The Impact of Tectonic Setting on Distribution of Kolosh Formation during Paleocene –Lower Eocene in Northern Iraq

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ABSTRACT

This study covered most of Kolosh Formation exposure areas in northern Iraq. Description of the lithology and measuring the actual thickness of the Formation from exposures and well logs were performed. The isopach map of the Formation was constructed. The sedimentation of the Formation was affected by the tectonic activity of the northeastern edge of the Arabian plate during the closure of the Neo-Tethys Ocean. The tectonic setting outlined the depozone of foreland basin system and controlled the variation of the deposits of the Kolosh Formation along the orogenic front (It revealed that there are more than one basin of deposition). The deviations of the depocenters of the Kolosh deposit basins from the current folds are depicted. The counterclockwise rotation of Arabian plate and its oblique collision with Iranian plate as well as the rejuvenation of the basement faults during the peak of the orogeny might cause such deviation.

Keyword: Kolosh formation-foredeep - backbulge- depozone-depocenters**.**

تأثير الوضع التكتوني على توزيع رواسب تكوين كولوش خلال الباليوسين – الايوسين الأسفل شمالي العراق

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تأثر توزيع رواسب تكوين كولوش الفتاتي بالنشاط التكتوني للحافة الشمالية الشرقية للطبق العربي أثناء مراحل إنغلاق محيط التيثس الجديد ونشوء حوض فورلاند زاكروس في جزئه العراقي. تم تفسير انتشار رواسب التكوين وفق المفاهيم التكتونية لانظمة احواض الفورلاند، حيث تم الاستنتاج من خلال التحري الحقلي ورسم خريطة السمك المتساوي الى تواجد أكثر من مركز(محور) ترسيبي تنحرف عن محاور الطيات الحالية وهي موزعة في نطاق الحوض الامام العميق (foredeep depozine) ونطاق خلف البروز (backbulge depozone).

الكلمات الدالة: تكوين كولوش، حوض الفورلاند، الحوض الامام، خلف البروز، زاكروس.

INTRODUCTION

Kolosh Formation is one of the widely distributed clastic sediments throughout northern Iraq. Many researchers considered the Formation as flysch deposits due to its lithological characteristics. Thus, the distribution of these deposits reflects the dynamic tectonic setting of Arabian northeastern edge during its subduction under Iranian plate and initiation of foreland basin system during late Cretaceous. The control of this tectonic setting on the distribution of the foreland basin deposits continued throughout early Tertiary. Kolosh Formation represents the clastic unit of fore-deep depozone (Znad, 2013). The constructed isopach map of the Formation depends on detailed fieldwork notes and measure of true thickness on all accessible outcrops, besides well logs. The southwestern rim of Kolosh basin is outlined at its transitional zone with Aliji Formation. The study area comprises most of northern Iraq (Fig. 1).

Fig. 1: Northern Iraq showing investigation areas

LITHOLOGY OF KOLOSH FORMATION

Kolosh Formation type section is cited and described by Dunnington (1952 in Bellen *et al*., 1959) in Koya within high fold zone of northern Iraq. Its age extends from Paleocene to early Eocene, with 777 meter thickness. The formation consists of rhythmic alternation of thin sandstone, siltstone, marlstone, and less common conglomerate and limestone with calcareous silt shale inter-layers. They resemble flysch-like sediments (Dunnington, 1958).

The Formation crops out on the most areas of northern Iraq without essential differences in lithological nature. Generally, the formation consists of dark grey easily drifted sandstone, shale and claystone (Fig. 2), making wet dark grey soil in the lowland. Sandstone beds range between (0.25m-3m) in thickness, of medium hardness and fine grained in general, occasionally pebbly (not more than 2-3 cm). Conglomerate beds have thicknesses of about (1-2 m) with pebbles (not more than 4cm in size). The

pebbles are mainly limestone and chert, spherical in shape, sorted and rounded. They are poorly cemented with sandy and clayey materials, and occasionally bituminous.

In Shaqlawa area, there is an increase in dark shale upward the section, with bituminous saturated sandstone beds and abundance of trace fossils and sedimentary structures (Fig. 3).

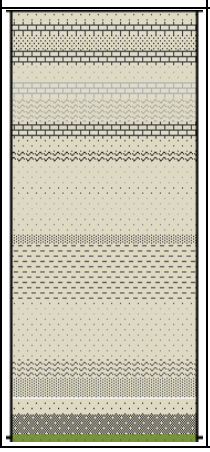
Description	Lithology	Thick (m)	Fm	Age
Light grey succession of thin layers; sandstone, marl and marly limestone. Dark grey succession of; sandstone, marl, clay and dark shale. Friable, wetted sometimes, (fine to coarse grain) Sedimentary structures, bituminous matter.		90 - 100	Kolosh Formation	Paleocene –Lower Eocene

Fig. 2: Lithology of Kolosh Formation in Bekhme area.

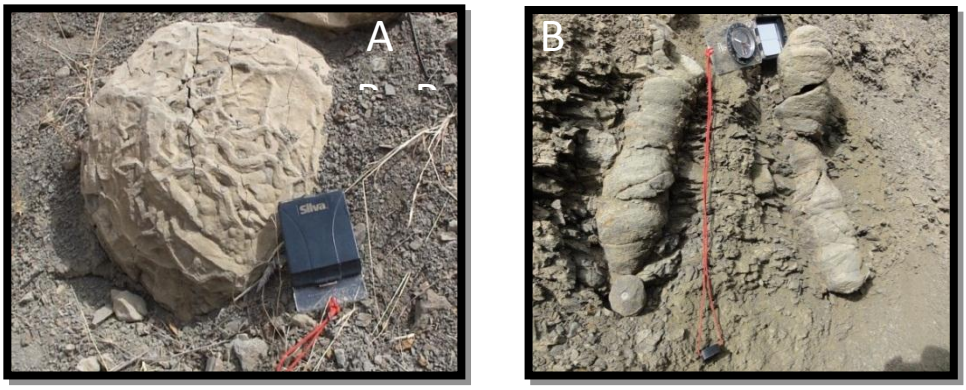


Fig. 3: Trace fossils in Kolosh Fm. Shaqlawa Area.

Fig. 4: Field photo illustrating the gradually altering of Kolosh Formation to Khurmala Formation in Bekhair anticline.

In Bekhair anticline, the ratio of thin limestone beds increases upward the section and alters gradually to dolomitic limestone of Khurmala Formation (Fig. 4).

In the Shiranish Islam area, there is an increase in the proportion of sandstone on expense of claystone beds and absence of limestone beds. The presence of trace fossils and Gastropoda molds were noted as well (Fig. 5).

Fig. 5: Trace fossils and Gastropoda molds from Kolosh Formation in Shiranish Islam area at Zakho district

The upper and lower boundaries of Kolosh Formation are varying geographically from one area to another of the study area. That is due to tectonic setting variance of the Formation depositional basin.

In Perat fold at Bekhme region, the formation overlies uncomfortably the Tanjero Formation (Late Cretaceous). The contact between them is identified there through color change from olive green rocks of Tanjero Formation to dark gray rocks of Kolosh Formation. Further, it is assured by fossil investigation.

In Safine anticline (Shaqlawa area), Bekhair anticline (Dohuk area) and in Shiranish Islam village (Zakho area), the lower contact of Kolosh Formation is not compatible with the Shiranish Formation. The contact is determined there in the field at appearance of first sandstone layer of Kolosh Formation after marl layers of Shiranish Formation.

In Mashura well (northwest of Mosul), the lower boundary of the formation is intercalated with Aliji Formation (Rafo, 1989). In Shaikhan Anticline, its lower contact is unconformable with Bekhme Formation (Al-Humaidi, 2007; Ahmad, 1980).

The upper contact of the formation in Bekhme area is gradational with Khurmala Formation. It is evident by increasing the number and thickness of marly limestone layers in the upper part of Kolosh Formation.

In Safine anticline (Shaqlawa area), the upper seam contact with the Gercus Formation is sometimes represented by a layer of conglomerate (2-3 m thick) near the city. However, sometimes it is intercalated with the Khurmala Formation, which appears in thickness of several meters compared to that in Bekhme area. While Al-Mutwali (2001) and Al-Qayim and Salman (1986) considered this intercalation as conformable between the two formations. In the Bekhair anticline, the upper contact of the formation is gradational with Khurmala Formation in certain sites, and there is a pinkish conglomeratic bed (not more 1.5 m thick). In other sites, the formation

contacts upward with Gercus Formation. In the Shiranish (Zakho Area), its contact with Gercus Formation is bounded with first appearance of red pinkish sandstone.

According to Al-Humaidi (2007) and Ahmad (1980), the upper contact of the formation is unconformable with the Gercus Formation in Shaikhan anticline.

Most sedimentological criteria reflect that turbidite deposits of Kolosh Formation are due to rapid subsiding tectonic basin (flysch-like origin) (Al-Mashaykh, 1979; Al-Qayim and Salman, 1986; Al-Juboury, 2006; Al-Sakry, 2006; Al-Humaidi, 2007; Al-Qayim et al., 2008).

ISOPACH MAP OF KOLOSH FORMATION

Isopach maps are valuable to define the tectonic framework or the structural relationships accountable for accumulation of a specific type of sediments. These include delineating basin shape, coastal line location and rising areas. However, to some extent and under certain circumstances, thickness variance maps with specific stratigraphic disjunctives are useful in estimating vertical uplift and erosion (Krumbein and Sloss, 1963). Practically, thickness maps are also valuable to explicate major depositional centers locations and borders, and as well depositional synchronous subsurface structural relieves where sediments become thinner and shallower (Miall, 1999). Also, the spread of detrital deposits reflects the dynamic of depositional basin because it is related to the sediment source and the transport mechanism. Detailed surface observations and field data were mainly based on the mapping, as well as some subsurface data were obtained from the records of exploratory wells and other sources listed in Appendix 1. The map is drawn using Surfer 6 software package.

In the beginning, the distribution of Kolosh Formation can be clarified according to the foreland basin system (Fig.6). The formation occupies the foredeep depozone basin in Rawanduz area and extends towards Suran and Barzan. The extension of the fore-deep depozone basin in southeast Turkey is occupied with Kolosh-like sediments known as Kermave Formation. The spread of Kolosh Formation is variable along the strike of the fore-bulge depozone. The formation is absent on both flanks of Mateen and Gara anticlines and towards Aqra anticline as well, indicating exposure of this zone during the Paleocene.

At Galley Zanta on northern limb of Aqra anticline and closer to its eastern plunge, there exposed a succession of fine-grained sandstones (with cross bedding and iron oxide traces), marl and limestone beds. Malak (2010) included the upper (30) meters of this succession within Kolosh Formation. This succession reflects facies deposited in a shallow marine extending between under-tidal and over-tidal environments. Then the formation continues from there toward southeast to Bekhme gorge (Perat anticline).

The isopach map of Kolosh Formation (Fig. 7) shows that the basin axis of deposition was extending northwest-southeast (the depocenters is located at maximum thickness contours, Selley, 1976). The southwestern boundary of the formation is an overlap with Aliji Formation extending along the Tigris River in Mosul district. It extends southeastward towards Kirkuk. The northeastern border of the formation extends adjacently to thrust zone along the northern limit of Rawanduz district,

passing through Suran area, to the eastern plunges of Gara and Mateen anticlines, and extends into the southeastern parts of Turkey along the Iraqi borders.

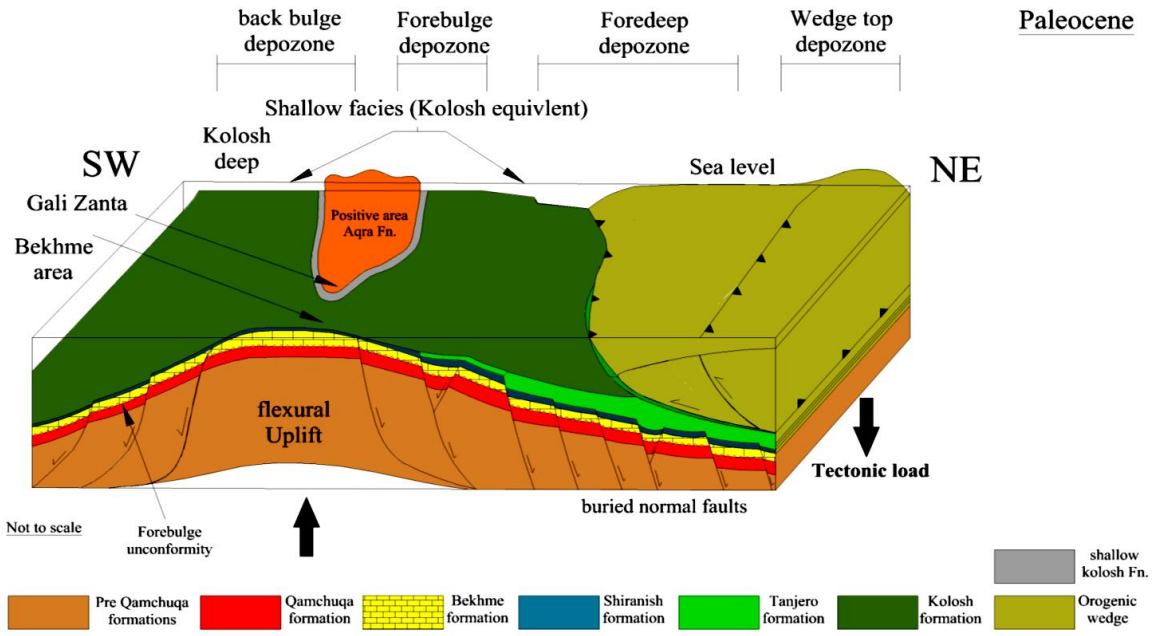


Fig. 6: A perspective illustrating the configuration of the foreland basin system deposition zones during the Paleocene.

Also, the map shows two major and another minor deposition centers in the back-bulge depozone. The first depositional center extends northwest-southeast at Duhok area, called Duhok-Qand basin. The northeastern boundary of this basin starts from west of Khabour River, through Mateen anticline (Galy Dhe), extending to the south Soura Tuka and Besari, and continues to the Galy Qeer in Shaikhan anticline. This limit outlines first appearance of Kolosh Formation where it is intercalated with Khurmala Formation in many localities.

The second sedimentary center extends northwest-southeast as well and called Shaqlawa basin. It is wider than the first basin and connected with the fore-deep depozone basin across the fore-bulge. This connection can be attributed to the reach of the fore-deep basin to fill stage during deposition of the upper parts of Kolosh Formation and the migration of the sedimentation center to the southwest, as well as the subsidence of the fore-bulge due to the sediment loads.

The minor sedimentation center lies south of Erbil and extends north-south. It may represent an inherited structural depression that is activated during the deposition of Kolosh Formation, as it corresponds to the location of a back bulge depozone, in which Jawan Formation had been deposited at the beginning of imitation of foreland basin in Kirkuk embayment (Znad, 2013). The isopach map denotes the reduction of Kolosh Formation in the area between the two main basins. This area extends mainly to the west of the Great Zab River. They correspond to the uplifted eastern boundary of Mosul basement block as pointed by Numan (1984).

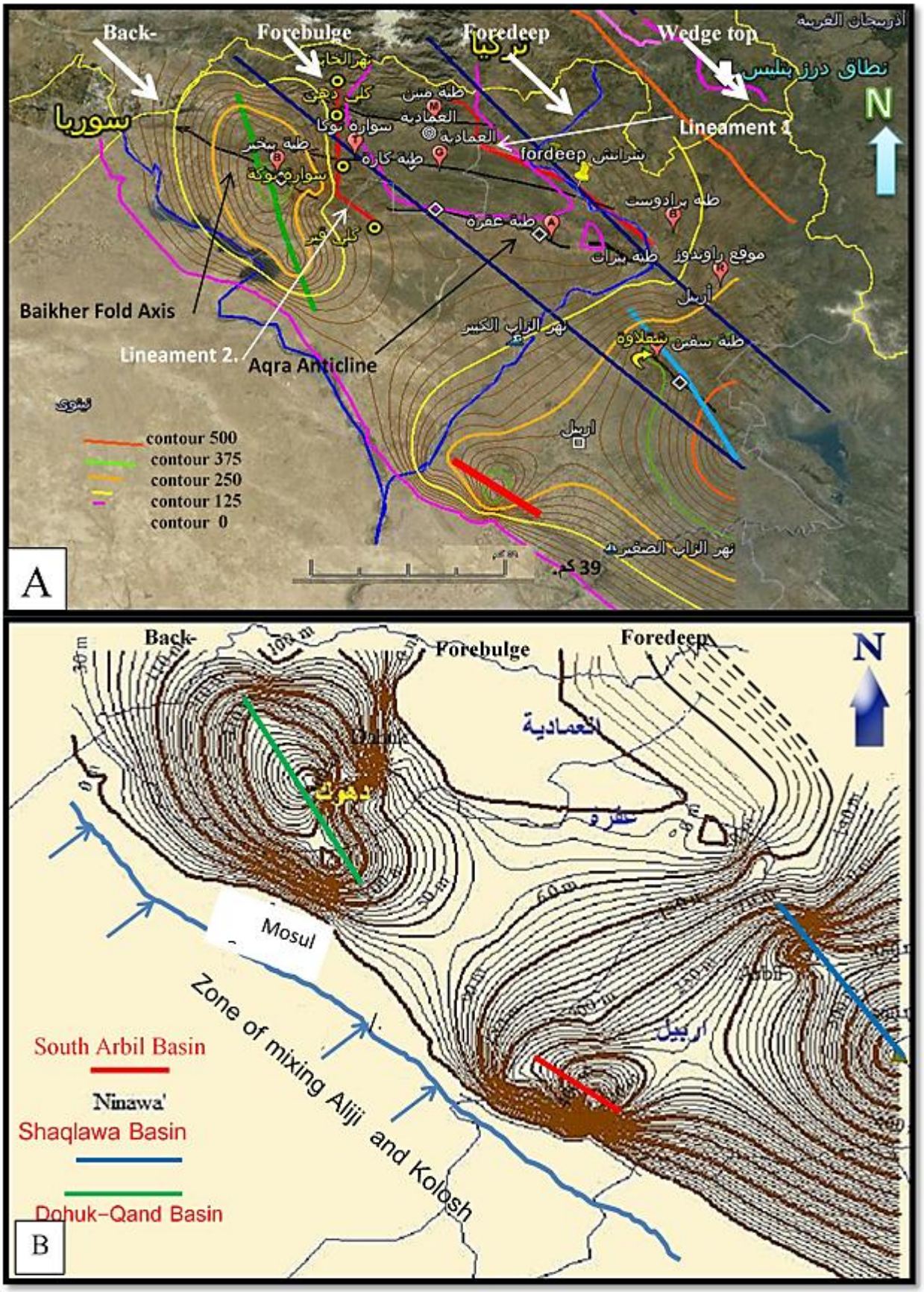


Fig. 7: Isopach map of Kolosh Formation

TECTONIC IMPLICATIONS OF THE AERIAL DISTRIBUTION OF KOLOSH FORMATION

It is clear from the distribution of Kolosh Formation in the study area that its sedimentary history is largely related to the closure of the Neo-Tethys Ocean and the subsequent convergence between Arabian and Eurasian plates. The absence of Kolosh Formation on northern and southern limbs of both Mateen and Gara anticlines, and ahead to Aqra anticline, indicates the uplift and exposure of this region during the deposition of Kolosh Formation, where Gercus Formation (Eocene) overlies Aqra Formation in this area with unconformable contact. However, low-up tide shallow marine facies overlies Aqra Formation in the Galley Zanta area toward the eastern plunge of Aqra anticline. Thus, this uplift is considered as the fore-bulge depozone concomitance of the fore-deep depozone that accompanied subduction of Arabian plate under Turkish plate. Noteworthy, there is an extension of Kolosh Formation of fore-deep depozone in southeast Turkey known as Kermave Formation there.

The present study identified some lineaments extending regionally (Fig. 7A, marked in red) which correspond roughly with the general boundaries of the fore-bulge depozone. So, these structures might be related to deep seated inherited or emergent faults during the flexural uplift of the fore-bulge caused by the tectonic load of Turkish plate on the edge of Arabian plate. These lineaments trend north-south in the northern parts of the study area, crossing the eastern and western domains of Mateen and Gara anticlines respectively, and then reorienting to northwest-southeast along with the general extension of the fore-bulge. The first main linear structure extends along with the course of the Great Zab River starting from its entry into Iraqi territory (Fig. 7A). Albarefkani (2008) recognized this structure as strike-slip fault; it is the start of a regional lineation related to Hatra-Bekhme fault separating Kirkuk from Mosul basement blocks (Numan, 1984; 2000).

The second main lineaments represent the northeastern boundary of Duhok-Kand basin (Fig. 7A&B) extending from west of Khabour River to the western part of the Galy Dhe, and passing through the western part of the Gara anticline (south of Suara Tuka), then close to Galy Besari (eastern plunge of Bekhair anticline), it deviates towards Galy Qeer (Shaikhan anticline), and finally its effect diminishes towards Aqra anticline.

These two main lineaments expanding along with the general trend of the so-called fore-bulge, played an important role in the distribution of Kolosh Formation sediments in Duhok sector, particularly in north-eastern direction (fore-deep depozone) and in the southwestern direction (back bulge depozone) as well.

Another important tectonic implication that can be derived from the isopach map is the axial parallelism of the two main sedimentary basins of Kolosh Formation, as well as their clockwise deviations from the current anticlinal axes. The Dohuk-Qand sedimentary basin axis deviates about (35)° from Bekhair anticline axis, and more than (80)° from Mateen and Gara folds

axes. The Shaqlawa basin deposition axis deviates approximately (15)° from Safine and Permam folds axes.

These variances of current folds axes from depositional axes of the two main Kolosh Formation basins is attributed to the counterclockwise rotation of Arabian plate during its collision with Eurasian plate; where the axes of generated folds are normal the regional compression direction resulted from this collision, and hence, the current folds axes became oblique to the inferred depocenters of the Kolosh Formation basins.

CONCLUSIONS

The present study has revealed the spread of Kolosh Formation sediments throughout an isopach map constructed for the formation. Two main and a minor sedimentation basins of the formation are determined. Areas of the formation non deposition in northern Iraq are detected and considered as emerge regions (bulge) during Paleocene-early Eocene. The tectonic activity influence of the Zagros foreland basin on the spread variance of the formation has been elicited. Also, the deflection of the formation depositional axes from current folds axes in the area has been deduced and attributed to a later counter clockwise rotation of Arabia during its collisional episodes.

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Appendix1

Data of Isopach map of Kolosh Formation

longitude	latitude	thickness	Location	Reference
42.42827	36.95097	138	Mashura Well	(Rafo, 1989)
42.85233	36.76353	284	Khanki Well	Albarefkani (2008)
43.01556	36.66945	337	Qand Well	Albarefkani (2008)
43.44721	36.50557	30	Maqloob Anticline	
43.97234	36.77582	30	Galley Zanta ,north	
43.97321	36.73253	10	Galley Zanta.south	
43.30475	36.78928	62	Shaikhan Anticline	Ahmed (1980) :
43.02267	36.87784	233	Bekhair anticline	Al-Hubiti,2008
43.08784	36.90798	371	Bekhair anticline	
43.04008	36.91326	306	Bekhair anticline	Al-Hubiti,2008
43.01592	36.93071	300	Bekhair anticline	
42.96801	36.9299	422	Bekhair anticline	Al-Hubiti,2008
42.99524	36.90663	421	Bekhair anticline	
42.85871	37.22851	110	Shiranish Islam	
43.14964	37.16169	110	Gale Dhe	
43.15544	37.25208	70	West khabour river	
42.81158	37.13719	310	Tawki Well	Al Barefkani (2008)
42.75481	37.29148	110	Zakho, kasrook	
43.15689	36.82773	100	Berifka Anticline	
43.06354	36.90397	209		
43.09958	36.87326	120		
42.9199	36.94749	400		
42.93959	36.96072	400		
43.21622	36.96822	50	West Suara Tuka	
44.03183	36.738	0		
43.69742	36.81527	15	East Aqra, Bakerman	
43.37681	36.83925	30		
43.32983	36.96461	0		
43.89012	36.76589	8	Aqra, Galley Abd Aziz	
44.141	36.72	0		
44.206	36.685	140	Bea Village	
44.235	36.662	90	Kolosh /Tanjero Contact	
44.281	36.706	100	Northern Bekhme	
44.283	36.6212	144	Spelik	
44.359	36.54	185	Harer	
44.3233	36.4125	510	Kolosh /Gercus, Shaqlawa	
44.3079	36.3707	310	Shiranish/Kolosh SW Hijran,Shaqlawa	

longitude	latitude	thickness	Location	Reference
44.2556	36.3561	331	Hijran Section	
44.5779	36.1218	662	Bana Bawi Anticline	Sakry,2006:
43.7512	36.1961	204	Dmer Dagh	North Oil Company
43.5087	36.0433	237	Quer	North Oil Company
44.37	36.652	110	Perat Anticline plunge	
42.31525	37.05267	0		
43.85801	36.83029	0		
43.81037	36.82602	0		
43.75857	36.83471	0		
43.71669	36.83047	0		
43.6896	36.83338	0		
43.64174	36.8373	0		
43.6174	36.84574	0		
43.58286	36.84913	0		
43.53774	36.85753	0		
43.50166	36.86001	0		
43.44938	36.86414	0		
43.40116	36.86741	0		
43.37153	36.8825	0		
43.34724	36.8996	0		
43.33289	36.9229	0		
43.3274	36.94433	0		
43.30408	36.98836	0		
43.29009	37.00277	0		
43.273	37.02157	0		
43.26247	37.04255	0		
43.24297	37.06091	0		
43.22591	37.08123	0		
43.20951	37.09998	0		
43.1947	37.1188	0		
44.52429	35.41831	0		
44.58496	35.3918	0		
43.1871	37.13608	0		
43.18762	37.14743	0		
43.18776	37.1573	0		
43.18242	37.16979	0		
43.17964	37.17934	0		
43.1777	37.19075	0	Atshan Well	
42.91667	36.15	0		
42.81635	36.4669	0		
42.30791	36.98961	0		
42.32038	36.90754	0		
42.38141	36.85167	0		

42.45147	36.79838	0		
42.50837	36.74662	0		
42.56698	36.69645	0		
42.61983	36.6456	0		
42.70122	36.63843	0		
42.80622	36.62388	0		
42.87756	36.59289	0		
42.9403	36.56175	0		
43.00221	36.52568	0		
43.05333	36.44604	0		
43.14791	36.36973	0		
43.23243	36.25507	0		
43.30059	36.16774	0		
43.35691	36.0782	0		
43.44847	36.00137	0		
43.52567	35.94483	0		
43.61875	35.92157	0		
43.73959	35.90403	0		
43.82987	35.83288	0		
44.18662	35.61321	0		
44.0913	35.67658	0		
44.034	35.72882	0		
44.2908	35.56047	0		
44.41821	35.4951	0		
44.53505	35.4204	0		
44.535	35.42104	0		
43.535	37.12381	0	Mateen , Amedi	
43.6035	37.12381	0	Gara. Amedi	
43.42809	36.8738	0		
43.42592	36.8657	0	South Gara	
43.27576	36.1218	0	Mankesh	
43.1751	36.971	0	Spendar,Gara	
43.77138	36.84572	0		
43.73789	37.0825	0		
43.77654	37.046	0		
43.81951	37.01009	0		
43.86236	36.979	0		
43.90926	36.9495	0		
43.95377	36.9039	0		
44.00053	36.8663	0		
43.97605	36.83854	0		
43.93125	36.83036	0		
43.89773	36.83049	0		