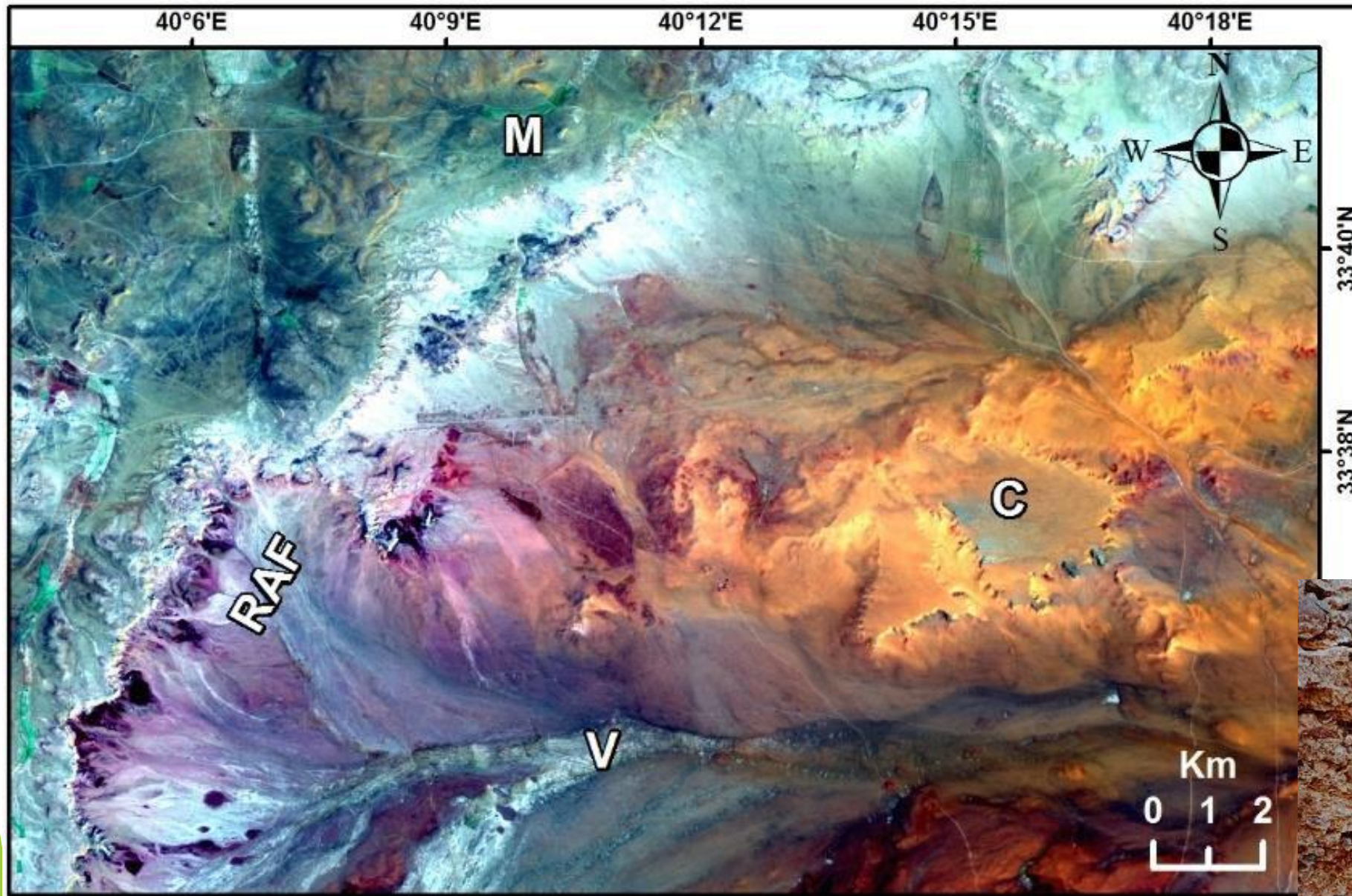
Geomorphology

*Alluvial Fans



Note the developed alluvial fans. (AF),
valley fill sediments (V),
AJ = Ajrumiyat locality,
SO = Shuaib (valley) Al-Ojah

Calcrete (Duricrust):



northwestern corner of the Ga'ara Depression. Note the calcrete (C), valley fill sediments (V) and recent alluvial fans (RAF). M = Marbat El-Hsan locality.

** Flood Plain and Valley Fill Sediments:*

** Isolated Plateaus and Hills:*

These are well developed along the rims of the Ga'ara Depression, especially the southern rim.

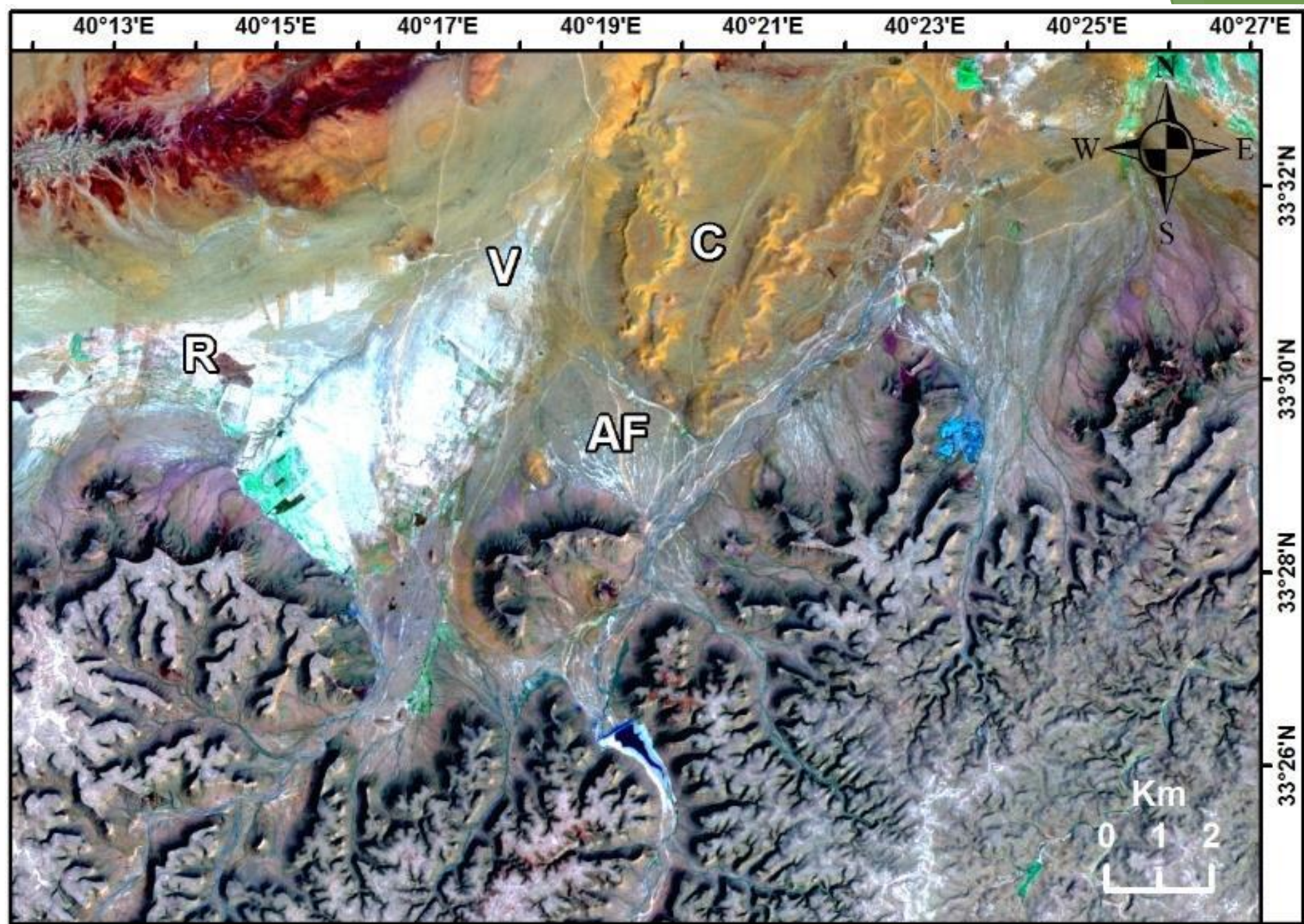
The Mulussi Formation is exposed in the southern rim, which consists of well bedded to massive very hard dolomite and dolomitic limestone.

The isolated plateaus and hills along the rims indicate active back ward erosion and retreatment of the cliffs, consequently indicating very wet climate during the Pleistocene and even in Holocene; otherwise such very hard carbonate with thickness attaining 100 m and locally more, are not easily eroded to form isolated plateaus & hills.

However, three large isolated hills called “Al-Afayif” are well known outstanding geomorphological features in the middle of the depression, east of Al-Rah water well.

Al- afayif hills





Note the isolated plateaus and hills along the southern rim of the Ga'ara Depression. Also note the N – S lineaments even in the developed calcrete (C).

AF = Alluvial fan, V = Valley fill sediments, R= Location of Al-Rah water well

Terraces:

Many main ephemeral valleys have formed their own terraces, like Mulussi, Al-Ojah.

Tamer-Agha [20] has mapped three terrace levels in the depression. The highest level is about 20 m above the alluvial plain.

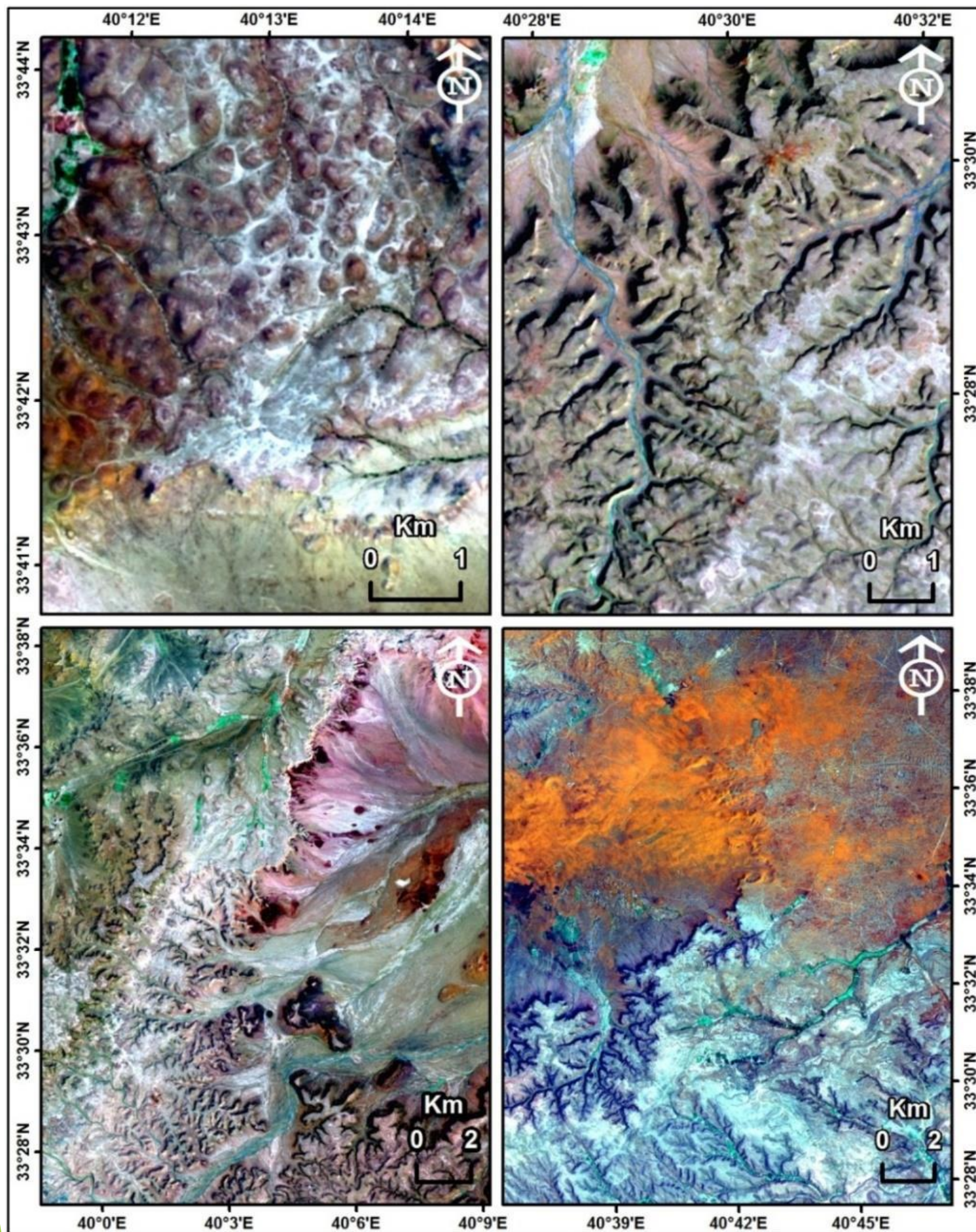
He described the active alluvium to represent the lowest level.

Some remnants of terraces are also preserved near Al-Halqoom outlet in the extreme northeastern part of the Ga'ara Depression.

Drainage Patterns:

The drainage patterns inside the Ga'ara Depression is quite different from those in the surroundings, and even along the four rims (Fig.5). This is attributed to the type of the exposed rocks, which are very different in all four rims, beside the slope of the rims.

Inside the Ga'ara Depression, the valleys are shallow and wide filled with gravely and sandy sediments (Fig. 4).



5--rims of the Ga'ara Depression.

(Upper left) -Northern,
 (Upper right) -Southern,
 (Lower left) -Western,
 (Lower right) -Eastern.

Note the difference in the drainage pattern on four rims

*In the northern rim, where the well bedded and jointed, and very hard carbonates of the Ratga Formation are exposed, the drainage pattern is trellis to dendritic, whereas on the slopes is dendritic (Fig.5 Upper left); because sandstones and claystones of the Ga'ara Formation are exposed.

* In the eastern rim where the sandstones and claystones of the Ga'ara Formation are exposed, the drainage pattern is very fine dendritic, even on the slopes (Fig.5 Lower right).

* In the southern rim, where the well bedded and very hard carbonates of the Mullusa Formation are exposed, the drainage pattern is trellis and oriented, on slopes is dendritic (Fig.5 Upper right).

* In the western rim where rocks of different formations are exposed, the drainage pattern is fine dendritic and partly oriented (Fig.5 Lower left).

Structural Geology and Tectonics

The Ga'ara Depression is located within the Inner Platform of the Arabian Plate.

* * Structurally, the two major Paleozoic orogenic movements (Caledonian and Hercynian) were identified by their effects on sea level changes rather than their orogenic deformation.

* On the other hand, however, the sedimentation pattern through most of the Mesozoic Era was a reflection to a fluctuating sea level and periodical movements of Hail – Rutbah Arch.

* However, the periodical movements of Hail – Rutbah Arch was not uniform, this is confirmed by the deposition of different formations over the Ga'ara Formation on the surrounding four rims of the Ga'ara Depression (Fig. 6).

* This complicated depositional system as manifested along the four rims of the Ga'ara Depression (Fig. 6) was also noticed and confirmed by different authors; among them is Fouad, *he added that “It is important to mention that at the time of the Hail – Rutbah Arch activity either by up warping or subsidence, it is not necessary that the entire arch display the same magnitude of activity, instead in many occasions the available data point out that some parts of the arch may remain inactive or at least show lesser activity than the others.*

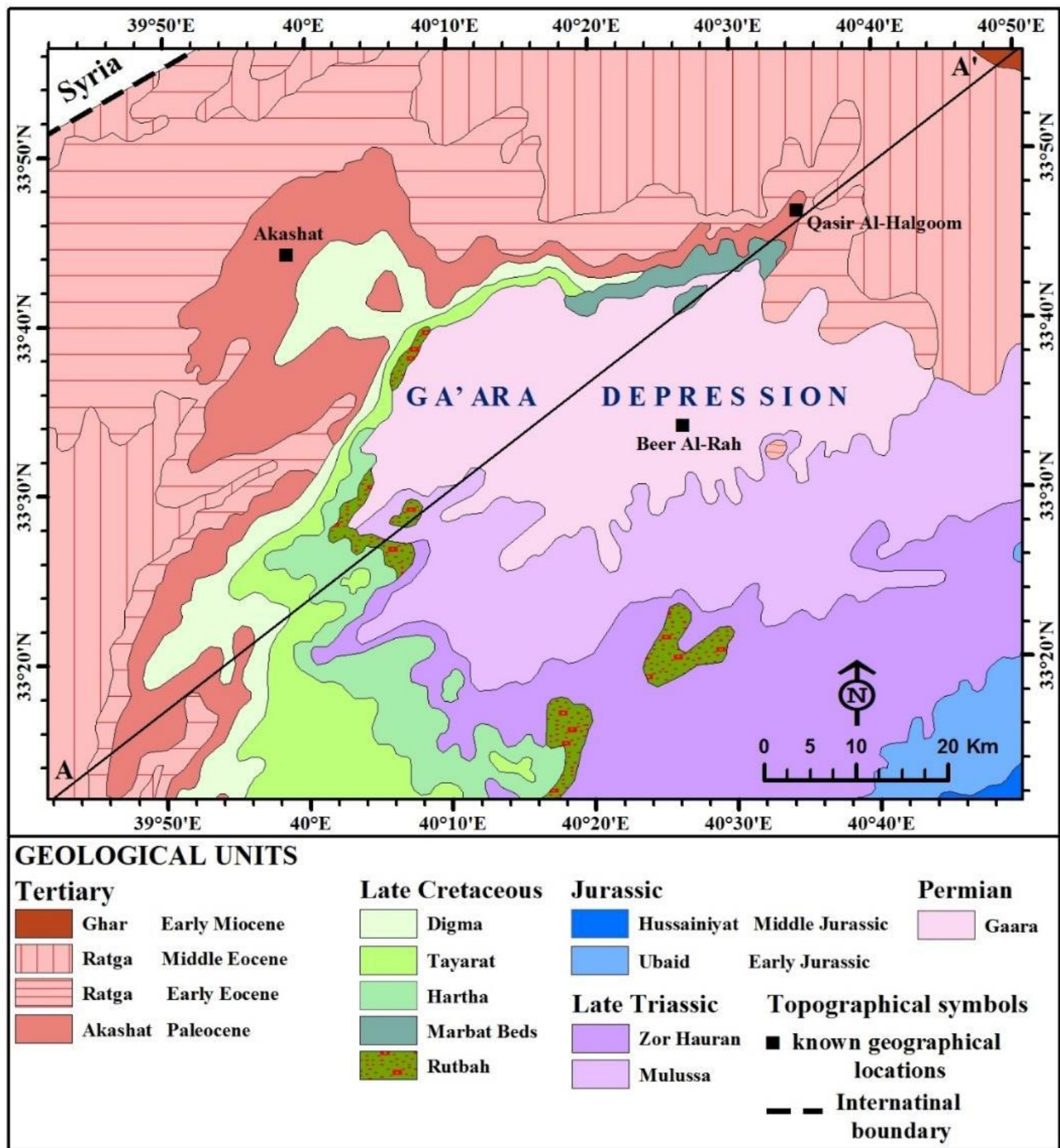
This is clearly reflected by the non-uniform spatial distribution of the unconformities or the erosional surfaces and their time span along and at the vicinity of the arch in the Western Desert.

Ga`ara Depression is an example to this where the Paleozoic Ga`ara Formation is overlain by Late Triassic carbonates with a break of about 30 Ma at the southern rim of the depression, whereas the same formation at the eastern rim of the depression is overlain by Eocene carbonate with about 200 Ma break .

All this drastic variation occurs within the 70 Km length of the depression. The differently oriented initial depositional dip of the exposed rock units around Ga'ara Depression supports this conclusion too”.

On the other hand, the role of the aforementioned movements along the Hail – Rutbah Arch have manifested two set of intense jointing and lineaments in N – S trend (Hijaz System) and NW – SE trend (Najd System), which represent weakness zones.

Consequently, played significant role in fragmentation of the bed rocks (Figs. 4 and 5 Upper left and right); facilitating their weathering and erosion and evolution of the Ga'ara Depression.



Stratigraphy of Gaara

Ga'ara Formation:

The oldest exposed rocks in the Ga'ara Depression belong to the Ga'ara Formation of Permian age; they also represent the oldest exposed rocks in the whole Iraqi Western Desert.

The formation consists of alternation of sandstone and claystone, the formers are hard, whereas the latters' are soft, as a whole the succession is not hard; therefore, when they are not overlain by hard rocks; they did not form scarps.

Mulussa Formation:

The formation is Lower Triassic in age and consists of very hard well bedded to massive dolomite and dolomitic limestone (Figs. 4 and 5 Upper left).

It is exposed only on the southern rim of the Ga'ara Depression (Fig. 6).

The well bedding nature and intense jointing have facilitated the back word erosion of the southern cliff.

It seems that the formation was not deposited in the entire area and has suffered from extensive erosion during the whole Lower Cretaceous Period.

Zor Horan Formation:

The formation is Upper Triassic in age and consists of very hard dolomite and limestone alternated with yellowish green soft marl. It is exposed only on the southern rim of the Ga'ara Depression .

The soft nature has facilitated the back word erosion of the southern cliff. It seems that the formation was not deposited in the entire area and has suffered from extensive erosion during the whole Lower Cretaceous Period.

Rutba Formation:

The formation is Upper Cretaceous in age and consists of soft sandstone.

It is exposed only on the extreme western part of the southern rim and as patches along the western rim of the Ga'ara Depression .

It seems that the formation was not deposited in the entire area and has suffered from extensive erosion during the whole Jurassic Period.

Hartha Formation:

The formation is Upper Cretaceous in age and consists of conglomerate, sandstone, limestone, and dolostone. .

It is exposed only on the lower half part of the western rim and southwestern corner of the Ga'ara Depression .

Tayarat Formation:

The formation is Upper Cretaceous in age and consists of conglomerate, sandstone, marl, siltstone, reddish limestone followed upwards by papery marl. It is exposed only on the western rim and western half part of the northern rim of the Ga'ara Depression.

Digma Formation:

The formation is Upper Cretaceous in age and consists of white to creamy limestone, dolostone with phosphorite horizon and green to ochre papery shale, with oyster shell horizon.

It is exposed only on the western rim and western half part of the northern rim of the Ga'ara Depression.

Akashat Formation:

The formation is Paleocene in age and consists of phosphatic conglomerate or breccia, followed by oyster bed, overlain by a sequence of calcareous siltstone, with layers of silty limestone and calcareous mudstone, locally phosphatic .

Its soft nature has contributed and facilitated the backward erosion of the W&N rims.

Ratga Formation:

The formation is Eocene in age and consists of nummulitic limestone, phosphorite and phosphatic limestone, fine crystalline limestone, with several chert horizons.

It is exposed only on the western and northern rims of the Ga'ara Depression; however, small patches are present as remnant on the Southern rim too (Fig. 6).

Its hard nature has contributed in development of continuous ridges .

Quaternary Sediments:

Different types of Quaternary sediments are developed in the Ga'ara Depression, like terraces, calcrete, alluvial fan sediments, slope sediments, valley fill and flood plain sediments.

The Characteristics of The Ga`ra Depression

** The Ga`ara Depression is the only large depression in the Western Desert; being structurally high and topographic low.*

**It has oblong shape; extends in E – W direction with length of 58.5 Km and width of 25 Km and total coverage area is 1383 Km².*

The highest point in the four rims is 596 m, 576 m, 669 m and 659 m in the northern, eastern, southern and western rims, respectively.

**The maximum elevation in the floor of the depression is 550 m in the western part, 504 m in the eastern part, whereas the lowest elevation is 446 m in the middle of the depression, near Al-Rah water well.*

**The relief difference in the four rims is 35 m, 11 m, 156 m and 96 m in the northern, eastern, southern and western rims, respectively.*

*The Ga'ara Depression is a structural high within the Hail – Rutbah Arch. Hail – Rutbah Arch is marked by a prominent positive gravity anomaly *indicating* the presence of basement at a relatively shallow depth.

*The shallowest locality within the arch is at the Ga'ara Depression. *The high is also indicated on surface by the exposures of the Permian rocks of the Ga'ara Formation.

*Moreover, the presence of complex joint systems accompanied with lineaments surrounding the depression, especially western and northern parts (Fig. 7) *is good indication for suffering the area from uplift movements.*

*Another indication for interrupted uplifting of the Ga'ara Depression is the complex stratigraphic succession on the four rims of the depression.

*The presence and absence of a certain formation within the normal stratigraphic succession along the four rims is a good indication about the uplift of the area.

*However, the uplift was not uniform in the area, which means certain parts have received more uplift forces than others.

However, the uplift was not uniform in the area, which means certain parts have received more uplift forces than others.

This is confirmed by the following facts:

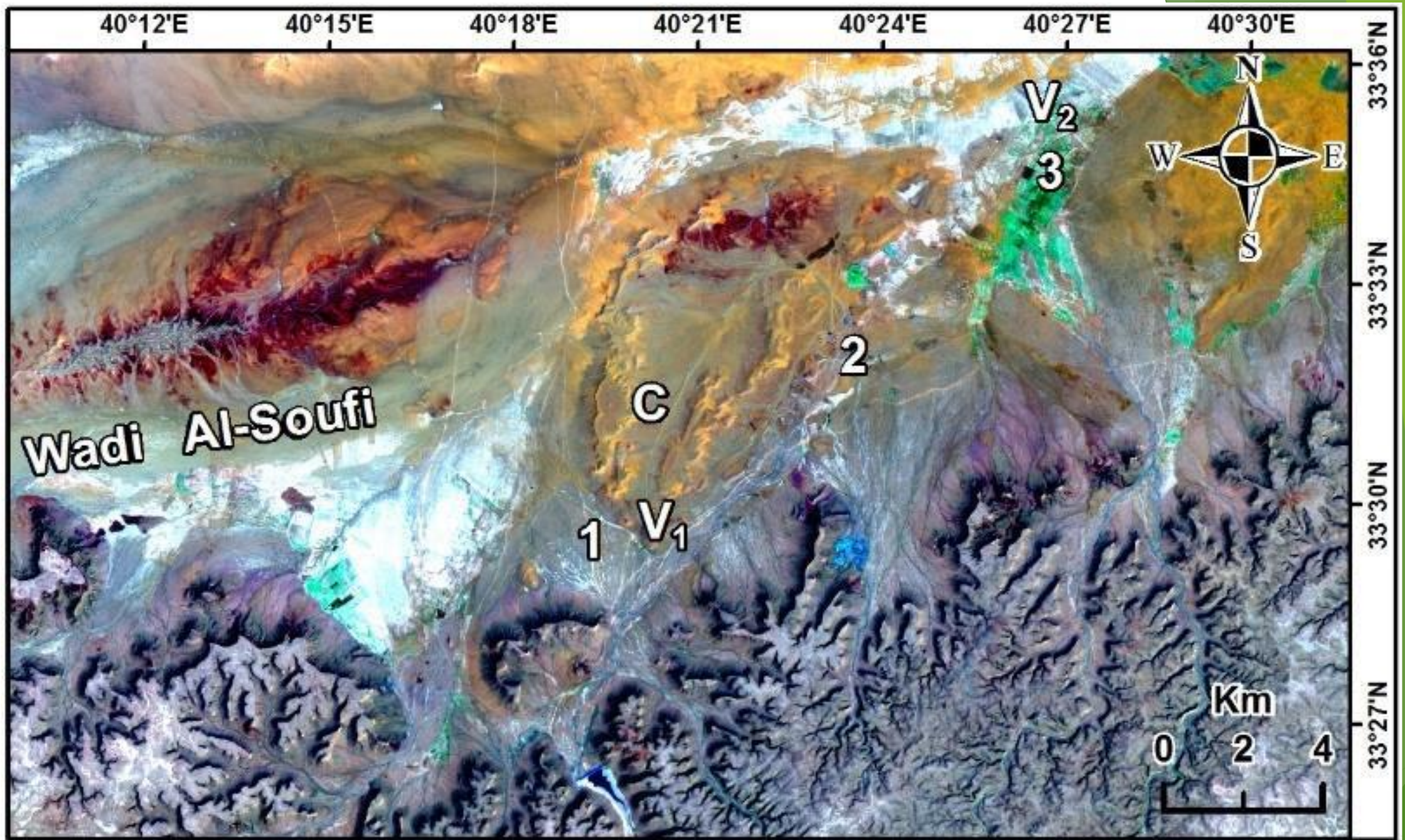
- 1- Absences of any formation younger than the Ga'ara Formation on the eastern rim bellow the Ratga Formation.
- 2- Absence of the Lower and Middle Triassic over the whole area.
- 3- Presence of the Upper Triassic rocks, Mulussa and Zor Horan formations only on the southern rim.
- 4- Absence of the whole Jurassic and Lower Cretaceous rocks over the whole area.
- 5- Presence of the Upper Cretaceous rocks of the Rutba, Hartha, Tayarat and Digma formations only on the western rim and parts of the northern rim.
- 6- Presence of Paleocene rocks, the Akashat Formation only on the western rim and parts of the northern rim.
- 7- Presence of the Ratga Formation only on the western and northern rims, and as remnant on the southern rim.

*This abnormal succession along the four rims of the Ga'ara Depression indicates that the uplift of certain part of the depression was higher during certain time interval than other sides and lower in other time intervals.

** This difference in the uplift rate of the depression has caused either non deposition of certain formation(s) or intense weathering and erosion of other formation(s) along the four rims.*

*The continuous retreatment of the rims by backwards erosion and continuous erosion of the top cover rocks due to the intense crossed jointing and presence of crossed lineaments (Fig.7) with continuous uplifting of the Ga'ara High, have facilitated and accelerated the development of the depression by weathering and falling down of the rims by mass movement phenomena and gravitational forces.

*Another indication for the uplift movement within the Ga'ara Depression is the presence of Neotectonic activity, indicated by the recent change of a valley (Fig.8, $V_1 - V_2$), that flows from the southern rim towards the central part of the floor



Note the recently changed direction of the valley (V1 – V2). 1, 2 and 3 locations of terminated alluvial fans by the recently changed valley. C = Calcrete

The Role of the Stratigraphic Sequence in the Development of the Ga'ara Depression

After the deposition of the Ga'ara Formation during the Permian, the whole area was uplifted and was a positive area without deposition during Lower and Middle Triassic (17.6 Ma).

**** This break in deposition was accompanied by weathering and erosion of the deposited fairly hard rocks of the Ga'ara Formation.***

**** During Upper Triassic, only the southern part of the considered area was down warped and deposition of hard rocks of the **Mulussa Formation** were deposited.***

**** These hard rocks were followed; without interruption by comparatively soft rocks (marl and thin limestone) of the **Zor Horan Formation**.***

**** This assumption is confirmed by the absence of the Triassic rocks in the drilled oil well Akaz 1 (4238 m deep and penetrated the full thickness of the Ga'ara Formation), north of the Ga'ara Depression.***

**** During the whole Triassic Period, the other parts of the involved area were positive areas too.***

**** During the Jurassic Period (56.3 Ma) the whole involved area; apart from the eastern far part was a positive without deposition and with continuous weathering and erosion.***

**** This long erosional phase has formed again uneven surfaces on the top of the Ga'ara Formation.***

*During the Lower Cretaceous (44.5 Ma) the whole involved area was continuously a positive area; apart from east and south far parts since the Jurassic Period; without deposition and with continuous weathering and erosion.

*This long erosional phase has formed again uneven surfaces on the top of the Ga'ara Formation.

*other aforementioned assumptions are confirmed by the absence of the Jurassic and Lower Cretaceous rocks in the drilled oil well Akaz 1 (4238 m deep and penetrated the full thickness of the Ga'ara Formation), north of the Ga'ara Depression.

*During the Upper Cretaceous (39.5 Ma), the western and northern parts were down warped and the rocks of the Rutba, Hartha, Tayarat and Digma formations were deposited.

* However, the eastern and southern far parts were down warped and the same formations were deposited too.

* *The non-continuous system of the exposed formations on the western and northern rims indicates the uneven surface of the involved area and the presence of paleo-highs and paleo-lows.*

*During the Paleocene (10 Ma), the western and northern rims were down warped and the comparatively soft rocks of the Akashat Formation were deposited, whereas the eastern and southern parts of the involved area were subjected to intense erosion.

* During the Eocene (22.1 Ma) the western and northern rims were down warped and the hard rocks of the Ratga Formation were deposited, whereas the eastern and southern parts of the involved area were subjected to intense erosion.

From the aforementioned scenario of the deposition of different formations on different parts of the involved area that is developed to the nowadays Ga'ara Depression, it is clear that different parts of the involved area were subjected to long periods of erosion.

* *Consequently, different types of hard and soft rocks were exposed in different parts; therefore, the topography was highly uneven*

The Role of the Tectonics in the Development of the Ga'ara Depression

The Ga'ara Depression looks like tectonic depressions .

*The continuous uplifting and down warping of different parts of the involved area with different rates; since the Permian has formed intense cross jointing (shear and tension) (Figs. 8 and 10),

beside long lineaments, which were occupied by valleys of different directions (SW – NE and SE – NW).

** The intense cross jointing system beside the crossed lineaments have accelerated and facilitated the weathering and erosion of the covering rocks, especially the soft and fairly hard rocks of the Ga'ara, Zor Horan, Rutba, Hartha, Digma and Akashat formations.*

*It is worth mentioning that Tamer Agha et al. have denied the presence of Ga'ara anticline (Fig.9). The current authors are in accordance with the suggestion of Tamer Agha et al. and they believe that the Ga'ara Depression is not an anticline.

This assumption is based on the following aspects:

1- If it is an anticline, then the axis should be E – W; because the depression has longitudinal extension in E – W direction.

This assumption cannot be valid; because there is no such tectonic style in the involved area and near surroundings.

2- The absence of two limbs with opposite dip directions (Figs. 1 and 6) .

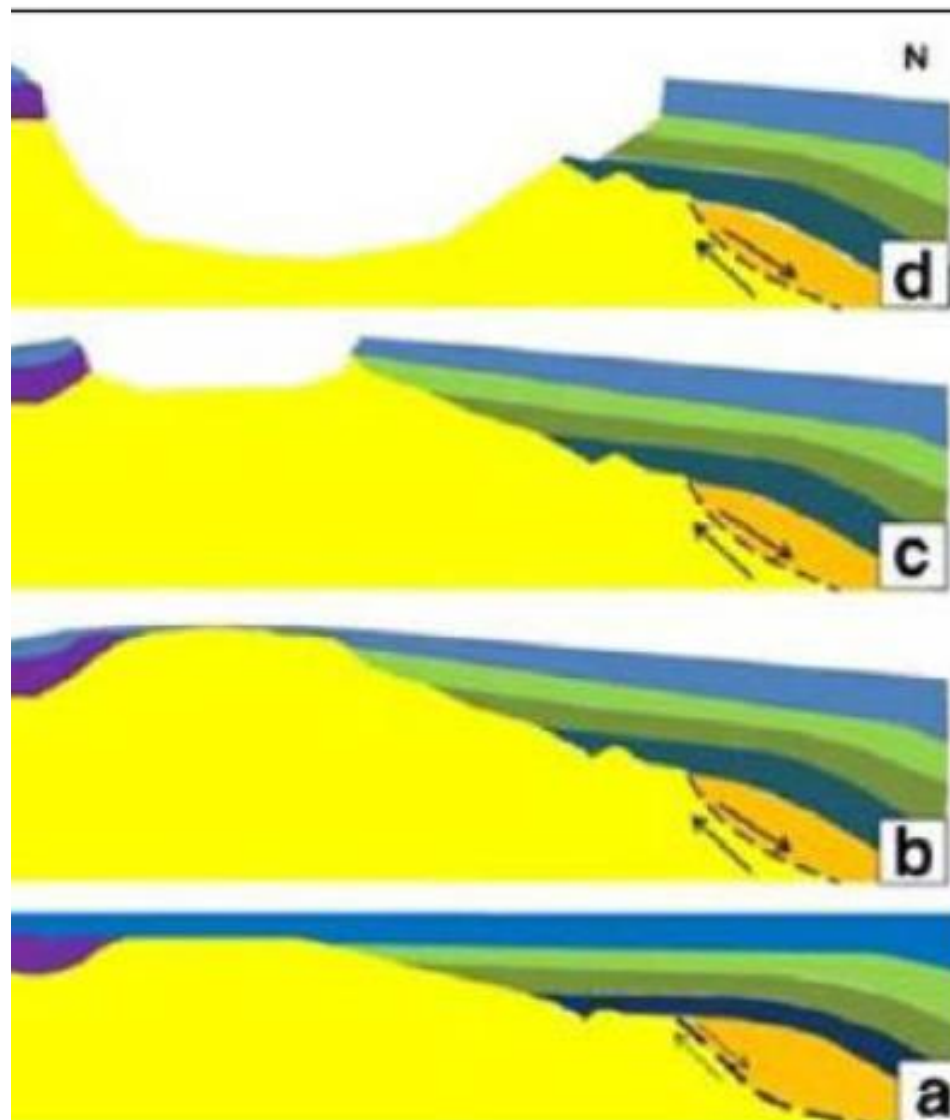
3- The exposed formations on the northern and western rims are not the same with long time interval between the exposed rocks.

Since on the southern rim Triassic rocks are exposed, whereas on the northern rim cretaceous, Paleocene and Eocene rocks are exposed (Fig. 6).

4- The developed joint system in NE – SW and NW – SE trends as well the present lineaments (Figs. 9 and 10) did not coincide with an E – W trending anticline.

5- Presence of small outcrops of the Ratga Formation of Eocene age on the southern rim directly above the Triassic rocks of the Mulussa Formation, whereas the northern rim is completely covered by the Ratga Formation with normal succession as related to the older rocks; Paleocene and Cretaceous.

Such differences in the distribution of the rocks cannot be found on both limbs of an anticline.



: Tough, massive and recrystallized limestone.

on: Phosphorite and medium bedded limestone.

r: Soft ocher marl and medium bedded limestone.

on: Tough Carbonates.

able gravelly sandstone and conglomerate.

: Tough carbonates.

The Role of the Erosion in the Development of the Ga'ara Depression

* Obviously, the weathering and erosion phenomena with contribution of mass wasting and mass movements; besides the gravitational forces have played a significant role in development of the Ga'ara Depression and still are acting in its enlargement.

According to Hamza the most recent plateau in the area is that of the oldest exposed Ga'ara Formation.

Sissikian et.al .are not in accordance with Hamza because the Ga'ara Formation was not covered totally by the youngest formations as it the case in normal stratigraphical successions.

This assumption is confirmed with the abnormal exposed successions along the four rims (Fig.6).

Therefore, the authors believe that the Ga'ara Formation was forming the top cover of the nowadays Ga'ara Depression for large parts and before long time intervals.

This assumption depends on the following facts:

1- The presence of many isolated hills that consist totally of clastics of the Ga'ara Formation in the Ga'ara Depression at different places, even in the central part, like Al-Afayef hills (Fig. 11).

Those hills range in heights from (25 – 55) m, with almost flat tops; among them are, Azlat Alighri (Azlat in local slung means isolated hill), Af'fayif, Chabid Al-Abid.

2- In the eastern rim, the only exposed rocks over the Ga'ara Formation are Eocene rocks of the Ratga Formation (Fig.6).

-This indicates that large parts of the Ga'ara Formation were not covered by younger formations until the Eocene Period.

- Otherwise, some remnants of Cretaceous formations should be found as it is in the eastern rim, where remnants of the Rutba Formation still exist over the Ga'ara Formation (Fig.6) and remnants of Eocene rocks of the Ratga Formation exist over the Triassic rocks of the Mulussa Formation.

3- The whole Ga'ara Depression drain out by one outlet that is through Halqoom outlet (Fig.1) leading to wadi Ratga, which starts with canyon shape. If the Ga'ara Formation in the depression was covered by different formations, then it was not possible to have such canyon like deep valley (wadi Ratga) in the upper reaches of the valley.

The authors believe that wadi Ratga had its upper reaches on the top of the Ga'ara Formation in shallow forms, before the development of the depression; as it is the case in all other valleys in nearby areas; like Al-Man'ai (Fig.12), Akash, Swab....etc.

Moreover, it is impossible to start a large valley like Al-Ratga, which has length of 74 Km inside Iraq (from Al-Halqoom outlet) with maximum depth of 75 m and width of about (35 – 100) m with such canyon like valley, as it is in Al-Halqoom outlet (Fig.12).

Since valleys normally start with shallow depths then may deepen their courses when the vertical erosion predominates , as it is in wadi Al-Man'ai, which has length of 92 Km, width of (35 – 100) m and maximum depth of about 100 m.

4- Long time intervals in the involved area were non-depositional represented by the Lower and Middle Triassic (17.6 Ma) and the whole Jurassic (56.3 Ma) and the Lower Cretaceous (44.5 Ma) totaling to 118.4 Ma without any deposition after the deposition of the Ga'ara Formation.

-However, this large time interval was accompanied by intense weathering and erosion acting on the top cover rocks of the Ga'ara Depression leading to uneven topography, especially the rocks of the Ga'ara Formation are fairly hard rocks. -- This was followed by the deposition of the soft clastics of the Rutba Formation, which seemingly filled the uneven surface of the top cover rocks of the Ga'ara Formation.

-However, the absence of the Msad Formation, which caps the Rutba Formation everywhere in far areas of the depression, indicates another non-depositional interval; otherwise some remnants of carbonates of the Msad Formation would be present over the rocks of the Rutba Formation.

- The wedging out of the Upper Cretaceous formations on the western and northern rims; successively (Fig.6) indicates another non-depositional interval through the Upper Cretaceous, consequently the already deposited rocks had suffered from erosion too. Moreover, since the end of the Eocene Period (33.9 Ma) the area suffered from non-deposition; therefore, the whole deposited sequence above the Ga'ara Formation were subjected to intense erosion leading to the development of the depression and continuous retreatment of the rims, which is still active, as witnessed by the present isolated hills and small plateaus along the rims of the depression (Fig.8).

Other Factors Contributing in the Development of the Ga'ara Depression

- The ***wind erosion*** (deflation) has also contributed in the enlargement of the Ga'ara Depression by mechanical weathering of the rocks, especially the soft rocks.
- During the non-depositional intervals; total of 152.3 Ma the whole area and surroundings was suffering from *dry climate* that facilitates the mechanical weathering.
- However, during the Pleistocene and onwards, the already developed depression witnessed wet *climates* in many phases.
- ***This is confirmed by the presence of thick calcrete in the floor of the depression in many places, beside the thick valley and flood plain sediments in different parts of the depression.***
- Another factor that had contributed in the development of the Ga'ara Depression and is still active is the ***mass movements*** (wasting).



Marbat El-Hisan locality along the northern rim of the Ga'ara Depression. Note the toppled blocks and thick colluvium indicating very active mass wasting

تقع اداريا ضمن اربعة محافظات ، ٩٥ ٪ منها ضمن حدود محافظة الانبار. يشكل نهر الفرات الحدود الشمالية والشمالية الشرقية لها. فيها ثلاثة بحيرات (حديثة ، الحبانية والرزازة) وهناك العديد من الوديان الكبيرة فيها واهمها وادي حوران.

