

Indications of Lateral Growth of Anticlines. Examples from Kurdistan Region, Northern Iraq

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Abstract

The Kurdistan Region of Iraq (KRI) forms the northeastern part of the Arabian Plate that is colliding with the Eurasian Plate. Due to the ongoing collision, the whole KRI territory is folded; accordingly, long anticlines are developed in NW – SE trend, they change west wards to almost E – W. The Cretaceous carbonate rocks form the bulk of the anticlines; in the central part of KRG. North and northwest wards, rocks of Paleozoic, Triassic and Jurassic ages are exposed in the core of some anticlines. Whereas southwards, Tertiary rocks are exposed in the core of anticlines. From tectonic point of view, the KRI territory is located in four tectonic zones; each has its own characteristics. Majority of the developed anticlines at the KRI are thrust and exhibit lateral growth. We have presented many examples of laterally growing anticlines with clear indications for their growth.

Keywords: Lateral Growth, Water and Wind Gaps, En-echelon Plunge, Dome, Wine Glass, Thrust Fault.

1. Introduction

The KRI is located in the northeastern part of the Arabian Plate (Figure 1). The plate is colliding with the Eurasian Plate (Alavi, 2004). Due to ongoing collision, the whole KRI territory is folded; accordingly, long anticlines are developed in NW – SE trend; however, the trend changes west of latitude 43° 30' E to E – W (Figure 2). This is attributed to the role of Zagros and Taurus folding, respectively on the Iraqi territory and especially in the KRI.

The bulk of the anticlines in the central part of KRI are built up mainly by carbonate rocks of the Cretaceous Period (Figure 3 and 4). North and northwest wards, however, rocks of Paleozoic, Triassic, and Jurassic ages are exposed in the core of some anticlines. Whereas southwards; Tertiary rocks are exposed in the core of anticlines (Sissakian & Fouad, 2015).

From the tectonic point of view, the KRI territory includes four tectonic zones; they are from NE towards SW: 1) Zagros Suture Zone, 2) Imbricate Zone, 3) High Folded Zone, and 4) Low Folded Zone (Fouad, 2015). However, the Zagros Suture Zone belongs to the Eurasian (Iranian) Plate.

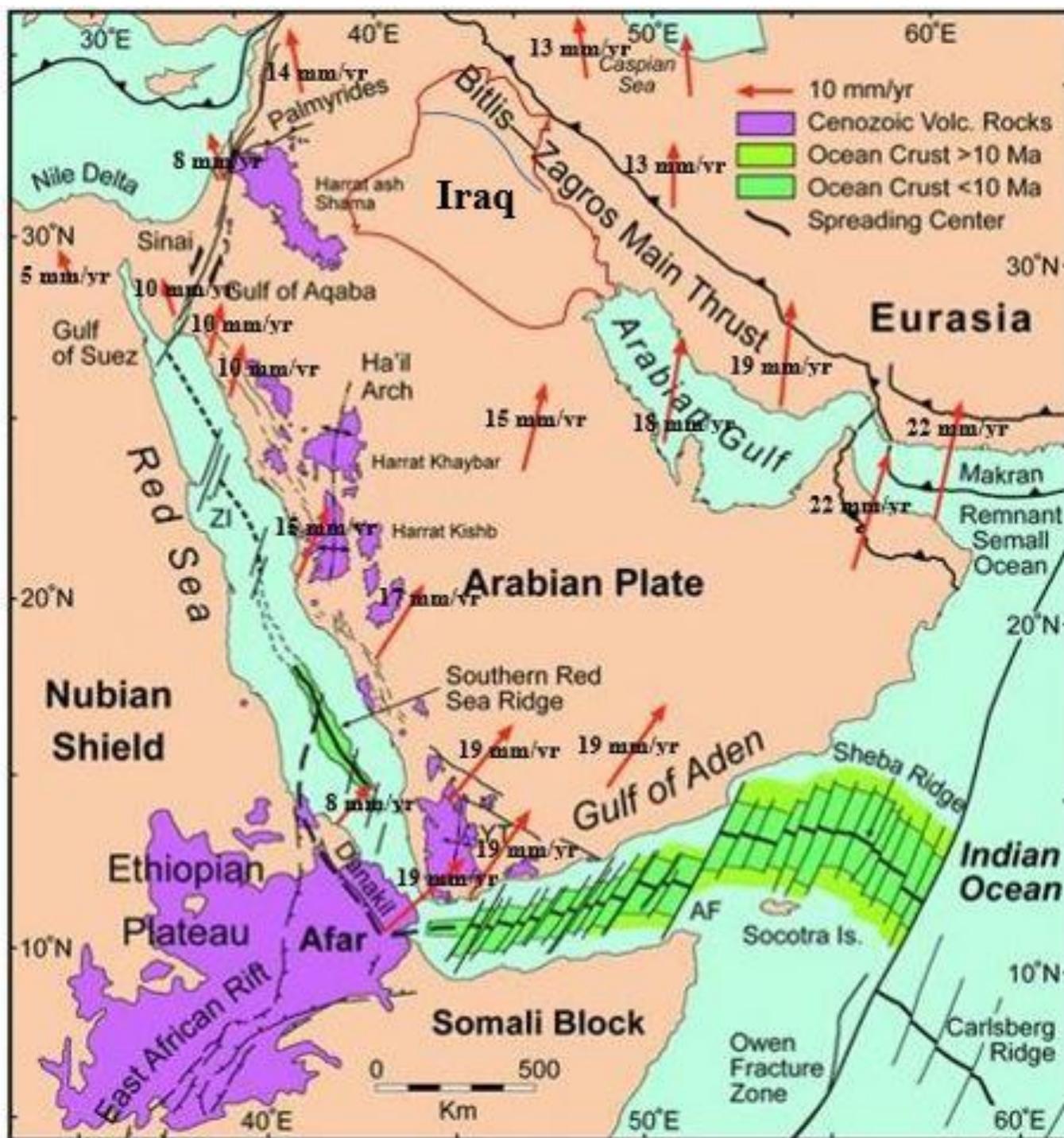


Figure 1. Tectonic map of Saudi Arabia and surroundings showing the rates of plate's movements (Bosworth, 2015). The Iraqi territory is added approximately to the map by the authors. The blue line represents approximate southern borders of KRI.

The intensity of folding decreases southwest wards as being far from the collision site between the two plates. Moreover, the mentioned four tectonic zones belong to the Zagros Fold – Trust Belt (ZFTB) which in term belongs to the Zagros foreland basin (Sissakian, 2013; Fouad, 2015).

Part of the developed anticlines in the KRI are thrust, locally the northeastern limb is thrust over the southwestern limb (Figure 3); however, rarely the whole anticline is thrust over the southwards existing anticline hindering the syncline in between (Figure 4, 5, and 6) (Sissakian & Fouad, 2015; Sissakian et al., 2022).

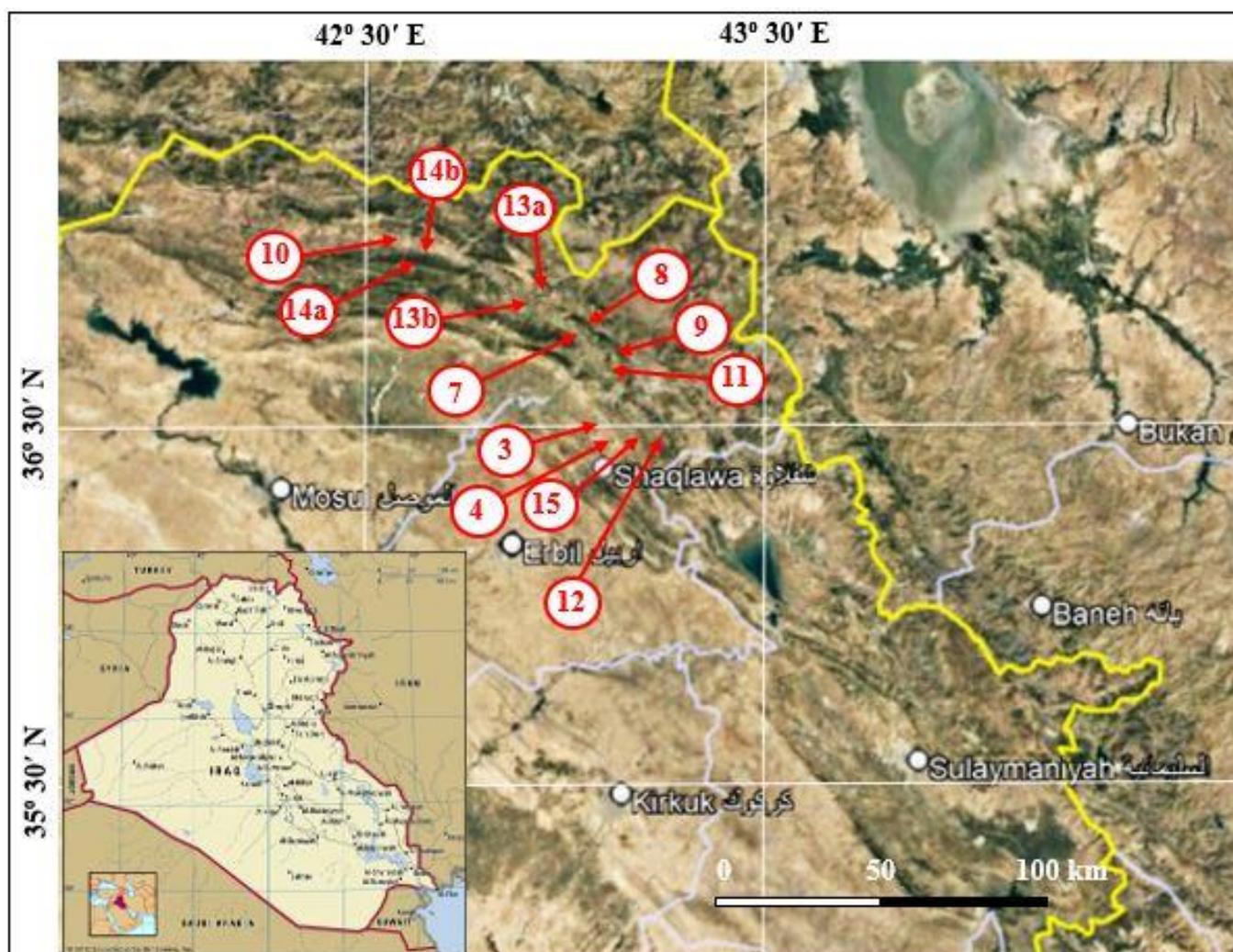


Figure 2. Satellite image showing the trend of the anticlines in KRI and the locations of presented figures in the text.

Other anticlines exhibit lateral growth mainly northwest wards. This is indicated by different geomorphological and structural features (Ghafur et al., 2019; Sissakian et al., 2020a, 2020b).

2. Lateral Growth of the Anticlines

The KRI is tectonically active area because it is located in the northeast of the Arabian Plate, which is in collision with the Eurasian Plate; therefore, the lateral growth of anticlines in such tectonically active areas is a very common phenomenon (Bennett et al., 2005; Ramsey et al., 2008; Ghafur et al., 2019; Sissakian et al., 2020a and b). The anticlines in the KRI are still active, as witnessed from different geomorphological and structural forms mentioned by different authors.



(a)



(b)

Figure 3. Field photograph of the Hareer anticline, note the thrust fault which runs between the northeastern limb over the southwestern limb, partly hindering the anticlinal axis. a) Central part, b) Southeastern part.



Figure 4. Field photograph looking SE. Hareer anticline (in the left) is thrust over Shakrook anticline (in the right) hindering the syncline in between them.

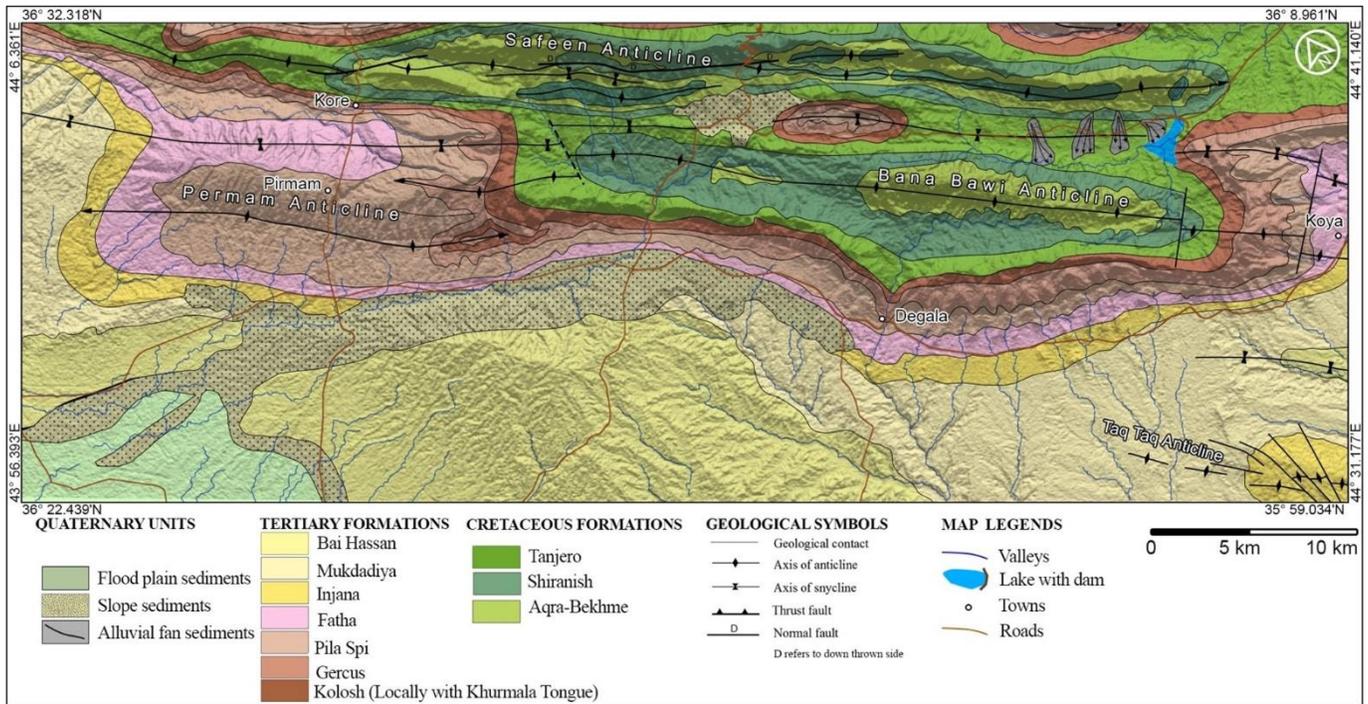


Figure 5. Geological map of Safeen, Pirmam and Ban Bawi anticlines. Note the widely exposed Cretaceous rocks in Safeen and Bana Bawi anticlines (Sissakian & Fouad, 2015).

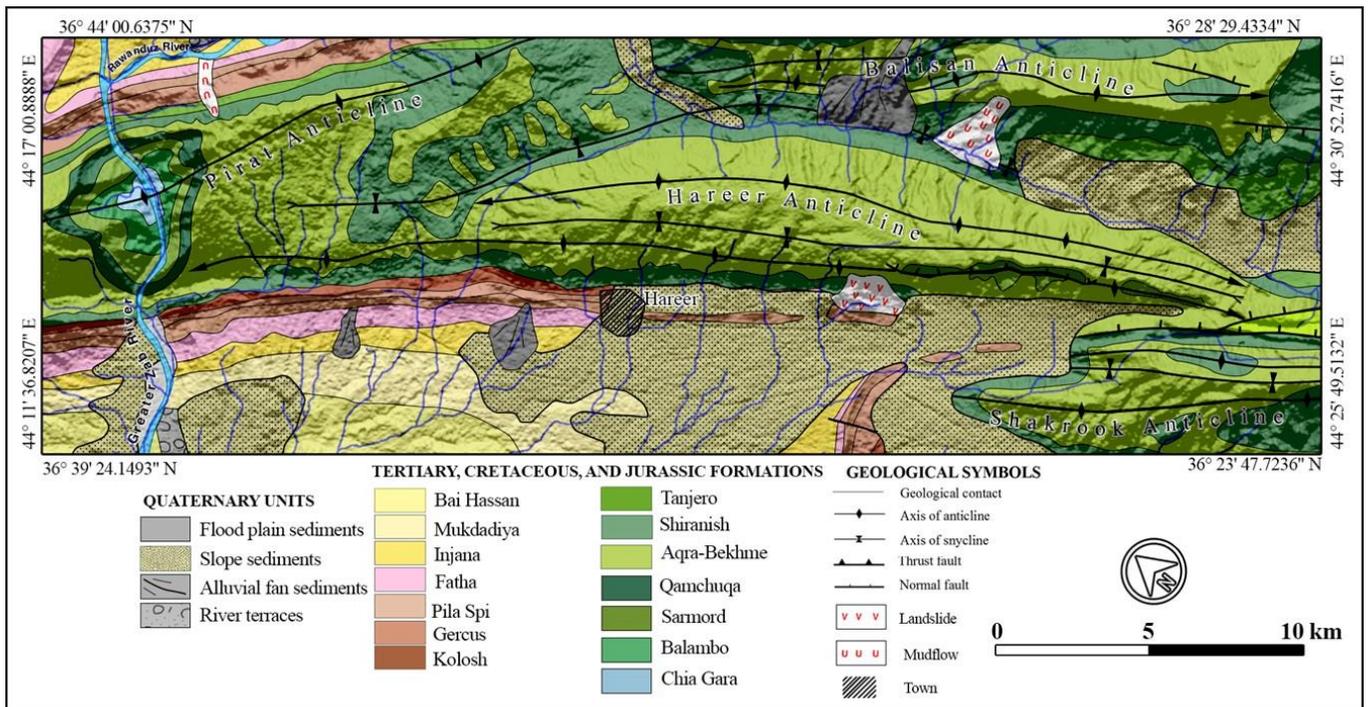
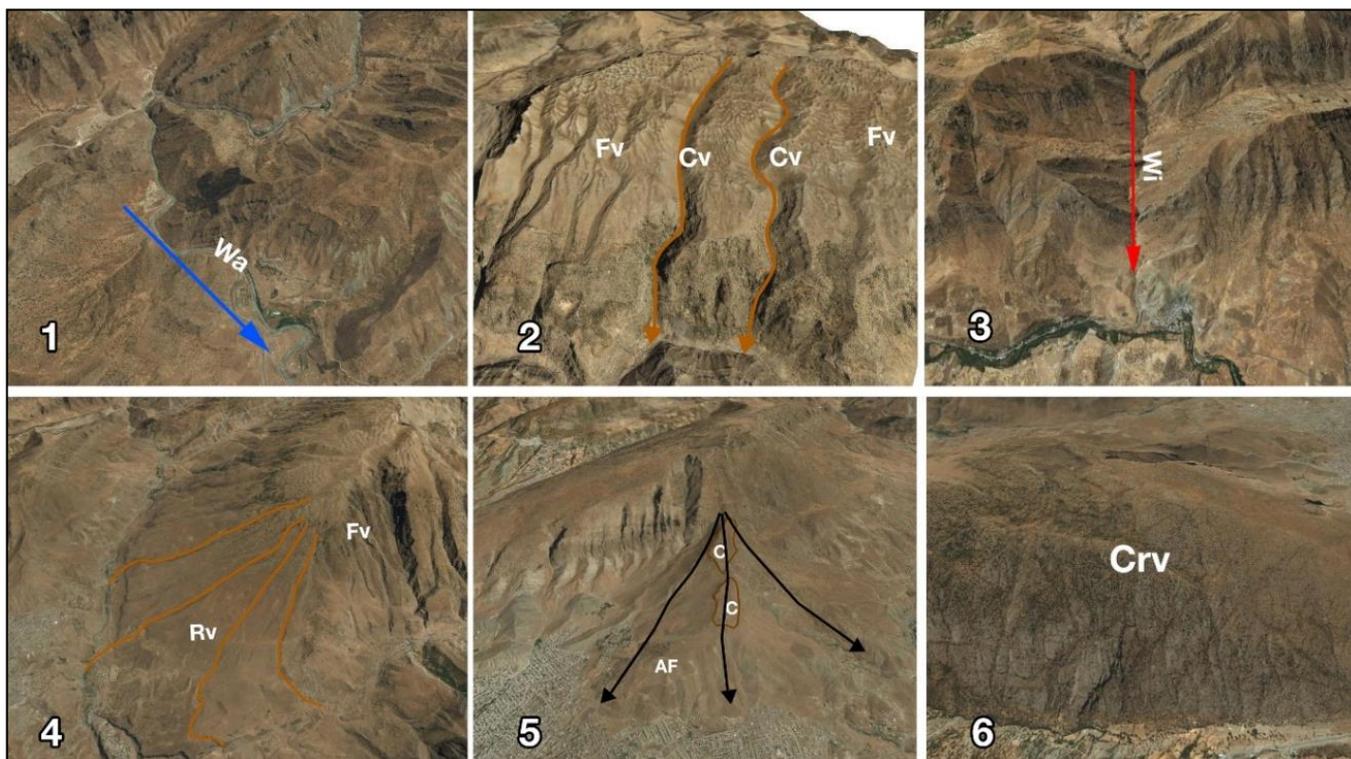


Figure 6. Geological map of Hareer, Pirat, Balisan and Shakrook anticlines, note the exposures of the Cretaceous rocks. Also note the trust fault, which has caused thrusting of the Hareer anticline over the Shakrook anticline, the syncline in between them is hindered due to a fault (Sissakian et al., 2022).

2.1. Geomorphological Features

Different geomorphological features are excellent evidence for the activity of the folds, like: Water and wind gaps, different shaped valleys such as inclined, radial, axial, fork-shaped, cross-shaped, and abandoned alluvial

fans (Burbank & Anderson, 2001; Keller & Pinter, 2002, Ramsey et al., 2008). However, the presence of one feature cannot be considered as an indication for its lateral growth. Figure (7) shows some of the mentioned



geomorphological features, which can be noticed almost in all anticlines within KRI.

Figure 7. Google Earth images of interpreted geomorphic features: 1) Wa: Water gap, 2) Cv: Curved valley; and Fv: Forked-shape valley, 3) Wi: Wind gap, 4) Rv: = Radial valleys, 5) Af: Abandoned alluvial fan, and C: calcrete, and 6) Crv: Cross-shaped valleys (Sissakian et al., 2020a)

Note: All images are northwards.

2.2. Structural Features

The structural features which indicate lateral growth of anticlines include: en-echelon folding, and domes along the anticlinal axis (Fossen, 2010; Burbank & Anderson, 2001). Figures (8, 9, and 10) present anticlines within the KRI, which exhibit en-echelon folds and domes, water gaps (WaG), Wine glass forms (WiG). Domes are given letters for each anticline, Z for Zozik, H for Handreen, and T for Tanoon anticlines. Different shaped valleys like Radial valleys (RV), Axial valleys (AxV), Inclined valleys (InV). Another indication for the growth of the anticlines is the decreasing of the valley's density towards the plunge areas (Keller et al., 1999). Good examples in KRI are in the Korek and Pirat anticlines (Figure 11).

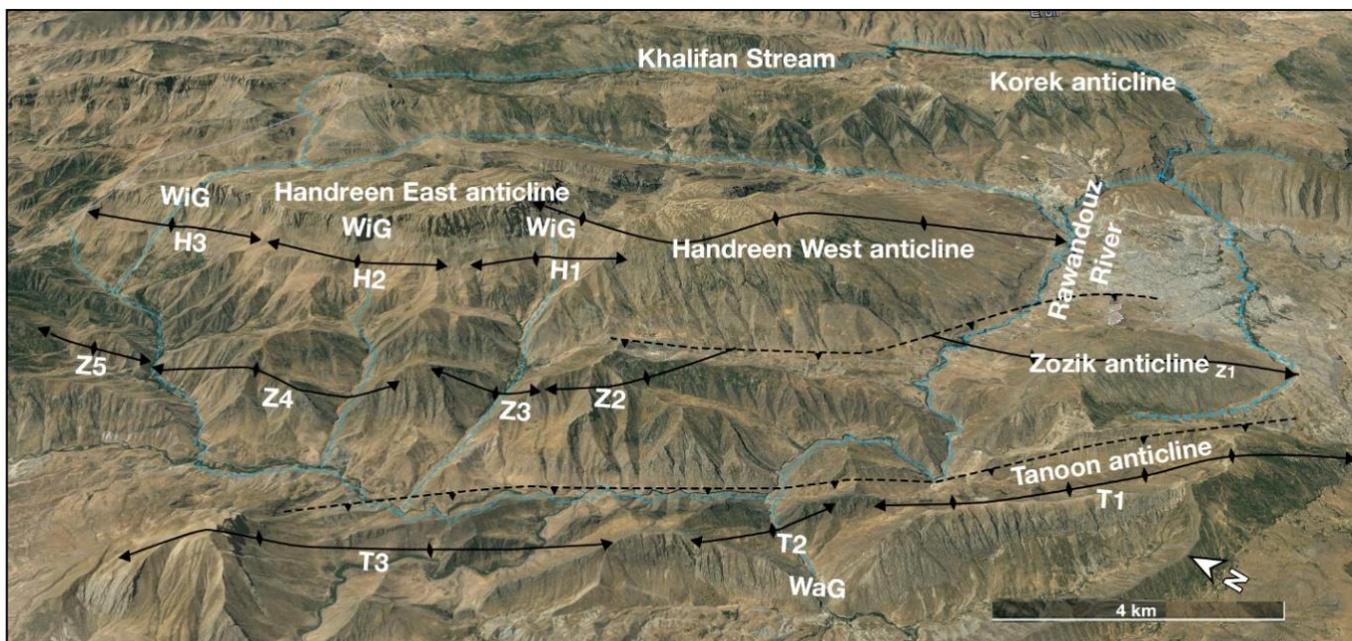


Figure 8. Google Earth image showing different interpreted geomorphic and structural forms. Thrust faults are in dashed black lines. Solid blue line is the Rawandouz river and its tributaries, dashed blue lines are wind gaps and some selected valleys (Sissakian et al., 2020a)

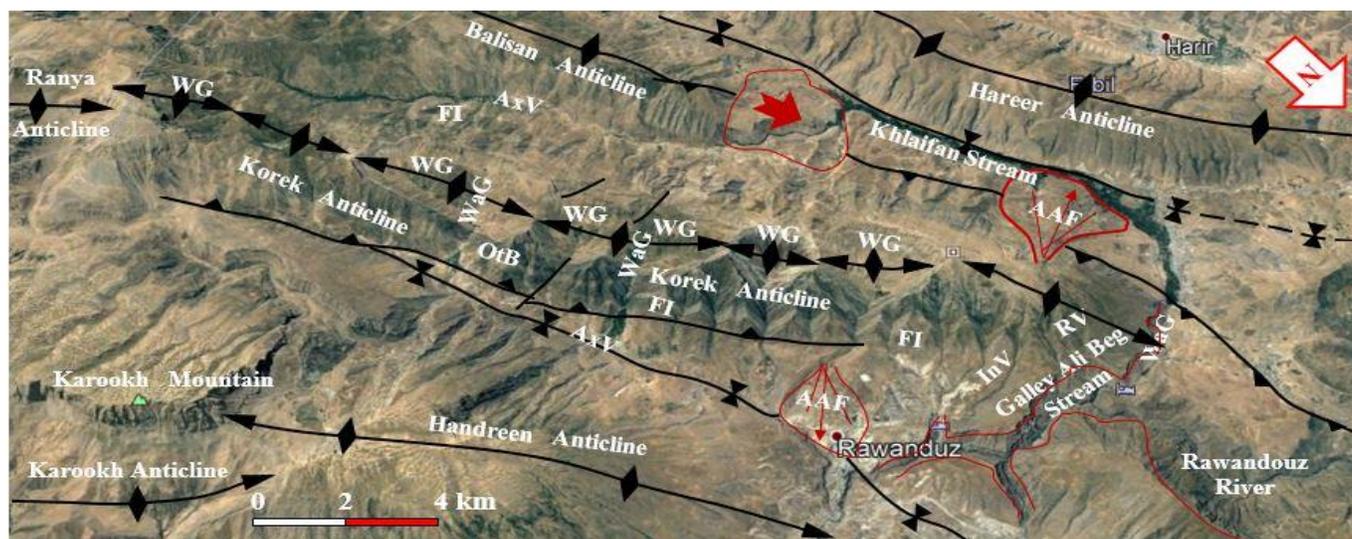


Figure 9. Google Earth image of the Korek anticline. OtB= Overturned beds, AAF= Abandoned alluvial fan, FI= Flat iron. The brown line represents extensive erosion. The black lines are strike-slip faults. The red arrow represents a very old slide (Sissakian et al., 2022).

Note: For other abbreviations refer to the text.

Many of the developed domes within some anticlines in KRI clearly show water gaps and wine glass forms (Figure 12), their presence together (Figure 13a) represents very rare geomorphological and structural forms. They are good indication for the presence of domes, which are excellent indicators for the growth of the folds, besides the radial valleys (Keller & Pinter, 2002).

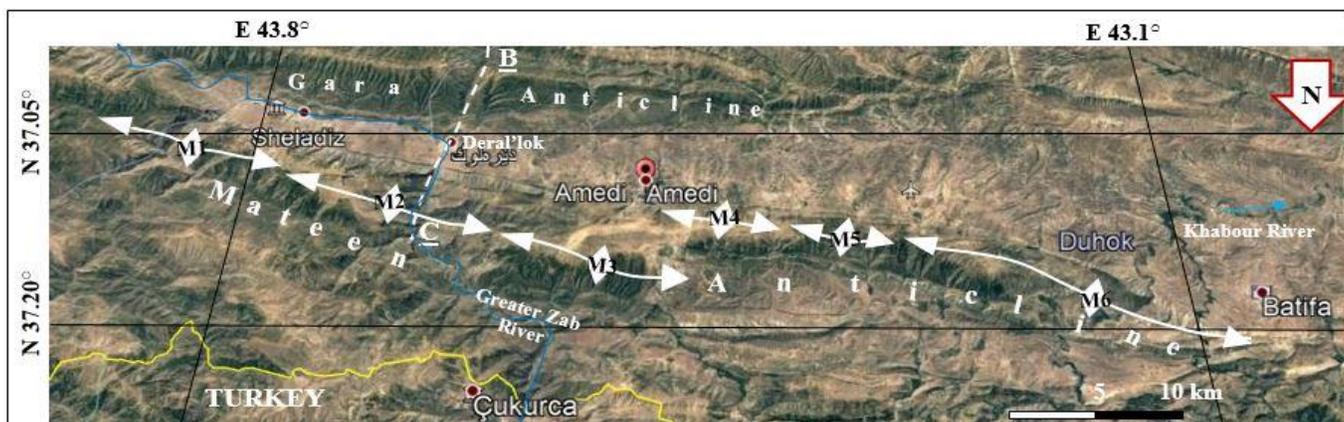


Figure 10. Satellite image of Gara and Mateen anticlines. Note the domes and en-echelon plunges (Sissakian et al., 2020b)



Figure 11. Google Earth image of plunge area: Left) Korek anticline, Right) Pirat anticline. Note the decrease in the intensity of the valleys towards the plunge area (red arrow) (Sissakian et al., 2022)

The southeastern plunge of the Chinara anticline (Figure 13b) shows typical radial valleys, Inclined valleys (Figure 14a) Fork-shaped valleys (Figure 14b), all are excellent indication for the activity of the folds (anticlines). Such indications are well developed almost in all anticlines of KRI.

Another rare structural form along the anticlines of the KRI is the presence of hanging synclines between long and narrow anticlines. A good example is the Hiran hanging syncline (Figure 15), which has a height of about 500 m from the surrounding area. It is developed by the released forces due to the convergence contact between the Arabian and Eurasian plates.

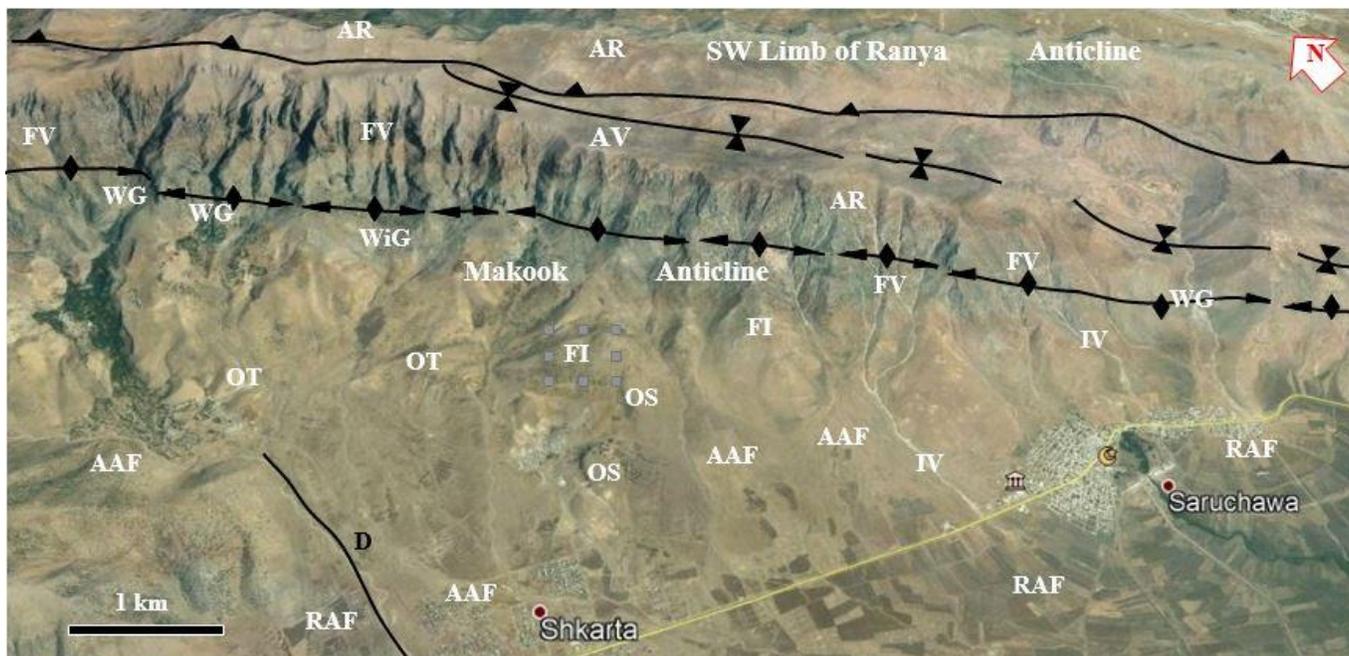


Figure 12. Satellite image showing Makook anticline. Note the thrust fault has hindered part of the syncline, also note the developed structural forms (Domes and anticlinal ridges) and different geomorphological forms. FV= Fork-shaped valley, IV= Inclined valley, WG= Water gap, WiG= Wine glass, FI= Flat iron, AAF= Abandoned alluvial fan, RAF= Recent alluvial fan, AR=Anticlinal ridge, OS= Old landslide, OT= Overturned bed.



Figure 13. Satellite images of Chinara anticline, a) Note the developed domes, water gaps (WG) and Wine glass forms (WiG), b) Typical radial valley along the southeastern plunge.



Figure 14. Field photos Ranya anticline, a) Inclined valley, b) Fork-shaped valley.

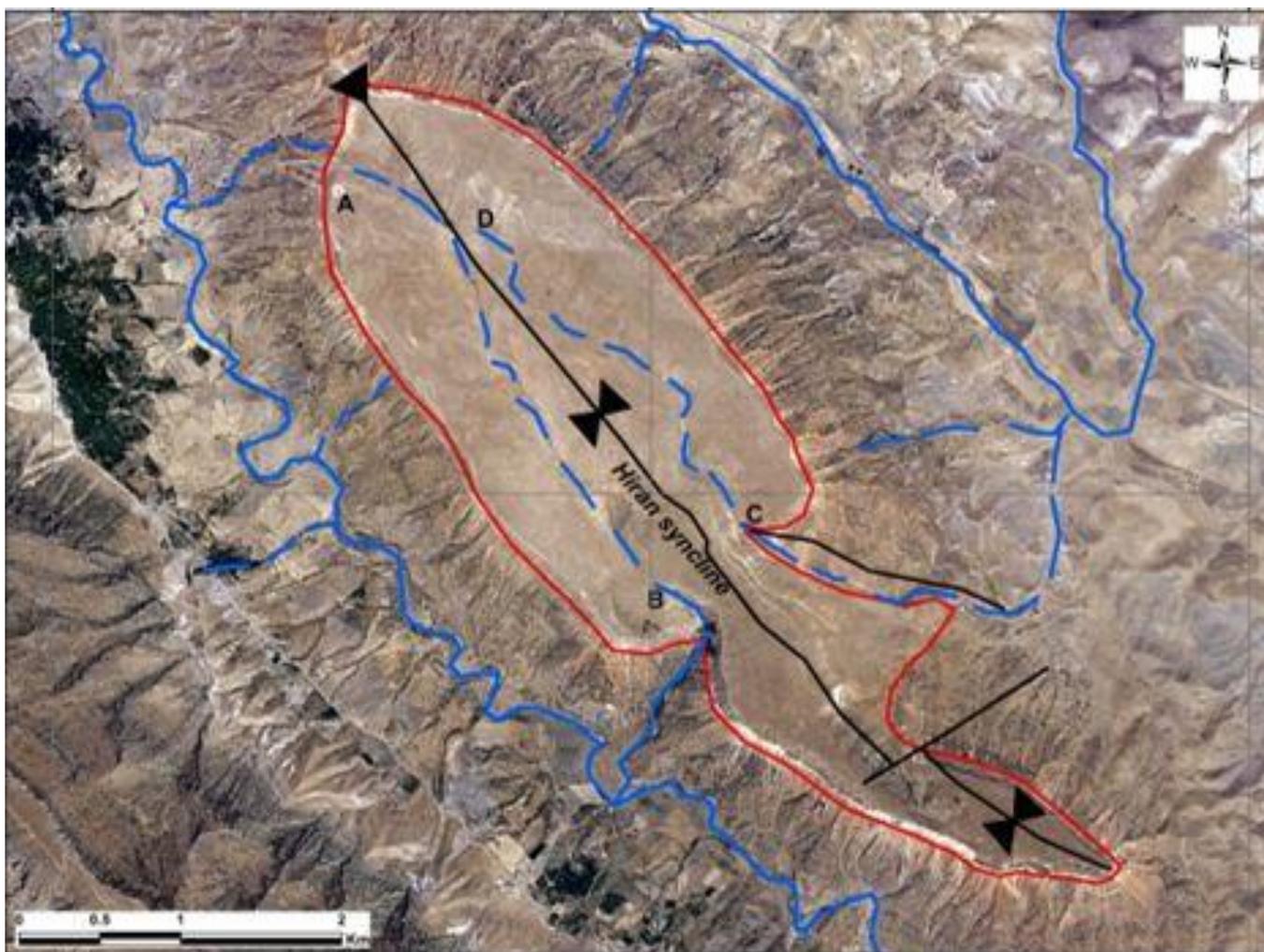


Figure 15. Satellite image showing Hiran hanging syncline.

3. Conclusions

From the presented data, we can conclude that majority of the folds (anticlines) in KRI show lateral growth as indicated by different forms and features of geomorphology and structure, which are mentioned in the text. The main trend of the growth is northwest wards. Moreover, some of the anticlines are thrust on the southerly existing anticlines causing; locally the disappearance of the syncline in between them. However, in some anticlines, there are thrust faults where the north-eastern limb is thrust over the south-western limb causing hindering of the anticlinal axes, either partly or totally.

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