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The Structural and Geomorphic Forms of Ranya Vicinity as Deduced from Satellite Images Data, Kurdistan Region, Northeast Iraq

Varoujan Sissakian[1, *], Ala Ghafur[1,2], Hassan Omer[3] and Hawkar Abdulhaq[4]

[1] Department of Petroleum Geology, Komar University of Science and Technology, Sulaimaniyah, Iraq
[2] University of Regina, Regina, Canada
[3] Ex-University of Kurdistan Hewler, Erbil, Iraq
[4] Department of Mineralogy, Geochemistry and Petrology, Szeged University, Szeged, Hungary
* **Correspondence**: varoujan49@yahoo.com

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Abstract

The structural forms (folds and faults) in the Iraqi Kurdistan Region exhibit more complexity in the northern and northeastern parts of the region; accordingly, complicated geomorphic forms were developed too. This is attributed to the collision of the Arabian and Eurasian plates with a convergent boundary that runs about 35 – 40 km northeast of the studied area. Many long and tight anticlines exist in the studied area, the majority of them exhibit very complex forms, such as being faulted and their axes being bent. The main characteristic structural and Geomorphic recognized forms based on the interpretation of high-quality satellite images are: Domes, en-echelon plunges, overturned beds, faulted anticlinal and synclinal axes, abandoned and recent alluvial fans, water and wind gaps, wine glasses, and different valley shapes. The recognized structural forms are quite different from those previously presented on the geological maps of different scales, and the forms are good indications for the lateral growth of the anticlines. A Field check was carried out to check some ambiguous interpreted data and to confirm the new findings.

Keywords: Overturned beds; Alluvial fans; En-echelon plunges; Dome forms; Wine glasses; Neotectonic activity.

1. Introduction

The Ranya (Raniya or Rania) vicinity and westwards is characterized by very complex structural style as compared to the neighboring areas, this is evidenced by the presence of many complicated anticlines and faults (Sissakian and Fouad, 2015). Majority of the anticlines exhibit doming and some of them are faulted, the beds are locally very steeply dipping and even overturned. This complexity is the result of the collision of the Arabian and Eurasian plates with a convergent boundary since the Late Cretaceous and still is on-going (Colman-Saad, 1978; Berberian and King, 1981; Beydoun, 1991; Beydoun and Hughes Clarke, 1992; Berberian, 1995; Alsharhan and Nairn, 1997; Blanc et al., 2003; Alavi, 2004; Jassim and Goff, 2006; Burberry et al., 2010; Burberry, 2015; Fouad, 2015). Moreover, the studied area forms the extreme southern part of the Imbricate Zone and the extreme northern part of the High Folded Zone (Fouad, 2015). This means, the area has received and still receiving compressional forces due to the collision more than those located south and southwest wards of the studied area.

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Sissakian and Fouad (2015) updated the Geological map of Iraq based on existing field investigations and interpretations of aerial photographs and satellite images.

Many researchers have studied the Ranya vicinity dealing with different subjects, those which are related with the current study are reviewed; briefly. Sharland (2001) and Jassim and Goff (2006) mentioned that "The tectonic structures of the Raniya region were formed by the Mid Miocene continental collision of the Arabian and Eurasian plates following the final closure of the Neo-Tethys Ocean during the Eocene". According to Allen et al. (2004) the Zagros Orogen (in which the studied area is located) is considered one of the largest regions of convergent deformation on Earth; due to the collision of the Arabian and Eurasian plates. Frehner et al. (2012) constructed a geological cross section that passes through the Ranya area, it was based on the field investigations and remote sensing data and shows a major northwest southeast-trending thrust fault that cuts the southwestern limb of the Raniya anticline. In the current study, we have also identified more than one thrust fault, which were not recognized previously. Fouad (2015) studied the tectonic framework of Iraq and concluded that "The intensity of deformation and amount of shortening increases towards the north and northeast. (Zebari and Burberry (2015) studied the deformation style within the fault-related folds in the Zagros Fold–Thrust Belt in IKR and they mentioned that "majority of the NW –SE trending anticlines are affected by thrust faults. The studied area covers Ranya vicinity located in the northeastern part of IKR, northeast of Erbil city by about 60 km (Fig. 1). The coverage of the studied area is about 1000 km^2. The area can be reached via different routes, Sulaimaniyah, Erbil, Rwandouz. The aim of the current study is to elucidate the tectonic framework of the Ranya vicinity based on structural and geomorphic forms, as deduced from interpreatation of satellite images and field investigations, especially to confirm the iterpeted data.

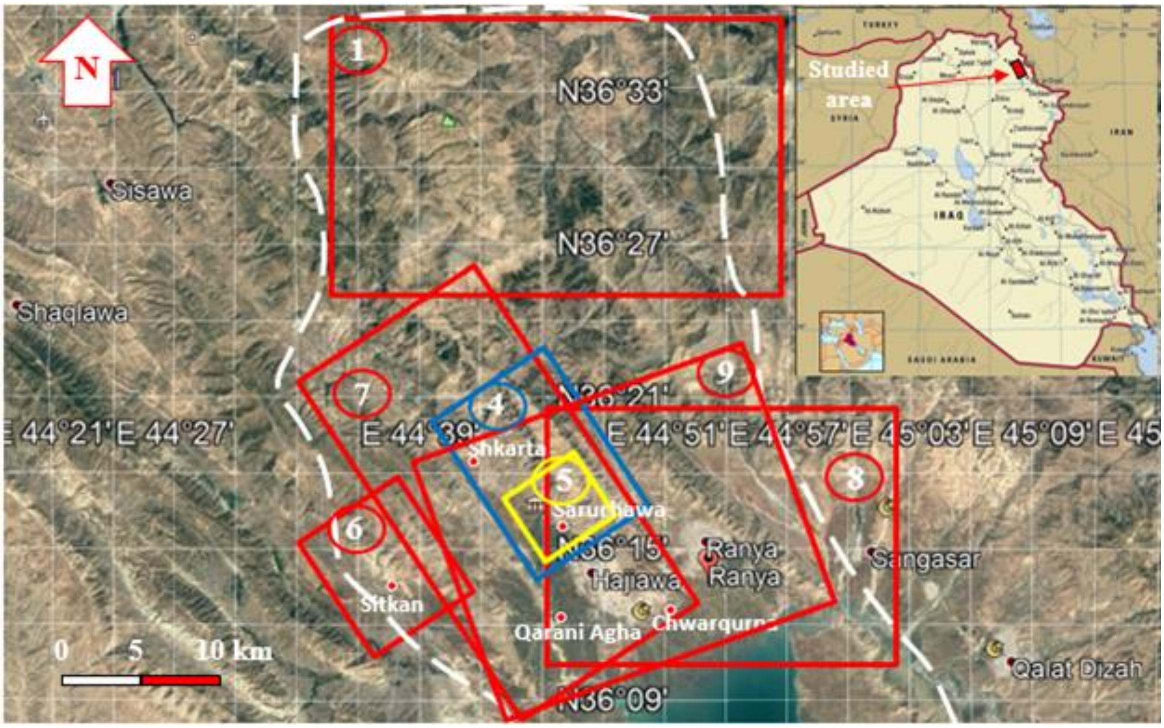

Fig. 1. Satellite image showing the studied area; approximately limited by the white dashed line. The red rectangles are the approximate locations of the presented images in the text with their relevant Figure numbers.

2. Materials and Methods

Different materials have been used, such as the existing geological map (Sissakian and Fouad, 2015) and high-quality satellite images for the purpose of updating the current geological data in the studied area. We have used and emphasized on the methods of many researchers for interpreting of different structural and Geomorphic forms about the presented data in the current study, among them are: Oberlander (1985); Burbank and Pinter (1999); Keller et al. (1999); Burbank and Anderson (2001); Keller and Pinter (2002); Ramsey et al. (2008); Bull (2009); Cowie (2009); Foosen (2010); Grasemann and Schmalholz (2012); Collignon et al. (2016). Some of the presented images in the text are not aligned northwards and have different tilt angles to show the clearest vison for the interpreted data. Accordingly, some of the images may cover different areas as compared to those which show some overlapping areas. We have conducted field investigations to check some of the interpreted data and to present field photographs for the interested structural and geomorphic features, which were interpreted in the current study. We also have estimated the rate of downward movement depending on the morphometry of the old and recent alluvial fans. This was done by dividing the height difference between the apex of the old and recent alluvial fans (which represents the downward amount) and the time span of the Pleistocene Epoch.

3. Geological Setting

The geological setting of the study area is briefed based on Sissakian and Al-Jiburi (2014); Sissakian et al. (2014); Fouad (2015) and Sissakian and Fouad (2015). The geological map of the studied area is presented in Fig. 2.

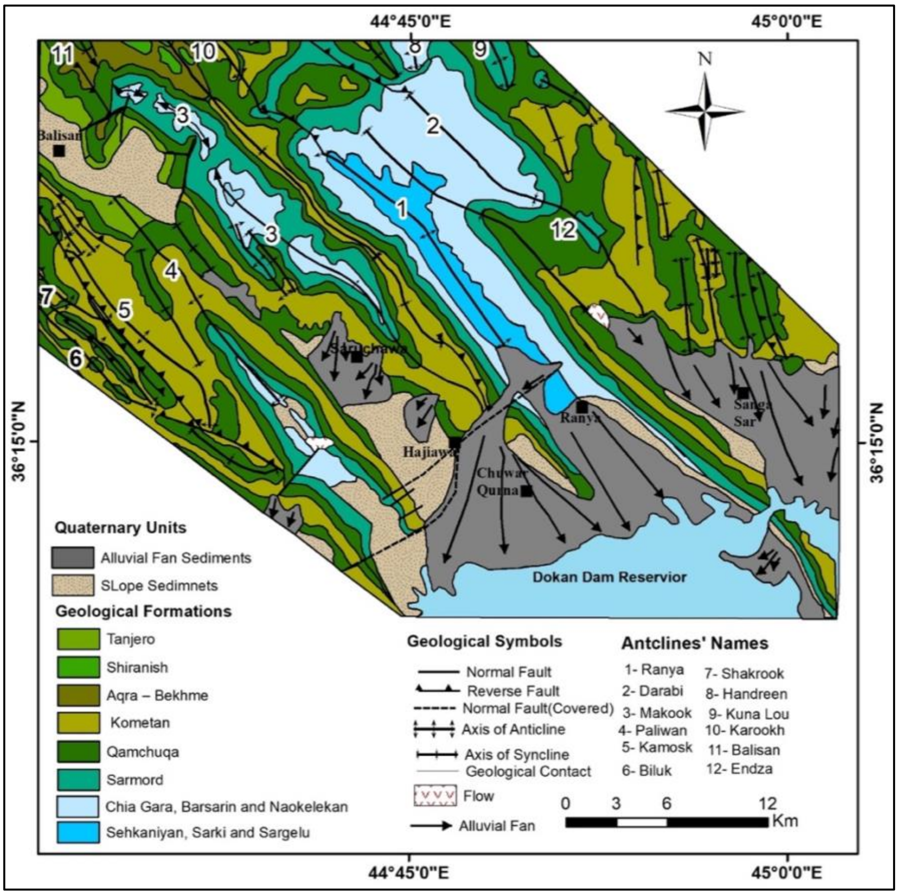

Fig. 2. Geological map of the study area (Modified and redrawn after Sissakian and Fouad, 2015)

3.1. Geomorphology

The studied area is mountainous with very rugged cliffs and steep slopes dissected by deep valleys and gorges. The highest peak is in Karookh mountain attaining 2672 m (a.s.l.), whereas the lowest height is along the Dokan Reservoir and attains about 499 m (a.s.l.). The main forms are presented in Figs. 3 and 4. Abandoned alluvial fans, recent alluvial fans, water and wind gaps, wine glasses, extensive karstification, different valley forms, anticlinal ridges, dissected slopes, and landslides. Such forms were confirmed by Burbank and Pinter (1999); Keller et al. (1999); Burbank and Anderson (2001); Keller and Pinter (2002); Ramsey et al. (2008) to be good indications for the lateral growth of anticlines.

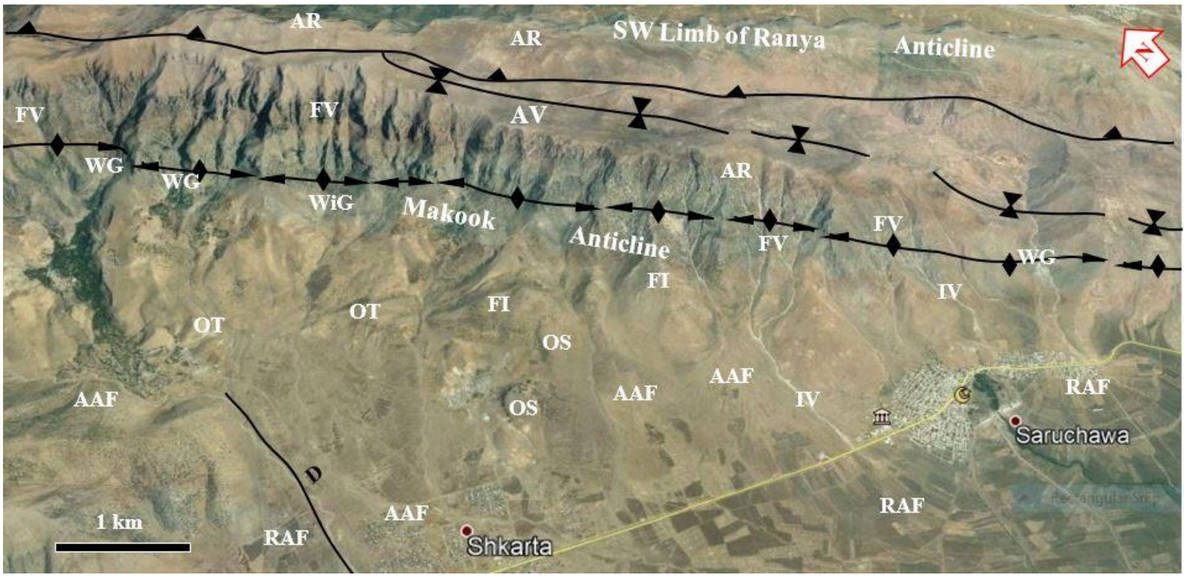

Fig. 3. Satellite image showing different Geomorphic and structural forms in Makook anticline. AAF= Abandoned alluvial fan, RAF= Recent alluvial fan, FV= Forked-shape valley, IV= Inclined valley, AV= Axial valley, WiG= Wine glass, WG= Water gap, OT= Overturned bed, AR= Anticlinal ridge, FI= Flat iron, OS= Old landslide. The black line is a normal fault (D is the down thrown side). Also note the domes and the thrusted Ranya anticline over Makook anticline. For location.

3.2. Tectonics and Structural Geology

Tectonically, the studied area is in the High Folded and Imbricate zones represented by Ranya, Darabi, Makook, Paliwan, Kamosk, Biluk, Kani Lou, Karookh and Balisan, other anticlines plunge in the studied area like Shakrook, Handreen, Endza (Fig. 2). Both mentioned zones are located in the Outer Platform of the Arabian Plate (Fouad, 2015), and are part of the Zagros Fold -Thrust Belt (Berberian 1995; Alavi, 2004; Ramsey et al., 2008). Many anticlines are thrusted over others like Ranya anticline is thrusted over Makook anticline (Figs. 3 and 4), Kamosk anticline thrusted over Biluk anticline, causing the disappearance of the syncline in between (Fig. 6).

The axes of many anticlines are truncated by different faults (Figs. 3, 5 and 7), and the limbs of many anticlines are dissected by faults, some of them are even not visible (Figs. 3 and 7). Some anticlines are highly asymmetrical, like Shkarta (Fig. 7), Makook (Figs. 4 and 5), and the beds are overturned (Figs. 4 and 7). Many anticlines exhibit doming, like Makook (Figs. 3 and 4), Biluk (Fig. 6), Kamosk (Fig. 6), Shkarta (Fig. 7).

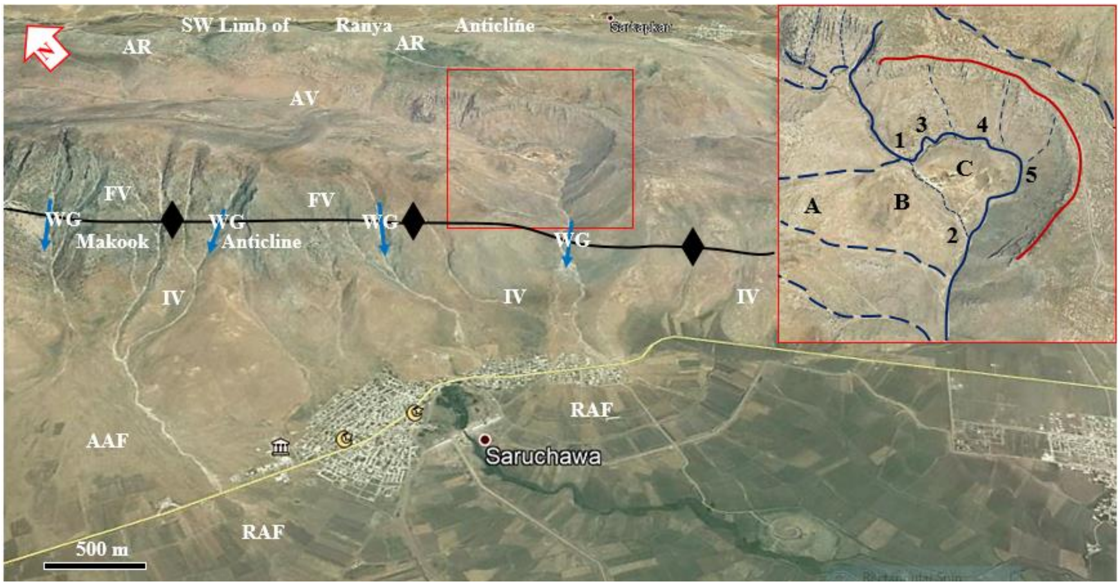

Fig. 4. Satellite image of Makook anticline. AR= Anticlinal ridge, AV= Axial valley, IV= Inclined valley, FV= Fork-shaped valley, RAF= Recent alluvial fan, AAF= Abandoned alluvial fan, WG= Water gap. Points 1 – 5 are stages of shifiting the valley. For more explanation of the insight, read the text (4.2.1.). The blue arrows are some of the marked water gaps. For location, refer to the Fig. 1.

3.3. Stratigraphy

The exposed formations in the studied area are shown in the geological map (Fig. 3). A columnar section of the exposed formations is shown in Fig. 8.

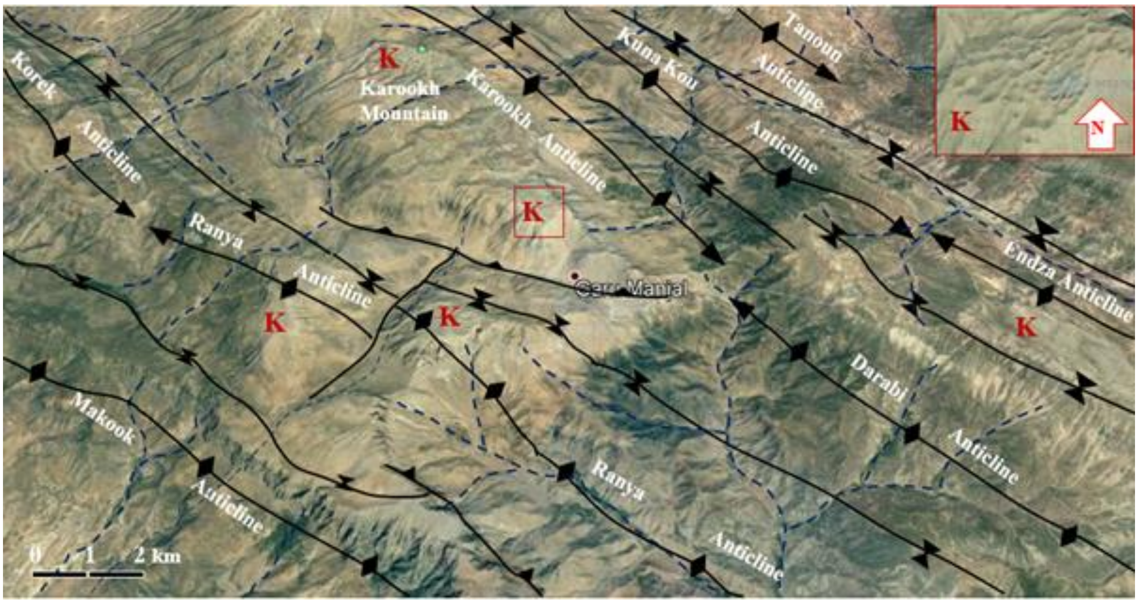

Fig. 5. Satellite image showing the structural complexity of Ranya vicinity. K refers to highly karstified areas, the insight is a close-up view. Note the crossing of the valleys to the anticlinal axes forming water gaps. For location, refer to the Fig. 1.

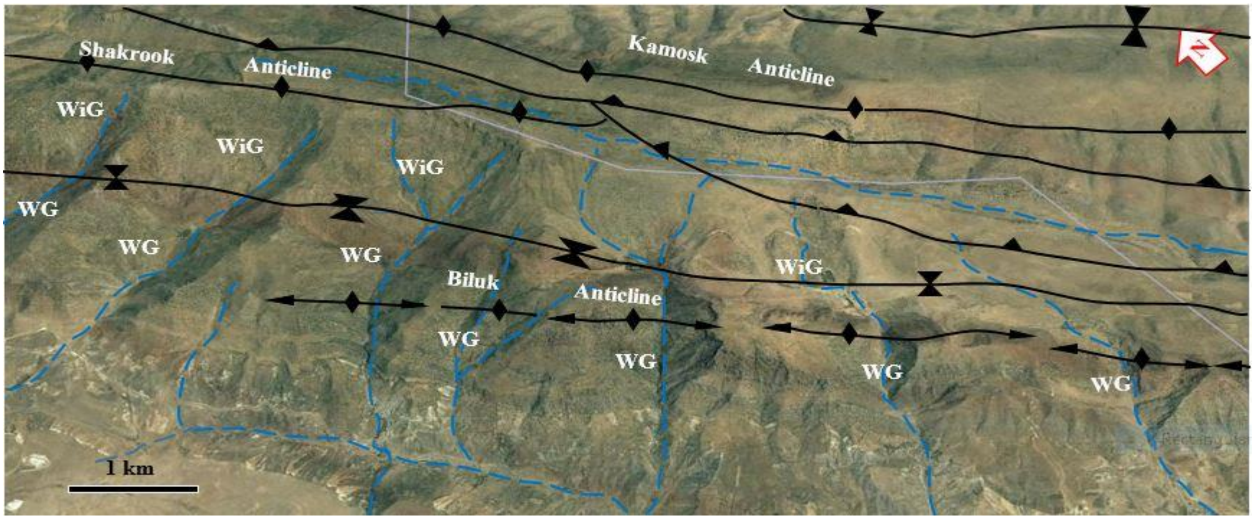

Fig. 6. Satellite image of Kamosk and Biluk anticlines. WG = Water gap, WiG= Wine glass. Note the domes in the Biluk anticline. For location, refer to the Fig. 1

4. Results and Discussion

4.1. Structural Forms

The following interesting structural forms were recognized and interpreted, they are good indications for the lateral growth of the anticlines and for Neotectonic movements.

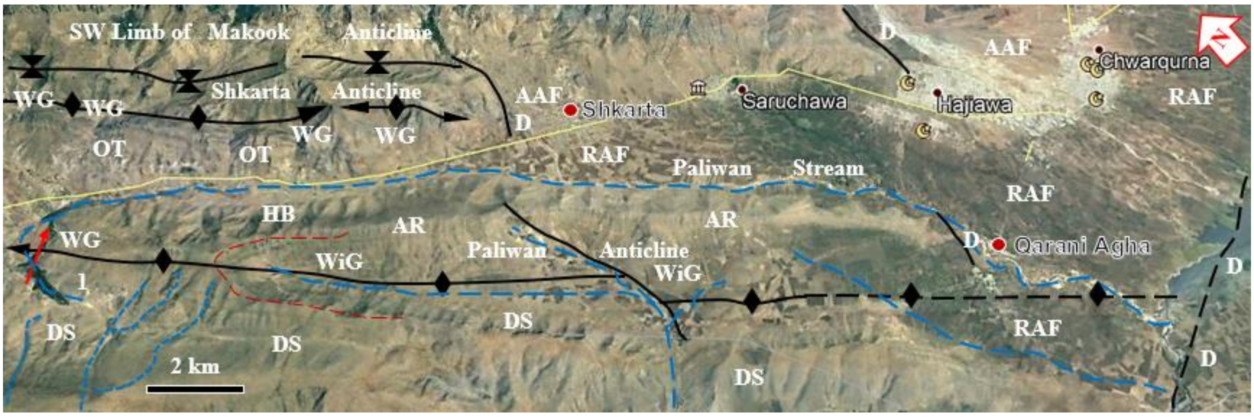

Fig. 7. Satellite image of Paliwan and Shkarta anticlines. WG = Water gap, WiG= Wine glass. RAF= Recent alluvial fan, AAF= Old (abandoned) alluvial fan, OT= Overturned bed, HB= Hogbacks, DS= Dissected slopes, AR=Anticlinal ridges, WG= Water gap. Brown dashed line is a bedding trace, black lines are faults, dashed blue lines are the main vallyes (D is the down thrown side of a normal fault). For location, refer to the Fig. 1.

4.1.1. Domes

When an anticline exhibit domes, then it is a good indication for the lateral growth of that anticline (Cartwright et al., 1995; Dawers and Anders, 1995; Cowie, 1998; Blanc et al., 2003 and Bennett et al., 2005). Folds during growing can join each other to form one single and long fold (Grasemann and Schmalholz, 2012). In the studied area, Makook (Fig. 4), Biluk (Fig. 6) and Shkarta (Fig. 7) anticlines are good examples for the joined domes to form one single anticline. Aligned fold segments; however, are likely to grow at the expense of other, non-aligned segments, by a positive feedback in the stress changes around the structure. Therefore, fold segments grow in length and divert drainage around their ends (Cowie, 1998); accordingly, en-echelon plunge can be developed, as between Kana Kou and Endza anticlines, Karookh and Durabi anticlines, Ranya and Korek anticlines (Fig.2), and in the extreme part of the Kamosk anticline, where the western dome makes a right-hand en-echelon plunge with the east wards located dome (Fig. 3).

4.1.2. Neotectonic indications

The most significant indications in the studied area for Neotectonic activity are the alluvial fans. Many recent alluvial fans are located adjacent to old (abandoned) alluvial fans where the abandoned feeder channels are still visible. Good examples are near Ranya (Fig. 9), Chwarqurna (Figs. 7 and 9), Hajiawa (Figs 7 and 8), Saruchawa (Fig. 5) and Shkarta towns (Fig. 4).

Formation	Age	Thickness (m)	Lithological Symbols	Description
Tanjero	Upper Cretaceous	700-1000		Interbedding of coarse-grained dark grey sandstone with claystone with some thin conglomerate beds. Occasionally thin limestone horizons may occur.
Shiranish		230 - 300		Green and blue papery marl underlain by well thinly bedded white marly limestone.
Bekhme		100 - 115		Thickly bedded limestone and dolomite
Balambo	Lower Cretaceous	500		Well bedded pale white marly limestone, with rare olive-green marl.
Qamchuqa		750		Thickly well bedded and massive dark grey and grey limestone, dolomite, and dolomitic limestone.
Sarmord		650		Thinly bedded marly limestone and marl with shale beds.
Chia Gara		25		Thinly bedded and papery limestone, dark brown shales, and dolomitic marl.
Barsarin	Upper Jurassic	10		Black bituminous dolomitic shales and thin dolomitic limestone with stromatolite
Naokelekan		15		Laminated shaley limestone with grey and brown limestone overlain by black carbonaceous shales
Sargelu	Lower Jurassic	70		Black limestone and shale with black chert and brown dolomitic marl, and highly fossiliferous limestone
Sehkaniyan		225		Massive dark dolomite with a sugary texture, generally bituminous
Sarki		230		Thinly bedded, light grey dolomitized limestone, generally bituminous and fossiliferous
Baluti		42		Green shales with intercalations of thinly bedded dolomitized limestone
Kura China	Upper Triassic	10		Black limestone, alternated with dolomites and papery shales

Fig. 8. Generalized column at section of the exposed formations in the studied area (based on Sissakian and Fouad, 2015).

In Fig. 9, the trend of the main-stream north of Ranya town was NW – SE (Points A – B, Fig. 9), which had deposited the alluvial fan of Ranya (Fig. 9). However, a fault that had dissected the southwestern limb of the Ranya anticline (at Point C, Fig. 9) had changed the direction of the main-stream towards southwest (C – D – E, Fig. 9) and the alluvial fan near Chwarqurna was deposited.

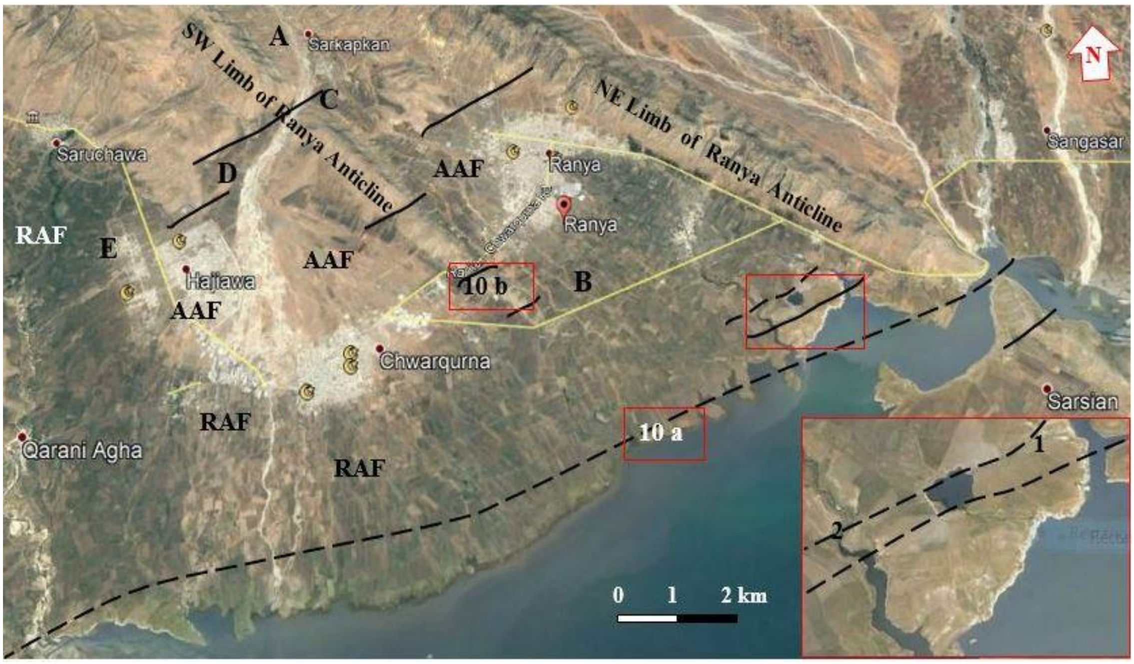

Fig. 9. Satellite image of Ranya anticline with the deposited alluvial fans. Note the old (abandoned) alluvial fans with the abandoned feeder channels, and the step type faults. AAF= Abandoned alluvial fan, RAF= Recent alluvial fan. Number 9 refers to an approximate location for two field photos (Figure 10a and 10b). For letters A, B, C, and D, refer to the text. The insight is a small pond with hot water spring, note the straight small valley (1 – 2) and the bend of the main valley at point 2. For location, refer to the Fig. 1.

Another fault (at Point D, Fig. 9) had changed the trend of the main stream towards SSE and a new alluvial fan was deposited near Hajiawa town (RAF, Fig. 9), which is still active, and the abandoned (old) alluvial fan near Chwarqurna town (AAF, Fig. 9) still can be seen with the old feeder channels. The feeder channels were shifted due to faulting, which means during the Pleistocene; because the age of the alluvial fans in Iraq is considered as Pleistocene (Sissakian et al., 2014); therefore, they are considered as Neotectonic activity.

A good example for a Neotectonic activity is a long stream that originates from the northwestern plunge of the Paliwan anticline (Point 1, Fig. 7) and turns around the plunge northwards crossing the axis forming a water gap and ten flows along the northeastern limb of the anticline for about 36 km then drains inside the Dokan Dam Reservoir, east of Qarani Agha town (Fig. 7). The crossing of the stream through a water gap is attributed to the lateral growth of the Paliwan anticline; accordingly, indicating a Neotectonic activity. It is worth to mention, that just 1 km east of the starting point of this stream (Point 1, Fig. 7) all the valleys along the southwestern limb of the Paliwan anticline flow southwards; some of them start near the axis of the anticline (Fig. 7). It is more likely that the long stream to flow southwards; as all other valleys, but due to the lateral growth of the anticline, the stream has carved in the hard rocks of the Qamchuqa Formation (Fig. 3) and crossed the axis of the anticline and forms a very long stream (Fig. 7).

Another good indication for a Neotectonic activity is the developed small pound (Fig. 9) with hot water spring that has no contact with the Dokan Dam Reservoir. Two faults can be seen on both sides of the pond (Insight of Fig. 9). The first one coincides with a small valley, which drains inside the pond and the fault's continuation towards southwest coincides with the bend of a main valley that drains inside the Dokan Dam Reservoir (Points 1 and 2, respectively, Insight of Fig. 9). Whereas the second fault coincides with the other bend of the main valley that drains inside the Dokan Dam Reservoir (Fig. 9). This valley is developed within the soft sediments of the recent alluvial fan, where all the valleys run almost in straight courses following the gradient. Therefore, the bends of the valley are developed due to the activity of the faults; accordingly, are considered as Neotectonic activity because it had happened during the Quaternary Period. Moreover, the water in the pond is isolated from the Dokan Dam Reservoir by the two faults; otherwise, it should be in contact with the reservoir's water that is few meters lower than the level of the water in the pond. The water in the pond comes through a hot water spring that has no hydrogeological relation with the water regime in the Dokan Dam Reservoir.

4.1.3. Faults

The studied area is characterized by tens of faults of different types and extensions (Figs. 2, 3, 4, 5, 6, 7 and 9). The normal and strike-slip faults have NE – SW trend, whereas the thrust and reverse faults have almost the same trends of the anticlines that is NW – SE with some exceptions; like the axis of the syncline that runs between Ranya and Makook anticlines (Fig. 2) or thrust faults which dissect each other (Fig. 5). The authors believe that a long normal fault or small normal faults in NE – SW trend had dissected the limbs of Ranya, Makook and Paliwan anticlines and formed a large depression which is occupied by the Dokan Dam Reservoir (Fig. 9). This fault was also confirmed by Sissakian et al. (2020). The continuation of the faulted beds along the southwestern limb of the Ranya anticline was seen (Fig. 10 a) along the western bank of the Dokan Dam Reservoir during 2016 when the water level was decreased by about 8 m, due to a drought year (Fig. 9 and Fig. 10b). All these faults are developed during the Quaternary Period (Neotectonic) as indicated from shifting the courses of the feeder channels of the alluvial fans, abandoning some alluvial fans, and developing recent alluvial fans (Fig. 9). Accordingly, are considered as Neotectonic activity.

Fig. 10. a) Limestone outcrops of the southwestern limb of the Ranya anticlines along the western bank of Dokan Dam Reservoir (July 2016); b) Faulted rocks along the southwestern limb of the Ranya anticline showing longitudinal Karren's (For location refer to Fig. 9).

4.2. Geomorphic Forms

The main and significant interpreted geomorphic forms from satellite images and confirmed during a filed investigation are presented hereinafter. The geomorphic forms are marked on many images in the current study.

4.2.1. Water gaps

Water gaps are developed almost along all anticlines in the studied area (Figs.2, 3, 4, 5, 6 and 7). Some of them form very special case; like that shown in Fig. 4. A semi-circular Wine Glass Valley was formed by an axial valley at the end of a southeast plunging syncline (Fig. 4) that leads to a water gap, the old stream was running from point 1 to point 2 (Fig. 4); however, a small landslide (From point A to points B and C, Fig.4) had shifted the course of the stream to its nowadays course (Points 1, 3, 4, 5 and 2, Fig. 4). With continuous sliding, small shifts can be seen along the stream (at Points 3, 4 and 5, Fig. 4). The semi-circular form is formed due to continuous erosion of the beds and falling of the upper parts. Usually, synclines are developed in lower elevations as compared to the adjoining anticlines; in this case; however, the syncline is higher than the Makook anticline. This attributed to the thrust faults which exist along the southwestern limb of the Ranya anticline (Figs. 2 and 4), and had raised the syncline; accordingly, this very rare and special form has been developed.

4.2.2. Wine glass valleys

These are very special Geomorphic forms developed in mountainous areas; usually along steep slopes, which are dissected by deep valleys (AG1, 2015). In the studied area, tens of Wine Glass Valleys are developed (Figs. 4, 5, 6 and 7), a special type of wine glasses; however, are developed along the trough of the syncline which exists between Shakrook and Biluk anticlines (Fig. 6). The wine glasses are followed by water gaps, which are developed along the Biluk anticline (Fig. 6). A very large wine glass is developed in Paliwan anticline at the core of the anticline (Fig. 7).

4.2.3. Anticlinal ridges

The anticlinal ridges are well developed in the studied area (Figs. 2, 3, 4, 5, 7 and 9). Locally, the ridges present the anticlinal form, especially, the crestal (curved) part like in the Paliwan anticline (Fig. 7), others' forms longitudinal cliffs extending for few kilometers, like in the Ranya anticline (Figs. 2 and 9), Makook anticline (Figs. 2, 3 and 4). However, some of the anticlinal ridges are densely faulted leading to being segmented, and the developed spaces between segments are utilized by some streams to deposit the alluvial fans (Fig. 9). Due to the activity of the faults, the streams have abandoned some alluvial fans and deposited recent fans (Fig. 9).

4.2.4. Alluvial fans

The studied area is characterized by the development of alluvial fans, especially at Ranya vicinity (Fig. 11). The alluvial fans in the studied area are either abandoned (their feeder channels have abandoned them) or are active (receiving sediments by the feeder channels) (Figs. 9 and 11). This is attributed to the active faults (Figs. 9 and 11), which have dissected the anticlinal ridges (Figs. 9, 10 and 11) and the lateral growth of the anticlines; accordingly, some of the feeder channels were shifted and their alluvial fans were abandoned. To reconstruct the heights of the apexes of the abandoned channels, their heights were measured from satellite image (Table 1). The heights of the apexes of the abandoned alluvial fans were estimated by the following equation:

H= Da – Dr = Height difference of the distal parts, where:

Da = Height of the abandoned alluvial fan, and Dr = Height of the recent alluvial fan
Both heights were measured from satellite images (Fig. 11).
Aa = Ar + R, where:
Aa= Estimated height of the apex of the abandoned alluvial fan
Ar= Height of the recent fan's apex (measured from satellite image)
The average of height differences in the apexes of the studied fans (Table 1) is 28.8 m.

To calculate the rate of the downward of the studied fans, we have considered that the age of the recent alluvial fans is older than the Holocene.This assumption was based on the age of an archeological site called "Girdi Tle" (Fig. 11) that is estimated to be between 9th and 7th century BC (Kalla and Dezso, 2019), which means older than the Holocene (Mike et al., 2009). Therefore, we have considered that the recent alluvial fans to be deposited within the Late Pleistocene (126000 yr, ICS, 2020). Accordingly, the rate of the downward will be (2.2857 and 4.183) cm/ 100yr; if we consider from the beginning and middle of the Late Pleistocene (68850 yr), respectively.

4.2.5. Karst forms

Most of the out crops in the study area are of carbonate rocks; therefore, karstic features are the dominant landforms in the area. The most common karstic features are karrens, and caves. The former is densely developed on the top of Karookh Mountain, as honeycomb karrens (Fig.5) and as longitudinal karrens (Fig. 10 b) at different parts of the study area.

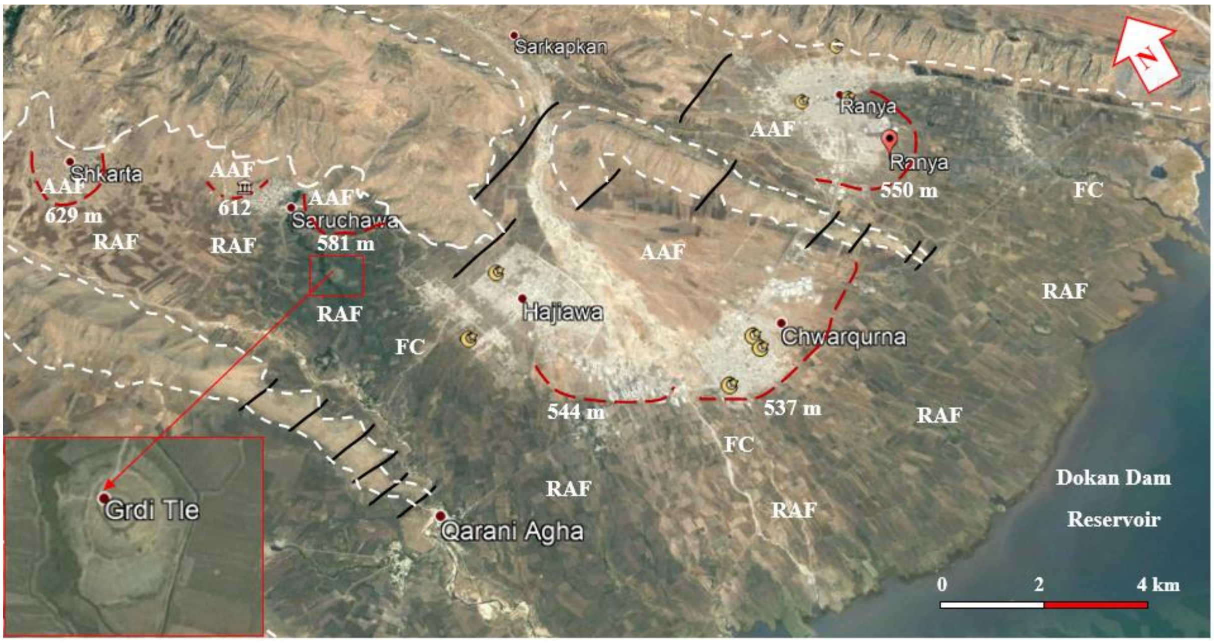

Fig. 11. Satellite image of five studied alluvial fans. The white dashed line represents the mountain fronts, the red dashed line represents the distal part of the abandoned alluvial fans with height in meters. RAC= Recent alluvial fan, AAF= Abandoned alluvial fan, FC= Main feeder channel. Black lines are normal faults, the eastern block is the down thrown. For location, refer to the Fig. 1.

Table 1. Characteristics of main alluvial fans in Ranya vicinity (* the apex height is estimated from the difference of the heights of the distal parts between recent (active) and abandoned fans, then the difference was subtracted from the height of the apex of the reent fan)

Name	Activity	Shape	Height (m)			Length (km)	Width (km)	Gradient (%)	Comments
			Apex (a.s.l.)	Distal Part (a.s.l.)	Difference in Apex				
Chwarqurna	Abandoned	Fan	566*	537	42	5.92	3.58	0.49	It is the largest fan in the Ranya vicinity. The fan is deposited by a stream that was flowing between Hajiawa and Chwarqurna, but due to active faults the feeder channel was shifted, and the fan was abandoned. The recent fan; however, is receiving sediments from the shifted feeder channel.
	Active	Fan	608	495		10.60	7.55	1.07	
Hajiawa	Abandoned	Fan	575*	537	33	4.28	2.90	0.77	This alluvial fan is deposited after the main feeder channel of Chwarqurna fan was shifted.
	Active	Longitudinal	608	504		11.42	4.58	0.03	
Saruchawa	Abandoned	Fan	616*	581	18	0.88	0.56	2.65	This alluvial fan has a typical fan-shaped, both the abandoned and the recent one.
	Active	Fan	598	563		2.24	2.22	0.80	
Saruchawa-Shkarta	Abandoned	Fan	601*	612	21	1.62	0.99	1.29	The recent alluvial fan has a longitudinal shape with dissected eastern side due to the feeder channel (Fig. 5).
	Active	longitudinal	580	591		2.46	1.57	0.85	
Shkarta	Abandoned	Fan	675*	629	30	1.91	1.10	2.41	The recent alluvial fan has a longitudinal shape with dissected western side due to the feeder channel.
	Active	Longitudinal	705	599		4.73	3.10	0.63	
Ranya	Abandoned	Fan	550	87		5.00	3.58	1.74	This fan was abandoned due to the active fault that has shifted the feeder channel near Sarkapkan village (Fig. 9)

5. Conclusions

The study area is characterised by very complex structural forms, this is attributed to the existence of many anticlines; majority of them are thrusted over the adjacent syncline and even the anticline. This has caused hindering of synclinal axes and partly the anticlinal axes. The thrust faults have almost the same trend of the folds. Tens of normal faults occur in the area, all have NE – SW trend and have caused dissection of the anticlinal ridges and locally their total disappearance from the surface. Different geomorphic forms are developed along all anticlines, like water gaps, fork-shaped valleys, axial valleys, inclined valleys, abandoned alluvial fans. These forms indicate the lateral growth of the anticlines, northwest wards. Special and very rare types of water gaps are developed, they cross more than one-fold axes; successively. Some of the water gaps are associated with wine glass forms and/ or valleys. The studied area is also characterised by the development of alluvial fans, most of them show two stages, old and recent mainly because of the shifting of the feeder channels due to faulting. From the morphometry of the old and recent alluvial fans, we have estimated the rate of the downward to be about 2.2857 cm/ 100 years if we consider from the beginning of the Late Pleistocene, and 4.183 cm/ 100 year if we consider during the middle of the Late Pleistocene.

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