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NEOTECTONIC MOVEMENTS IN WEST OF IRAQ

Varoujan K. Sissakian[*] and Duraid B. Deikran[**]

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ABSRTACT

The contact between the uplifted and subsided areas that represents the Neotectonic movements, which are presented by mean of contours, in West of Iraq, are revised and reconstructed. The contours, previously, were constructed depending on the contact between Fat'ha and Injana formations, which represents the last sea level during the Middle Miocene. The contours, in West of Iraq, are reconstructed depending on the top of the Nfayil Formation that is the equivalent of the Fat'ha Formation.

Previously, the contours, in the extreme western parts of Iraq, where the Injana Formation is not exposed, were constructed depending on the bottom of the Zahra Formation. In this study, these contours are canceled, because the Zahra Formation is proved to be of Pliocene – Pleistocene age, therefore it is younger than the considered contact. The re-constructed contours, which are hypothetical, have different values, shapes and extensions, as compared to the previously constructed contours. The calculated rate of uplifting has changed too, depending on the values of the re-constructed contours.

Many features indicating Neotectonic movements were recognized. Majority of them are related to active faults, dislocated drainage system and their control. These are indicated mainly using remote sensing techniques.

الحركات البنيوية الحديثة في غرب العراق

فاروجان خاجيك سيساكيان و دريد بهجت ديكران

المستخلص

إن الحد الفاصل بين المناطق المرتفعة والهابطة للحركات البنيوية الحديثة في مناطق غرب العراق قد تم دراستها وتحديثها. وان الحد الفاصل والخطوط الكنتورية الممثلة للمناطق المرتفعة اعتُمدت على الحد الفاصل بين تكويني الفتحة وانجانة والذي يمثل مستوى البحر في المايوسين الأوسط. وان هذا الحد والخطوط الكنتورية الممثلة للمناطق المرتفعة، في غرب العراق قد تم توليفها من جديد اعتمادا على تكوين النفايل والذي هو مكافئ لتكوين الفتحة.

إن الخطوط الكنتورية الممثلة للمناطق المرتفعة، في غرب العراق، حيث لا يتكشف تكوين انجانة، كان قد اعتمد على ارتفاع قاعدة تكوين الزهرة. في هذه الدراسة، ألغيَ هذا الحد والخطوط الكنتورية المعتمدة على قاعدة تكوين الزهرة لان تكوين زهرة قد اثبت كونه من عمر البلايوسين – البلايستوسين، وهذا يعني لا يمكن اعتماد تكوين الزهرة لأنه احدث من عمر الحد الفاصل. إن الخطوط الكنتورية المولفة في هذه الدراسة لها قيم وشكل وامتداد جديد يختلف عن الخطوط الكنتورية السابقة. كما ان معدل الارتفاع قد تغير أيضاً واعتماداً على قيم الخطوط الكنتورية الجديدة الممثلة للمناطق المرتفعة.

تم تحديد عدة ظواهر خاصة للحركات البنيوية الحديثة. وان معظم هذه الظواهر تتعلق بالفوالق النشطة ونظام التصريف وحيود الوديان من مساراتها الأولية. ومعظم هذه الظواهر استنبطت باستخدام تقنيات التحسس النائي.

[*] Expert, State Company of Geological Survey and Mining, P.O. Box 986, Alwiya, Baghdad
e-mail:varoujan49@yahoo.com
[**] Kirkuk University, College of Sciences

INTRODUCTION

The Neotectonic Map of Iraq, scale 1: 1000 000 (Sissakian and Deikran, 1998) depends on the concept of Obruchev (1948). The main concept is to consider the last sea level during the Middle Miocene as the zero line and to define the uplifted and subsided areas, by means of contour lines, as related to the Middle Miocene sea level, because Middle Miocene is accepted by many researchers to be the beginning of the Neotectonic movements (Becker, 1993 and Markovic *et al.*, 1993). This is known from the present location of the contact between Fat'ha and Injana formations (will be referred as the **Target**, hereinafter). The two formations represent the change from the last marine phase to continental phase, in Iraq and near surroundings. Therefore, the zero line represents the Miocene sea level. The positive values represent the relatively elevated areas, whilst the negative values represent the relatively subsided ones, in the Neotectonic Map of Iraq (Fig.1) (Sissakian and Deikran, 1998). The map was constructed by using the locations and relative heights of the **Target**, depending either on outcrops or oil and water wells data; above or below sea level. Occasionally, geological cross sections were constructed from geological maps to indicate the location and height of the **Target**.

NEOTECTONICS

The Neotectonic, which is attributed to Obruchev (1948), indicates the recent movements, occurred in the Late Neogene and Quaternary. Since then, no essential changes were introduced to amend the meaning of the term "Neotectonic" although some authors have used the synonym term of "active tectonics", while others considered the start of the Neotectonic from the Middle Miocene (Pavlides, 1989; Becker, 1993; Markovic *et al.*, 1996 and Cloetingh *et al.*, 2002). However, there has been a disagreement as to how far back in time "geologically recent" is, with the common meaning being that Neotectonic is the youngest, not yet finished stage in Earth tectonics. A general agreement has been emerging that the actual time frame may be individual from each geological environment and it must be set back in time sufficiently far to fully understand the current tectonic activity (Koster, 2005). Pavlides (1989), however, suggested, "Neotectonic is the study of young tectonic events, which have occurred or are still occurring in a given region after its orogeny or after its last significant tectonic set-up"

In Iraq, the Neotectonic concept was used for the first time by Atomenergoexport (1985) considering the contact between ex-Lower Fars and ex-Upper Fars formations (currently, Fat'ha and Injana formations, respectively); consequently, the Neotectonic and Seismotectonic maps of Iraq were compiled. The selection of the **Target** was done successively, because it represents the change from the last marine phase (Middle Miocene) to continental phase (Late Miocene), in large parts of the Iraqi territory, although in the majority of the western, extreme northern and northeastern parts the non-depositional phase was prevailing. However, Early Miocene sediments cover considerable parts of the Western Desert; part of these sediments is of continental origin, represented by the Ghar Formation that is deposited by fresh water rivers and deltas. In some parts it is interfingering with its age wise equivalent the Euphrates Formation (Early Miocene). These were followed by Nfayil Formation, in the majority of the western parts of Iraq. It is the last marine formation and the equivalent of the Fat'ha Formation, which has very limited extensions in West Iraq. The uppermost part of the Nfayil Formation, the Clastic Member, shows clear transition sediments from marine to continental environment (Sissakin *et al*., 1997) that is the same case between Fat'ha and Injana formations. Therefore, the upper part of Nfayil Formation is the best equivalent for the involved **Target** and is considered, in this study for the beginning of the Neotectonic movements in West Iraq.

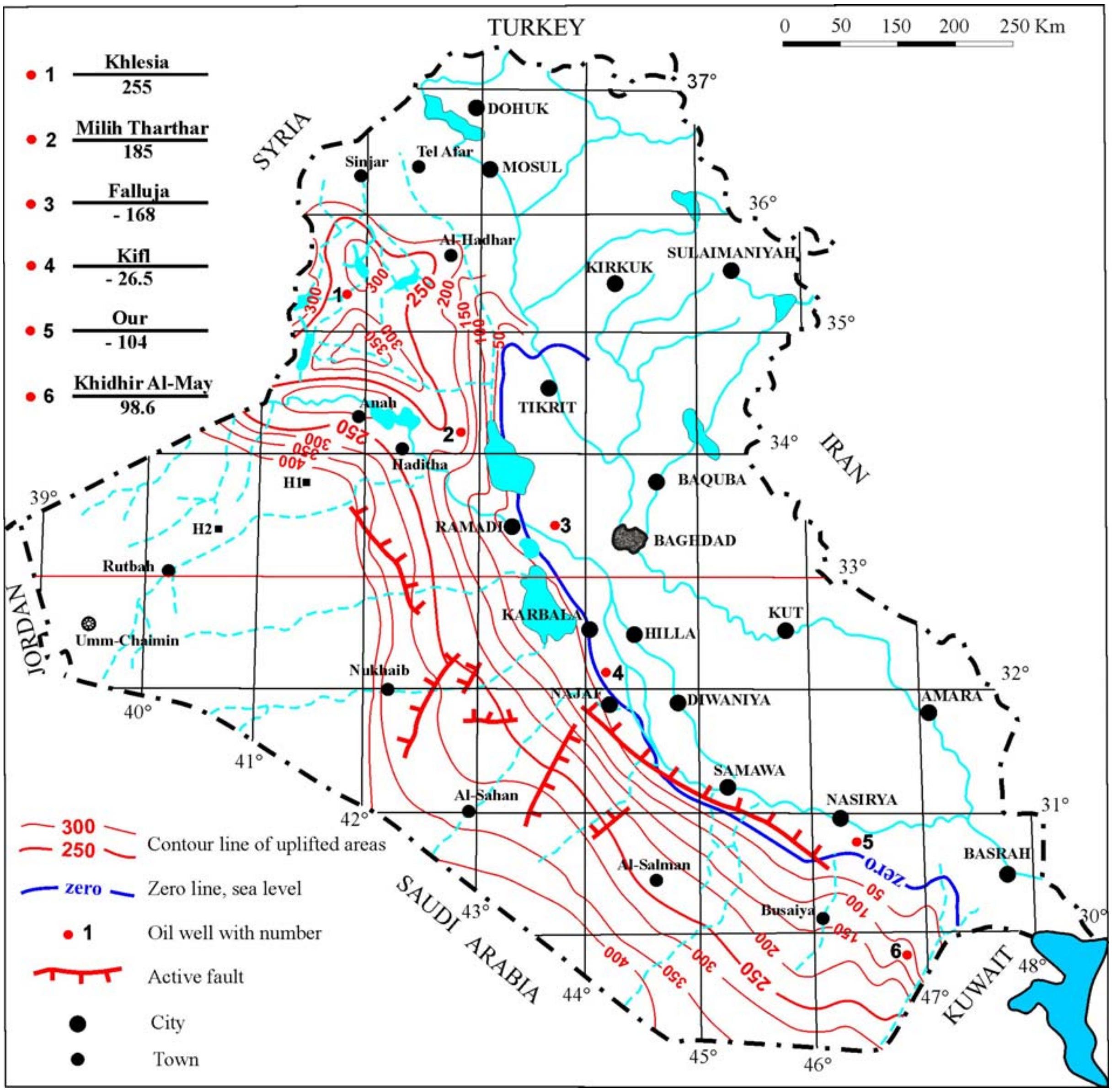

Fig.1: Neotectonic Map of Iraq, the concerned part only
(after Sissakian and Deikran, 1998)

THE NEW CONCEPT

The new revised and reconstructed **Target** between the uplifted and subsided areas, in West Iraq, depends on the same idea followed by Sissakian and Deikran (1998). But, instead of using the contact between Fat'ha and Injana formations, in areas where the Fat'ha Formation is not exposed, the contact between Nfayil and Injana formations is considered. Because the recently announced Nfayil Formation (Middle Miocene) is found to be the equivalent of the Fat'ha Formation (Sissakian *et al*., 1997) and clear interfingering was found in the field between the two formations (Hassan *et al.*, 2000, 2002 and 2004). Moreover, the extensions of the Nfayil Formation over the exposed areas, in western part of Iraq, are clearly indicated by Sissakian (2000).

In areas where the base of the Zahra Formation was used by Sissakian and Deikran (1998) in construction of the contours, instead of the contact between Fat'ha or Nfayil Formation with the Injana Formation, in such areas, the constructed contours are either deleted or reconstructed. The Zahra Formation, which was considered as the best equivalent to the Injana Formation and was used to define the uplifted areas for the Neotectonic movements, in West Iraq, by Sissakian and Deikran (1998) is found to be of Pliocene – Pleistocene age (Salman, 1993). This means that the base of the Zahra Formation cannot be considered for construction of the contours, because it is deposited after the beginning of the Neotectonic movements (according to the concept of the present study), which is defined as Middle – Late Miocene, in Iraq and the age of the Zahra Formation is Pliocene – Pleistocene, this means a difference of about 5 Ma years (ICS, 2008) from the age of the considered Neotectonic movements. This difference will also affect on the calculated rate of uplifting and subsiding by Sissakian and Deikran (1998) for the Neotectonic activities in the western parts of Iraq. Therefore, the assumption of considering the base of the Zahra Formation in construction of the contours is cancelled.

In extreme western parts of the exposure areas of Euphrates Formation, Al-Mubarak and Amin (1983) described the uppermost parts of the Euphrates formation as "red claystones and siltstones with subordinate thin limestone horizons, which locally are underlain by green marls and limestones, rich in oysters". It is worth mentioning that the described succession is not a normal succession of Euphrates Formation; it is more common to Nfayil Formation, especially the uppermost part. Unfortunately, no paleontological evidence is available to prove the age of this succession, except the presence of the oysters that are very common in Nfayil Formation. This succession, however, is considered in this study as the uppermost part of the Nfayil Formation in construction of the contours, instead of the base of the Zahra Formation, in areas where Sissakian and Deikran (1998) used the latter in the construction of the contours.

METHODOLOGY

Although there are many methods for indicating Neotectonic movements and construction of Neotectonic maps, like the "energy analysis method" and "analysis of difference between the present and theoretical model of its development" (Markovic *et al.*, 1996) and "using lineaments and tectano-geomorphic anomalies deduced from remote sensing data" (Kumanan, 2001), but the present authors preferred to use the same method, which depends on the elevation and/ or the depth of the **Target** (contact between Middle and Late Miocene rocks) from the present topography (above the sea level), which is the same concept of Obruchev (1948) and adopted by Atomenergoexport (1985), and is confirmed by Pavlides (1989); Markovic *et al.* (1996) and Koster (2005). The data is represented by means of contour lines; consequently the Neotectonic map is reconstructed (Fig.2).

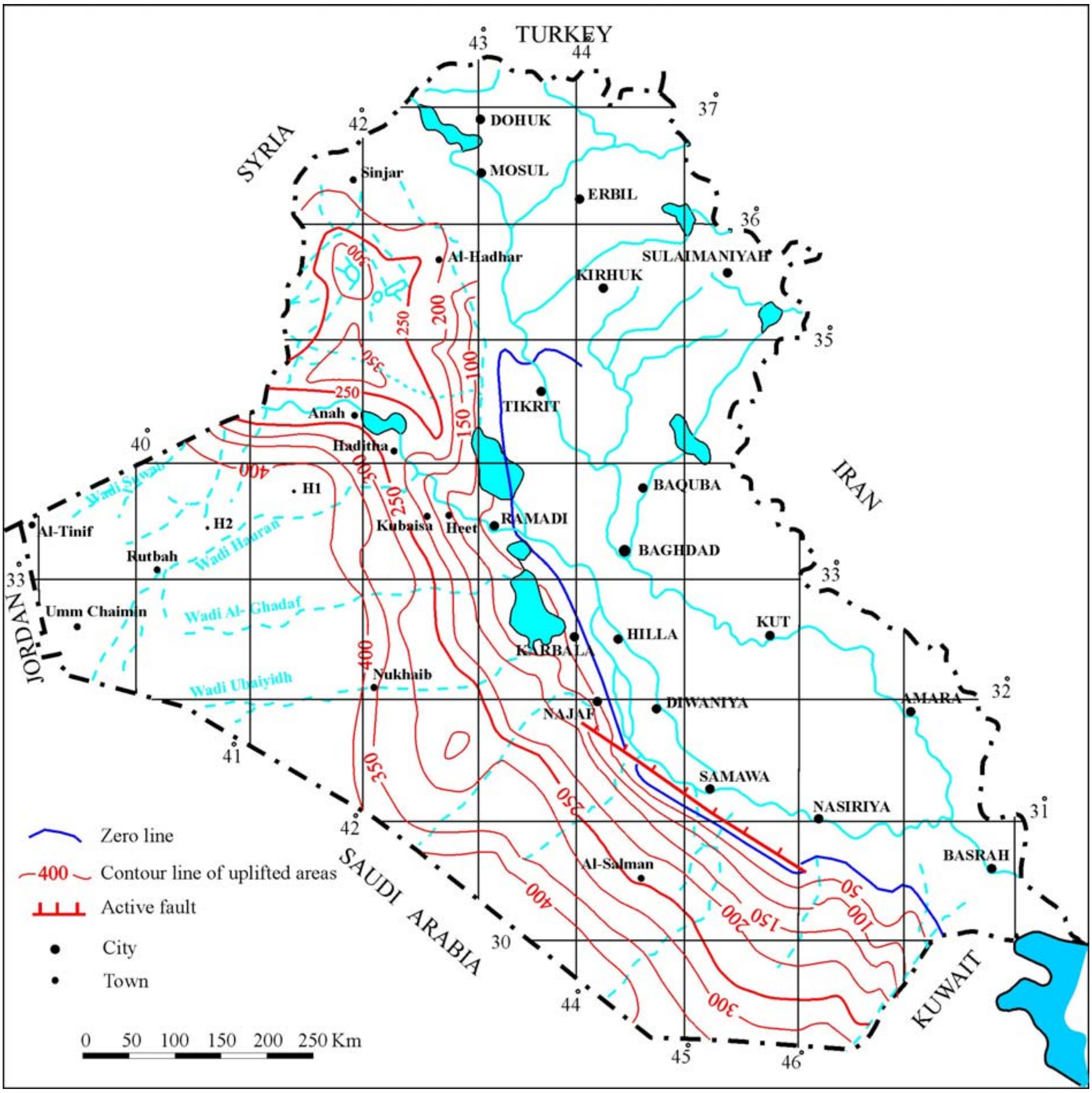

Fig.2: Reconstructed Neotectonic map of the western part of Iraq

To achieve the aforementioned data, hundreds of outcrops that represent the elevations of the **Target** are indicated from geological maps of different scales (1: 100 000 and 1: 25 000) and manifested over a base map of scale 1: 1000 000 and then are contoured in interval of 50 m. Moreover, tens of outcrop descriptions are reviewed, in GEOSURV's archive, to indicate the true geological formation; wherever doubtful boundaries between Early, Middle and Late Miocene formations were met, on the geological maps. Locally, cross sections were constructed to estimate the depth of the **Target**. In other areas, oil and water wells data were used too, for the same reason.

NEOTECTONIC EVIDENCES

Although the Iraqi Western Desert is considered as a Stable Shelf (Buday, 1980; Buday and Jassim, 1984; Al-Kadhimi *et al.*, 1996; Jassim and Goff, 2006 and Fouad, 2009) due to its location as an intraplate region, but vast parts witness different indications for Neotectonic movements. Such intraplate regions, which were believed to be seismotectonically inactive, indicate, by new observations and concepts of present-day deformation in intraplate regions, a significant level of Neotectonic activity, both seismic and aseismic leading to significant deformation of the Earth's crust (Cloetingh, 2002).

Within the studied area, Neotectonic movements characterize considerable parts (Fig.3). The active Abu Jir Fault Zone (Fig.3) and its extension the Euphrates Fault Zone are good examples (Fouad, 2007). The continuous changes of valley trends and abnormal terrace accumulation along them, the dislocated valleys and controlling of their courses, are good indications for Neotectonic movements. Such activities are attributed to Neotectonic movements by different researchers (Markovic *et al*., 1996; Kumanan, 2001; Cohen *et al*., 2002; Mello *et al*., 1999; Bhattacharya *et al.*, 2005; Jones and Arzani, 2005; Philip and Vidri, 2007 and Woldai and Dorjsuren, 2008).

Two types of main evidences for reviewing Neotectonic movements were considered in this study, these are:

- **Evidences Associated with Active Faulting**

– Abu Jir Active Fault (Euphrates Fault) Zone

This fault zone is the most expressive active fault (Neotectonic movement) in the Iraqi Western Desert; it is accompanied with gas emission, bitumen seepages, dislocation of valleys and controlling their trends (Fig.3). It shows clear rupture in relief, along which the authors believe the gas emission and bitumen seepages are located, besides offset of streams, which indicate strike-slip movement (Fouad, 1997, 2000, 2004 and 2007), such phenomena are confirmed by Philip and Virdi (2007) to be indications for Neotectonics. Such ruptures reveal that the fault is still active, indicating Neotectonic activity (Markovic, 1996). It is worth to mention that the fault could be considered as a regional, due to its length that extends for about 150 Km, but with its extension that is called Euphrates Fault, it is about 500 Km (Fig.4). Unfortunately, there is no obvious data about their extension and width. The extension of the Abu Jir Fault Zone (Euphrates Fault Zone) is evidenced by a straight escarpment (5 – 15 m high) that forms the boundary between the Mesopotamian Plain and the Southern Desert; and forms abrupt and sharp contact between Quaternary sediments with pre-Quaternary rocks. Many valleys are terminated along this escarpment; such phenomenon might be an evidence for Neotectonic movements (Bhattacharya *et al*., 2005; Philip and Virdi, 2007 and Woldai and Dorjsuren, 2008). Tens of springs are located along the fault, yielding mineralized water (sulphatic) (Al-Basrawi and Abdul Ameer, 2007); the springs also may indicate the activity of the fault.

– Euphrates Formation

The uppermost part of the Euphrates Formation contains highly deformed beds, called "Brecciated Unit" that includes oriented fragments of hard silicifeid limestone within a mass of marly and chalky limestone. This unit is overlain by highly undulated, jointed and deformed limestone, called "Undulated Limestone Unit". Bolton (1954) in Fouad (2007) attributed this phenomenon to shakes originated from earthquakes, during the deposition in marine environment. Although Euphrates Formation is of Early Miocene age, but the beginning of the Neotectonic movements still could be considered as continuation for this phenomenon.

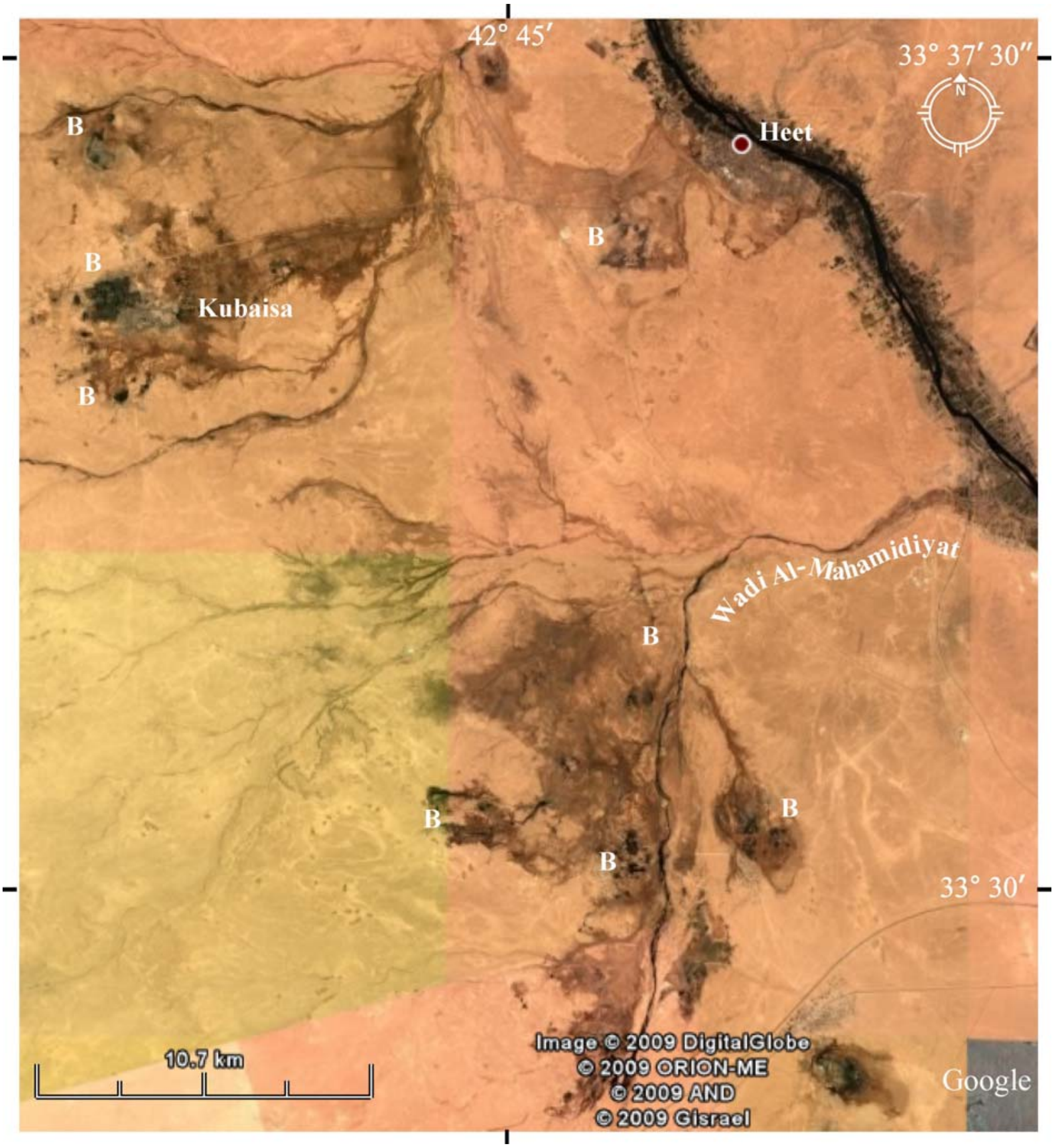

Fig.3: Google Earth image showing abnormal drainage system and bitumen seepages (B), in Heet – Kubaisa vicinity

▪ **Evidences Inferred From Drainage System**

One of the clear evidences for Neotectonic movements is the structural control to the drainage system; including dislocation, abnormal bending and being controlled in parallel directions (Mello *et al*., 1999; Kumanan, 2001; Battacharya *et al*., 2005; Philip and Virdi, 2007 and Woldai and Dorjsuren, 2008).

The following five localities were recognized and studied (Fig.4):

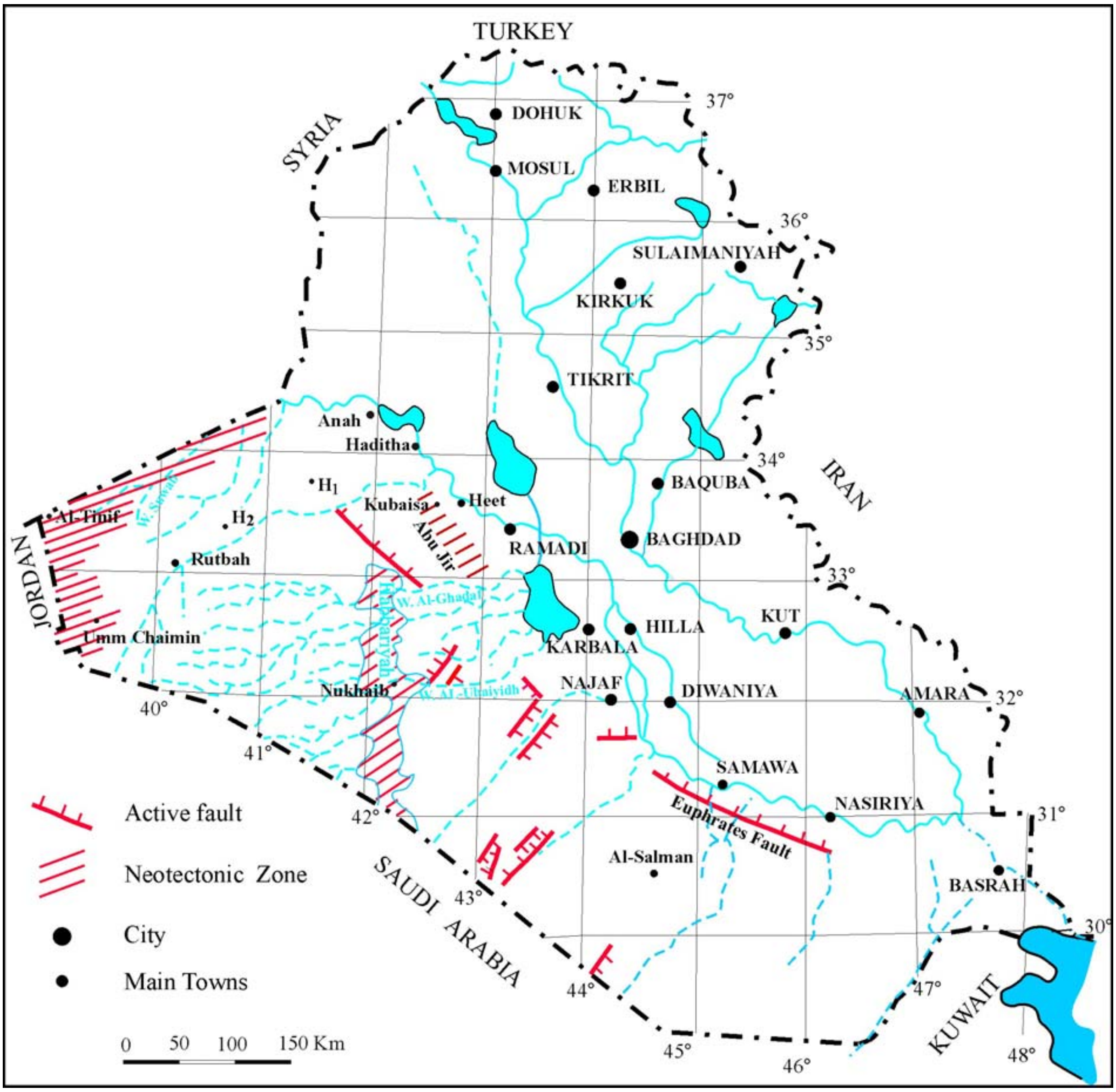

Fig.4: Locations of active features indicating Neotectonic movements, West Iraq

– **Heet – Kubaisa Vicinity**, along Abu Jir Fault Zone (Fig.4), the valleys show abnormal bending and locally are dislocated from their original trends, which could be the opposite of the original direction. Many valleys are structurally controlled towards N – S, which locally contradicts the regional gradient of the area that is towards northeast (Fig.3). Moreover, the abnormal terrace accumulation of the valleys that indicates continuous subsiding due to abnormal incision of the area (Sissakian and Ibrahim, 2007). The presence of bitumen seepages and gas emission (Fig.3) are good indications for the activity of the Abu Jir Fault. Along this zone, many depressions are developed including bitumen seepages and mineralized springs, these depressions are interpreted by Fouad (2000, 2004 and 2007) as sag ponds.

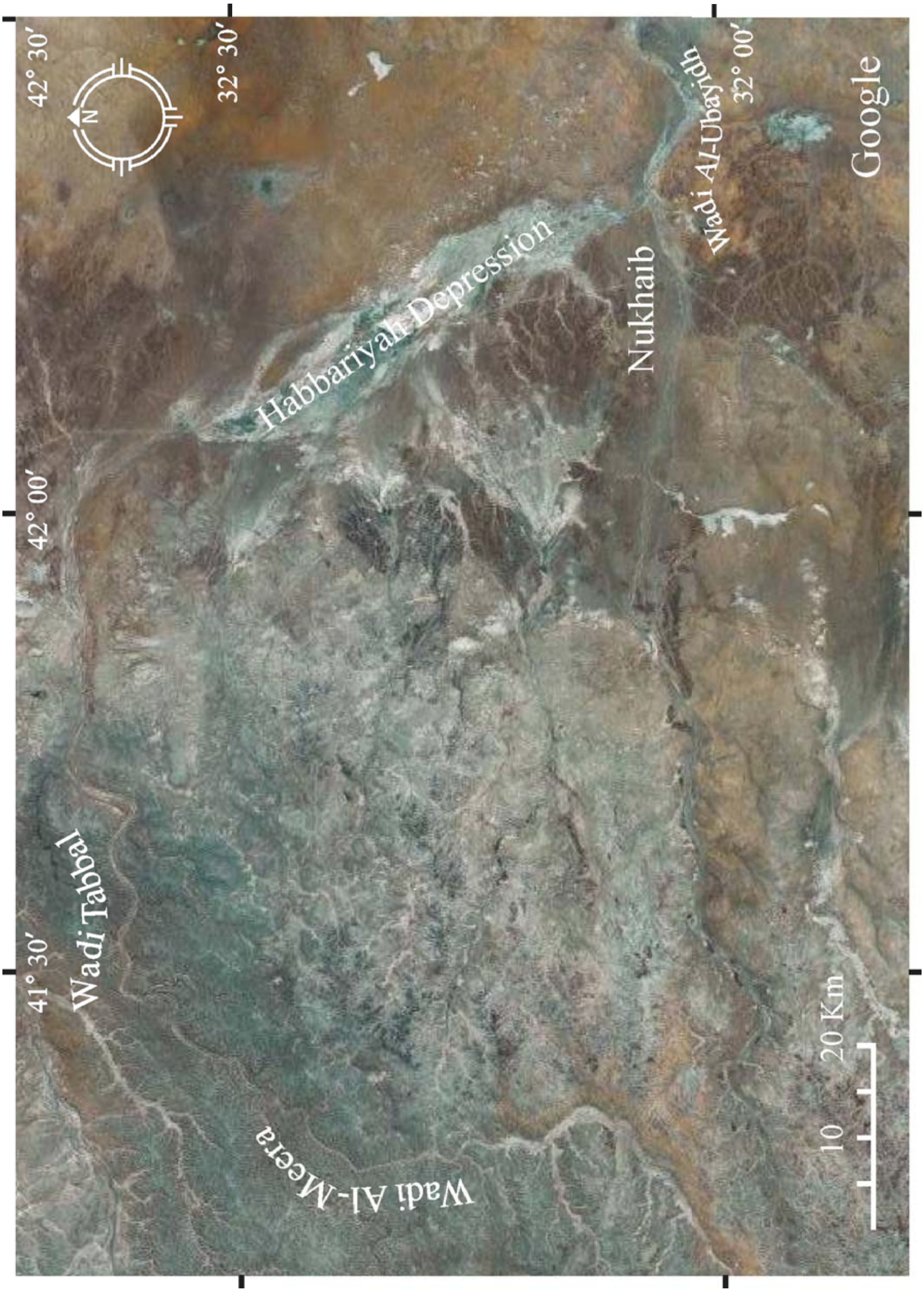

Fig.5: Google Earth image, in Habbariyah vicinity, showing abnormal drainage system and active alluvial fans. Note the abnormal trend of wadi Al-Meera

Fig.6: Google Earth image, in Habbariyah vicinity, note the divide line between wadi Tabbal and wadi Abu Kahaf (marked as D)

– **Habbariyah Vicinity**, the regional trend of the valleys, in the eastern margin of the Western Desert, is eastwards, but some main valleys exhibit abnormal bending towards north, and then retain their regional trend (eastwards) (Figs.4 and 5). Moreover, almost all valleys, except wadi Al-Ubayidh and wadi Al-Ghadaf discharge in the main Habbariyah Depression (Figs.5 and 6), these two valleys cross the depression and continue their courses eastwards. A good example is wadi Tabbal and its continuation, west of Habbariyah Depression, wadi Abu Kahaf; originally these two valleys were one, as the authors believe, but due to subsidence of the depression, the main valley is divided into two valleys (Fig.6). The authors believe that previously the valleys were continuously flowing eastwards and discharging either to Razzaza Depression or the Euphrates River. But, due to subsidence of the Habbariyah Depression the valleys are terminated in the depression. The subsidence of the depression is also indicated by thick accumulation of gravels, called Habbariyah and Hauran Conglomerates (Al-Mubarak and Amin, 1983 and Sissakian, 2000). Many alluvial fans are developed in areas where the valleys merge to Habbariyah Depression, many of them are still active (Figs.5 and 6), such active fans may indicate active subsidence, possibly indicting Neotectonic movements (Mello, 1999; Jones and Arzani, 2005; Philip and Virdi, 2007 and Woldai and Dorjsuren, 2008).

– **Al-Tinif Vicinity**, it is near the Iraqi – Syrian – Jordanian borders (Fig.4). It is characterized by longitudinal valleys that have SSE – NNW trend and are dislocated by transversal valleys that trend ENE – WSW (Fig.7). The dislocation is towards west, with clear bending of some valleys. Some of the valleys are accompanied with circular or oval depressions; many of them are still active. In Al-Tinif vicinity, the depth of a depression exceeds 190 m, although is filled by inhomogeneous sediments (Sissakian, 2007). Such dislocated valleys and active depressions are clear indications for Neotectonic movements.

– **Umm Chaimin Vicinity**, it is located in the southwestern part of the Western Desert (Fig.4). Two sets of main valleys drain the area. The first one is almost S – N, whereas the second is almost E – W (Fig.8). The first set is clearly dislocated by the second and locally are shifted towards west. Such dislocation of valleys is clear indication for Neotectonic movements; such areas could be assigned as an active Neotectonic zone (Markovic *et al*., 1996 and Kumanan, 2001).

– **Anah Vicinity**, it is located in the northwestern part of the Western Desert (Fig.4). The main valleys that flow northwards drain to the Euphrates River. Many of them exhibit abnormal nick points that are aligned along one line in E – W trend, which is parallel to the axis of Anah anticline. These nick points are good indication for Neotectonic activity, they have heights of (8 – 15) m; all are within very hard, thickly bedded limestone of the Lower Member of the Euphrates Formation. The nick points can not be originated from normal erosion, because the length of the valleys (before the nick points) does not permit to the valleys to have such erosional ability to erode the very hard and massive limestone. Therefore, the only reliable reason for the development of the nick points is the Neotectonic activity (Sissakian, 2008), being not effected by fault.

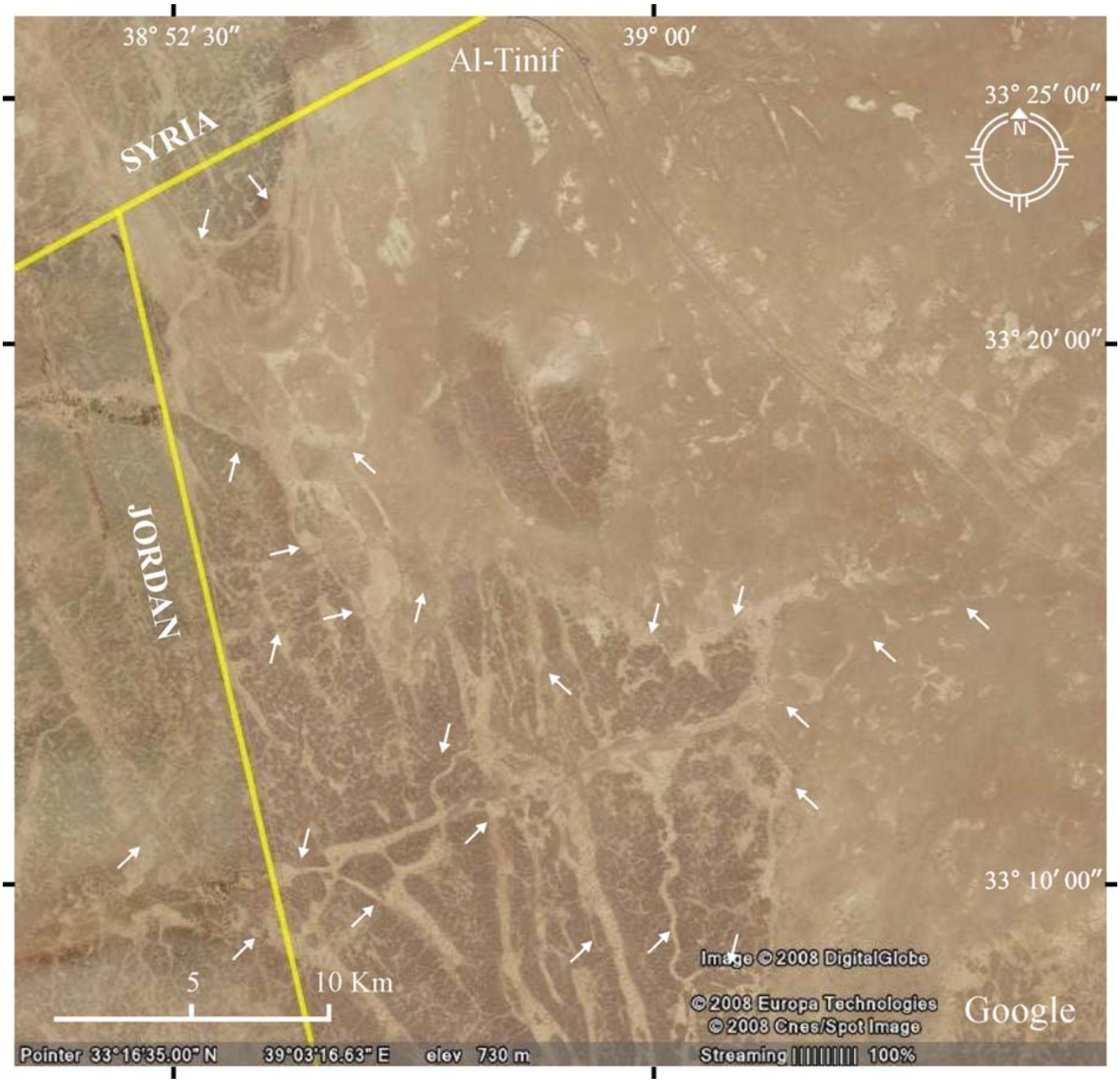

Fig.7: Google Earth image, in Al-Tinif vicinity, note the shifted and controlled drainage patterns (pointed by arrows, which indicate locations, not directions)

CONCLUSIONS

From this study, the following could be concluded

- A Neotectonic map of the western part of Iraq is re-constructed depending on a new concept, concerning the Middle – Late Miocene contact.
- The contour lines have different shapes and values, as compared to those presented in the previously constructed Neotectonic map.
- Different evidences for Neotectonic movements are recognized and explained, majority of them depend on the drainage pattern; their dislocation, abnormal trends and bends and abnormal terrace accumulations.
- The bitumen seepages, gas emissions were found along active faults that indicate recent activity (Neotectonic movements).

Fig.8: Google Earth image for the Umm Chaimin vicinity, note the abnormal patterns of N – S and E – W trending valleys (pointed by arrows, which indicate locations, not directions)

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