



Surface and sub-surface study to interpret the paleo basin morphology during Hauterivian-Albian in Kurdistan Region and North-Iraq

Sirwan H. Ahmed^{1*}, Amanj I. Fattah¹ & Aram Namiq¹

¹ Geology Department, University of Sulaimani, 1838, New campus, Bakhibakhtiary, Sulaimani, Iraq
Email: Sirwan.ahmed@univsul.edu.iq

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Abstract

The depositional basin shape configuration and evolution of western flank of the Neo-Tethys can be modelization during Hauterivian-Albian depends on (1) detail study of the outcrops in Northeastern Kurdistan and (2) seismic interpretation in the south and western of Kurdistan-Iraq. During Hauterivian-Albian, the Kurdistan was a path through series basin changes. Lateral and vertical facies changes are directly related to the (1) final active rifting phase of the Tethys and (2) the Kurdistan was located on the western margin of the depositional basin. During Hauterivian-Barremian, the northwestern flank of the Tethys extends to the extreme northwestern of Iraq. The distribution facies of shallow clastic (Zubair Formation) in the west inner-shelf facies in the center (Garague Formation), outer-shelf Lower Sarmord Formation in the northeast of Kurdistan and deep open-sea Balambo Formation in the extreme east of Kurdistan indicate the gentle sloping of the Tethys. No exist (1) shallow facies between deep-facies, (2) Shallow to deep facies change step by step regularly and (3) no any large scale extensional Syn-depositional faults in the seismic lines are clearly indicate no any active graben formed during this period. Consequently during Hauterivian-Berriasian most possibly the rift of the Tethys was slow. The Aptian-Albian period is the time of development the reefal platform that formed among deep-open sea and outer-shelf in the east and west consequently. The N-S longitudinal large Qamchuqa Platform well developed with the final opening of the Tethys. The Qamchuqa platform is the factor in terminating the Hauterivian-Barremian outer-shelf and changed into the shallow basin in the west and deep opens sea in the East. The fast vertically and laterally facies change without any interruption of deposition indicate the active period of N-S extension faults corresponding to the Tethys rifting. During Albian, the continuous development of the Qamchuqa reefal platform and deep-open-sea in the east indicate nearly same situation as much as Aptian time. But in the northwest and west, the dominant marly facies of Upper Sarmord Formation developed that is deeper than shallow Shuaiba and Nahr Omer formations. From the Seismic line and interpretation, we clearly identified the NW-SE trend graben in the Kirkuk and Mosul area. Occur of the graben nearly perpendicular to the main Qamchuqa reefal indicating of the development of the NW-SE trending extension fault as a result of the flexibility of the Arabian Plate between final steps of rifting and initiating the Arabia-Eurasia obduction event.

Introduction

The current study tries to explain the depositional environment of the rock units during the Hauterivian-Albian period. The explanation lateral and vertical facial changes and correlation the stratigraphy of Kurdistan with the west and south of Iraq is helpful to construct the sedimentary basin situation and its evolution periodically. During this period, the Kurdistan was a part of the passive margin of the Neo-Tethys (Aqrabi et al., 2010). Focusing stratigraphic and tectonic study on the Hauterivian-Albian outcrops sequence in Kurdistan is significance; because the sediment succession in these areas represents sediments that deposited between deep and shallow environments respectively. More detail study and explanations are necessary for depositional environment interpretation of the designated rock units, which has been discussed previously by different authors. Necessary to re-study and reviewed most of the Early Cretaceous sequences for Iraqi Territory, which can give reliable idea about the sedimentary basin during this period. One of the uncertain designated is the Sarmord Formation. Because this formation first assigned by Wetzel in 1950 (Bellen et al., 1959). The Chatton and Hart (1960) added another sequence into Sarmord formation and named as Albian Sarmord. However the Buday (1980) divided Sarmord Formation into two individual formations (Lower Sarmord and Upper Sarmord formations).

Area of investigation:

Mainly the research area to study the Early Cretaceous outcrops is in the Northeast of Kurdistan. The study area depend on the tectonic division of Iraq locates on the high and low fold zones (Fig.1). This study concentrates on three different areas: (1) Northeastern of Kurdistan region-Iraq for study outcrops, (2) Kirkuk area using wells information and (3) Northwestern of Iraq using sub-surface seismic data. The field work made in the Zagros fold and thrust belt part especially the high folded zone (Fig. 1). However the western and southern of Iraq we concentrate on the different previews works and publications that done before. Because of in the moment time these areas are risky and it's impossible to make any geological research on it.

The Kurdistan Region is occupied the north and northeastern part of Iraq. The territory of Kurdistan is mountainous, mainly consist in NE trending elongated ranges due to the reflection of the Arabia-Eurasia collision. The Hauterivian-Albian sequences are cropping out from several localities within Kurdistan territory.. This sequence has constrained the shield and the core of the anticlines such as Azmar, Pirmagroon, Surdash, Ranya, Korek, Handren, and Bekhme anticlines.

Previous ideas of Facies distribution in Kurdistan and northwest of Iraq:

Many authors' try to study North Iraq and especially Kurdistan parts given Facies distribution and basin configuration. The detail studies started in the middle of the nineteen century. Within the current study try to show these ideas and discuss some of them:

Dunnington (1958) study the generation, accumulation, and dissipation of the oil as well as paleogeographic maps of Kurdistan. He believes during Valanginian-Aptian the reefal platform of Qamchuqa Formation has the NNE-SSW trends. This platform divided the basin of Iraq into two parts: (1) Shallow Facies in the west and (2) deep basinal facies of Balambo Formation in the East (Fig. 2.A). As well as the same situation extends until Albian, only the change from the Valanginian-Aptian period is the existing lagoonal environment within shallow part of the basin (Fig. 2.B). That means the reefal of the Qamchuqa Formation still existed during whole Valanginian-Cenomanian periods.

Bellen et al. (1959) published "Lexique Stratigraphic International of Iraq". Part of this book described the lithofacies that distributed during Early Cretaceous in The North of Iraq. During Valanginian-Hauterivian periods, the deep basinal deposited and developed within the extreme northeastern of Kurdistan and outer shelf in the high folded zone. The Center and West of Iraq covered by the Shallow facies of Garagu Formation (Fig. 3-A). Hauterivian-Barremian period is nearly some configuration but starting development of the Qamchuqa Platform (Fig. 3-A). During Aptian, the Kurdistan and West of Iraq covered be two facies: (1) deep basinal in the northeastern and (2) reefal and shallow limestone of Qamchuqa and Shuaiba in other

areas. Albian is the period of development of lagoonal Rim and Jawan formations (Fig. 3-A) and shallow facies of Nahr Umr and Mauddud formations in the West.

Depend on Ditmar et al. (1971), Chatton and Hart (1960) and Buday (1980) they have described the facies identification of Hauterivian-Barremian and they mentioned some differences from the Bellen et al. (1959). SW to the NE starting of shallow clastic facies in the Salman area, Outer Shelf in Kirkuk and Foot-Hill Zone and deep open marine in an extreme northeastern area (Fig.4). As well as during Aptian-Albian are the same configuration except existing of Qamchuqa platform in the in the High Folded and Foot-Hill zones (Fig. 3-B). Moreover, they have divided the Sarmord Formation into two individual formations (Lower Sarmord and Upper Sarmord formations).

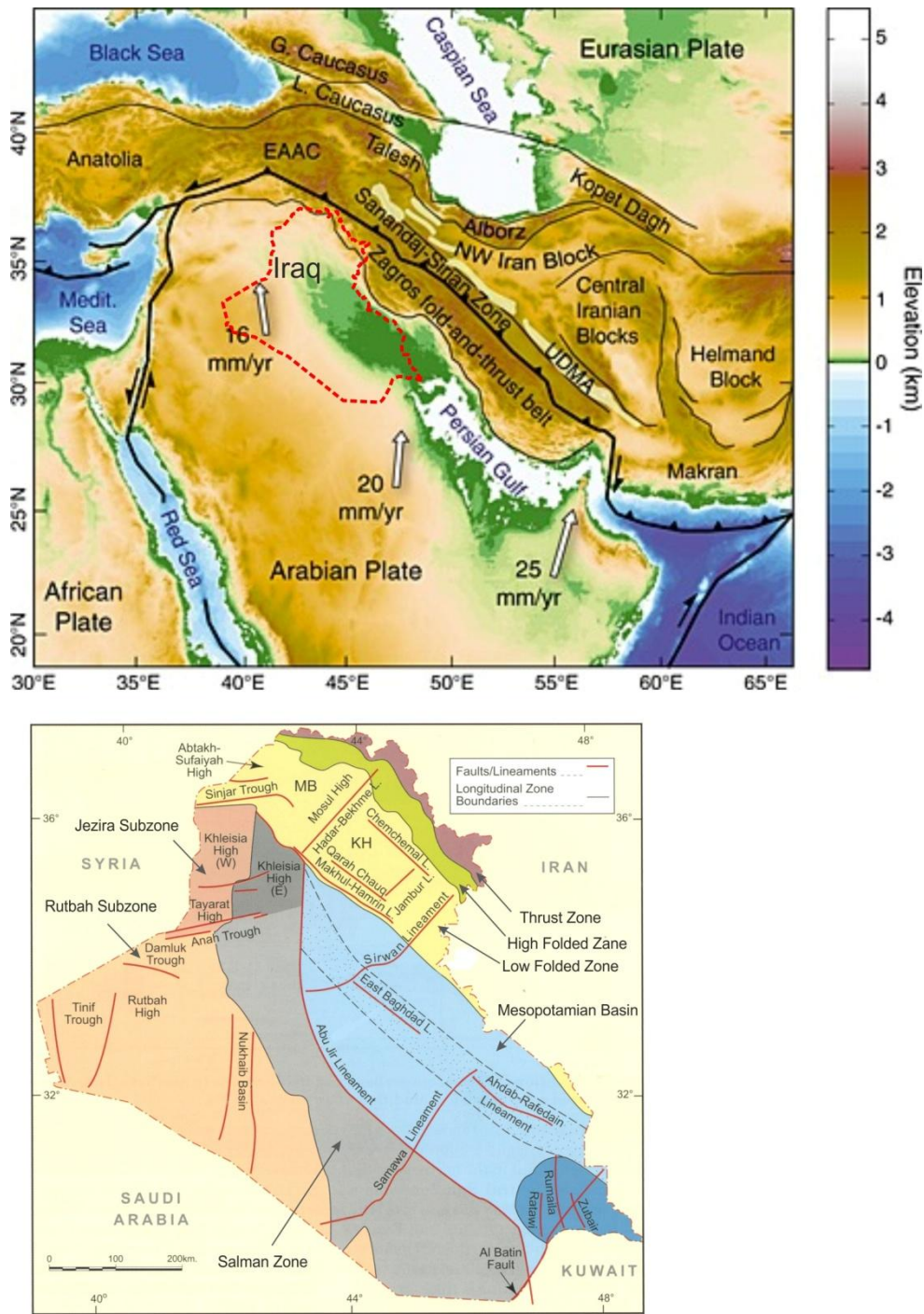


Figure 1: upper map: Tectonic setting of the Arabia-Eurasia collision zone after Homke et al. (2009) and Mouthereau et al. (2012). Lower map: Tectonic map of Iraq (Aqrabi et al., 2010) the study area concentrates in the High and Low Folded zones.

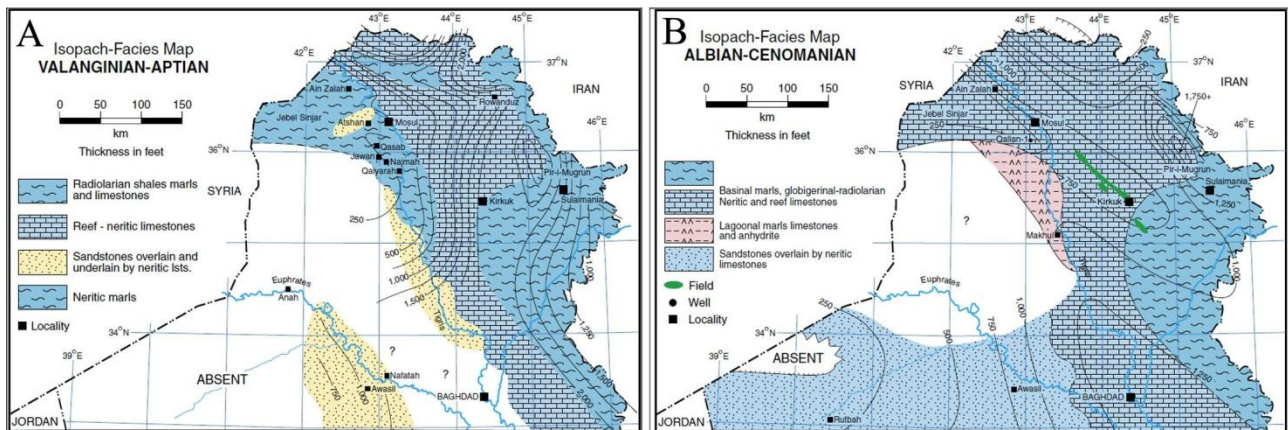


Figure 2: Paleogeographic and Isopach maps of North and Center of Iraq during A-Valanginian-Aptian and B-Albian-Cenomanian periods (Dunnington, 1958)

Recently Jassim and Goff (2006) explain and constrain new correlation chart (Fig. 3-C) to show the Early Cretaceous formations. From this diagram (Fig. 3-C) illustrate the Lower Sarmord Formation, which started from Valanginian to Late Aptian and Upper Sarmord Formation in Early Albian. In addition to that, the Upper Sarmord Formation does not belong to the type Locality of Sarmord Formation, but it exists only in the Foothill zone. The Qamchuqa Formation divided into two formations (Lower Qamchuqa and Upper Qamchuqa formations). In the High Folded Zone only the Albian Upper Qamchuqa Formation Exist (Fig. 3-C).

On the contrary, Karim (2010) constrain new chronostratigraphic column of Northeast Iraq (Fig. 3-D). From this chart show that during Hauterivian the Lower Sarmord deposited in the low and high folded zones, as well as recently Karim et al. (2013) approved that the facies of the Sarmord Formation was more extended until the imbricated zone. In the Figure-6 illustrate three main cycles and basin changes: 1-Balambo, Lower Sarmord and Shuaiba formations (Hauterivian); 2- Balambo, Qamchuqa, Upper Sarmord and Nahr Umr formations (Barremian-Aptian) and 3-Balambo, Qamchuqa and Mauddud formations (Albian).

Outcrops study and stratigraphic succession in Northeastern Kurdistan:

The Hauterivian-Albian outcrops involve outer shelf Sarmord, reefal Qamchuqa and part of deep open sea carbonate Balambo formations (Bellen et al., 1959; Ditmar et al., 1971; Chatton and Hart 1960; Buday, 1980; Jassim and Goff, 2006; Ahmed, 2007; Amen, 2008). In this research, we try to describe the properties of the formations during Hauterivian-Albian periods and then discussing the lateral facial change between them.

Sarmord Formation:

The facies of this formation cropped out in the longitudinal zone trended NW-SE (Fig. 4) that started in the Sulaimaniyah area and ended in the Soran area. The Sarmord Formation more extend to the southeast (Karim et al., 2013). The Formation is designated by Wetzel (1950 from Bellen et al., 1959) in the Surdash Anticline. They are identifying as Sarmord Formation only. However, Buday (1980) changed to the Lower Sarmord Formation. This formation cropped out in the Imbricated and high folded zones (Fig. 4). Mostly you can see the Hauterivian-Barremian marl-limestone facies in the eroded core of the huge anticlines (Fig. 4). We try to touch and study the Sarmord Formation in many places such core of the PiraMagroon, Surdash, Korek, Rania and Bekhme anticlines, as well as in the Balakaiaty and Barzinja-Azmar areas.

The typical rhythmic marl-limestone facies of Sarmord Formation are cropped out in the core of the Surdash anticline (Fig. 5). The total thickness of the formation in most sections exceeded 400m thick (Fig.5-A). The main lithofacies characteristic of Sarmord Formation is regular rhythmic alternation between marl and limestone (Fig. 5-B). This reputation of the marl-limestone bundle of Sarmord formation is due to the

diagenesis process of change original aragonite to calcite cement inside the small particle of limestone (Ahmed, 2007).

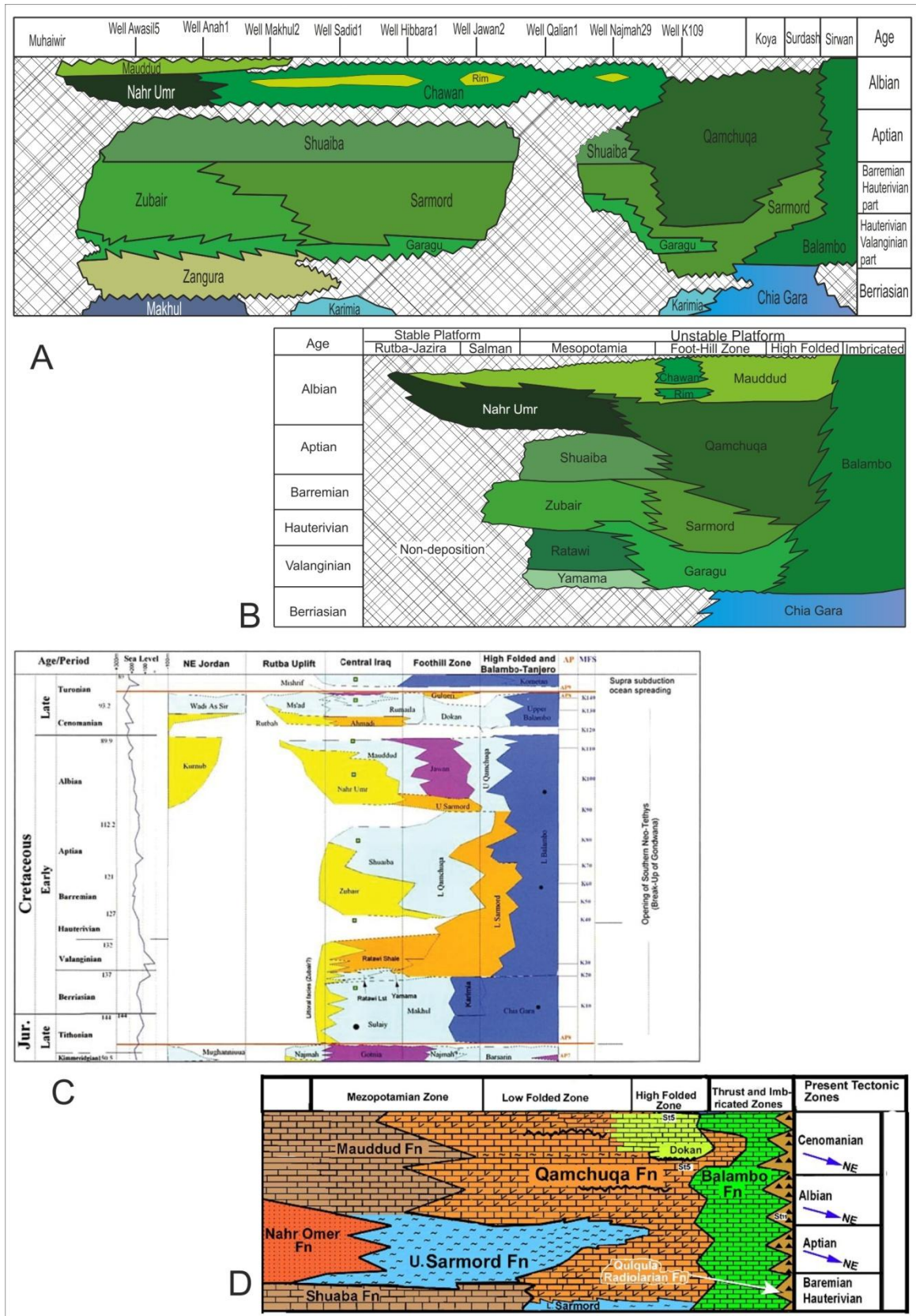


Figure 3: Stratigraphic charts and correlation of the formations during Cretaceous A- Bellen et al. (1959), B- Modified by Basim Al-Qayim after Buday and Jassim (1980 and 1987), C- Jassim and Goff (2006), D- Karim (2010).

The Formation conformably overly and underlay by Qamchuqa and Balambo formations respectively (Bellen, 1958; Buday; 1980, Jassim and Goff, 2006, Ahmed, 2007; Sissakian and Al-Jiburi, 2014). Also, in all outcrops same contact situation. In Surdash, Rania and Bekhme anticlines we collect samples of nanofossils in the lower and upper formations we identify the Lower Sarmord Formation conformably underlay the Aptian-Albian Qamchuqa Formation (Fig. 5-A) and conformably overlies the Berriasian-Valanginian Balambo Formation.

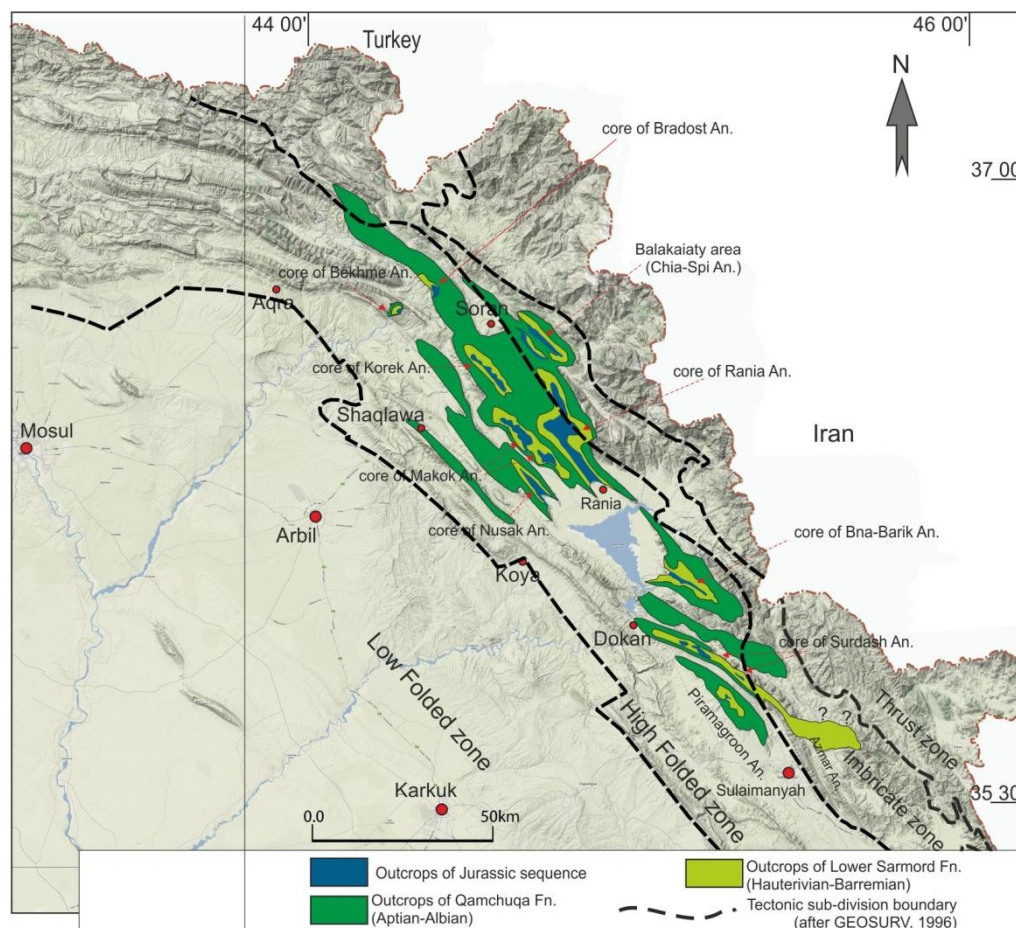


Figure 4: Surface distribution of Qamchuqa and Sarmord formation on the Kurdistan Terrain map. The dash lines are the boundary of tectonic division parts (maps modify from the GEOSURV, 1996).

The lithofacies of Sarmord Formation in whole outcrops are homogenous, which is composed of reputation bundles of marl and limestone beds. The only change from area to another and from part to another is the thickness variable of the limestone and marl beds. This facies represent the open sea outer-shelf or deep carbonate ramp environment (Ensile and Richen, 1991).

We study the Microfacies of the Sarmord Formation we mostly found in the thin sections Lime-Mudstone to Wackestone Microfacies types. Depend on classification Dunham (1962), Wilson (1975) and Flugel (1982) those Microfacies types in the Lower Sarmord Formation represent outer shelf environment (SMF 2, and 3). The age of the formation is supposed to be Hauterivian in the base and Barremian in the top (Bellen et al., 1959). However, Ditmar et al. (1971) and Chatton and Hart (1960) designated the Sarmord Formation that appears in the outcrops as two parts: (1) Tithonian-Berriasian and (2) Valanginian-Aptian parts. However, Buday (1980) supposed the age of Sarmord Formation as Berriasian-Aptian. As well as the Karim et al. (2013) believed all the Berriasian-Aptian sequence in the Sulaimaniyah area belongs to the Sarmord Formation. We collect several samples in the base, middle and upper part of the Sarmord Formation in different outcrops for nanofossil assemblage analysis. The result of these nanofossil samples gives the Early Hauterivian in the base and Late Barremian in the top (Table 1 and Fig.6). This result is convinced with the result of Bellen et al. (1958) that reported on the age of Sarmord Formation.



Figure 5: Sarmord Formation in the core of the Surdash anticline. A- Thick sequence (about 400m) Hauterivian-Barremian of the marl-limestone of Sarmord Formation overly conformably by massive limestone of Qamchuqa Formation (type section area). B- Marl-limestone bundles is specific lithofacies characteristic of Sarmord Formation.

Qamchuqa Formation:

This Formation was described by Wetzel (1950 from Bellen et al., 1959) in the Qamchuqa gorge located east of Dokan town. The Qamchuqa Formation is highly fractured and heterogeneous. Most of the shields of the anticlines in Kurdistan are formed from limestone of Qamchuqa Formation (Fig. 4 and 7). Lithology composed of thick massive reefal limestone and dolomitic limestone (Fig. 7). Easily recognized of Qamchuqa Formation in the field by existing of huge sequence exceed 700m of limestone (Fig. 7) and widely geographical distribution (Fig. 4). Qamchuqa Formation deposited on a platform including several repeated environments such as reef (barrier reef), lagoon, forereef and slope (Ameen, 2008).

Chatton and Hart (1960); Ditmar et al. (1971) and Buday (1980) divided the Qamchuqa into a Lower and upper Qamchuqa formations. This division made depend on the age. Nevertheless, the Aptian carbonate reef represents Lower Qamchuqa Formation, and Albian part represent Upper Qamchuqa Formation. We collect samples for nannofossil analysis in the friable layers between thick limestones. The result of samples gives Aptian for lower part and Albian for Upper part of Qamchuqa Formation (Table 1 and Fig. 6).

The fossil content allows to firmly establishing the age of the Lower Qamchuqa Formation is as Hauterivian till Aptian (Buday, 1980), and the age of the Upper Qamchuqa Formation is the Albian (Chatton and Hart, 1960; Bellen et al., 1959).

The Upper Qamchuqa Formation supposed to extend into the Cenomanian because of the frequent occurrence of some species of the *Orbitolina* (Jassim and Goff, 2006), but in the western Iraq the fossil content in the Upper Qamchuqa (Mauddud) Formation indicating the Albian age only (Jassim et al., 1984).

The lower contact is conformable with Sarmord Formation (Fig. 7) in all the areas of the investigation in NE Kurdistan. However, the upper contact of the formation is disconformable with Kometan Formation (Lawa et al., 2013) or is conformable with Dokan Formation (Karim et al., 2013) in Sulaimaniyah area.

Table 1: Age determination and Nannofossil assemblages and species that we found in the Qamchuqa and Sarmord Formation. Figure 9 are linked to this table.

Sarmord Formation				Qamchuqa Formation	
Lower	middle		upper	lower	upper
Early Hauterivian	Late Hauterivian	Early Barremian	Late Barremian	Aptian	Albian
<i>Calcicalathina oblongata</i> (Fig.6-A)	<i>Calcicalathina oblongata</i>	<i>Calcicalathina oblongata</i>	<i>Calcicalathina oblongata</i>	<i>Eprolithus floralis</i> (Fig.6-G)	<i>Eprolithus floralis</i>
<i>Cyclagelosphaera margerelii</i>	<i>Cruciellipsis cuivillieri</i> (Fig.6-C)	<i>Cyclagelosphaera margerelii</i>	<i>Ellipsagelosphaera communis</i>	<i>Lithraphidites carniolensis</i>	<i>Lithraphidites carniolensis</i>
<i>Ellipsagelosphaera communis</i>	<i>Ellipsagelosphaera communis</i>	<i>Micrantholithus hoschulzii</i>	<i>Nannoconus circularis</i> (Fig.6-F)	<i>Micrantholithus obtusus</i>	<i>Micrantholithus bastilliformis</i>
<i>Micrantholithus obtusus</i>	<i>Lithraphidites bollii</i> (Fig.6-D)	<i>Micrantholithus obtusus</i> (Fig.6-E)	<i>Nannoconus colomii</i>	<i>Nannoconus elongatus</i>	<i>Micrantholithus obtusus</i>
<i>Nannoconus colomii</i>	<i>Nannoconus colomii</i>	<i>Nannoconus colomii</i>	<i>Nannoconus kamptnerii</i>	<i>Nannoconus quadriangulus apertus</i>	<i>Nannoconus elongatus</i>
<i>Nannoconus globules</i> (Fig.6-B)	<i>Nannoconus steinmannii</i>	<i>Nannoconus kamptnerii</i>	<i>Micrantholithus hoschulzii</i>	<i>Nannoconus truitti truitti</i>	<i>Nannoconus quadriangulus apertus</i>
<i>Nannoconus kamptneri</i>	<i>Micrantholithus hoschulzii</i>	<i>Nannoconus wassallii</i>	<i>Nannoconus steinmannii</i>	<i>Watznaueria barnesae.</i>	<i>Nannoconus quadriangulus quadriangulus</i> (Fig.6-H)
<i>Nannoconus steinmannii</i>	<i>Watznaueria barnesae</i>	<i>Nannoconus steinmannii</i>	<i>Watznaueria barnesae</i>		
<i>Parhabdololithus embergeri</i>					
<i>Watznaueria barnesae.</i>					

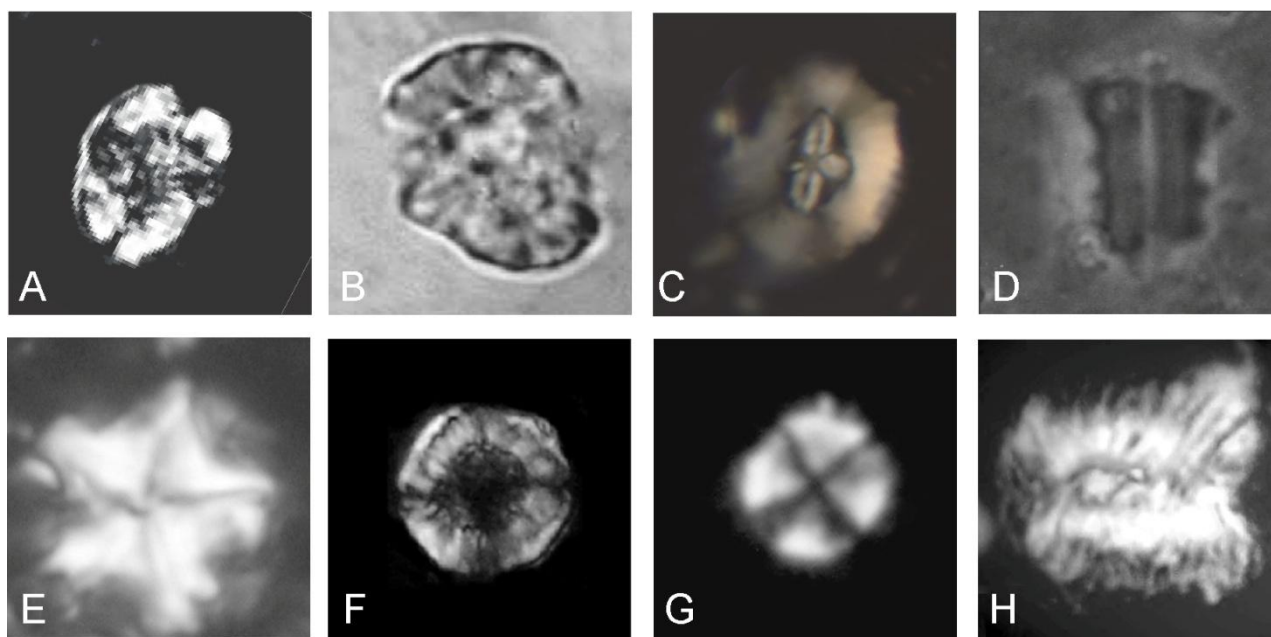


Figure 6: All they are microphotographs of nannofossils.

A- *Calcicalathina oblongata*, range: Valanginian-Hauterivian (Bown et al., 1998)

B- *Nannoconus globules*, range: Berriasian-Aptian (Perch-Nielsen, 1985a and Bralower et al. 1989)

C- *Cruciellipsis cuivillieri*, range: L. Hauterivian-E. Berriasian (Bown et al., 1998)

D- *Lithraphidites bollii* range: L. Hauterivian (Bown et al., 1998)

E- *Micrantholithus obtusus*, range: Berriasian-Barremian (Bown et al., 1998)

F- *Nannoconus circularis*, Range: Late Valanginian-Aptian (Perch-Nielsen, 1985a; Bown & Concheyro, 2004)

G- *Eprolithus floralis*, Range: Aptian- E. Campanian (Burnett, 1998 and Bown et al., 1998).

H- *Nannoconus quadriangulus quadriangulus*, Range: Aptian (Perch-Nielsen 1985a)



Figure 7: The outcrops of Qamchuqa Formation in Kurdistan. 1- Core of Korek anticline show the Qamchuqa Formation above friable sequence of Sarmord Formation, 2- Thick sequence of reefal limestone of Qamchuqa in Sangasar road, 3- the sequence limestone of Qamchuqa Formation conformably overlay Sarmord Formation in core of Piramagroon anticline, 4- fragments and skeletal represent shallow environment, 5- highly dolomitic limestone beds, 6- Shanadar Cave in the massive limestone of Qamchuqa Formation in Barzan area, 7- Highly thick carbonate sequence of limestone and dolomitic limestone of Qamchuqa Formation in core of Surdash anticline, and 8- shield of Piramagroon anticline composed of massive limestone of Qamchuqa Formation.

Lateral Facies Changes of Sarmord and Qamchuqa formations to Balambo Formation:

In the extreme northeastern of Kurdistan, the Hauterivian-Albian sequences have rapid lateral change from shelf and reef to deep open-marine environments. We tried to visit these areas that appear the phenomenon

of the lithofacies change between shallow and deep facies. The superior areas to study in detail are the northeast and eastern of Sulaimani and Qandil area. However, the Qandil area now is unsafe and risky area, so we try to focus on the Sulaimaniyah area only. The main factor direct to rapid change in the environments is fault (Chaqchaq Fault), form during the Early Cretaceous between the Qamchuqa-Sarmord formations and the Balambo Formation (Aziz et al., 2001). Al-Hakary (2011) assumed lateral facies change related to the activity of the Chaqchaq normal fault during the Tithonian to Cenomanian period (Fig.8-A) that mean the fault is the main factor for change both Sarmord and Qamchuqa formations to Balambo Formation. But Ahmed (2013) concludes the change Qamchuqa to Balambo formations is related to normal faults, and these faults were active during Aptian-Albian (Fig. 8-B).

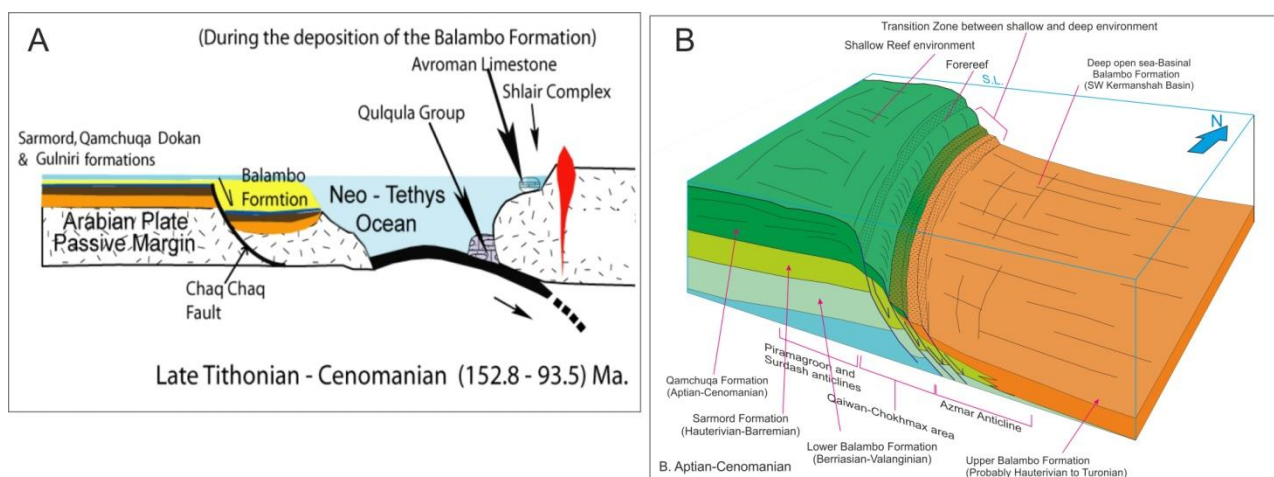


Figure 8: A- Basin model of the Balambo, Sarmord and Qamchuqa during Late Tithonian to Cenomanian (Al-Hakary, 2011). B- Part of the Qamchuqa-Balambo basin During Aptian-Albian (Ahmed, 2013).

The termination of the Qamchuqa reefal is in the echelon plunging of Azmar and Surdash anticlines. Disappear of Qamchuqa is due to change laterally to Upper Balambo Formation. We claimed this lateral rapid change is due to normal fault activated during Aptian-Albian.

For interpretation the termination Sarmord Formation and laterally changes to Balambo Formation we select Chngian section (Fig. 9). This section geographically locates about 20km toward ENE of Sulaimaniyah city near Barzinja district (Fig. 9-A). In this locality three succession facies exist: 1- outer shelf facies of marl-limestone, which is similar to the lithofacies of Sarmord Formation in the type sections (Fig. 9-F and G); 2- deep open sea carbonate alternate with thin layers of shale and occur chert band facies (Fig. 9-D); 3-- Wight color stylolites open sea limestone contain chert nodules (Fig. 9-E).

From the nannofossil results, we found the age of marl-Limestone sequence is Hauterivian-Barremian (Fig. 9-B). Depend on the stratigraphic position; lithofacies and age this rhythmic marl-limestone sequence can be identified as Sarmord Formation (Fig. 9). The stratigraphic successions for this section are not similar to compared to the Piramaqroon and Surdash anticlines because Hauterivian-Barremian sequence is Sarmord Formation, but the Aptian-Albian sequence is Balambo Formation (Fig. 9). Facies of Sarmord are terminate to the east and southeast before arriving the Saisadiq district.

From this section and field investigation, we identify boundary between Sarmord-Balambo and Qamchuqa Balambo. Therefore, the Figure-10 is map show the estimate boundaries of the lateral facies change. These two boundaries do not match, and they are several kilometers faraway from each other.

Subsurface study of the Hauterivian-Albian sequences

The only way to explore the Hauterivian-Albian formation in Kirkuk and western Iraq are only subsurface study. For understanding the basin shape during this period, we need at least the lithofacies data of the wells and seismic sections. The environmental and depositional basin change in Kurdistan and Iraq directly reflected the rifting of the Arabia-Eurasia plates (opening of Tethys) especially during Early Cretaceous,

which known as major rifting phase of Neo-Tethys (Barrier and Vrielynck, 2008; Berra and Angiolini, 2014). Many extensional faults identify during Early to Late Cretaceous in Eastern of Syria (Al-Abdalla, 2008). These previous research illustrate the extensional Eurasia-Arabia tectonic activity in the passive margin have direct effect to facies change laterally and vertically during Early Cretaceous in the north of Iraq.

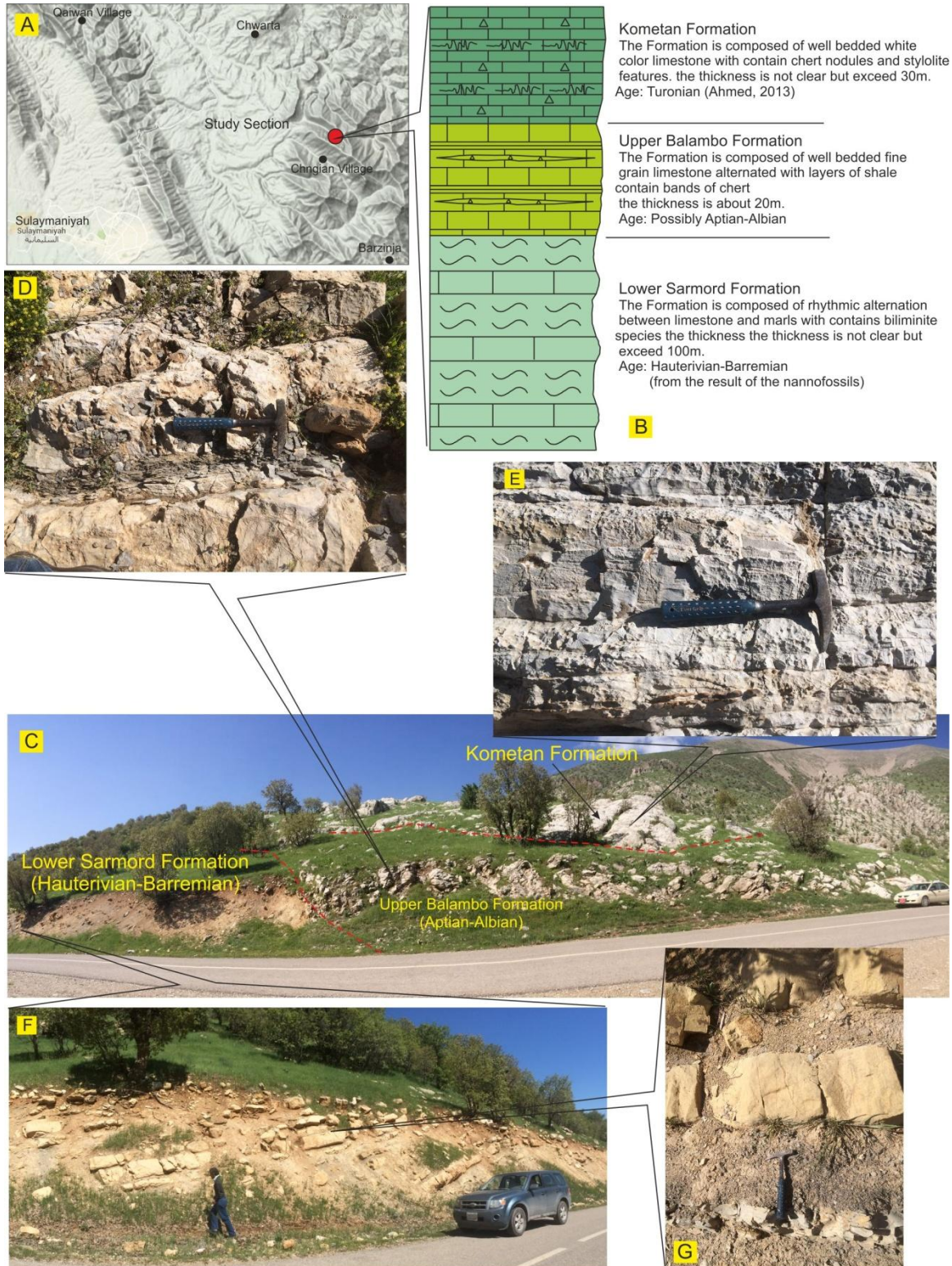


Figure 9: Chingian study section **A-** Location map of the section, **B-** Stratigraphic log of the Chingian section, **C-** Panorama photo show the Lower Sarmord, Upper Balambo and Kometan formations (from older to younger), **D-** Aptian-Albian facies of deep limestone alternated with thin layers of shale (Upper Balambo Formation), **E-** Stylolitic limestone contain chert nodules (Kometan limestone), **F-** Hauterivian-Barremian sequence of Sarmord Formation, and **G-** Rhythmic of Marl-limestone of Sarmord Formation.

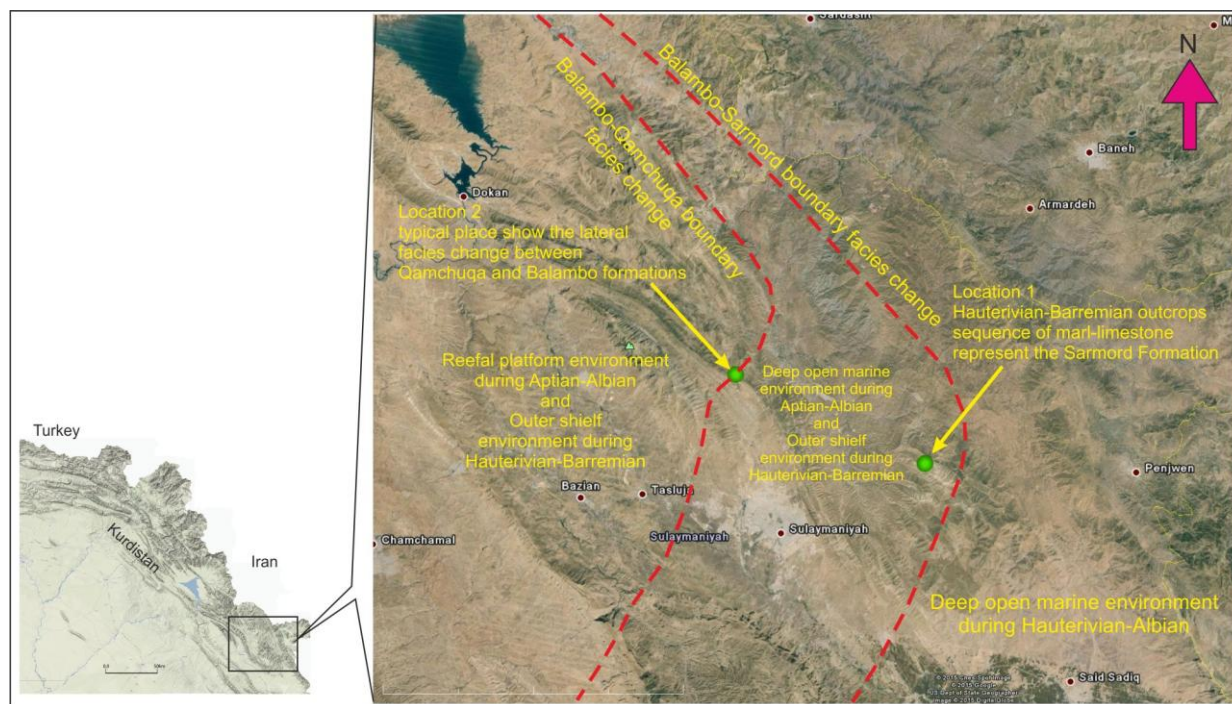


Figure-10: Google map of east and northeastern Sulaimaniyah governorate plotted the estimate boundary area between Sarmord-Balambo formations during Hauterivian-Barremian, and Qamchuqa-Balambo formations during Aptian-Albian periods.

Until Campanian time, the shoreline of the western part of Neo-Tethys was in the western of Iraq with existing of Rutba and Khlesia uplift during Cretaceous periods (Buday, 1980; Jassim and Goff, 2006; Barrier and Vrielynck, 2008; Aqrabi, 2010; Ahmed, 2013). That means During Early Cretaceous the Kurdistan was a passive margin of the Neo-Tethys and Kermanshah basin. Kurdistan and West of Iraq covered by shallow and alluvial clastic, Shelf, Lagoonal, reefal and Open marine and deep marine during Hauterivian-Albian. Therefore, three wells were selected within the Erbil and Kirkuk areas and represented by Demr-dagh-1 (Erbil area), Kirkuk-109 (Kirkuk area) and Jambour-13 (South of Kirkuk).

Well Demr-dagh-1 located in the west of the Erbil city (Fig. 11). The well was drilled to 2271m depth. The marl-limestone sequences of Upper Sarmord Formation were disconformably overly the shallow limestone of Garagu Formation. In this well no Lower Sarmord Formation recorded, indicating nondeposition or eroded during Aptian time. The Early Cretaceous sequence from older to younger is Garagu, Upper Sarmord, Qamchuqa, Jawan and Qamchuqa formations consequently (Fig. 11). The facies change and reputation of carbonate sequences are due to the regression and transgression of sea level. So the location of Demir-Dagh-1 well is near to the western termination limit of the Qamchuqa platform.

In Well Kirkuk-109 is the key to understanding the basin configuration from the northeast of Kurdistan to west and southwest of Iraq (Fig. 11). The Early Cretaceous sequences in this well from older to younger are starting from the Lower Sarmord, Garagu, Upper Sarmord (or part of Qamchuqa), Qamchuqa, Jawan and Qamchuqa formations consequently. These sequences are indicating that the Kirkuk area was part of in the outer-shelf during Hauterivian, shallow carbonate shelf (Garagu Formation) during Barremian and outer shelf-lagoonal (Upper Sarmord and Jawan formations) during the Aptian-Albian time.

Well-Jambour-13 located in the south of Kirkuk area near Hamrin Mountain (Fig. 11). This Well gives an idea about geographical distribution of Upper Sarmord Formation is limited because no record of Albian sequence of marl-limestone (Fig. 11).

Seismic interpretation of Subsurface

Most importance part in this study to understanding: the termination of the Qamchuqa reefal Formation to the west and exist of deep facies (upper Sarmord Formation) or lagoon between two shallow facies. The exits

of these deep facies related to sea level changes or extensional tectonic activity (normal faults). Consequently, this investigation tries to explain why deeper restricted basins (Upper Sarmord and Jawan) between two shallow environments (Qamchuqa platform and Nahr Umr classics).

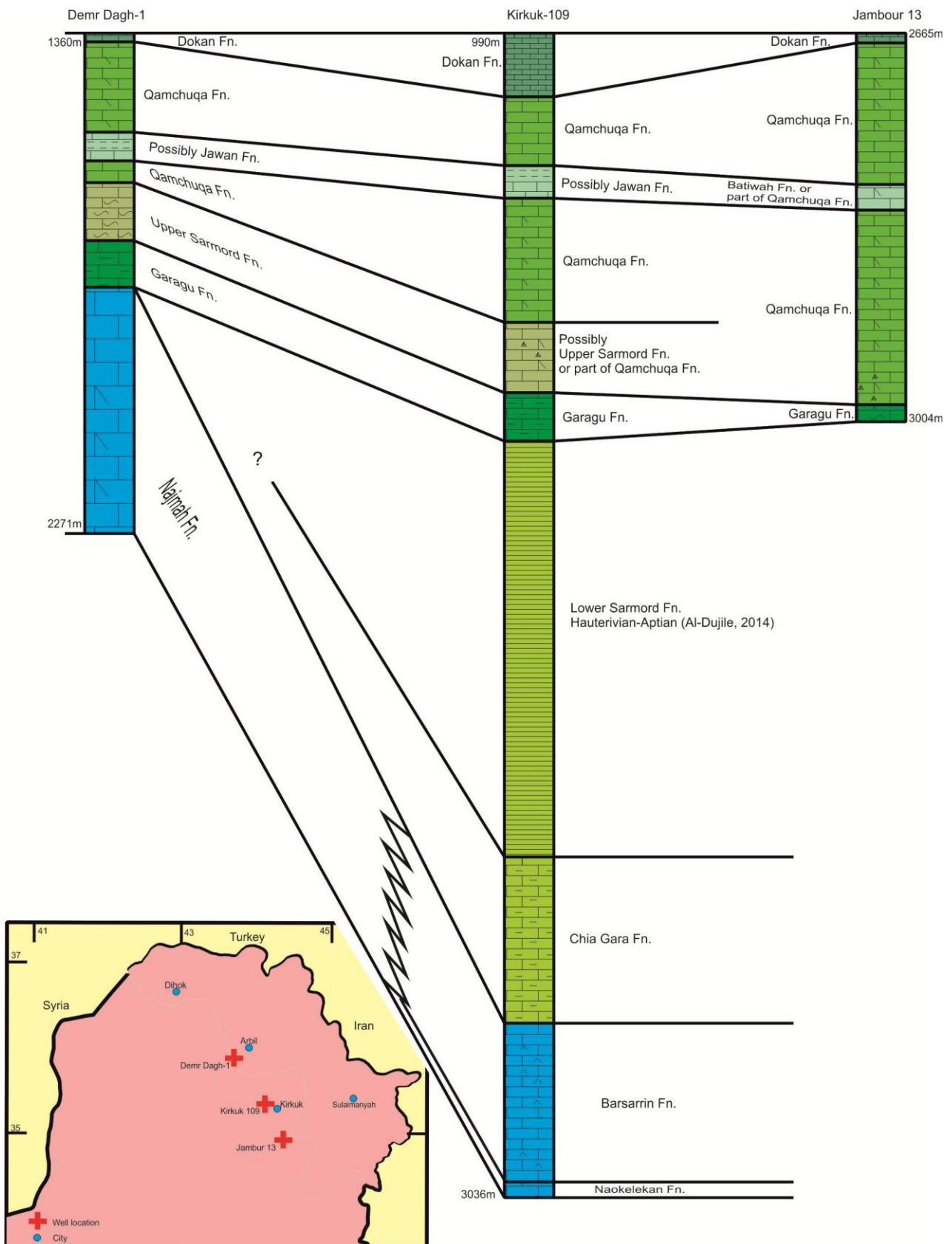


Figure 11: Stratigraphic logs of Damir Dagh-1, Kirkuk-109 and Jambur-13 wells and stratigraphic correlation between them (modify from Final Report of Kirkuk Oil Company, and Ditmar et al., 1971; Ditmar et al., 1979).

From the outcrops study in the northeast of Kurdistan, we found the outer-shelf environments during Hauterivian-Barremian and shallow reefal environment during Aptian-Albian. We explain the developments of the Qamchuqa reef are directly related to the normal faults (Aziz et al., 2000, Al-Hakary, 2011; Ahmed, 2013). During Aptian-Albian only reefal Qamchuqa developed and no any environmental change is clear evidence of no grate sea level change happen in during Aptian-Albian. Therefore, the only aspect of forming the environment of Upper Sarmord and Jawan is only the extensional tectonic movement and formation grabens.

At some stage in Cretaceous especially before and during the obduction and formation the Foreland basin the normal faults and formation of graben were active on the Arabian plate especially in Iraq, Syria and southern part of the Arabian Plate. The trends of the extensional fault not only correspond to the opening of the Tethys but also the normal faults developed in different direction especially perpendicular to the rifting trend (Henson, 1951; Berberian and King, 1981; Stoesser and Camp, 1985; Alsharhan and Nairn, 1997; Kent and Hickman, 1997; Al-Husseini, 2000; Hessami et al., 2001; Al-Abdalla, 2008; Kent, 2010; Ahmed, 2013).

Depend on the Peel and Wright (1990) and Fouad (2012) they described and identified several extensional fault in the western and Mussel area through seismic interpretation. Depend on these seismic profiles (Fig. 12) we identify these extensional faults are Early Cretaceous Syn-depositional faults and it's a good indication of existing the faults during this periods.

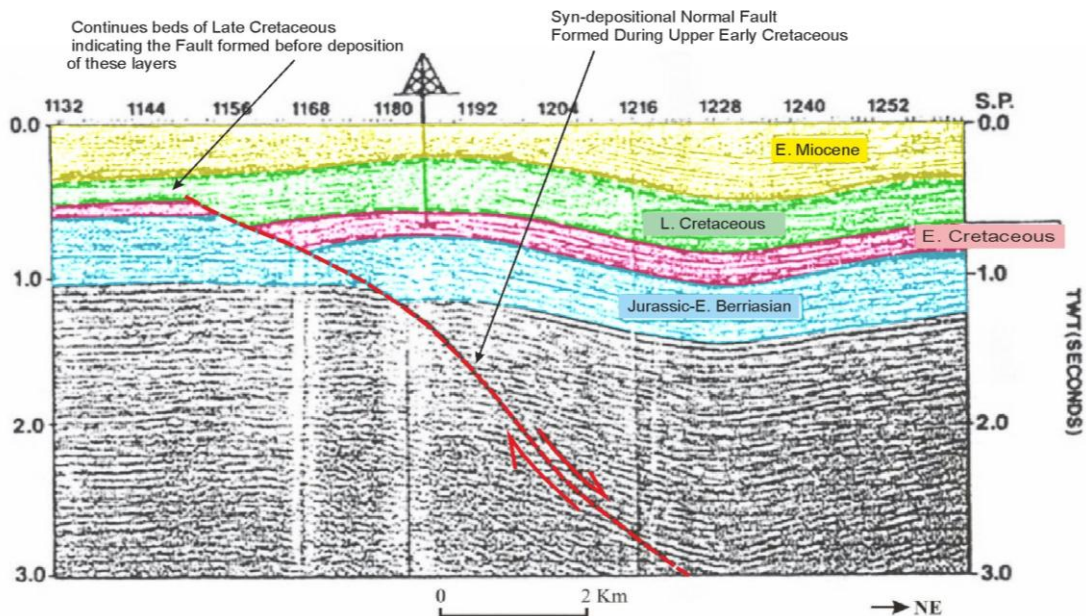


Figure 12: Seismic profile of northwest of Iraq show the Early-Late Cretaceous Syn-depositional normal fault. The Fault show a part of the grabens (modify from Peel and Wright, 1990; Fouad, 2012)

We study two seismic lines located in the west of Kirkuk city. The area of these lines is Kirkuk-Bai Hasan-Khabbaz. The type of the lines is single seismic lines (Fig. 13). Through the results of the seismic lines we identified two types of faults (Fig. 13), they are (1) Normal fault (extensional type) and (2) Reverse fault (compressional type). The compressional faults mostly cross the Late Cretaceous-Tertiary sequences (Fig. 13) it is clear indication these type of faults formed during collisional phase of Arabia-Eurasian boundaries. For extensional fault systems (Normal faults) the faults are cross Jurassic-Cretaceous Sequences and most of them they are terminated in the Late Cretaceous formations (Fig. 13). The terminology and dimensional of the extensional fault in the Kirkuk-Bai Hasan-Khabbaz structures are explained these faults are Early-Late Cretaceous Syn-depositional faults. Kurdistan and Iraq suffered from extensional stress during two periods Aptian-Albian and Campanian times (Kent, 2010; Ahmed, 2013) resulted from several grabens in large scale in the Kurdistan area. The sources of the extensional stress are most possibly related to the final rifting of Tethysian and starting the converging of the Arabia-Eurasia plates.

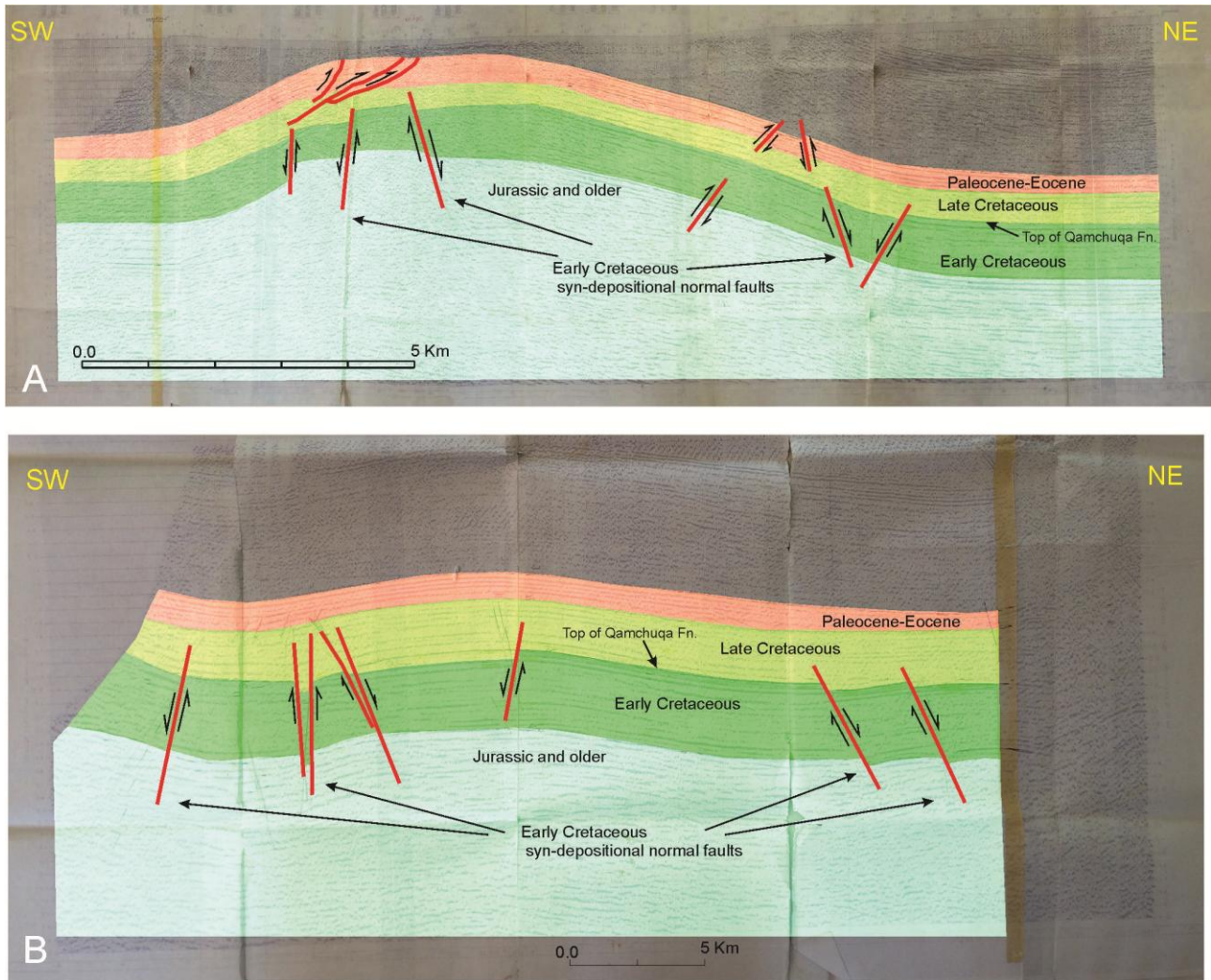


Figure 13: A- Seismic Line KK-54 with interpretation show gentle Asymmetrical anticlines located in the west of Kirkuk area. B- Seismic Line KK-54A with interpretation show gentle Asymmetrical anticlines located in the west of Kirkuk area. From these seismic interpretation we can illustrates Early-Late Cretaceous Syn-depositional faults in different part of the structures.

Basin evolution of Kurdistan and West Iraq during Hauterivian-Albian periods:

Through the results and interpretations of tectonic, stratigraphy, and seismic of the Kurdistan we obtain evolutionary model show the basin geometry and developments of the depositional basin during Hauterivian-Albian periods (Fig. 14).

During Hauterivian period, the Kurdistan was a part of southern of Tethys and specifically was a West passive margin part of Kermanshah basin (Ahmed, 2013). The western of Iraq during this period suffered from the uplifting and these areas were acting as source area for supplying sediment to the basin lead to deposition the clastic of Zubair Formation until Barremian (Al-Obaidi, 2009) or until Aptian (Bellen et al., 1959; Buday, 1980) (Fig. 14). Gradationally the depth of the basin increased eastward. Zubair clastic Formation laterally changes to marl-limestone (silica-carbonate) of Lower Sarmord Formation in area between Kirkuk and Mosul (Fig. 14). The sediments of Lower Sarmord widely distributed into the north and northeast that extended to the east of Sulaimani area. The fixed lithofacies of the Lower Sarmord indicate low angle wide distance ramp cover most of the Kurdistan during Hauterivian (Fig. 14). The end point of the ramp and inflection point from ramp to deep environment of Balambo Formation conclude two importance points: (1) the steep slope after the ramp occurs in the imbricate zone and (2) the Balambo Formation is open sea not very deep basinal environments.

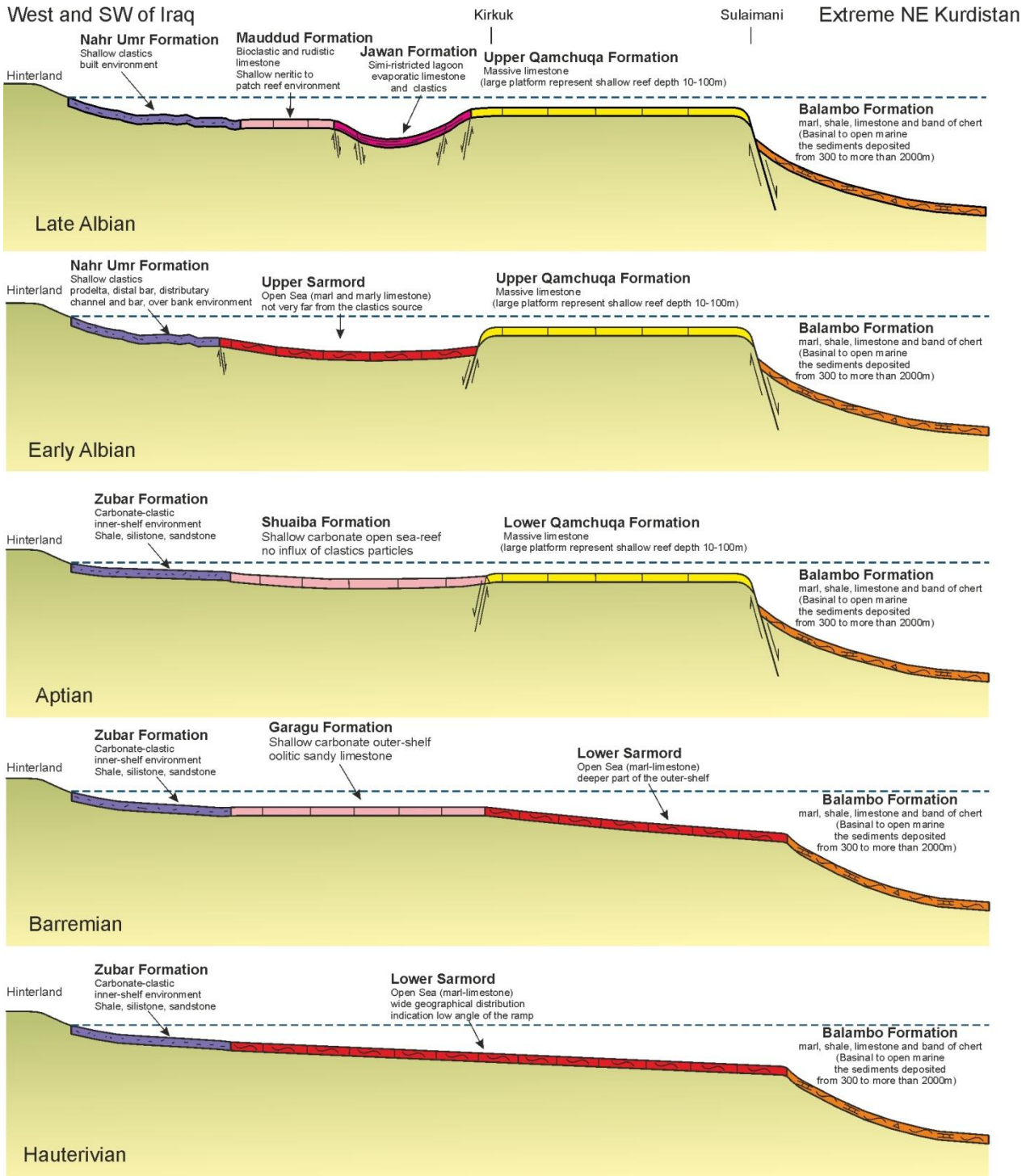


Figure 14: Schematic cross sections model of the western passive margin of Tethys (western Kermansha basin) during Barremian-Albian. These sections started in the NW and West of Iraq (Khlesia and Mosul area) in to the extreme NE and East of Kurdistan. The age, depositional environments and lithology of Nahr Umr, Zubair, Mauddud and Shuaiba formation are takes from *Al-Dabbas et al. (2012)*, *Al-Obaidi (2009)*, and *Hasan (2007)*. *Al-Ameri (2009)*. Vertical depth is estimate.

Depositional basin shape in North Iraq and Kurdistan during Barremian are mostly like Hauterivian time but with the slight change (Fig. 14). The change is only widely developed inner-shelf and extend toward east when the shallow carbonate of Garagu Formation deposited following the Zubair Formation. Because the Garagu formation represents inner shelf shallow environment (Ditmar, 1971; Bartenstein and Abawi, 1984; Jassim and Karim, 1984; Amin, 1998). The line Position of the border between ramp (outer shelf) and deep open sea during Barremian is similar to the Hauterivian periods with same configurations. Well developed of

Shallow Garagu Formation possibly related to the decrease the influence of the material from the west land to the depositional basin.

Aptian-Albian Sedimentary sequences package in Kurdistan and West Iraq exhibit the rifting record of the Tethys. Because of exists shallow facies between two deep facies (horst) or deep between two shallow facies (graben). The Qamchuqa reefal platform locates among deep open sea Balambo Formation in the east and Lagoonal and outer-shelf in the western (Upper Sarmord, Jawan, Shuaiba formations) (Fig.14).

During Aptian the NE-SW trend large scale extensional faults active especially in the northeast of Kurdistan by forming the rapid lateral facies change between open sea Balambo and reefal Qamchuqa platform (Fig. 14). In Kirkuk until Mussel area the normal faults are slightly less displacement relatively to the northeast Kurdistan by forming grabens deposited the shallow open marine of Shuaiba Formation (Fig. 14). The extensional faults active during Albian by changing the shallow environments of Shuaiba carbonate to the deeper outer shelf of Upper Sarmord and after to semi lagoonal of Jawan Formation inside the grabens. The western and northwestern of Iraq during Aptian-Albian occupy by the shallow clastics facies of Nahr Umr Formation (Fig. 14).

Conclusions:

The study tries to give an idea of the western margin of Tethys basin during Hauterivian-Albian in Kurdistan. All the Facies in this margin are represent the sedenment of passive margin indicating the contineous rifting progrece during Early Cretaceous. The graditional lateral facies change from inner shelf (Zubair and Garagu formations) to outershelf (Sarmord Formation) to marine open sea (Balambo Formation) explain slow extension activity during Hauterivian-Bariemian. Aptian-Albian reflecting Tethysian rifting clearly printed in the Kurdistan and NW of Iraq due to rapid lateral changing of shallow/deep (Qamchuqa to Balambo formations) during Aptian and deep/shallow/deep (Upper Sarmord/Qamchuqa/Balambo formations) during Albian. The lateral and vertical facies change directly linked to the NE-SW extensional stress by forming the NW-SE normal faults. The grabens and horst in the shelf part of the basin have direct role in producing the shallow-deep-shallow environmental respectively.

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