Tectonically Stable Parts in Iraq are not Stable

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Abstract

The Iraqi territory is located in the extreme northeastern part of the Arabian Plate which is in collision with the Iranian (Eurasian) Plate. The collision which is still ongoing has created tens of folds some of them exhibit different types of faults. The exerted compressional forces are believed to be decreasing southwest wards as being far from the collision area. Accordingly, all the existing tectonic and geological maps compiled by different authors and all the existing published articles, reports and books have considered two main tectonic domains in Iraq. The Stable Shelf and Unstable Shelf or Inner Platform and Outer Platform. The contact between these two main divisions follows almost the Euphrates River; towards west of the river is the Stable area and towards east and north is the Unstable area.

In the current study, we have recognized tens of different Neotectonic evidences in the Stable part indicating that the area is tectonically not stable. Among those indications are abandoned valleys, development of sinkholes along certain lineaments, bending of valleys in normal angles, development of Nick points in valleys along certain lineaments.

1. Introduction

The Iraqi territory is in the northwestern part of the Arabian Plate (Figure 1) which is colliding with the Iranian Plate (Alavi, 2004, Fouad, 2015). Due to the collision, tens of anticlines are developed in the northern and northeastern parts of the country known as the Iraqi Kurdistan Region. Many researchers have studied the tectonic activity of the collision, among them are: Colman-Saad, 1978, Berberian and King (1981), Beydoun (1991), Beydoun and Hughes Clarke (1992), Alsharhan and Nairn (1997), Blanc et al. (2003), Burberry et al. (2010), Burberry (2015), they all reported about the Zagros Foreland Basin which is a continuously subsiding basin including the Zagros Thrust – Fold Belt which itself includes different tectonic zones with different terminologies. All existing tectonic (Figure 2) and geological maps of Iraq present the main tectonic zones but with different terminologies (Dunnington, 1958, Buday and Jassim, 1987, Jassim et al., 1990, Al-Khadhimi et al., 1996, Numan, 1997, Jassim and Goff, 2006, Aqrawi et al., 2010, Sissakian, 2013, Fouad, 2015, Sissakian and Fouad, 2015).

All the aforementioned authors have used “Stable Shelf” and “Unstable Shelf “terms expressing the tectonic activity indicating that the intensity of the folding decreases southwest wards until culmination of the forces, then the area becomes tectonically stable. However, Fouad (2015) used two main terms “Inner Platform” and Outer Platform” (Figure 2 D) instead of “Stable Shelf and Unstable Shelf”, but still confirmed that there are two main tectonic parts in Iraq tectonically stable and unstable.

The aim of the current study is to prove that the tectonically stable parts in Iraq as stated by all the existing tectonic and geological maps, and all published articles and geologic books are not stable. Moreover, the current study suggests deleting the terminology of “Tectonically Stable” term from the dictionary of Iraqi Geology and new suggestion is given for the terminology of the tectonic zones in Iraq.

All previous studies have divided tectonically the Iraqi territory into two main parts: Stable and unstable. In all previous studies (Dunnington, 1958, Buday and Jassim, 1987, Jassim et al., 1990, Al-Khadhimi et al., 1996, Numan, 1997, Jassim and Goff, 2006, Aqrawi et al., 2010, Sissakian, 2013, Fouad, 2015, Sissakian and Fouad, 2015) the following aspects were used in their introduced tectonic zones: 1) intensity of folding, 2) shape and size of the folds, 3) amplitude of the folds, 4) physiographic provinces, 5) occurrence of major thrust faults, 6) presence of subsurface salt layers, 7) tectonic scenarios (Geosyncline Theory and Plate Tectonic Theory), 8) Age of the exposed formations, and 9) depth of the basement. However, not all the mentioned aspects were considered by each of the mentioned researchers. Moreover, none of the mentioned researchers have considered the Neotectonic activities and the existing active fault zones, especially in the Iraqi Western and Southern deserts where no surface folds occur apart from Anah anticline and other not well-known folds, like Akaz and Samawa anticlines. It is worth mentioning that Abdulnaby (2018) considered the Neotectonic activities in his study which deals with the structural geology and Neotectonics of Iraq. However, he again considered the two main divisions: Stable and Unstable and he mentioned that Neotectonic activities cannot be seen in the Inner Platform (Stable part of Iraq). Al-Bana and Ali (2018) presented a study which deals with the Abu Jir Fault Zone and represents the contact between the two main tectonic divisions in Iraq and they mentioned again as stable and unstable parts.

2. Materials And Methods

To fulfill the main aim of the current study, the following materials were used,

- The existing tectonic and geological maps of different scales.
- Satellite images of different resolutions.
- Tens of published articles and books which deal with the core of the current study.
- Filed data, as achieved for long period of geologic investigation at different parts of Iraq.

As it is mentioned by all the aforementioned authors that the Arabian and Iranian plates are colliding, accordingly, the exerted forces have developed the tectonic framework of the Iraqi territory. Moreover, all previous researchers have mentioned that the compressional forces are decreasing south westwards from the collision boundary between the two plates. This assumption is quite true, however, among the whole Iraqi territory, there is no part which lacks tectonic deformation, not necessarily to be in form of surface folds as it is the case in the so called “unstable” parts of Iraqi territory.

Tens of tectonic and geological maps, published articles, and satellite images are reviewed and interpreted to recognize indications for active tectonic features, especially Neotectonic activities emphasizing on the Western and Southern deserts which are included by all the previously mentioned researchers within the tectonically stable parts of Iraq. Since the current terrain and geomorphic forms are developed during Pleistocene and onward, therefore, all the recognized abnormal geomorphic and tectonic features mean Neotectonic activities (e.g. Obruchev, 1948, Markovic et al., 1996, Kumanan, 2001).

3. Tectonic Framework Of Iraq

Buday and Jasim, (1987), Al-Kadhimi et al. (1996), Numan (1997), Jassim and Goff (2006), Aqrawi et al. (2010), Fouad (2015), Sissakian (2013), Sissakian and Fouad (2015) have presented tectonic and geological maps and relevant articles which deal with the tectonic framework of Iraq (Figure 2). They all studied the tectonic framework of Iraq and different tectonic maps are presented by different authors. All those authors have agreed upon the main tectonic framework of Iraq, being a part of the extreme north-eastern margin of the Arabian Plate, which is in collision with the Iranian (Eurasian) Plate (e.g. Alavi, 2004, Fouad, 2015). However, different authors have used different terminologies to different tectonic units, nevertheless, they all agreed about existing of two main parts: Stable Shelf (Inner Platform) and Unstable Shelf (Outer Platform). But the tectonic contacts between those two main parts is quite different (Figure 2). In the current study, the Tectonic Map of Iraq (Fouad, 2015) (Figure 2 D) with slight modification in the contact between stable and unstable parts is adopted because the presented tectonic units are more applicable when compared with the tectonic framework of Iraq. However, the most recently published tectonic map of Iraq (Fouad, 2015) although doesn't show Stable and Unstable shelves, as all other previously published maps, but still in its concept clearly show tectonically stable and unstable parts.

4. Indications For Tectonic Disturbances

The tectonically stable parts of Iraq (Buday and Jasim, 1987, Al-Kadhimi et al., 1996, Numan, 1997, Jassim and Goff, 2006, Aqrawi et al., 2010, Sissakian, 2013, Fouad, 2015, Sissakian and Fouad, 2015) which include the Western and Southern deserts are focused to deuce any tectonic disturbance. The disturbances are in form of: 1) surface folds, 2) subsurface folds, 3) active faults, 4) dislocated valleys, 5) dislocated terraces, 6) right-angle meandering of valleys, 7) Knickpoints oriented along parallel lineaments, 8) karst forms oriented along parallel lineaments. Some of the recognized indications for active tectonics are presented hereinafter.

4.1 Surface folds

The following anticlines are located in the Iraq Western Desert which is considered by all previous researchers to be tectonically stable.

4.1.1. Anah anticline

Anah anticline is a double plunging anticline trending ENE – WSW about 95 km long and about 5 km wide (Figure 3), it has a monoclinal form, since the southern limb is very gentle (~ 4●) whereas the northern limb attains 43● (Fouad, 2006 and 2015). The anticline is located in the northern part of the so-called Stable Shelf or Inner Platform. The anticline includes many geomorphological and structural indications that it is still active and exhibiting lateral growth (Sissakian et al., 2016 and 2021).

4.1.2. Akash and Al-Man'ia anticlines

These are two surface anticlines as deduced from the mapping of the concerned area (Al-Jumaily, 1974, In Sissakian and Mohammed, 2007). We will call the two anticlines as Akash and Al-Man'ia referring to the two main valleys which run along the axes of the two anticlines. The double closures of the rocks of the Euphrates Formation in both valleys is a good indication for the presence of the two anticlines (Figure 3). The detailed unpublished geological maps at scale of 1:25000 (Archive of Iraq Geological Survey, Baghdad) show more details about the presence of both anticlines.

4.2 Subsurface folds

The following anticlines are located in the Iraq Western and Southern desertt which are considered by all previous researchers to be tectonically stable.

4.2.1. Akaz (Akkas) anticline

Akaz anticline is a subsurface double plunging anticline located in the Stable Shelf or the Inner Plat Form, Western Desert Subzone (Fouad, 2015). Geographically, it is located south of Anah anticline and is proved to be a gas field (Figure 4). Although it is located in Wadi Al-Ratgah, but it is called Akaz (Akkas) referring to one of the main valleys in the extreme northwestern part of the Western Desert (Figure 3).

4.2.2. Al-Samawa anticlines

This is a subsurface anticline also located in the Stable Shelf or Inner Plat Form, Southern Desert Subzone (Fouad, 2015). Geographically, it is located south of the Euphrates River and SW of Samawa city about 50 km (Figure 4).

4.2.3. Diwan anticline

This is a subsurface anticline also located in the Stable Shelf or Inner Plat Form, Southern Desert Subzone (Fouad, 2015). Geographically, it is located south of the Euphrates River and SE of Samawa city about 70 km (Figure 4).

4.2.4. Salman anticline

This is a subsurface anticline also located in the Stable Shelf or Inner Plat Form, Southern Desert Subzone (Fouad, 2015). Geographically, it is located south of the Euphrates River and south of Samawa city about 100 km (Figure 4).

4.2.5. Abu Khaima anticline

This is a subsurface anticline also located in the Stable Shelf or Inner Plat Form, Southern Desert Subzone (Fouad, 2015). Geographically, it is located south of the Euphrates River and SE of Samawa city about 140 km near Iraqi – Kuwaiti International boundaries (Figure 4).

4.3 Dissected Quaternary sediments

Al-Batin alluvial fan is one of the largest alluvial fans in Iraq with four stages (Figure 5). The feeder channel is wadi (valley) Al-Batin which forms part of the Iraqi – Kuwaiti International borders. To the west of the fan, the Quaternary sediments are dissected by a long fault (Figure 5, A – B) which trends NNE – SSW. The left side of the fault is the downthrown block indicating a normal fault, as it is clear from the gradient map, with measured downthrown amount to be about 5 m. Moreover, there is a horizontal displacement too, as indicated from the shift of the gradient intervals (Figure 5, near point A). The horizontal shift is estimated to be about 20 km. There are also many NW – SE trending lineaments developed in the Quaternary sediments and rocks of the Dibdibba Formation (Pliocene – Pleistocene), they are also dissected by the fault with horizontal displacement of about (2 – 3) km. The dissected lineaments also are indication for Neotectonic activity.

4.4 Tectonically controlled and dissected valleys and cliffs

In the Iraqi Western Desert, along the Iraqi – Syrian – Jordanian International borders, where tens of valleys are tectonically controlled in NW – SE and ENE – SSW trends and are locally dissected (Figure 6). West of the longitude 39●18' (Figure 6), the valleys exhibit different shapes and trends. A lineament (A – B in Figure 6) dissects the valleys which flow in SE – NW direction (A_1 – A_2 – A_3 in Figure 6). Another lineament (C – D – E in Figure 6) dissects many valleys and even change their shapes (C_1 – C_2 and C_1 – D_1 in Figure 6). A set of shallow depressions are oriented in NW – SE trend (F – G in Figure 6) indicating that they are tectonically controlled. East of longitude 39●18', the valleys are flowing in SW – NE direction (H – I in Figure 6) and are dissected by a lineament (I – J in Figure 6) which trends NE – SW. These abnormal valleys and shallow depressions, which are dissected by a set of lineaments are good indication for tectonic unrest and good indications for Neotectonic movements, not only in Iraq but even in Syria and Jordan (Figure 6) indicating regional tectonic activities. Moreover, one of the large shallow depressions near Al-Waleed border point (Figure 6) includes very thick (more than 196 m, as the deepest borehole was drilled by Al-Bdaiwi et al., 2005, In Sissakian, 2007) sediments which include different igneous rocks which are derived from the basaltic flows in Syria. This indicates that the depression is still active, otherwise, how to have such thick Quaternary sediments filled in the depression. Moreover, the topography was opposite which is nowadays, otherwise, how to receive sediments from Syria towards Iraq when the nowadays topography is sloping towards west and northwest (Sissakian, 2007).

It is worth mentioning that all the shallow depressions in Al-Waleed vicinity are structurally controlled and their shapes are not circular or oval, but at least two edges are almost straight parallel to the main lineaments in the area which is NW – SE.

Other example for tectonic disturbances in the Iraqi Western Desert, along the Iraqi – Syrian – Jordanian – Saudi Arabian International borders, where tens of valleys and cliffs are tectonically controlled in NW – SE and NE – SW trends and are locally dissected (Figure 7). Towards north, west and south of Umm Chaimin crater (Figure 7), the valleys are controlled by large lineaments and locally dissected forming cross-shaped valleys which flow in SE – NW and SW – NE directions. Towards northeast, east and southeast of Umm Chaimin crater, the cliffs and valleys are controlled by large lineaments in NE – SW trend which are dissected by NW – SE lineaments (Figure 7).

Another example for tectonic disturbances in the central part of the Iraqi Western Desert, where tens of valleys and cliffs are tectonically controlled in NW – SE trend and are locally dissected (points A to H in Fig. 8). Towards north, west and southeast of Faidhat (Depression) Talha (Figure 8), the valleys are controlled by large faults (Sissakian and Fouad, 2015) and locally dissected. Faidhat Tlaiha is a large karst depression with diameter of about 4 km filled by Sabkha sediment (Sissakian and Fouad, 2015). Since it is a karst depression, then the shape should be a circular or oval. However, the shape is neither circular nor oval, this is attributed to the active tectonic lineaments which surround the depression, therefore, some edges are almost straight lines rather than circular or curved (Figure 8). This is another indication for the tectonic activity in the central part of the Iraqi Western Desert.

5. Results

From the presented data (as examples shown in Figures. 3 – 8) which indicate Neotectonic activities in the Iraqi Western and Southern deserts, it is very clear that both deserts are tectonically not stable. All the previous reserachers have considered the whole are to be “stable”, although different terms were used to refer for the tectonic stability.

6. Discussion

The Iraqi territory id divided tectonically into two main units: Stable and unstable by all the existing tectonic maps, geological maps and other relevant published scientific articles (e.g. Dunnington, 1958, Buday and Jassim, 1987, Jassim et al., 1990, Al-Khadhimi et al., 1996, Numan, 1997, Jassim and Goff, 2006, Fouad, 2015, Aqrawi et al., 2010, Sissakian, 2013, Sissakian and Fouad, 2015). The mentioned researchers have used the nine mentioned factors as basic data in initiating their tectonic units. However, many contradictions occur in the used factors and the created classifications of the tectonic units by different authors. The recognized contradictions are discussed hereinafter:

6.1 Al-Jazira subzone

This subzone is considered by Fouad (2015) to be part of the Mesopotamia Foredeep and accordingly is unstable tectonic unit (Figure 2). Buday and Jassim (1987) and Al-Kadhimi et al. (1996) also considered the unit to be unstable although they used different names (Figure 2). Whereas Jassim and Goff (2006) considered the unit to be stable (Figure 2). This unit is characterized by: **1)** Lack of any fold on the surface, **2)** the oldest exposed rocks are of Lower Miocene age, and **3)** the topography is a gently rolling plain. These three factors do not coincide with those factors which exist in the unstable units, such as the Low Folded Zone, High Folded Zone.

6.2 Basrah subzone

This subzone is considered by Fouad (2015) to be part of the Mesopotamia Foredeep and accordingly is unstable tectonic unit (Figure 2). Buday and Jassim (1987) and Al-Kadhimi et al. (1996) also considered the unit to be unstable although they used different names (Figure 2). Whereas Jassim and Goff (2006) considered the unit to be stable because there are no surface folds (Figure 2). This unit is characterized by: **1)** lack of any fold on the surface, **2)** presence of tens of subsurface folds, **3)** the oldest exposed sediments are of Quaternary age, and **4)** the topography is a gently rolling plain. These four factors do not coincide with those factors which exist in the unstable units, such as the Low Folded Zone, High Folded Zone.

6.3 Low folded zone

This zone is considered by Fouad (2015) to be part of the Western Zagros Fold – Thrust Belt within the Outer Platform and accordingly is unstable tectonic unit (Figure 2). Buday and Jassim (1987) and Al-Kadhimi et al. (1996) also considered the unit to be unstable although they used different names (Figure 2). Whereas Jassim and Goff (2006) considered the unit to be stable because there are no surface folds (Figure 2). The southern parts of his unit include two major anticlines called Sinjar and Qara Chough, both anticlines are characterized by:1) exposure of Cretaceous rocks in their cores, and 2) very high topography which attains about 1425 m and 814 m in Sinjar and Qara Chough folds, respectively. These two factors do not coincide with those factors which exist in the other parts of the Low Folded Zone.

6.4 Inner platform

This unit is considered by Fouad (2015) to be stable tectonically (Figure 2). Buday and Jassim (1987), Al-Kadhimi et al. (1996), Jassim and Goff (2006) and all other researchers considered this unit to be stable tectonically and have used “Unstable Shelf” (Figure 2).This unit is characterized by: 1) Presence of surface folds (Figure 3, Anah, Akash and Al-Ma’niyah anticlines), 2) Presence of subsurface anticlines (Figure 4**,** Akaz, Al-Samawa, Dewan, Al-Salman and Abu Khaima anticlines), 3) Presence of active faults which have dissected Quaternary sediments (Figure 5, Al-Batin Alluvial Fan), 4) presence of active lineaments which have controlled and/ or dissected valleys and cliffs (Figures. 6, 7 and 8). These four

factors are present in the Inner Platform (Fouad, 2015) or the Unstable Shelf (Buday and Jassim, 1987, Al-Kadhimi et al., 1997, and Jassim and Goff, 2006) including the Low Folded Zone, Al-Jazira Subzone and Basrah Subzone (Figure 2).

7. Conclusions

From the presented data concerning tectonic disturbances such as surface and subsurface anticlines, dissected alluvial fans, dissected valleys, and cliffs in the tectonically stable parts, it is clear that all tectonic units in the Iraqi territory are unstable. Therefore, the whole Iraqi territory is tectonically unstable.

Declarations

Authorship contribution statement

Varoujan Sissakian: Writing the original first draft, conceptualization, and field investigations. **Dr. Nadhir Al-Ansari** and **Dr. Jan Laue**: Reviewing, editing and conceptualization of the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

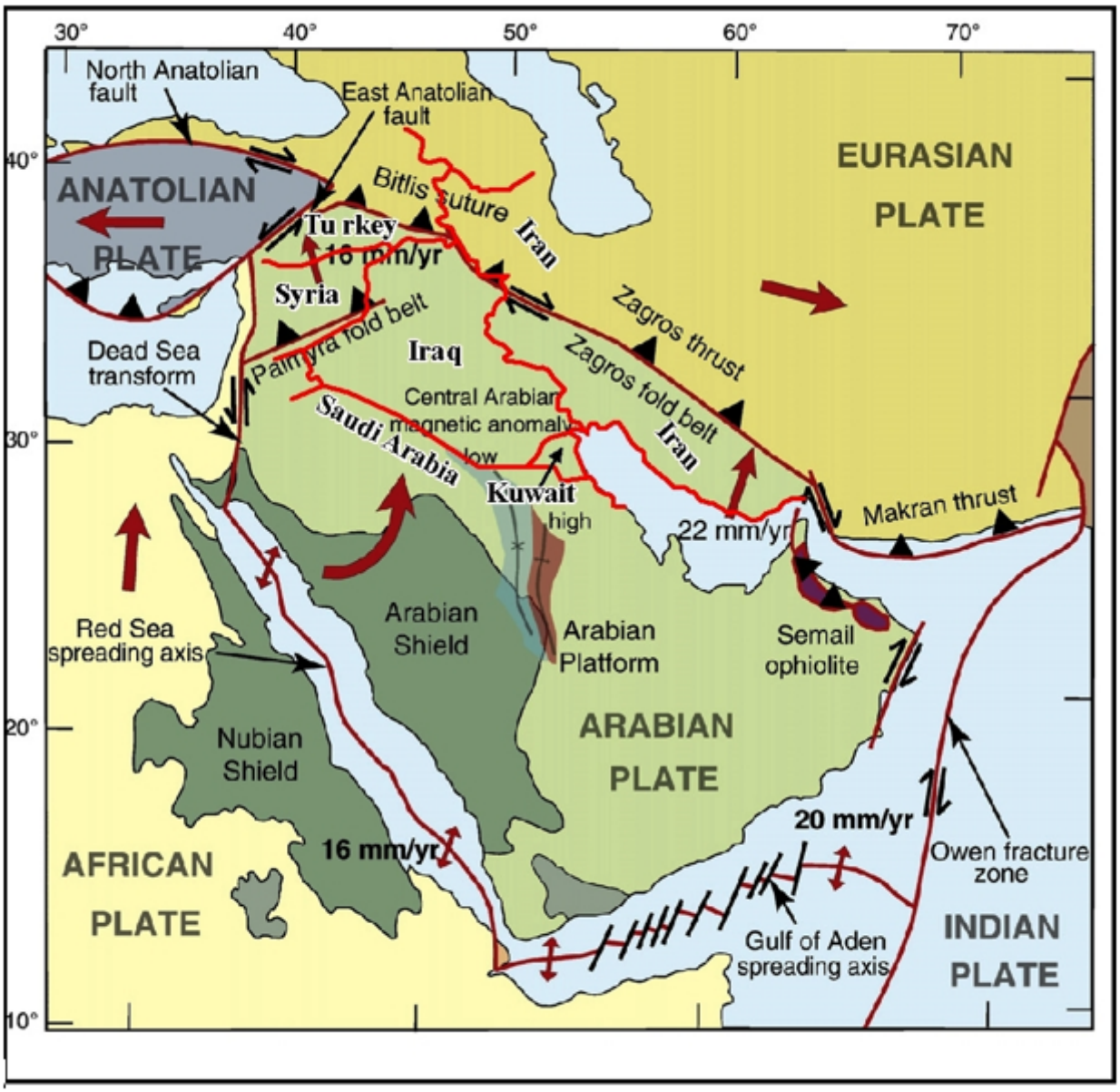

Figure 1

Tectonic Map of Saudi Arabia and surroundings (after Johnson, 1998).

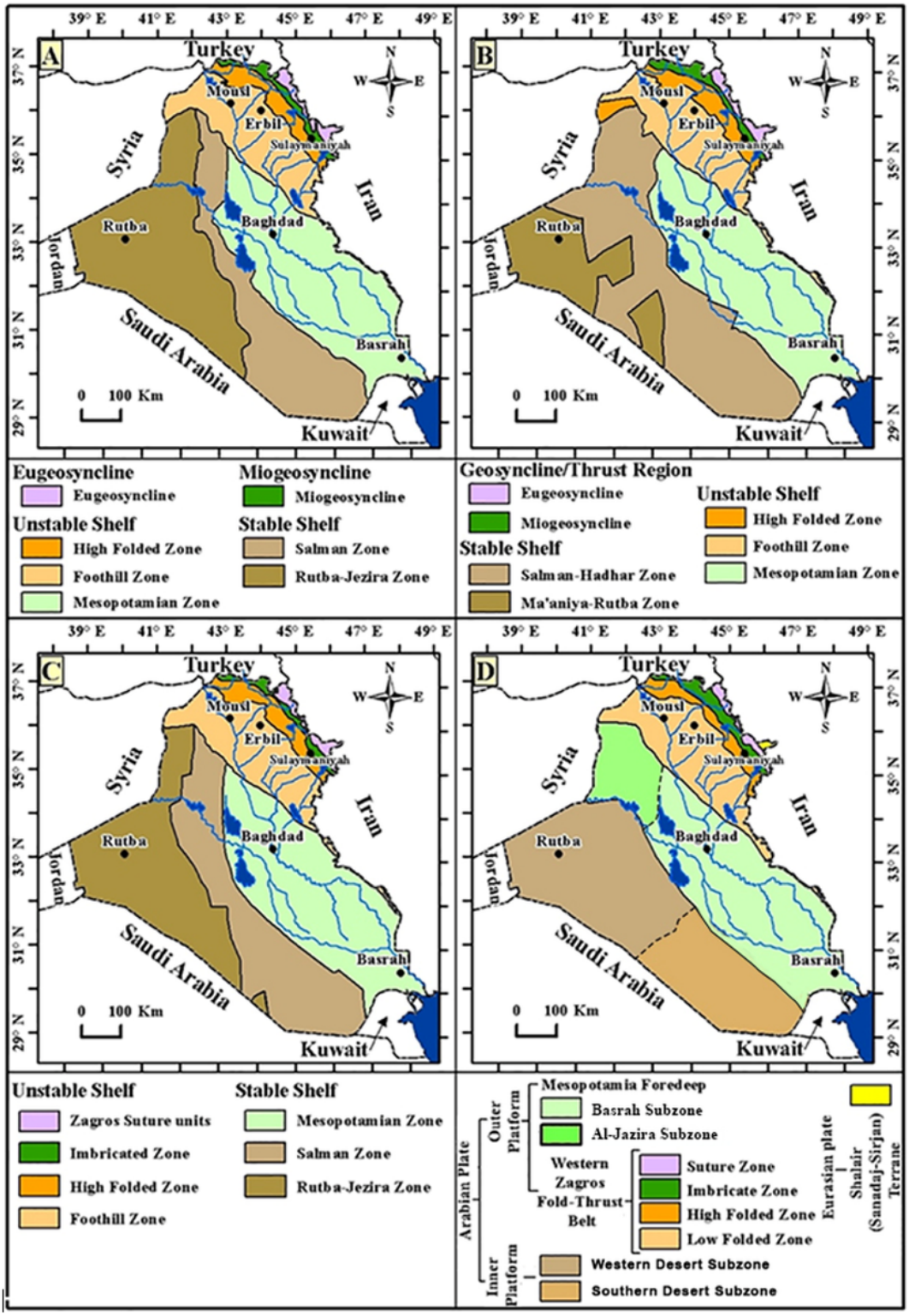

Figure 2

Main tectonic division zones of Iraq, **A)** after Buday and Jassim (1984 and 1987), **B)** after Al-Kadhimi *et al*. (1996), **C)** after Jassim and Goff (2006), and **D)** Modified from Fouad (2008 and 2012) (Modified from Sissakian et al., 2017).

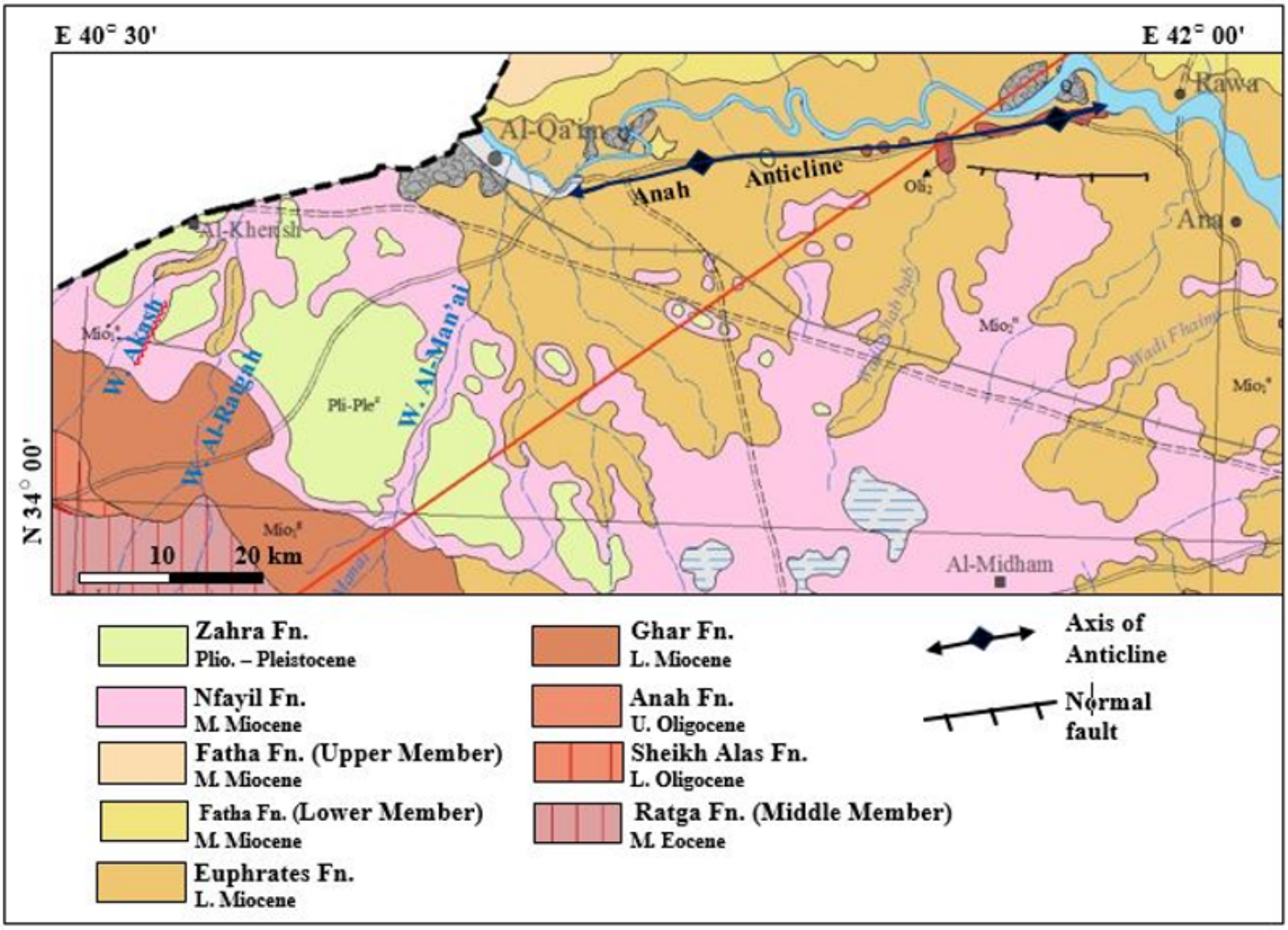

Figure 3

Geological map of Anah anticline and surrounding area. Notethe double closure of the Euphrate Formation in Wadi Akash and Wadi Al-Ratgah in the extreme western part of the map (After Sissakian and Fouad, 2015).

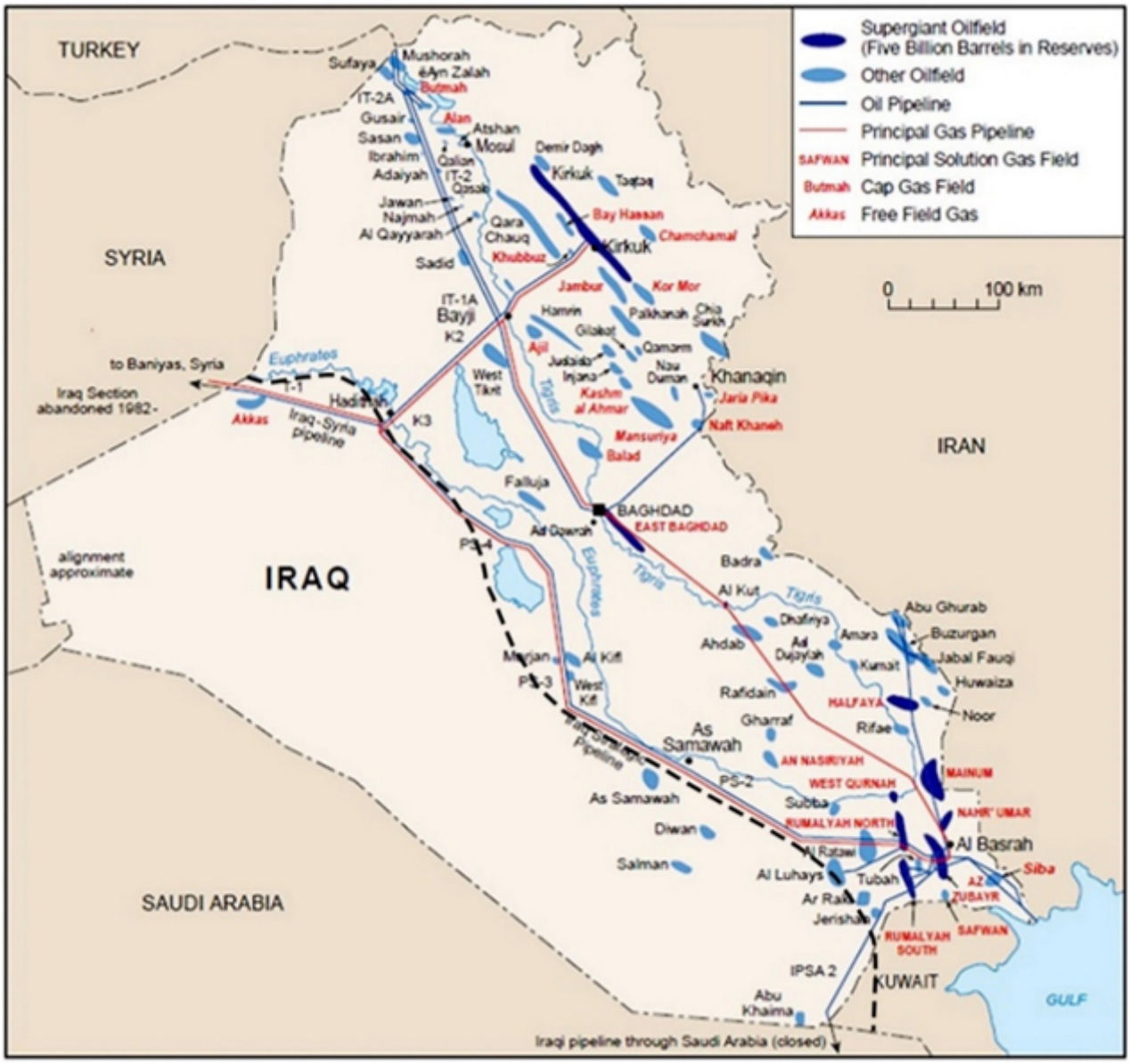

Figure 4

Oil fields map of Iraq (Internet data). Note the subsurface oil fields located in the so called “Stable Shelf” southeast of the contact between the

Stable and Unstable shelves (the dashed black line)

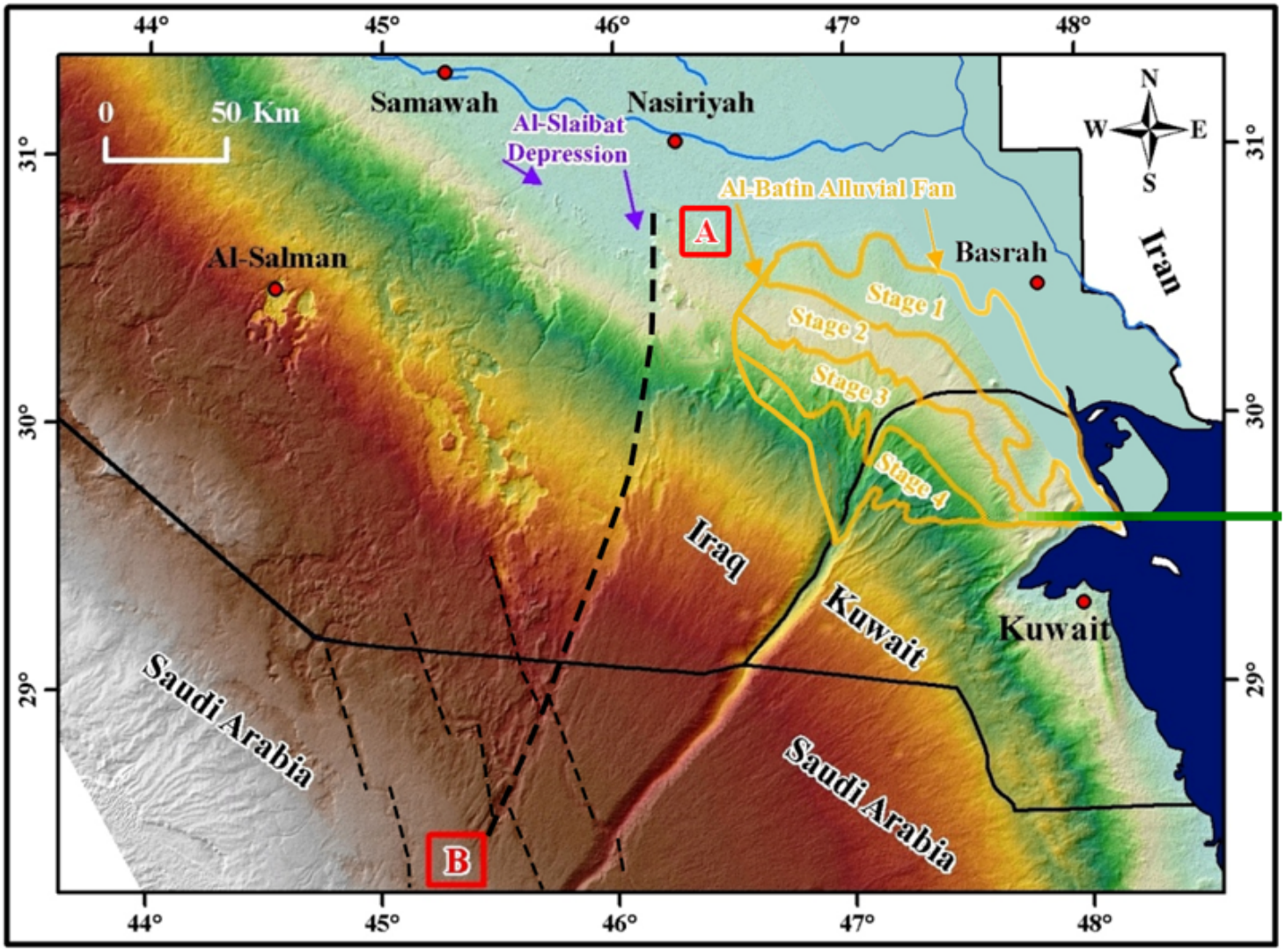

Figure 5

Gradient map of the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) 7.5 arc-second spatial resolutions, showing the fault (A – B) and

the four stages of Al-Batin alluvial fan (Modified from Sissakian *et al*., 2014)

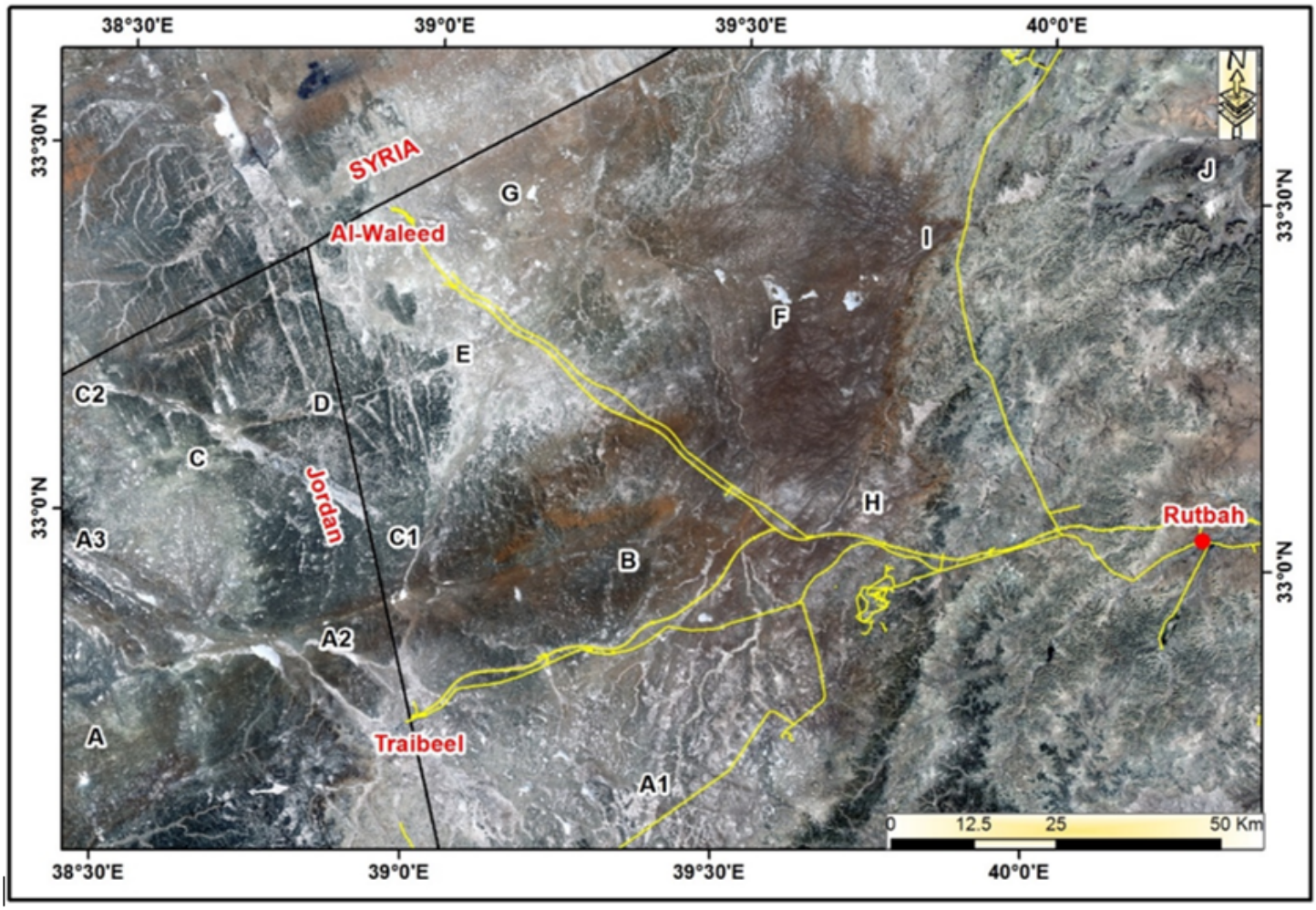

Figure 6

Satellite image west of Rutbah town showing tectonically controlled valleys with SE – NW and SW – NE running directions and shallow depressions.

Note the dissection of the valleys by lineaments of NE – SW trend.

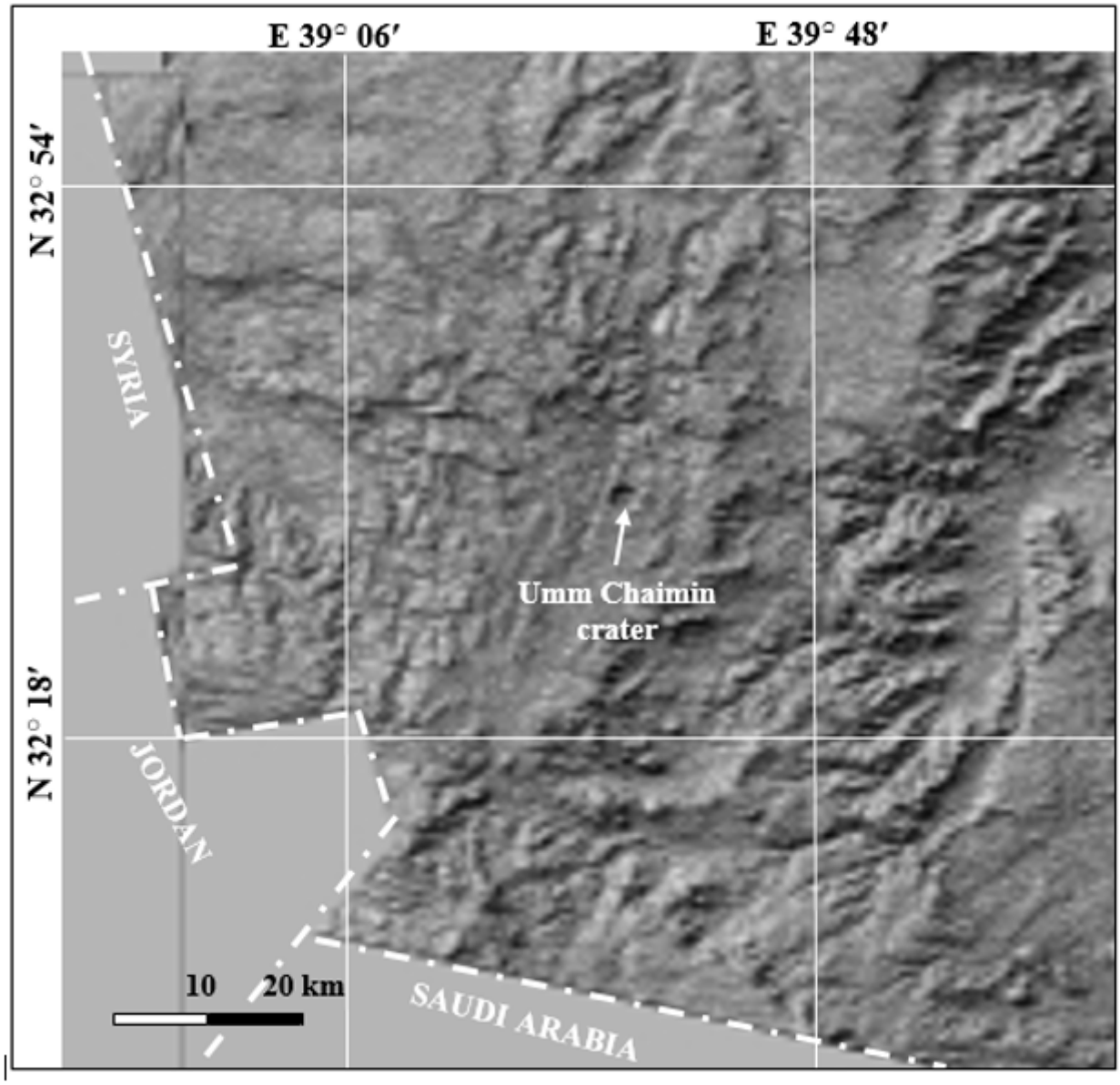

Figure 7

DEM image showing tectonically controlled and oriented valleys and cliffs indicating Neotectonic activities

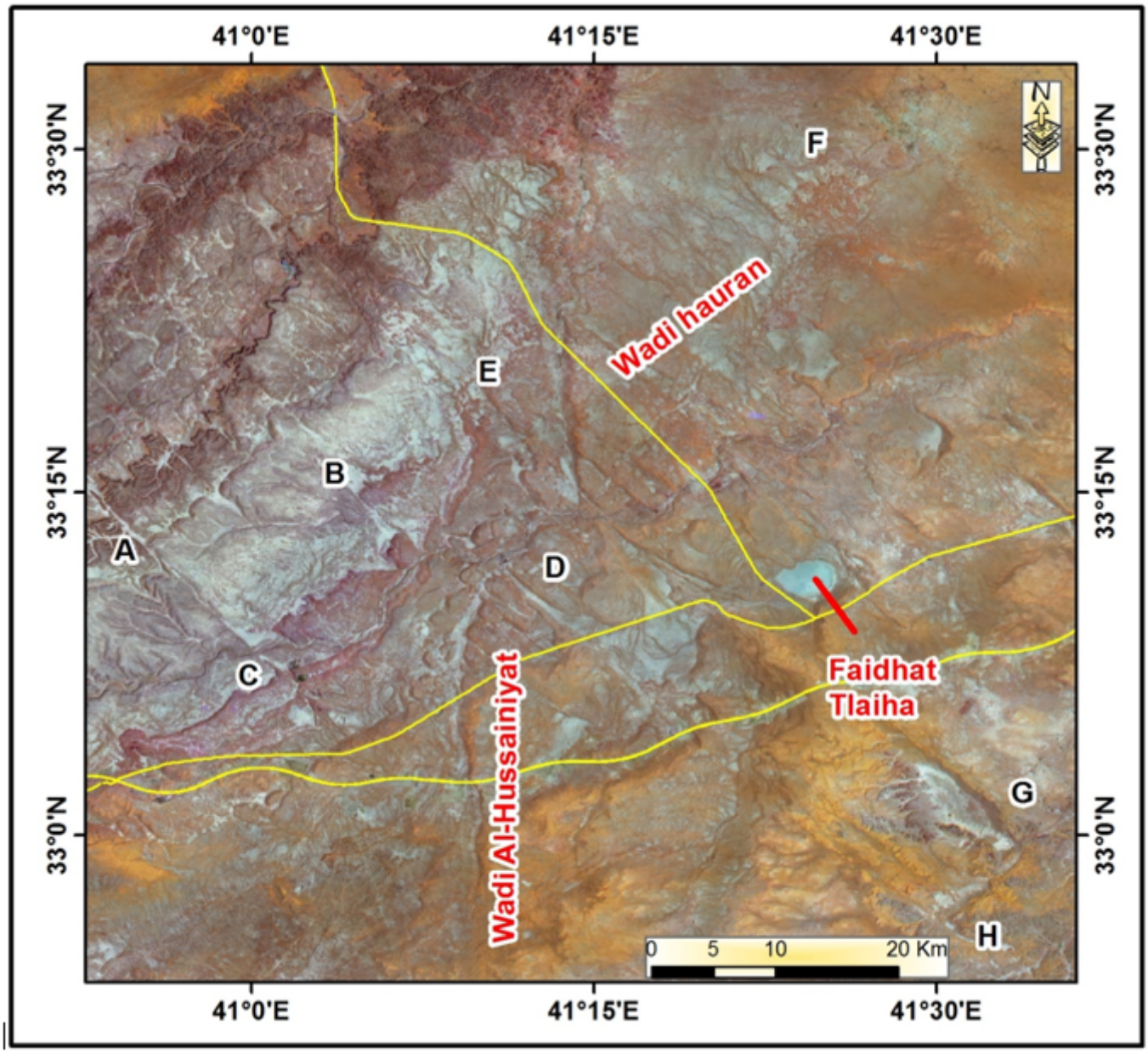

Figure 8

Satellite image (east of Rutbah town) showing dissected valleys and cliffs. Some of the dissected locations are encircled in red with letters.