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Structural Style Analysis of Maqlob Anticline Using Seismic Data

Ahmed Abbas Hasan [1], Shahad Adil Al-Qaraghuli [2], Linaz Anis Fadhil [3], Muaid Jassim Rasheed [4] and Cristina Dallos Mosquera [5]
[1, 2, 3] AlKarkh University of Science, College of Remote Sensing and Geophysics, Remote Sensing Department, Iraq
[4] University of Baghdad, College of Science, Department of Geology, Iraq
[5] Geology Department, Faculty of Exact and Natural Sciences, University of Caldas, Manizales, Colombia
ahmad.a.h@kus.edu.iq

Abstract:
The interpretation of the two-dimensional seismic line of the Maqlob anticline to ascertain the structural Style is the main problem in this paper. The geological interpretation and the seismic interpretation were completed simultaneously. One 2D seismic line and the depth contour maps of the three different reflector formations in this region (Top Kurra Chine, Top Najmah, and Top Shiranish) were analyzed. These depth structural maps show that five thrust faults are present in the region.
As seen in the interpreted seismic section and depth contour maps, the faults have also been identified as thrust faults and back thrust that created pop-up structures.
According to the interpretation of the seismic data, the Maqlob structure is made up of pop-up anticlines and triangular zones as a result of compressional regimes. The triangular zone is seen in the top Najmah Formation reflector.
The study area is characterized by a complex fault pattern and trend (major and minor faults) in the NW-SE direction. The majority of the main and minor faults spanned both the Mesozoic and Cenozoic eras. The structure is a compressional, asymmetric anticline with a faulted southern limb and a minor back fault growth to the north. This fault extends parallel to the fold axis by 21 km. These faults were formed by the same compressional stresses forming an Maqlob anticline towards the northeast and led to the overturning of the layers of the southern limb.
Key words: Structural Style, Thrust Systems, Pop-up and Triangular Zones, Maqlob Anticline, Iraq.

Introduction:
North West Iraq lies near the northern tip of the Arabian plate, which, relative to the Eurasian plate, is advancing northwards [1]. The study area is represented by part of the Foothill Zone which lies within the Arabian Unstable Shelf. Study area is located 32 km to the northeast of Mosul City and few kilometers from Bashiqa anticline (Figure1) [2].
While more recent subsurface excavating and seismic techniques have expanded the awareness of subsurface structures, most former workers relied on surface measurements obtained during geological exploration or stratigraphic investigation. In addition, a study of the available information pertaining to the geological of study area and previous geological surveys in the region was conducted in order to provide the appropriate control for the analysis of the collected data [3].
Structurally, Maqlub anticline forms an elongated anticline trending almost NW-SE, following the general trend of most of the structures in neighborhood (e.g. Bashiqa, Aqra and Zawita anticlines). Its length is about 15 km. and its maximum width is about 5 km. Dunnington (1958) mapped the Maqlub Structure near by the southern margin of the Folded Zone [4]. Buday (1973) included this area within the Unstable Shelf [5].

This area has also been studied by [6] and [7] but little or no previous work has been done on the study of the thrust systems. A new detailed morphotectonic map of the Maqlub Structure was Prepared from aerial photographs on a scale of 1:50,000 approximately. This follows earlier field work supplementing [7] basic stratigraphy and structure of the area, so that, the lithology and structural control on the morphotectonic is well understood.

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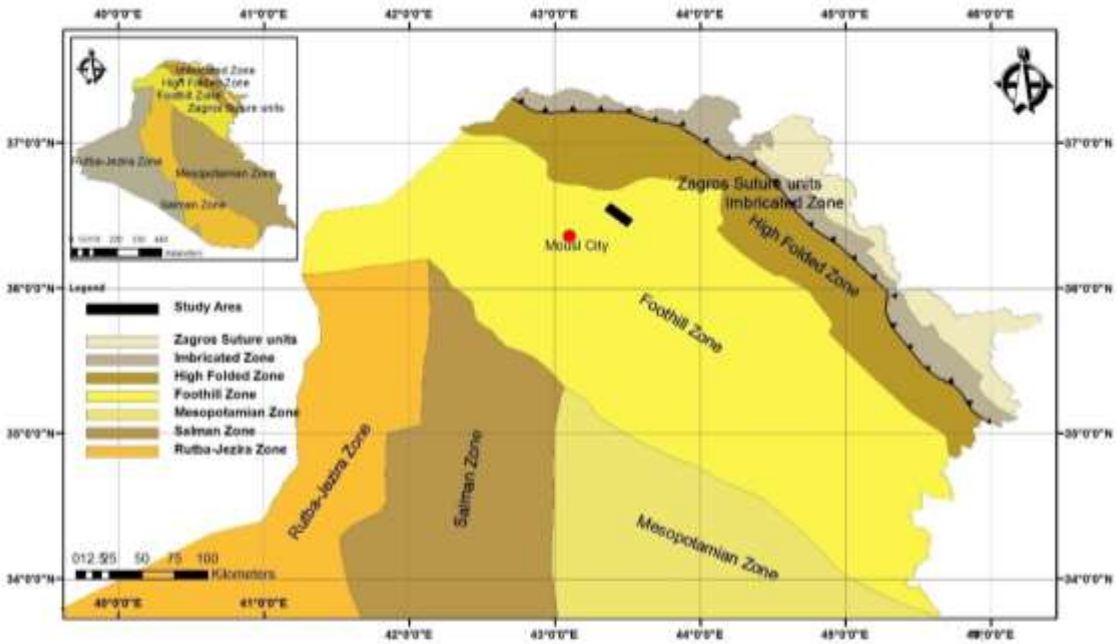

Figure 1: Location map of the study area (after [2]).

Maqlob anticline is a double plunging and high anticline with NW-SE trend which changes westwards to almost N-S trend (Figure2) [8]. In the core, Kolosh Formation is exposed, whereas the Pilaspi Formation forms the bulk of the anticline and of Maqloub anticline. The northern plunge is hidden under Quaternary deposits. A main reverse fault, parallel to the axis runs along the southwestern limb. The fault has brought the Fatha Formation in structural contact with the Injana Formation [2].
The syncline between Maqloub and Bashiqa Anticlines is obscure. It is mainly covered by Quaternary deposits, especially in its middle parts. Moreover, the associated reverse fault with the southwestern limb of Maqlob anticline, might had disturbed the synclinal axis [9].

Figure 2: Shows Maqloub anticline

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The southwestern limb is thrusted against Bashiqa anticline without expressive syncline between them, moreover this part is characterized locally by box-folding and overturning [8]. The mean dip of the northeastern limb is about 20°, while the mean dip of the southwestern limb is about 52° (Figure3) [10].

Figure 3: Shows the dip of the beds in the southern limb.

The exposed geological formations in study area range in age from Upper Miocene-Pliocene age (Mukdadiya or Bakhtiari Formation) to Paleocene-Lower Eocene age (Khurmala Formation), and it includes several formations shows in Figure 4. These formations include limestone, shale, marl, claystone, siltstone and sandstone.

The scope of this article was to characterize structural settings to show the geometry and mechanisms of thrusts in the study area and their relationships with the other features and then to suggest possible causes of the complexity of Maqlob Structure.

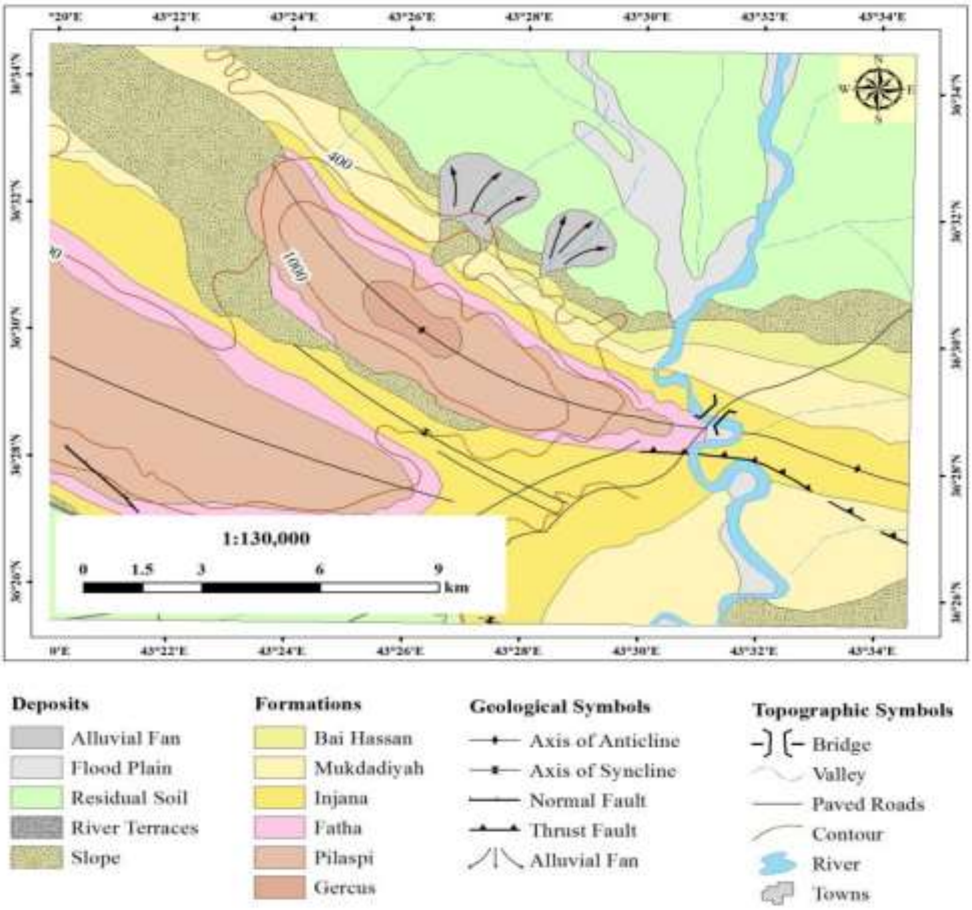

Figure 4: Geologic map of study area [11].

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Material and Methods:

Maqlob anticline was studied using two-way travel times (TWT) of 2D seismic sections, field survey and depth structure contour maps. The current effort is also based on the interpretation of 2D seismic data that is already accessible. Seismic interpretation for the interpreted faults and horizons makes up the bulk of the methodology for data analysis. From maps of the structure's contours, a geologic cross section was created.

Results:

The thrust mechanism controls one of the most significant deformation styles of the study area during the later stages of Orogeny. To comprehend the forces causing this deformation, it is essential to determine the tectonic development of the thrust systems.

According to [12] thrust faults show variation in dip as they pass from one lithology to another. A thrust will cut up section in the transport direction [13]. Rich suggested that thrusts are parallel to bedding in mechanically weak rocks, cuts upward across bedding in strong rock and again becomes parallel to bedding in weaker rock units higher in the stratigraphic section. A "Flat" is where the thrust sheet slides along a relatively weak bedding plane. A regional flat is called a "decollement plane" or "detachment surface" or "sole". The thrust cuts "Ramps" through are sections where the stratigraphic upwards sequence.

The terminology of thrust systems has been reviewed by [14]. The significance of connected thrust systems was underlined. Especially duplexes. Repeated strata on sigmoidal faults connected to a floor thrust and a roof thrust are what define duplexes. The duplex system's individual fault blocks are referred to as horses.

A simple hinterland to foreland sequence, such as a [15]; [16] and [14], is the most often used model of thrust propagation. Most often, the displacements or thrust propagation occurs on a new fault surface that forms in the footwall of the previously active zone. The segment of new fault will finally climb a new ramp' and if this process continuous in a multiple fashion, an array of thrusts will be generated, all appearing to splay from a single detachment level, or "floor thrust" [16]. Earlier faults are a bandoned and passively carried by later, deeper level displacements; hence, this thrusting propagation sequence is termed "piggy-back" [13] and [17].

Slickensides and associated lineations developed on faulted surfaces, were used in many part of this study as indicator of movement and mechanism of deformation. These striations indicate the direction of the last movement, and the steps indicate the sense of movement.

A combination of seismic mapping, dip seismic section and depth structure map were used to study this structure. These data were used to draw structural section and in its simplest terms, this structure is a compressional, asymmetric anticline, with the two major thrust faults in the north east and in the south west limbs.

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The depth structure contour maps of three different reflectors Top Kurra Chine, Top Najmah and Top Shiranish formations were used to analyze structural settings and draw geologic section of this area

The depth structure contour maps of three different Top Kurra Chine, Top Najmah and Top Shiranish reflectors were used to evaluate structural settings and draw geological sections of this area.

These depth structural maps show that three significant thrust faults dipping to the southwest have affected the Jurassic Formations in the study area. Faults have a reasonable amount of throw distance ranging from 200 meters to 1900 meters, going from northwest to southeast. The significant fault's thrown magnitude is quite significant and exceeds 1900 meters.

Based on 2D seismic data, the depth structure contour map of the upper Kurra Chine Formation (Figure 5) depicts three major thrust faults trending NW-SE and throwing northeast. Folding has, in general, had little impact on how the study area's structural settings were established.

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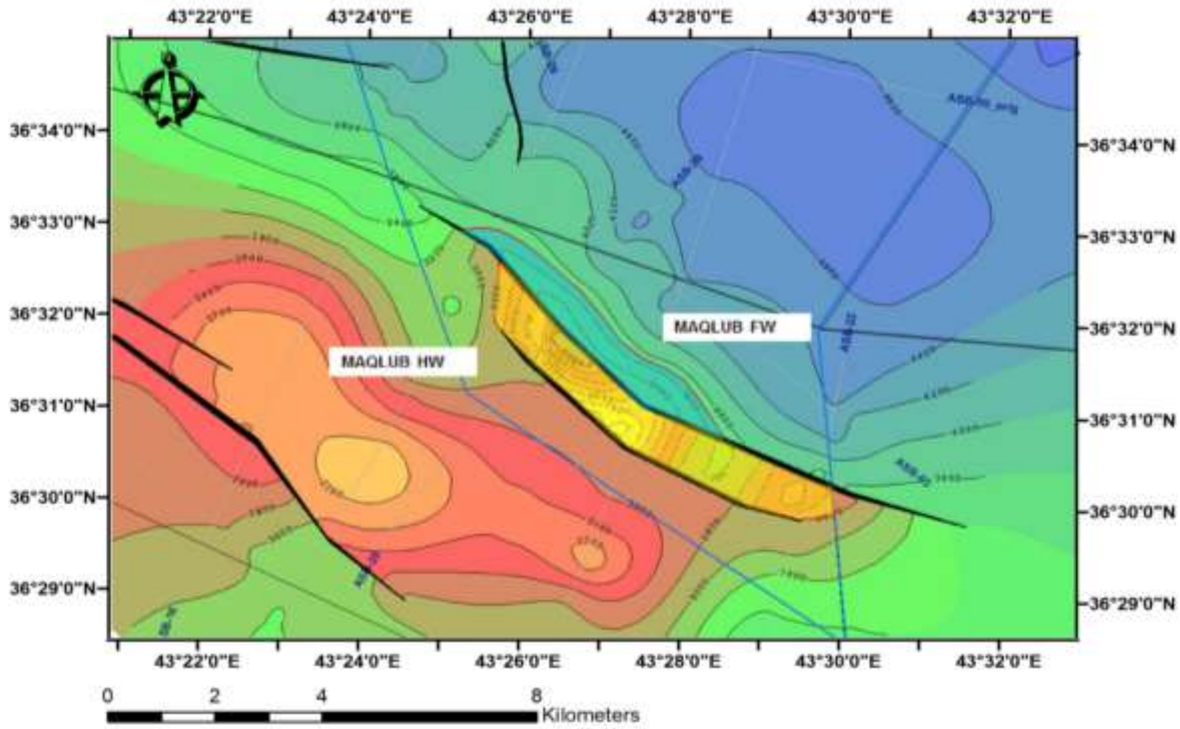

Figure 5: The map of structure contour on the top Kurra Chine Formation in studied area (Modify after [18]).

The distributions of the majority of the deformation systems that were active throughout the Najmah Formation are still visible on the structural contour map at the upper of the formation (Figure 6). The faults are thrust, trending NW-SE, and throwing toward the northeast, generating a triangle zone and pop-up structure (Figure 7).

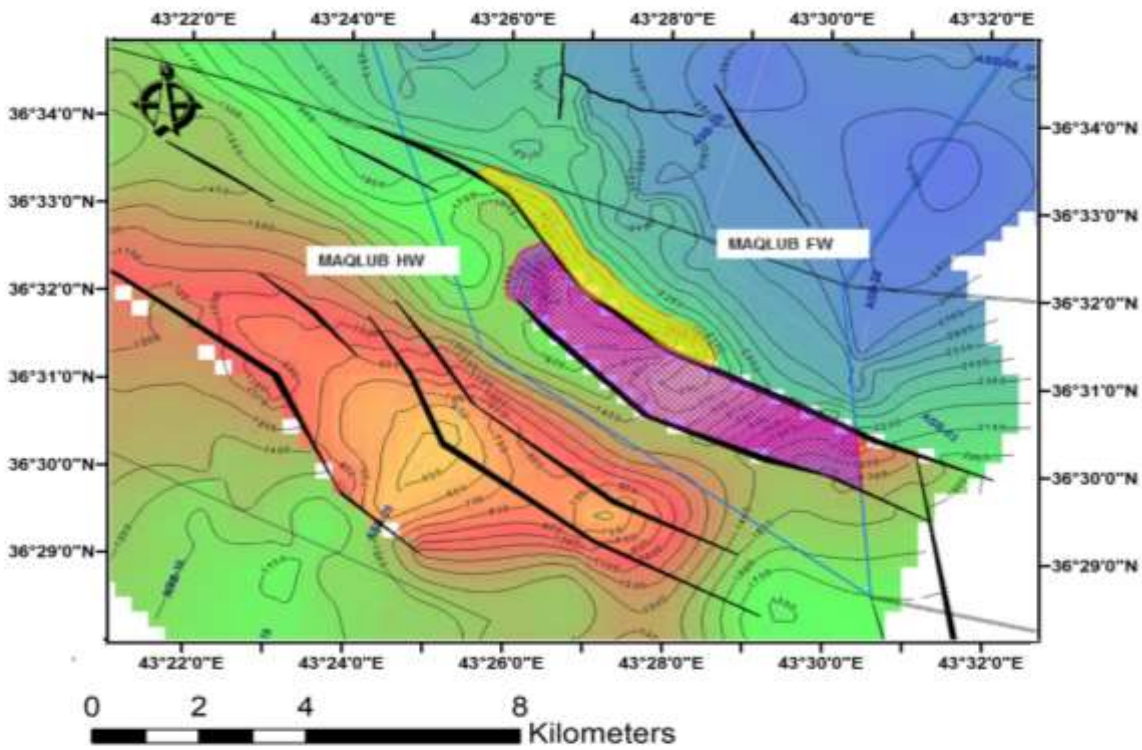

Figure 6: Structure contour map on the top Najmah Formation in study area (Modify after [18]).

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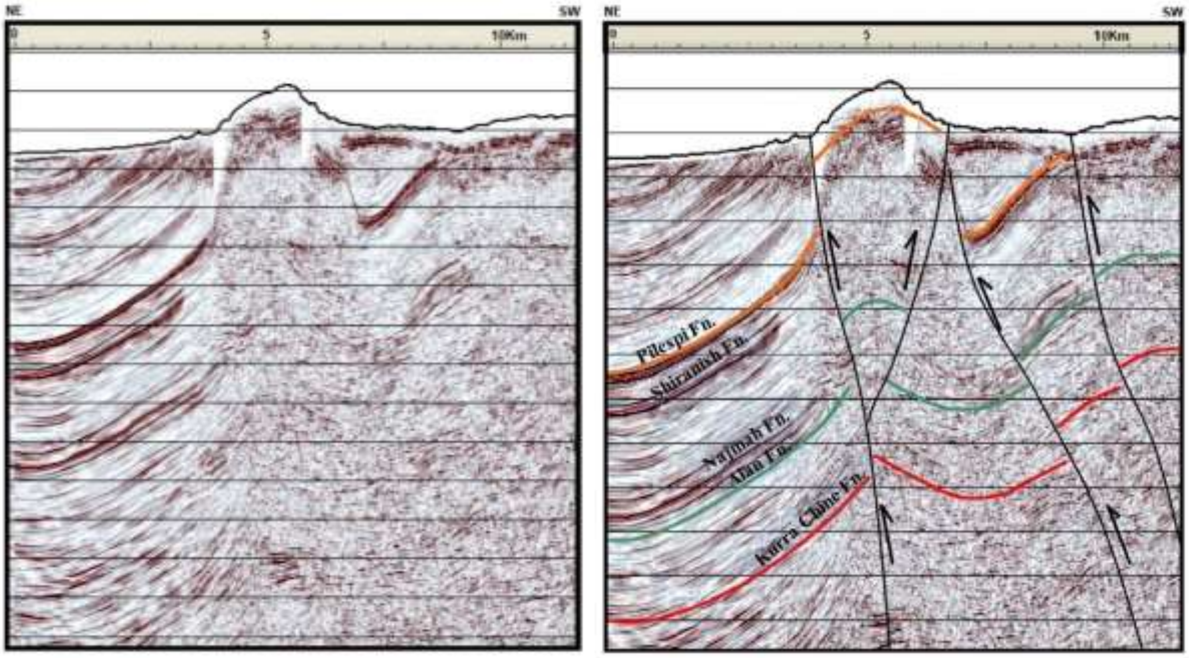

Figure 7: Un-interpreted and interpreted seismic section ASB-28 with NE-SW direction (Modify after [18]).

A structure map at the top of Shiranish formation shows distributions of most deformation systems. The faults are thrust and trending in the direction of NW-SE and on the top of Shiranish formation were observed throwing towards the north east, forming Pop-up structure (Figure 8).

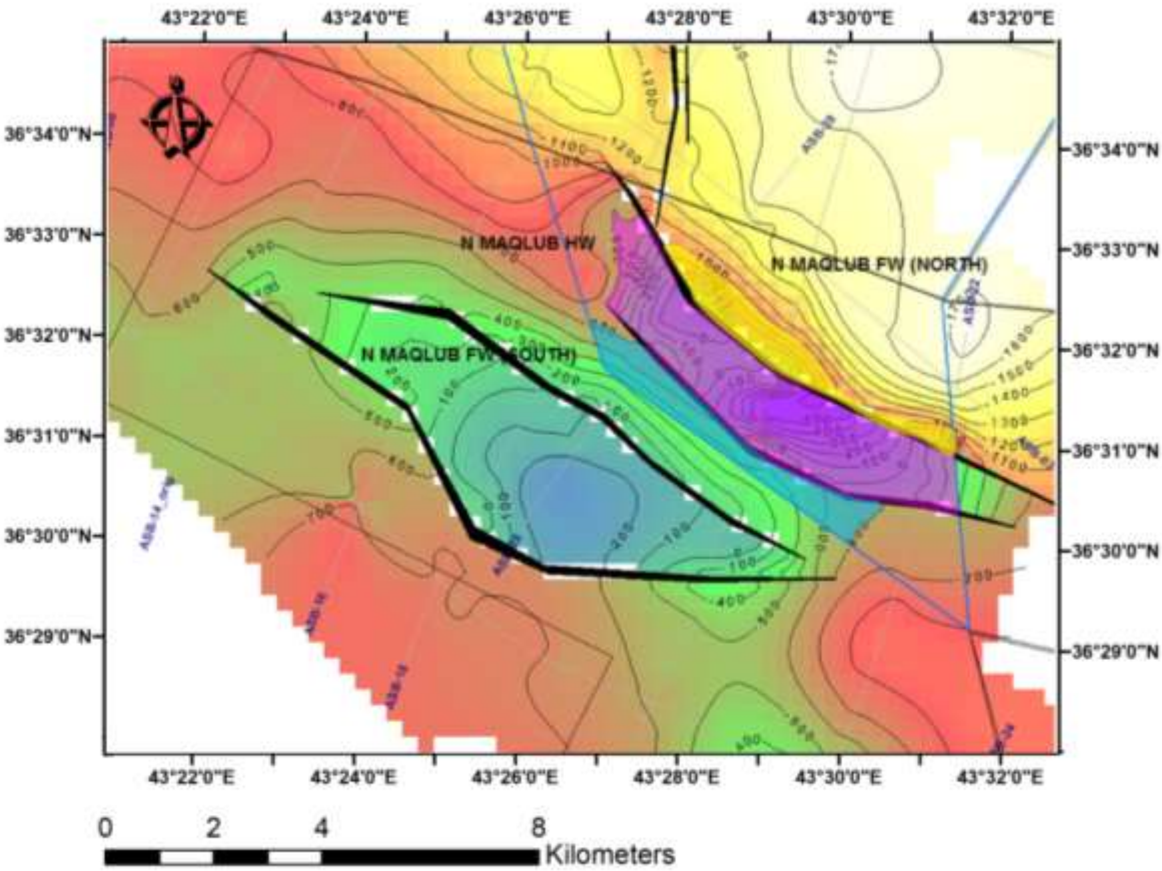

Figure 8: Structure contour map on the top Shiranish Formation in study area(Modify after [18]).

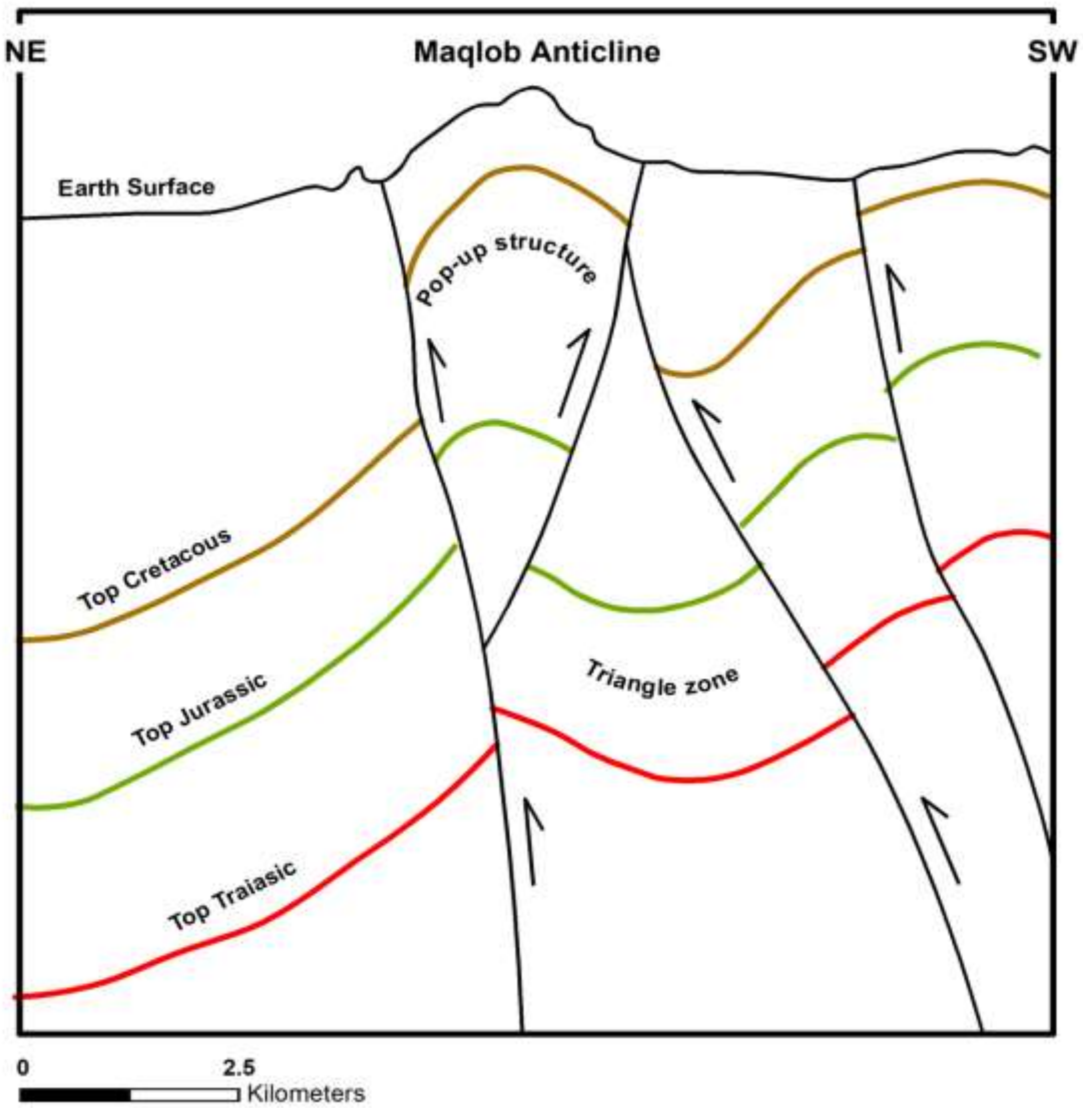

Figure 9: North east to south west dip section of Maqlob anticline showing the growth of Pop-up structure and Triangle zone.

Discussion and Conclusions:

Geometrically, Maqlob anticline is a parallel fold. The field survey showed that the thickness of the competent layers, represented by the units of rocks of the Pila spe and Fatha Formations, in which the true thickness is constant, and that the radius of curvature in the hinge zone is not fixed, and these features are considered among the characteristics of Parallel folds.

The constant true thickness of the layers in the most of the exposed formations and the presence of slickenside structures on the bedding planes and parallel to the axis perpendicular to the fold axis indicates that the folding process was formed by flexural-slip mechanics and the bedding planes are surfaces of mechanical anisotropy and mechanical control appears over the folding process as most of the stresses are released thrusting on the bedding planes.

The structural contour map in the studied region allowed for the identification of five main faults. The thrusts in this work show a feature that may be useful in researching other thrusts in other fields. The connection thrust faults are sigmoidal and asymptotic to the floor and roof thrust, making them one of this area's most ineffective characteristics (Figure 9). The differences in dip angles of the succession of thrusts can be explained by either a simultaneous but heterogeneous slide on practically all of the faults at the same time, or by the rotation of early faults by forward propagation of later faults.

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According to evolving theories, folding occurs mostly in the hanging wall in the research area (for example, hanging wall anticlines) (Figure 9). Thrusts are believed to spread primarily in the direction of transport, starting with the first thrust in the series. A string of thrusts arise from this one. In the direction of the transport, several thrusts gradually form and become almost layer parallel. A roof thrust is created when these thrusts come together. The data mentioned above allow for the following model to be suggested.

In early stage of deformation the wide Maqlob Anticline developed in response to a NE-SW compression after the Pliocene. Due to continuous squeezing from the SW (as a result of movements of Arabia relative to Africa plates) and from the NE (as a result of collision of Arabia with Iranin Plates).

The thrusting and folding were developing simultaneously, but with the dominance of thrusting. This mechanism is reflected on the outline of the structure.

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