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MORPHOMETRIC ASSESSMENT OF TECTONIC ACTIVITY IN "GALAL AL-DURA" DRAINAGE BASIN, EAST OF IRAQ

Luay D. Yousif[1] and Ra'ad M. Dawood[1]

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ABSTRACT

"Galal Al-Dura" is a small drainage basin of an area of 1035.4 Km^2, located at the middle part of the eastern borders of Iraq, south of the town of Mandili. This basin is a small seasonal stream, locally called as "Galal Al-Dura". It is drained in "Hour Al-Shibicha" to its southwest, which is a part of Tigris River basin. The studied basin is investigated to examine the influence of tectonic activity through analysis of the geomorphic indices computed using Geographic Information System (GIS).

The results of the calculated geomorphic indices indicate that both the of Asymmetry Factor (*Af*), and Basin Shape (*Bs*) indices show relatively high tectonic activity, whereas, the Hypsometric curve and the Hypsometric Integral (*Hi*), valley floor width to height Ratio (*Vf*), stream length-gradient (*Sl*), and mountain front sinuosity (*Smf*) indices, indicate that the old stage of the stream shows less tectonic activity. This low tectonic activity is characterized by a landscape with very subdued relief associated with low uplift rates, due to the weak sediments type of the alluvial fan that cover large part of the basin. Furthermore, the relative tectonic activity index (*Iat*) is found to be 2.33 (within class 3), which suggests a moderate tectonic activity in the basin. Two hundred and thirty eight structural lineaments, based on GIS aspect spatial analyst tools are drawn manually; their bearings are measured and represented as rose diagrams.

التقييم المورفوميتري للنشاط التكتوني لحوض تصريف "گلال الدرة"، شرق العراق

لؤي داود يوسف و رعد محمد داود

المستخلص

گلال الدرة هو حوض تصريف صغير بمساحة 1035,4 كم^2 يقع في وسط الحدود الشرقية للعراق، جنوب مدينة مندلي. هذا الحوض يعود لمجرى نهر موسمي صغير يسمى محليا "گلال الدرة"، مياهه تصرف الى الجنوب الغربي في منخفض هور الشبيجة الذي هو جزء من حوض نهر دجلة. تم دراسة هذا الحوض لتحديد تأثير النشاط التكتوني، من خلال تحليل الدالات الجيومورفولوجية باستخدام نموذج الارتفاعات الرقمية DEM بدقة 30 متر في برنامج نظم المعلومات الجغرافية (GIS). وبينت نتائج الدالات المقاسة ان كلا من معاملي عدم التماثل (*Af*) وشكل الحوض (*Bs*) يظهران تأثر الحوض بنشاط تكتوني عالي نسبيا، في حين ان كلا من دالة Hypsometric curve and hypsometric integral (*Hi*) ونسبة طول الجدول الى انحداره، ودالة تعرج (التواء) واحهة الجبل، قد بينت ان الحوض ذو مجرى يمر في مراحله النهائية (الشيخوخة) مصاحب بنشاط تكتوني

[1] Senior Chief Geologist, Iraq Geological Survey, P.O. Box 986, Baghdad, Iraq,
e-mail: luaygeo@yahoo.com

ضعيف ويمتاز بأراضي ذات تضاريس واطئة مقترنة بحركات رفع خفيفة، بسبب الترسبات الضعيفة (الرخوة) للمروحة النهرية التي تغطي الجزء الأكبر من الحوض. علاوة على ذلك، تم تقييم دالة النشاط التكتوني النسبي في الحوض والتي تبين انها تساوي 2,33 وتقع هذه القيمة ضمن الرتبة 3 التي تشير الى تأثر الحوض بالنشاط التكتوني المتوسط. وتم رسم 238 تركيب خطي يدويا بالاستفادة من خاصية اتجاهات الميول (الانحدارات) وقياس امتداداتها في برنامج GIS، ومثلت على مخطط الوردة، باستخدام برنامج RockWorks15.

INTRODUCTION

In mountainous regions, recent and active tectonics can be viewed as the main factor contributing to uplifts, their present day topography being the result of competition between tectonic and erosional processes (Andermann and Gloaguen, 2009; Perez Pent *et al*., 2009). The drainage pattern in tectonically active regions is very sensitive to active processes such as folding and faulting which are responsible for accelerated river incision, basin asymmetries, drainage geometry and complexity and river deflection (Cox, 1994).

Some geomorphic indices have been developed as basic reconnaissance tools to identify areas experiencing rapid tectonic deformation. Geomorphic indices are particularly useful in tectonic studies, because they can be used for rapid evaluation of large areas, and the necessary data often can be obtained easily from topographic maps and satellite images (Keller and Pinter, 2002; Chen *et al*., 2003). Some of the geomorphic indices are most useful in studies of active tectonic; they include: Asymmetry Factor (*Af*), Hypsometric curve and Hypsometric Integral (*Hi*), valley floor width to height Ratio (*Vf*), stream length-gradient (*Sl*), basin shape (*Bs*) and mountain front sinuosity (*Smf*).

The studied area is a small, intermittent drainage basin, locally known as "Galal Al-Dura", located at the Iraq – Iran, borders, south of the town of Mandili in Diyala province. It has an area of 1035.4 Km^2 with a perimeter of 233.2 Km and flows only during the rainy months of October to June.

The aim of this paper is to study the relationships between the morphometry and the tectonic activity of the drainage basin.

- **Geological Setting**

The studied area is located within two tectonically active zones of the Outer (Unstable) Platform of the Arabian Plate (Fouad, 2012); a very small northeastern part occurs the Low Folded Zone, represented by Himreen anticline and the largest part occurs in the Mesopotamia Foredeep of asymmetrically subsiding basin (Fouad, 2011). The northeastern part is of mountainous terrain, belonging to the Zagros Mountainous belt, is covered by pre-Quaternary rocks, while the other parts are of gently undulating to flat terrain covered by fluvial and aeolian morpho-genesis units (Barwary, 1991). In the northeastern mountainous terrain occurs the weak clastic sedimentary rocks of the Mukdadiyah Formation (Late Miocene – Pliocene age) while the other parts are covered by slope sediments along the main ridges of the southwestern limb of Himreen anticline. The Mukdadiyah Formation consists mainly of cyclic repetition of sandstone, siltstone and claystone; the cycles are coarsening upwards; some of the sandstone beds are pebbly. In the central and the southwestern parts, the alluvial fan sediments (Fig.1) are developed along the main mountain chain, during the Pleistocene – Holocene (Sissakian and Al-Jibouri, 2012).

The stages, composition, thickness and areas of the alluvial fan are highly variable, but they are not well recorded. The thickness ranges from (1 – 8) m. The alluvial fan sediments, lie unconformably over the pre-Quaternary sediments, and form a continuous belt along the southwestern limb of Himreen anticline, and they represent the marginal facies of the Mesopotamian sedimentary basin. The alluvial fans commonly consist of poorly sorted clastics, usually gravels, cobbles and boulders with subordinate amounts of sand, silt and clay (Barwary, 1991). The weak clastic sediments, which build the studied area, are dissected by the intermittent valley of "Galal Al-Dura", which merge finally with "Hour Al-Shibicha" within the flood plain of the Tigris River. The studied drainage basin is a part of the Tigris basin. According to the I.M.O (2000), the studied area has an arid to semiarid climate, with steppe precipitation and hot arid temperature conditions.

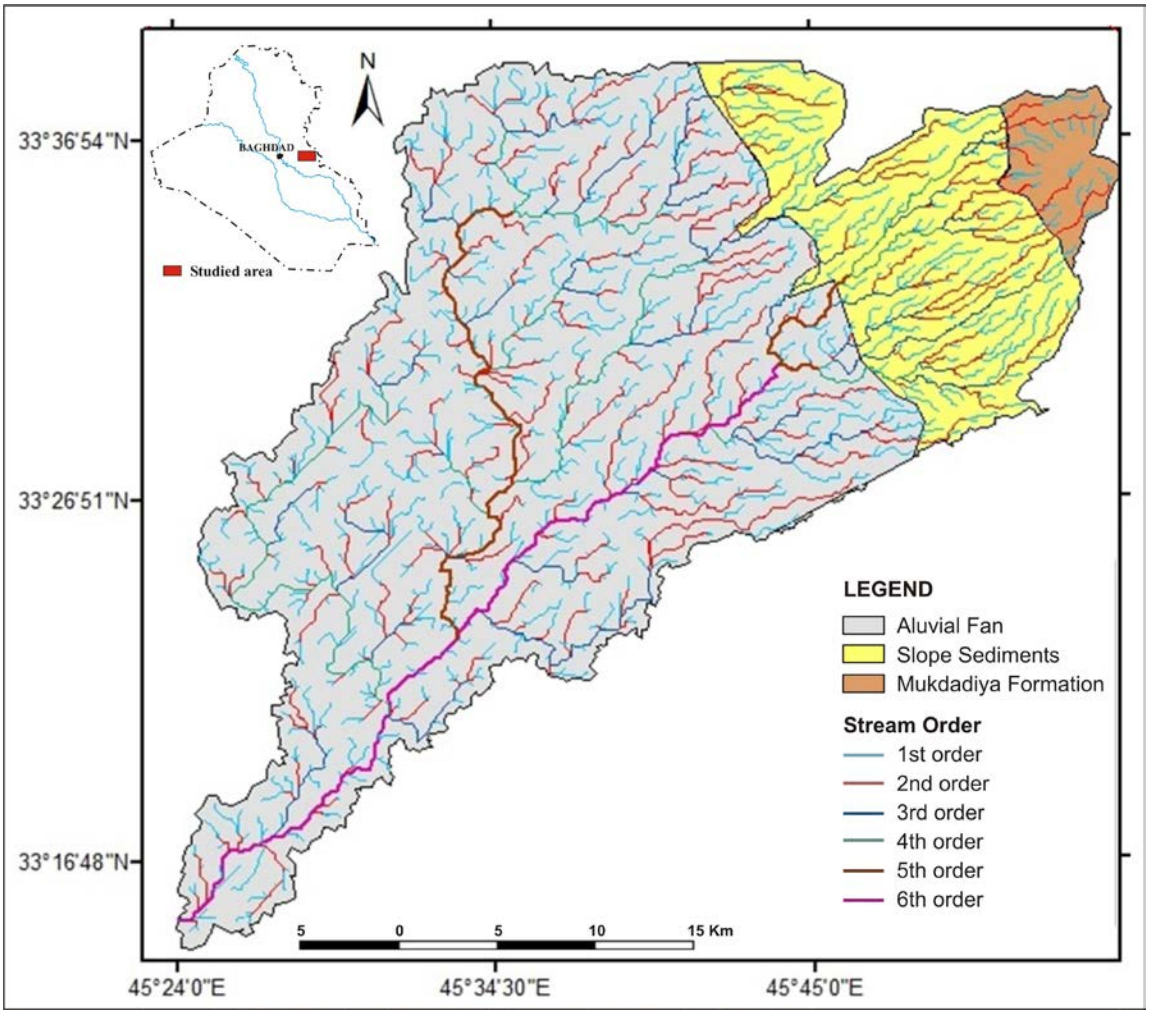

Fig.1: Location and geological map of the studied drainage basin (Barwary, 1991; Sissakian, 2014)

METHODS AND RESULTS

In tectonic geomorphology, the Digital Elevation Model (DEM) is used for better analyses of topographic parameters. It provides an opportunity to quantify land surface geometry in terms of elevation. The possibility of extracting river networks, stream gradients and catchments' areas is one of its most important features (Perez Pena, 2009). For the current study, the digital elevation model (DEM) with 30 m spatial resolution, of Iraq territory, is used as a base map in ARC GIS 9.3. The drainage basin boundary and other characteristics are identified through an extension called arc hydrology tools 9 in ARC GIS software (Table 1).

Table 1: Basin Parameters of Gala Al-Dura Drainage basin

Basin Parameters	Area (Km²)	Perimeter (Km)	Length (Km)	Highest Point (m)	Lowest Point (m)	Average Height (m)
Values	1035.4	233.2	64.54	640	20	163.3

Stream ordering method as suggested by Strahler (1957) is employed and 6 stream orders are identified. When reviewing the stream order map (Fig.2), it can be seen that Galal Al-Dura basin is characterized by two drainage patterns; a parallel pattern in the northeast, that reflects the lithological influence, and a rectangular pattern in the southwest due to the structural effects of the jointed and fractured subsurface rocks. These two drainage patterns are a sign of the heterogeneity in texture of the watershed (Sing *et al*., 2014). However, the general trend of the main streams is NE – SW, which coincides with the regional trend of the structural lineament in Iraq.

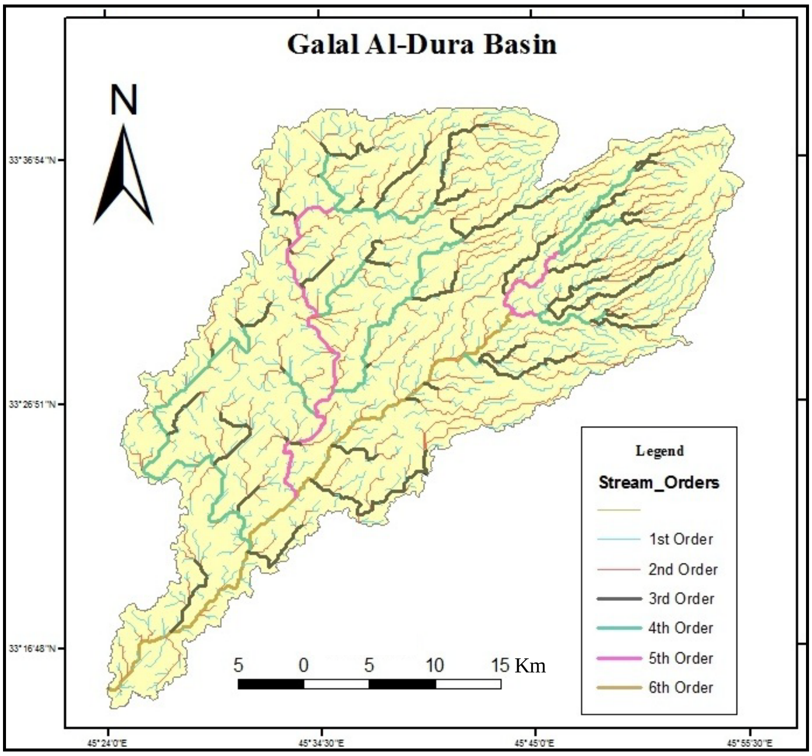

Fig.2: Stream Orders map of the studied watershed

A perusal of Table (2) shows that the total number of 1124 streams has a total stream length of 1620.92 Km, with the number and the total length of each other are shown, in the table.

Table 2: Stream characteristics of Galal Al-Dura drainage basin

Stream Orders	1st order	2nd order	3rd order	4th order	5th order	6th order
Number of Stream Segments	961	106	42	11	3	1
Length (Km)	771.97	460.3	186.08	108.76	44.57	49.24

▪ **Drainage Density (*Dd*) and Drainage Texture (*T*)**

Drainage density, which indicates channel spacing, is a measure of the total length of the stream segments of all orders per unit area. It is controlled by the slope and relative relief of the basin (Horton, 1932). The drainage density of the studied basin is 1620.923/ 1035.4 = 1.57, which is classified as low drainage density and indicates a highly resistant, permeable subsurface materials and low relief (Singh and Sinha, 2009). Smith (1950) has classified the drainage density into five different textures. A density of less than 2 indicates very coarse, that between 2 and 4 is considered coarse, that between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. As such, the present basin is very coarse textured.

▪ **Drainage Frequency (*Sf*)**

Stream frequency *(Sf*) or channel frequency is the total number of stream segments of all orders per unit area (Horton, 1932). The S*f* values indicate a positive correlation with drainage density of the basin. The calculated drainage frequency of Galal Al-Dura basin is; 1124/ 1035.4 = 1.08, and this low value indicates low relief and almost flat topography (Horton, 1945). Due to permeable rocks, the surface runoff is low and infiltration capacity is high (Praveen *et al*., 2012).

▪ **Asymmetry Factor (*Af*)**

This morpho-tectonic indicator, described by Keller and Pinter (2002), with values range from 0 – 100%, is indicative of the tectonic control quantitatively. If the basin is not tilted, then the *Af* is 50%. Values under and over 50% represent rightward and leftward tilting (according to the main stream flow), respectively (Fig.3).

According to El-Hamdouni *et al.* (2008), *Af* is classified into three classes; **1)** ($Af \geq 65$ or $Af < 35$), **2)** ($35 \leq Af < 43$ or $57 \leq Af < 65$) and **3)** ($43 \leq Af < 57$).

$$Af = 100\ (Ar/At)$$

Where: ***Af*** = Asymmetry Factor, ***At*** = Total area of the basin, ***Ar*** = Area of the basin

$Af = 100 * (682.4 / 1035.4)$

$Af = 66\%$ class 1

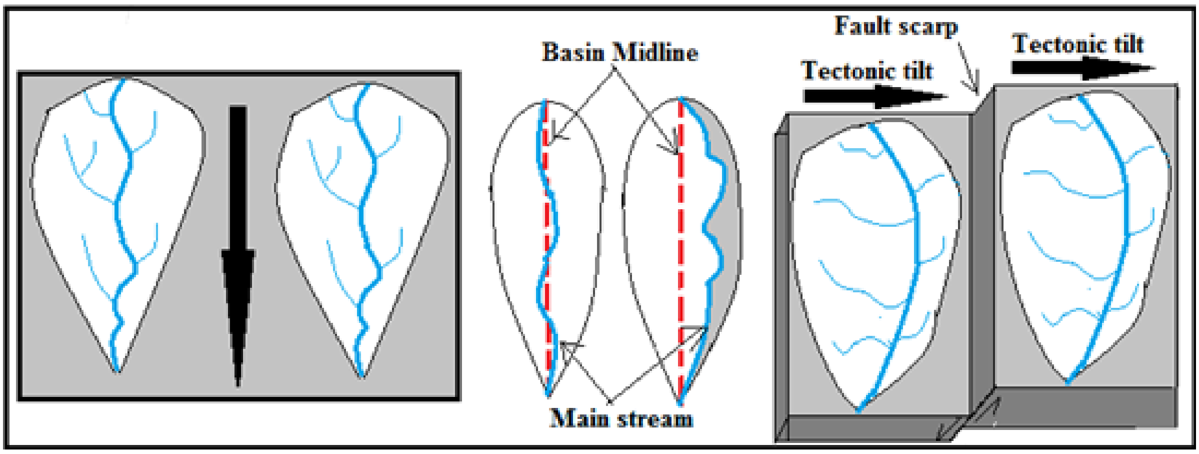

Fig.3: Drainage response to uplift along a fault by migrating laterally in a down tilt direction (after Keller and Pinter, 2002, in Mahmood and Gloaguen, 2012)

The *Af* of the studied basin is 66%, which represents a leftward tilting and northwestward rotation along NE – SW trend, parallel to the main stream. This means that the whole area is affected by the NW – SE thrust fault along Himreen anticline northeast of Zurbatiya region to the southeast of the study area.

- **Transverse Topographic Symmetry Factor (*T*)**

This vector indicates migration of stream perpendicular to the drainage basin axis (Cox, 1994). Transverse topographic symmetry factor is a vector with a bearing and magnitude from 0 to 1, and is calculated by the following equation:

$$T = Da/Dd$$

Where ***Da*** is the distance from the basin midline to the midline of the main stream, and ***Dd*** is the distance from the basin midline to the basin divide.

For perfectly symmetrical basin, *T* = 0. As asymmetry increases, *T* increases and approaches a value of 1, which indicates the state of motion, sinuous bottom layer (below the surface) or cracking, which leads to the displacement of the main stream in the direction of the cracked subsurface. Values of *T* are calculated for different segments of streams (Fig.4) and indicate preferred migration of streams perpendicular to the drainage basin axis. This analysis is most appropriate to dendritic drainage patterns, where evaluation of tributary valleys as well as the main or trunk valley allows for a larger range of *T*.

The three sections, along which the asymmetry factor is calculated, are the up-, mid- and downstream. The calculated *T* values are; 0.4, 0.5 and 0.53 for the up, mid and downstream, respectively. All of these values, in addition to the average value of *T*, is moderate (= 0.48), which indicates that this basin is asymmetrical (Burbank and Anderson, 2001).

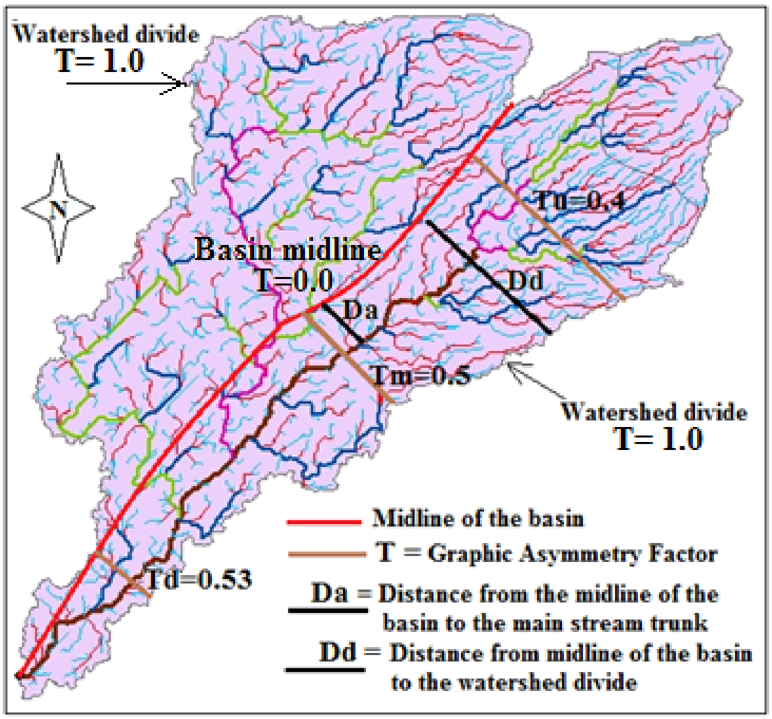

Fig.4: Sketch of the graphic asymmetry factor (not to scale)

- **Hypsometric Curve and Hypsometric Integral (Hi)**

– The hypsometric curve of a catchment area presents the distribution of area and altitudes within a basin (Strahler, 1952). This index is defined as the relative area below the hypsometric curve and thus expresses the volume of a basin that has not been eroded (Dehbozorgi *et al*., 2010).

The curve is drawn by plotting the proportion of total basin height (h/H = relative height) against the proportion of total basin area (a/A = relative area). The total height (H) is the relief within the basin (Max. elevation – Mini. elev.). The total surface area of the basin (A) is the sum of the areas between each pair of adjacent contour lines (Table 3).

The area (a) is the surface area within the basin above a given line of elevation (h). The value of relative area (a/A) always varies from 1.0 at the lowest point in the basin (where h/H = 0.0) to 0.0 at the highest point in the basin (where h/H = 1.0). A useful attribute of the hypsometric curve is that drainage basins of different sizes can be compared with each other, because area and elevation are plotted as function of total area and total elevation.

Table 3: Hypsometric curve parameters

Elevation (m)	**a (m)**	**A (m)**	**a/A**	**h**	**H**	**h/H**
200	83.769	1035.1	0.08	200	640 – 200 = 440	0.45
160	109.021	1035.1	0.1	160	640 – 160 = 480	0.35
140	133.794	1035.1	0.13	140	640 – 140 = 500	0.28
120	161.863	1035.1	0.16	120	640 – 120 = 520	0.23
80	203.800	1035.1	0.19	80	640 – 80 = 560	0.14
40	771.893	1035.1	0.746	40	640 – 40 = 600	0.07
20	1035.1	1035.1	1.0	20	640 – 20 = 620	0.031

The Hypsometric curve of the studied basin is initiated across areas above the elevations of the following contour lines 200, 160, 140, 120, 80, 40, 20. The resulted hypsometric curve (Fig.5) indicates that the old stage of the stream is characterized by a landscape with very subdued relief (Strahler, 1952), because the concave form of the curve indicates that the majority of basin area lies at comparatively low relief. Away from the mouth, the relief increases, but area decreases. So, if the majority of basin area lies at low elevations; the area proportion will decrease more quickly than the height proportion. This will produce a concave hypsometric curve. However, if the majority of the basin area lies at high elevations; the height proportion will decrease more quickly than the area proportion. This will produce a convex hypsometric curve.

– The Hypsometric Integral (*Hi*) Index describes the relative distribution of elevation in a given area of a landscape particularly a drainage basin (Strahler, 1952; in Dehbozorgi *et al*., 2010). Only three height values, two of which obtained from topographic maps, are necessary to calculate the integral. The maximum and minimum elevations are read from the map. Mean elevation is obtained by point sampling from grid on the map and hence the mean, or by analysis of the Digital Elevation Model (DEMs). High values of the integral indicate that most of the topography is high relative to the mean, such as a smooth upland surface cut by deeply incised streams. Intermediate to low values of the integral are associated with more evenly dissected drainage basins.

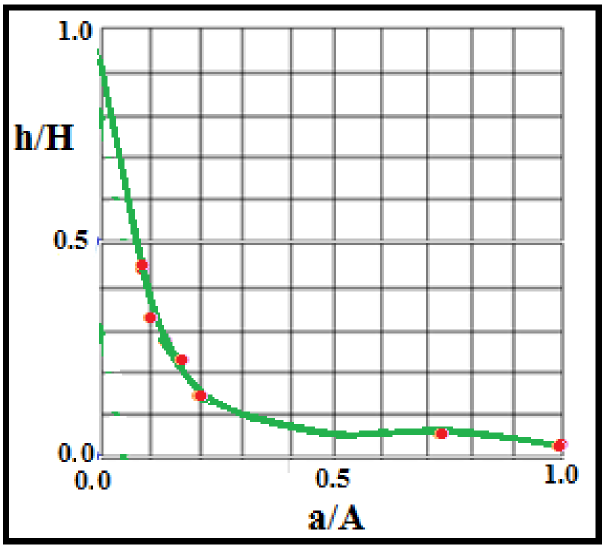

Fig.5: Hypsometric curve of the studied drainage basin

This index is classified into three classes: **1)** ($Hi \geq 0.5$), **2)** ($0.4 \leq Hi < 0.5$) and **3)** ($Hi < 0.4$) according to El-Hamdouni *et al*. (2007), and can be approximated by means of the following equation (Mayer, 1990; Keller and Pinter, 2002):

Hi = (Mean elevation ─ Mini. elev.) / (Maxi. elev. ─ Mini. elev.)

Using this equation, the Integral Index (Hi) is calculated for the Up, Mid and Downstream along the main stream trunk.

Therefore the Integral Index (Hi) was calculated for the main stream trunk:

$$Hi = (273 - 20) / (649 - 20) = 0.402$$

The value of 0.402, suggests a class order No. 2, indicating that Galal Al-Dura basin is evenly dissected. High values of Hi could also result from recent incision into a young geomorphic surface formed by deposition. If part of the hypsometric curve is convex in the lower portion, it may be related to uplift along a fault. Low values are related to older landscapes that have been more eroded and less impacted by recent active tectonics (Mahmood and Glaoguen, 2012).

▪ **Valley floor width to height ratio**

Transverse valley profile is defined using a valley floor width-valley height ratio variable. Comparison of valley floor with its height provides an index that indicates whether the stream is actively down cutting or eroding laterally (Ramrez – Herrera, 1998). This index is divided into three classes (El-Hamdouni *et al*., 2007): **1)** ($Vf \leq 0.5$), **2)** (0.5 $Vf < 1.0$) and **3)** ($Vf \geq 1.0$) and can be calculated by:

$$Vf = 2\, Vfw / (Ald + Ard - 2Asc)$$

Where Vfw is the width of the valley floor, ***Ald***, ***Ard*** and ***Asc*** are the altitudes of the left and right divides (looking downstream) and the stream channel, respectively (Bull, 2007).

In the current study, the valley floor width to the valley height ratio is averaged for the three parts along the main trunk (Table 4). Each part involved two sections (A and B) for the upstream, midstream and downstream (Figs.6, 7 and 8).

Table 4: Valley floor width to height ratio calculation

Factors	*Vfw*	*Ald*	*Ard*	*Asc*	*Vf*
Upstream	55	180	178.6	173	8.7
Midstream	67.5	51	49	45.5	15
Downstream	55	34.5	29.5	20	4.6

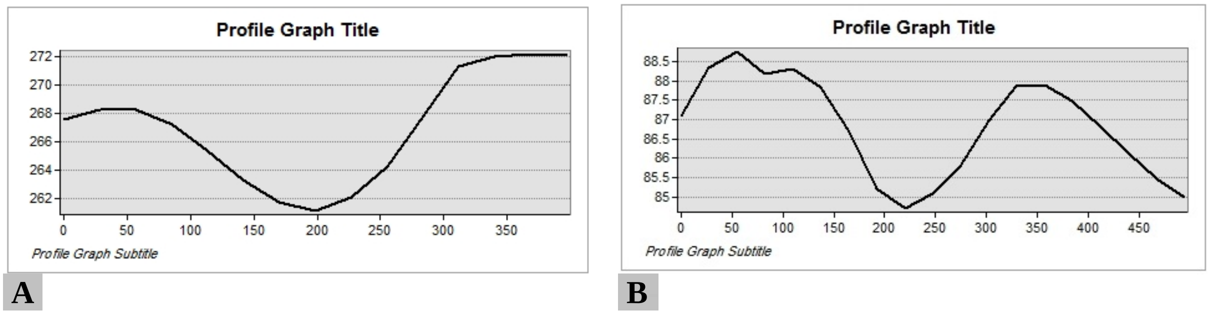

Fig.6: Valley floor width at the high (A) and down (B) parts of the Upstream

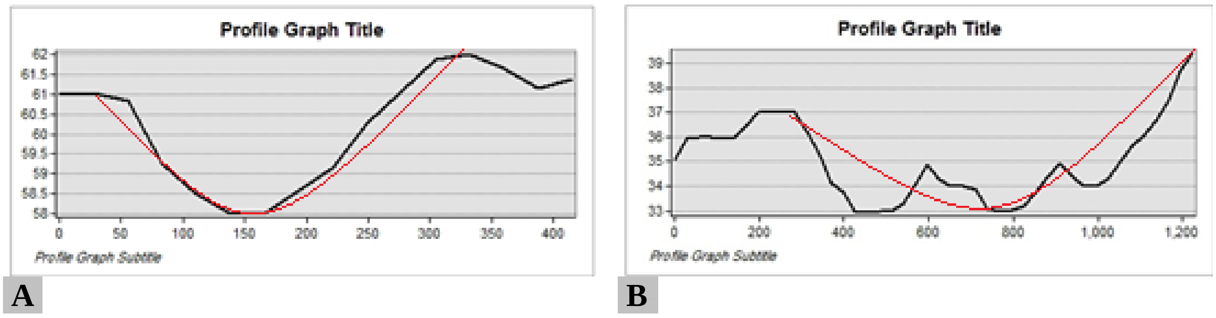

Fig.7: Valley floor width at the high (A) and down (B) parts of the Midstream

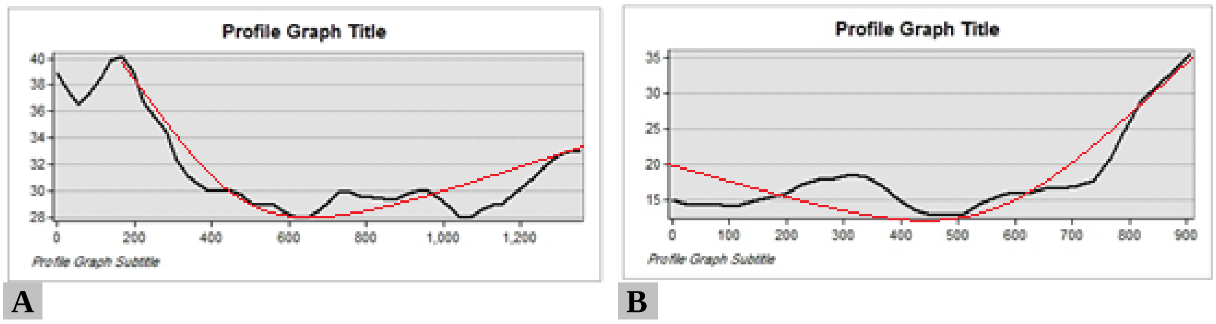

Fig.8: Valley floor width at the high (A) and down (B) parts of the Downstream

The results showed that the average values of *Vf* ratios are 8.7, 15 and 4.6 for the up, mid and downstream, respectively. All these values are more than 1.0, which is indicating a flat floored "U" shaped valley which major lateral erosion mainly in response to relative tectonic quiescence (Keller and Pinter, 2002). The above figures, show that the profiles 6A, 6B, and 7A, have a "U" shape close to "V", indicating active incision, commonly associated with uplift, whereas the last three profiles seem wider, thus associated with low uplift rates.

- **Stream length – gradient index (*Sl*)**

Rivers that are tectonically disturbed are predicted to approach a gradient profile rapidly (Snow and Slingerland, 1978). Thus, perturbation in river profiles may be interpreted as a response to ongoing tectonism. The stream length-gradient index, calculated for a particular reach of interest, is defined by Hack (1973) as:

$$Sl = (\Delta H / \Delta L) \bullet L$$

Where ***Sl*** is the stream length-gradient index in a the channel reach, ***ΔH/ ΔL*** is the channel slope, and ***L*** is the total channel length from the central point of the river reach where the *Sl* is calculated to the watershed divide (Fig.9).

The *Sl* index highlights anomalies in river longitudinal profiles, providing criteria to the slope changes (Hack, 1973; Keller and Pinter, 2002; Pérez-Peña *et al*., 2009a). The *Sl* index is very sensitive to changes in channel slope. The changes are mainly due to lithologic, tectonic, or climatic factors.

(*Sl*) is classified into three classes; **1)** ($Sl \geq 500$), **2)** $300 \leq Sl < 500$, and **3)** $Sl < 300$ (El-Hamdouni *et al*., 2007).

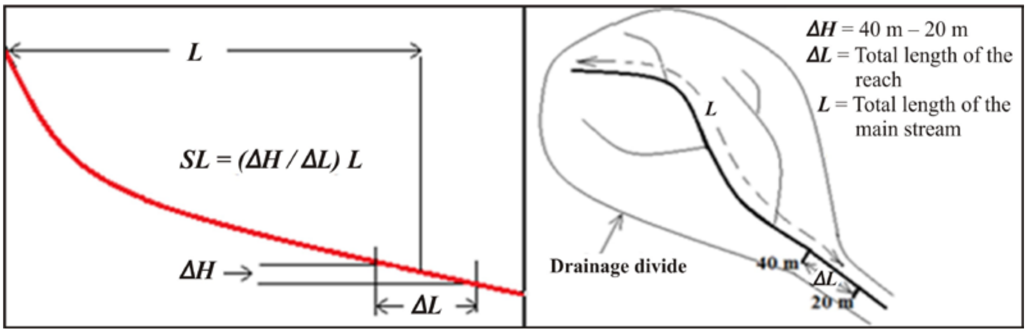

Fig.9: Idealized diagram for *Sl* index calculation

Accordingly, *Sl* is calculated for seven sections along the main stream, which are: 233.0, 160.0, 107.2, 81.8, 62.2, 69.2 and 82.9 with an average of 113.8 (Table 5). These low values are within class 3, due to the weak alluvial sediments (Sarp *et al*., 2010) which occupy the larger part of the basin.

Table 5: Stream length-gradient parameters of Galal Al-Dura basin

L	8.3	13.6	23.05	29.85	38.9	52.95	71.75
ΔL	0.713	1.7	4.3	7.3	12.5	15.3	17.3
ΔH	20	20	20	20	20	20	20
Sl	233	160	107.2	81.8	62.2	69.2	82.9

- **The Longitudinal Profile**

The longitudinal profile of a stream is the stream geometry that provides clues as to the underlying materials and an insight into geologic processes of an area (Hack, 1973). The profile is a graph of distance verses elevation. The construction of the profile provides an interpretation as to the erosional and evolutional history of the river (Kumar and Pandey, 1981). The longitudinal section along Gala Al-Dura (Fig.10) reflects instability in the upstream portion and gentle and stable relief along the long downstream portion. The instable gradient of the upstream is due to the tectonic activity of the Alpine Orogenic impact on the Low Folded Zone.

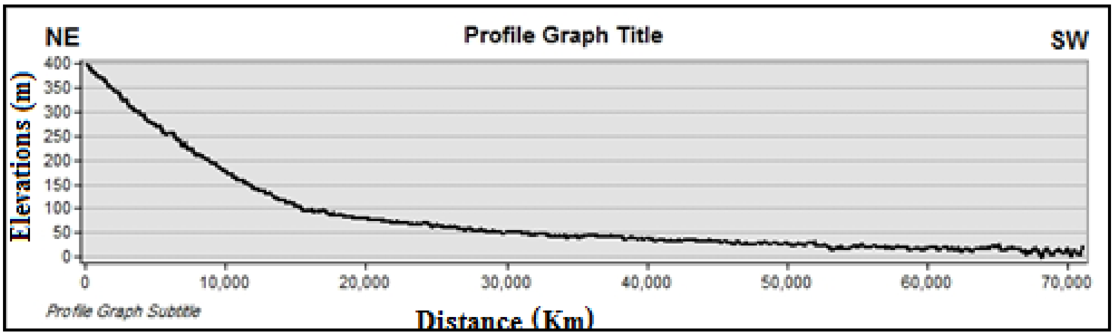

Fig.10: Longitudinal section along the main trunk of Galal Al-Dura

- **Basin shape index *(Bs)***

Relatively young drainage basins in active tectonic areas tend to be elongated in shape parallel to the topographic slope. The elongated shapes are transformed into circular basins, as tectonic activity reduces with time and continued topographic evolution (Bull and McFadden, 1977). The reason of this transformation is because the drainage basin widths are much narrower near the mountain front in tectonically active areas where the energy of the stream is primarily down cutting; by contrast, a lack of continuing rapid uplift permits widening of the basins upstream from the mountain front. The horizontal projection of a basin may be described by the basin shape index or the elongation ratio, *Bs* (Ramirez-Herrera, 1998). The elongation ratio is expressed as:

$$Bs = Bl / Bw$$

Where ***Bl*** is the length of a basin measured from the source point to the mouth, and ***Bw*** is the width of a basin measured at its widest point (Fig.11).

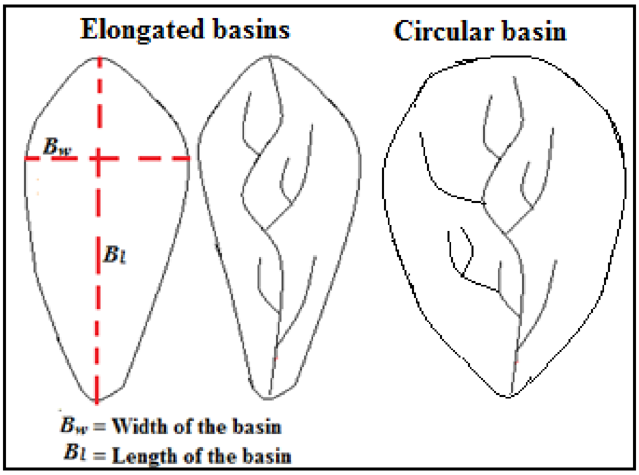

Fig.11: Basin shape parameters

High values of *Bs* are associated with elongated basins, generally associated with relatively higher tectonic activity. Low values of *Bs* indicate a more circular-shaped basin, generally associated with low tectonic activity. *Bs* is computed using the DEM and classified into three classes: class 1 (1.77 – 3.22); class 2 (1.21 – 1.76) and class 3 (1.11 – 1.20).

The calculated value of the studied basin is (Bs = 64.056/ 29.154 = 2.197 ≈ 2.2) which is class 1 (1.77 – 3.22), indicating an elongated basin, generally associated with relatively high tectonic activity.

- **Mountain front sinuosity *(Smf)***

This index is used to evaluate the tectonic activity along mountain fronts (Bull and McFadden, 1977). It is based on the observation that tectonically active mountain fronts are often more straight than mountain fronts in regions where erosion dominates over tectonics (Wells *et al*., 1988). The index is divided into three classes: **1)** (*Smf* < 1.1), **2)** (1.1 ≤ *Smf* < 1.5) and **3)** (*Smf* ≥ 1.5) and defined as:

$$Smf = Lmf / Ls$$

Where ***Smf*** = mountain front sinuosity index, ***Lmf*** = true distance along the same contour line, ***Ls*** = straight line distance along a contour line.

According to Bull and McFadden (1977), *Smf* values less than 1.4 indicates tectonically active areas, values between 1.4 and 3 indicate slightly active areas, whereas values greater than 3 indicate inactive areas. In the present study, *Smf* values computed are shown in Table 6 and Fig.12. The average of *Smf* is 2.41. The first two values represent slightly tectonically active mountainous area, whereas the last value represents inactive area.

Table 6: Mountain Front Sinuosity index determinations

Contour Line (m)	*Lmf*	*Ls*	*Smf*	Interference
280	22.18	13.393	1.66	Slightly active area
200	26.09	13.83	1.9	Slightly active area
100	84.29	22.881	3.68	Inactive area

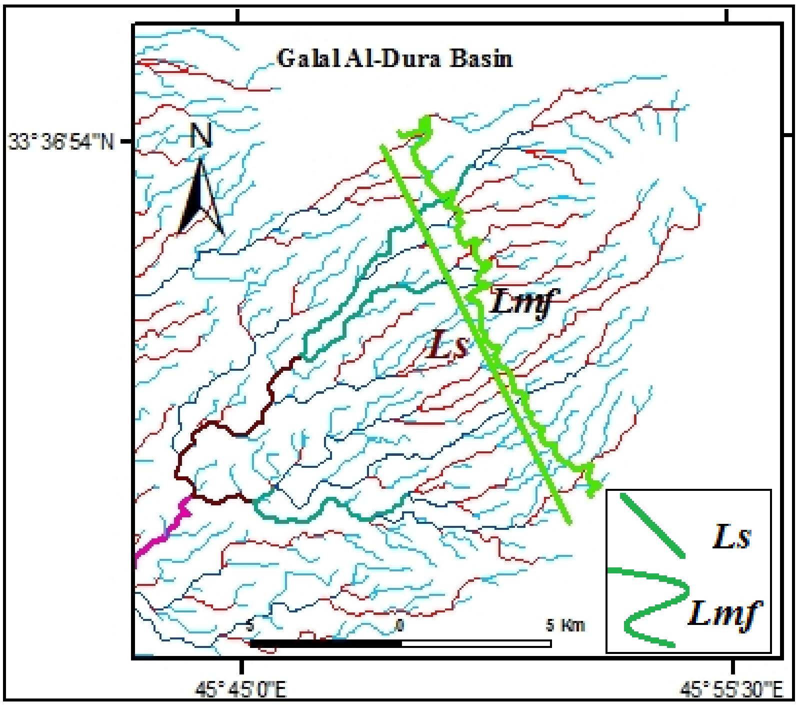

Fig.12: Mountain Front Sinuosity determination

- **Evaluation of relative tectonic activity**

In the current study, the average of the above geomorphic indices have been used to evaluate the relative tectonic activity, following El-Hamdouni *et al*. (2007), who classified the values of the index into four classes to define the degree of tectonic activity: **1)** Very high (1.0 ≤ *Iat* < 1.5), **2)** High (1.5 ≤ *Iat* < 2), **3)** Moderate (2.0 ≤ *Iat* < 2.5), and **4)** Low (*Iat* < 2.5). The resulting (*Iat*) for the studied basin is equal to 14/ 6 = 2.33. This value is within class 3, which refers to moderate tectonic activity (Table 7).

Table 7: Geomorphic indices of Galal Al-Dura drainage basin

Asymmetry Factor (*Af*)	Hypsometric Integral (*Hi*)	Ratio of Valley Floor Width to Height (*Vf*)	Stream Length-Gradient Index (*Sl*)	Basin Shape Index (*Bs*)	Mountain Front Sinuosity (*Smf*)
0.66	0.5	9.43	103.73	2.2	2.42
Class 3	Class 1	Class 1	Class 3	Class 3	Class 3

MAPPING THE LINEAMENT FEATURES

The detection of structural lineament is significant in studying geohazards. By using the aspect technique of image processing, which was applied on DEM 30 m image (Fig.1), the extraction of fracture zones were manually drawn and then plotted as rose diagram, Fig. (13).

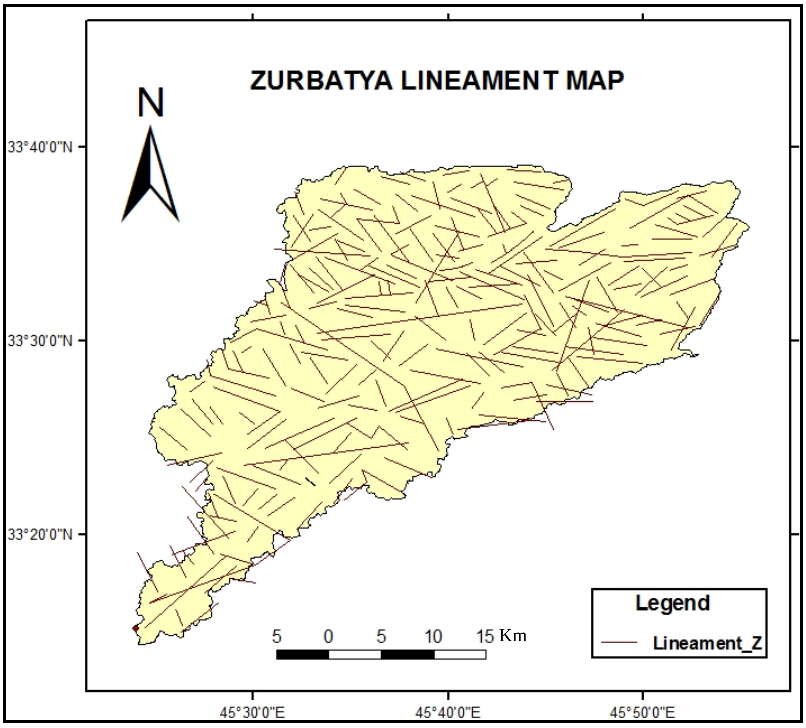

Fig.13: structural lineament map of Galal Al-Dura Drainage Basin

Figure (14) shows that the major part of the structural lineaments lies in the northwest with maximum peak at N70° – 80°W, with subordinate directions of NNW – SSW, E – W and ENE – WSW. This result agrees well with the effect of Zagros major tectonic phase.

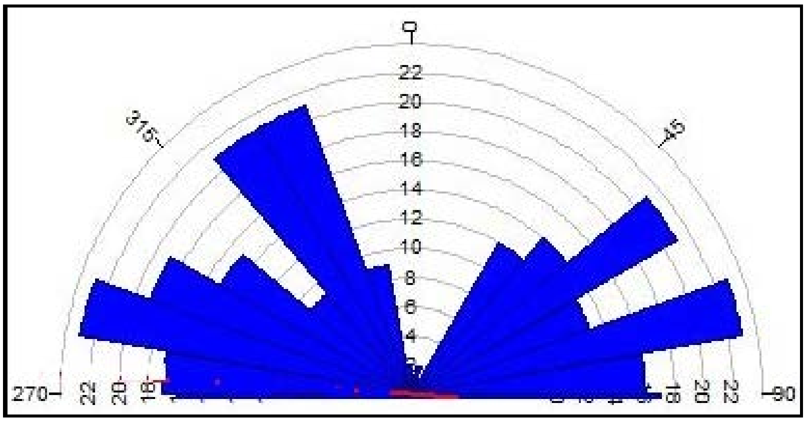

Fig.14: Rose diagram of the structural lineaments of the studied basin

The previous tectonic studies revealed that the tectonic implications of such structural lineaments elucidate that the main folding and faulting episode of the Low Folded Zone had occured during the Pliocene – Pleistocene time, in the east and northeast of Iraq.

- **Lineament Indices**

– Number of lineament per unit area (Structure frequency)

N = 238 / 1035.4 = 0.23

– Total length of lineament per unit area (Structure density)

L = 860.58 / 1035.4 = 0.83

This value (0.83) of lineament density being less than 1.0 is classified as low density according to Gurugnanam *et al*. (2014). It indicates that for every 1.0 square kilometer of the basin, there is 0.83 kilometers of structural lineaments. This makes the study area falls into the group of low density that reflects the low impact of tectonic activity.

DISCUSSION OF RESULTS

According to the asymmetry factor results, the area shows high values of *AF*, mostly more than 50, which means the main tributaries or drainage channels are subjected to tectonic curvature (concavity) and this will be reflected on the lengths of tributaries on either side of the main channel of the basin. This leads to the hypothesis that the development of tributaries to the left of the basin are shorter compared to those of the right side, which reflects the asymmetry, (Keller and Pinter, 2002).

Based on the analysis of the results of transverse topographic symmetry Factor (*T*), the basin shows moderate migration or displacement (average = 0.48) of the main stream of the basin. The sinuosity indices *Smf* computed for the contour lines; 280, 200 and 100 m are 1.66, 1.9 and 3.68 respectively, with average of 2.41. The first two represent low tectonic activity of the mountainous area and its slopes, whereas the last represents the gentle pediment area of inactive tectonics.

The low tectonic activity is mainly due to folding and faulting which are located in the northeasternmost part of the studied area and surroundings. The location within the Low Folded Zone of the Zagros Mountain Front has little impact in the low tectonic activity area. The southwestern limb of those folds is steeper than the northeastern limb as a result of increasing intensity towards the SW.

It is found that inactive tectonics control the majority of the study area, which is covered by the alluvial fan sediments, while the low tectonic activity part is covered by the pre-Quaternary sediments of Mukdadiyah Formation at the extreme NE of the study area.

CONCLUSIONS

- Investigation of the geomorphologic indicators of the neo-tectonic activity such as drainage basin asymmetry, transverse topographic symmetry, mountain front sinuosity and ratio of valley floor width to valley height show that the area is subjected to lesser tectonic activities.
- Tilting and differential uplifts are related to the active movement on regional longitudinal thrust fault affecting the neighboring southeastern area (Zurbatiya area)
- Erosion on the surface played important role in the revitalization of geomorphological processes, which reflect the prevailing climate role in the study area.

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About the author

Ms. Luay Dawood Yousif, Graduated from Assiut University, Egypt Arab Republic, in 1979 with B.Sc. in geology. He got his M.Sc. degree from Baghdad University in 2005, in rock slope Engineering Geology. He joined GEOSURV in 1990, and was nominated as Senior Chief Geologist in 2004. His main field of interest is rock slope stability, rock and soil mechanics and raw construction materials. He contributed to many of the Iraq Geological Survey projects, especially in engineering geology and geological mapping. He has many unpublished reports and six published papers.

e-mail: luaygeo@yahoo.com
Mailing address: Iraq Geological Survey (GEOSURV), P.O. Box 986, Baghdad, Iraq.