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Stratigraphy and Mineralogy of Balambo Formation (Aptian - Cenomanian) near Chomabrok village, Imbrication Zone, Iraqi Kurdistan Region

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ABSTRACT

The stratigraphy and mineralogy of Balambo Formation (Aptian - Cenomanian) in exposed surface section near Chomabrok village in the Imbrication zone, northeastern Iraq is studied. The Formation is 450 meters thick and consists of thin to medium to thick bedded yellowish-brown, and black to dark gray limestones, marly limestones, with thin-medium bedded, grayish - black marl and shale, with thin bands of black cherts and abundant nodules and lenses. From the field observations and petrographic studies, the formation mainly made from two main lithofacies types; marly limestone-marl lithofacies and cherty limestone lithofacies. The petrographic study of carbonate rocks deepened on 79 thin sections and demonstrated that the carbonates of Balambo Formation composed of micrite ground mass with abundant skeletal grains; planktonic and some benthic foraminifera, radiolaria, calcisphere, ostracods, pelecypods, larva-ammonoids, small-brachiopods, sponge spicules, echinoid spines, and bioclasts. Non-skeletal grains include peloids only. Using extraction method and according to an assessment of foraminiferal assemblages and based on the defined planktonic foraminifera the assigned age of Balambo Formation in the studied section is Aptian to Cenomanian as upper Balambo age. The results of X-ray diffraction (XRD) analysis for bulk mineralogy of selected shale and marl samples suggested the presence of phyllosilicate with abundant calcite, common quartz, and moderate Fluorapatite with minor dolomite content. Illite is the dominant clay mineral in the Balambo Formation and indicates a hot, arid climate during most of the Cretaceous period in the Imbrication zone, Northeastern Iraq.

1. Introduction

The Balambo Formation is one of the Cretaceous successions that have a considerable thickness and wide distribution throughout the northern Iraq (Kurdistan region) and corresponds to the Wasia Group that present throughout the whole country [1]. The formation represents deep-water sediments that deposited in the Imbrication zone of the northeastern Iraq during almost the whole Cretaceous, exactly from the Early Hauterivian up to the Turonian [2]. In the Imbrication Zone, the formation is carbonate-siliciclastic unit, composed of alternation between thin, yellowish- gray-black marly limestones and dolomitic limestones, with thin and medium-bedded gray-black shales. Thin to medium bedded, lenses and nodules of cherts are present all over parts of the formation. While in the subsurface sections, it defined in different tectonic zones from various wells, such as Chamchemal No. 1, Injana No. 5, Pulkhana No.5 and Jambur-18 in northeastern Iraq. In subsurface, the formation contains different lithological facies, and sediments of younger than Turonian age. A brief description of the formation was given in Iraq Geological Lexicon [3], were it was first described and recognized from the Sirwan valley near Halabja in NE Iraq. Due to its accessibility and widespread distribution in the western Zagros Folded

belt, the Balambo Formation has been studied by several authors. These are including the studies of [4, 5, 6, 7]. The present study aims to describe the stratigraphy, petrography, lithofacies, age determination and mineralogy of the Balambo Formation in the imbrication zone of northeastern Iraq.

Fig. 1: Location map of the study area.

Study area

Well outcropped and a thick succession of Balambo Formation chosen near Chomabrok village in the Imbrication Zone of northeastern Iraq, about 35 km east of Soran City, Erbil Governorate at Latitude 44˚ 42′ 02″E and Longitude 36˚ 38' 22" N (Fig. 1). The studied section lies on the Smelan road at Rwsty Valley.

Geological setting

The Balambo Formation was first described by [3] from the Sirwan valley near Halabja in NE Iraq. The Balambo Formation previously divided into two units of Valanginian-Middle Albian and Late Albian-Turonian ages, representing the Lower and Upper Balambo respectively. The Upper Balambo Formation widely crops out in the Imbrication Zone of northeastern Iraq. In the High Folded Zone, the Lower Balambo Formation changes laterally into the Qamchuqa (Mauddud and Shu'aiba) and Sarmord formations to the west and southwest. Whereas, in the most part of the high folded zone the upper Balambo passes laterally into the Kometan, Gulneri, and Dokan formations. The studied section is part of the Zagros folded belt. In the Northeastern Iraq, the imbrication zone characterized by thrust folded structures in northwest trend to the southeast. The region was affected by two major thrust faults, in the southwest Handarin and from the Northeast Zagros structure. in general, both faults are trend to SW [9], he also described two major structural belts, Zozik – Rola anticline in the SW and Spi Balies-Mama Ruta anticline in the NE, whereas the Chombarok section located in the northeast limb of Spi Balies – Mama Ruta anticline. The core of anticline exposure is start with Sarki Formation and followed by Sehkanyian, Sargelu, Naokelekan, Barsarin, Chia Gara, Sarmord, and Tanjero formations (Fig. 2).

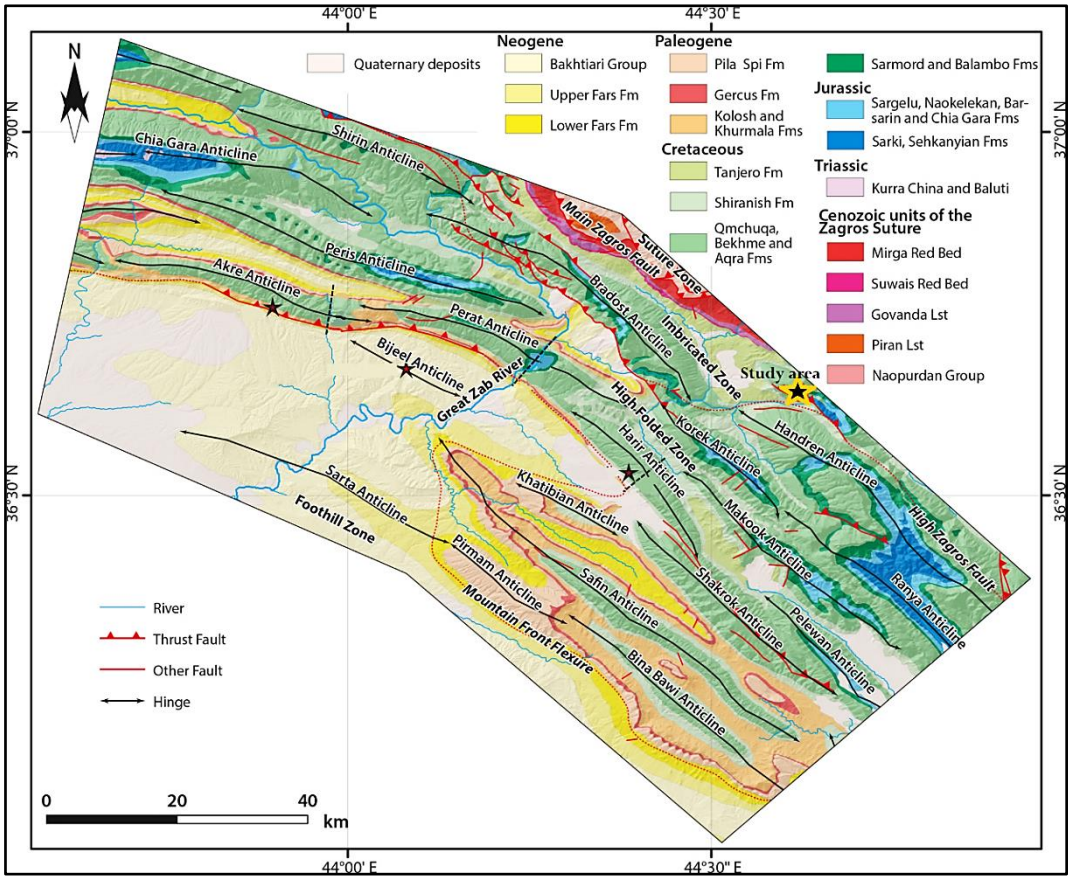

Fig. 2: Geological map of the Imbrication Zone, NE-Iraq (modified after Csontos et al., 2012; Zebari and Burberry, 2015).

2. Material and Methods

The field work was done in the imbrication zone of northeastern part of Iraq (Kurdistan region), were several geological formations including the Balambo Formation are cropping out. The outcrop of studied formation described in detail in terms of lithology, mineralogy, macrofossils, and sedimentary structures. 130 samples of marly limestone, limestone, marl, and shale collected. Petrographic investigation of 79 thin sections of carbonate rocks was studied by using a polarizing microscope. 9 samples of shale and marl selected for fossils extraction by using a standard extraction method for the purpose of the isolation of foraminiferal contents. The microfossil description and microphotographs were handled by binocular microscope. In addition, 8 samples of marl and shale examined by XRD analysis in order to identify their mineralogy contents, which were run in laboratories of T.M.U Analytical lab (Tarbiat Modarres University) in Tehran city, Iran.

3. Results and Discussion

3.1 Lithostratigraphy of Balambo Formation

The thickness of the Balambo Formation in Chombarok section (Imbrication Zone) is about 450 meters. The formation consists of an alternation of thin, medium, and thick beds of yellowish-brown in weathered surface and black to dark gray in fresh of limestones, marly limestones, with thin - medium beds of dark grey-black marls and thin to medium beds of shale intercalations. Thin (nearly 8 cm) of black chert with abundant nodules and lenses is also present. In the studied section, the Balambo Formation is underlies the Qamchuqa Formation (Lower Cretaceous) and overlies the Chia Gara Formation (Upper Jurassic - Lower Cretaceous). The nature of boundaries is gradational and conformable. The lower contact taken at the base of thin to medium bedded, buff to yellowish-dark grey marly limestone and thin-bedded grey marls of Balambo Formation Whereas, the top of Chia Gara Formation is covered with a slope deposits. The upper contact is taken at the top of dark gray of marly limestone and marl beds of Balambo Formation, and at the base of massive beds of Brownish dolomitic limestone of Qamchuqa Formation (Fig.3). Depending on the field and petrographic studies, the formation made from two lithofacies types (Fig. 6), which are the following:

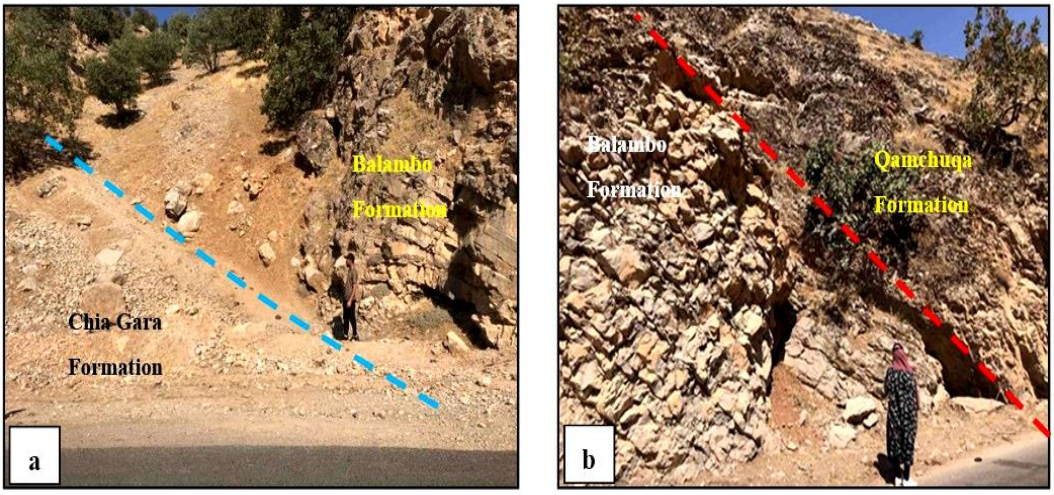

Fig. 3: Field photographs represents: a) Chia Gara-Balambo boundary (lower contact), b) Balambo-Qamchuqa boundary (upper contact).

3.1.1 Cherty limestone Lithofacies

This facies composed of the rhythmic alternation between thin, medium and thick bedded, yellowish and dark gray hard limestones and marly limestones, altering with thin black papery shale and marl, with chert beds of 8 cm and bands of 3-5 cm in addition to chert lenses and rare nodules (Fig.4, a).The facies start with the appearances of black cherts in the form of thin beds/bands, lenses and rare nodules in all parts of the studied formation. In the lower part, the thickness of the facies is about 30 m and increases to 60m and 85 m in the middle and upper parts of formation, respectively. Petrographic components of chert include calcitized radiolaria only (Fig.4, b). Also, Micro fractures were seen that filled by sparry calcite cement. Authogenic minerals include cubic pyrite. Carbonate petrography contains abundant pelagic planktonic foraminifera, Radiolaria, Sponge spicules, Calcisphere, pelagic Ostracod, and Pelecypods valve, ammonite and micro- gastropods (Fig.4, c).

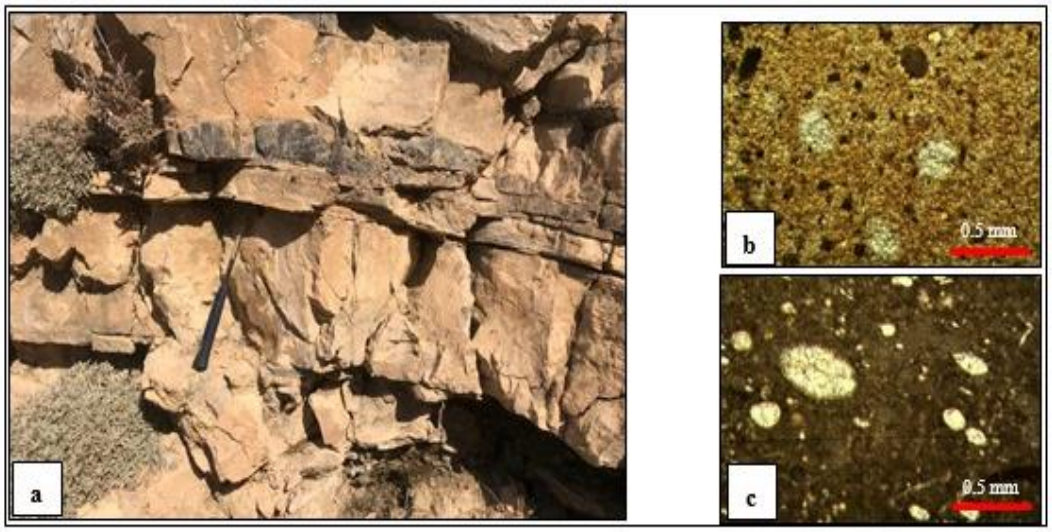

Fig. 4.a) Field photograph shows Cherty limestone lithofacies. b) Photomicrographs of Chert contain silicified radiolaria Ch2, P.P. c) Photomicrographs of limestone contain calcitized radiolaria in micritic matrix.ch1, P.P

3.1.2 Marly limestone-marl Lithofacies

The facies exhibits rhythmic deposition that consists of thin, medium, thick (8 cm- >1 m), brownish to light grey-dark gray marly limestones with thin, medium and thick-bedded (4 cm->2m), brownish and dark grey marls and black papery shales intercalations (Fig.5, a). The total thickness is about 275 m. Petrographic components included: abundant pelagic planktonic foraminifera, with some benthonic fauna in the lower part of lithofacies. Radiolaria, Sponge spicules, Calcisphere, pelagic Ostracod, Oligostegina and Pelecypods valve, ammonite and micro- gastropods. in addition, bioclasts are also present (Fig.5, b, c). Non-skeletal component included: peloids, Intra-clasts, pyrite, and Phosphatized grains. Macro-fossils; belemnite (Fig. 5, d), ammonite (Fig. 5, e), bivalve (Fig. 5, f) are seen within this lithofacies.

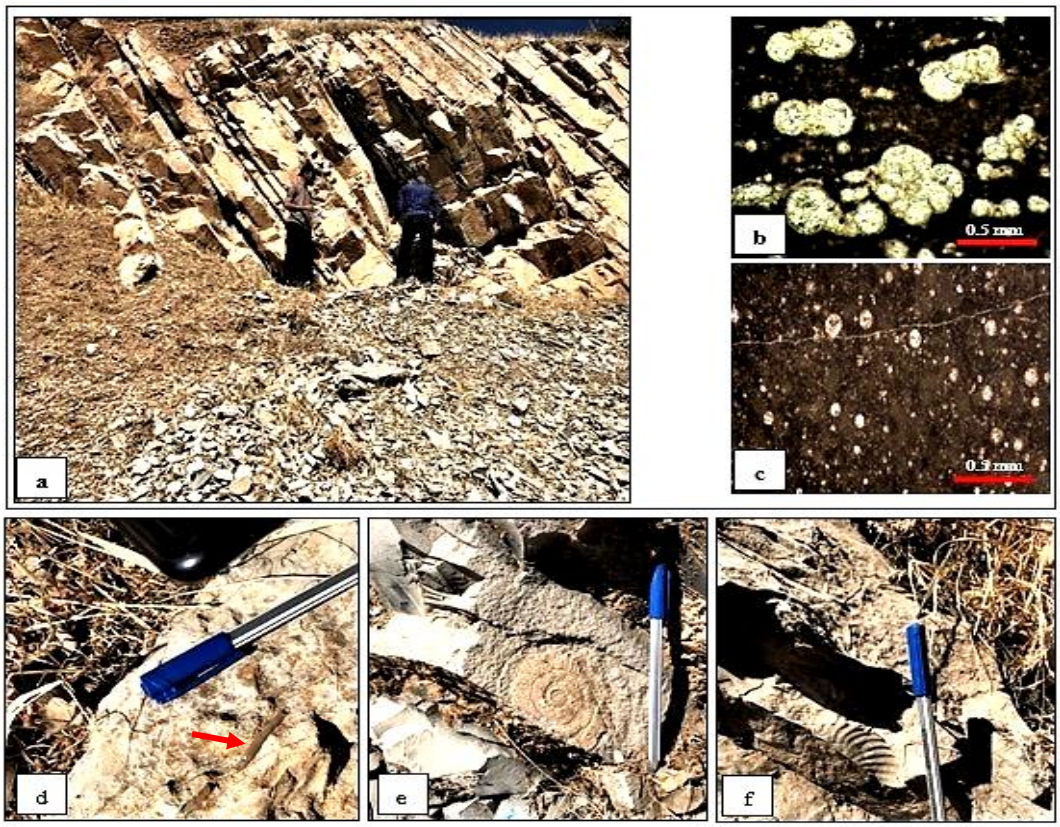

Fig. 5: a)Marly limestone-marl lithjofacies. b) Photomicrographs, Planktonic foraminifera in a micritic matrix Ch.25, P.P. c) Radiolaria in micritic matrix Ch43, P.P. d) Belemnite (arrow) in the marly limestone bed. e) Ammonite mold preserved in marly limestone. f) Bivalve preserved in the hard marly limestone:. Key: Ch, Chombarok; P.L., Plain polarized, A.S; Alizarin stained.

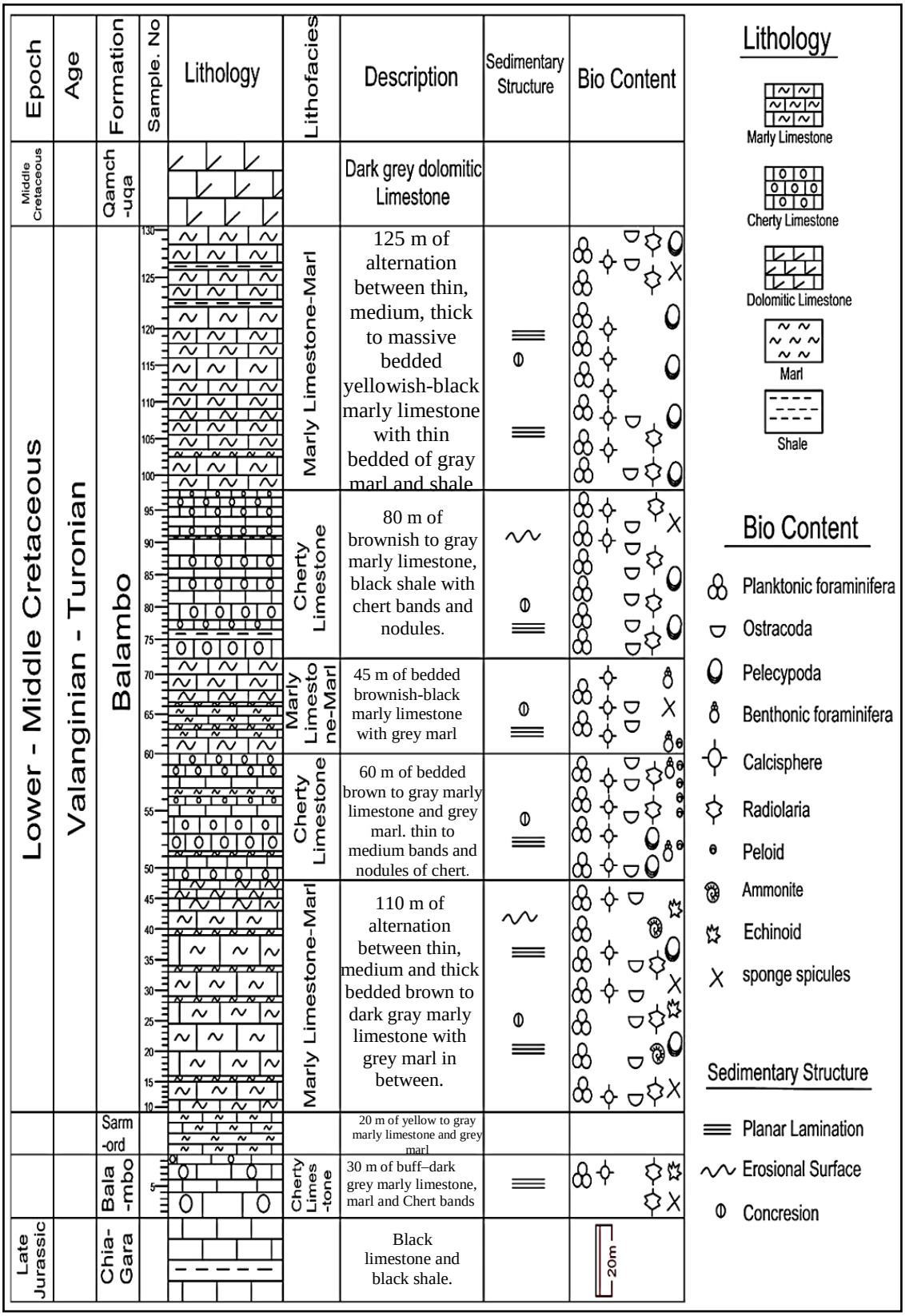

Fig. 6: Stratigraphy column of Balambo Formation, (Aptian - Cenomanian), Chombarok section, Imbrication Zone, NE- Iraq.

3.2 Age determination of Balambo Formation

The biostratigraphy of Lower-Middle Cretaceous sequences was studied by several authors in order to detect the accurate dating of the Balambo succession. [4] suggested the Middle-Late Albian age, and according to Al-Dulaimi and Mahdi (2008), the formation is dated as Late Albian-Early Turonian interval. [5] mentioned the Berriasian- Valanginian

age for Balambo Formation. In addition, [6] gave the Early Hauterivian - Late Aptian age for studied formation, also [7] select Late Early Hauterivian - Late Aptian. Lately, [8] suggested Late Albian for the Balambo formation.

In this study, 9 samples of marl and shale were selected for extraction of the foraminiferal assemblages by using standard extraction methods. The investigation of foraminiferal assemblages within the studied section revealed that, the Balambo Formation planktonic and benthonic foraminifera can be used for biostratigraphic study, according to an assessment of foraminiferal assemblages within the examined samples, enabling to identify 9 planktonic foraminiferal species with one benthonic foraminifer's species (Plate. 1). Based on the defined planktonic and benthonic foraminifera, the assigned age of Balambo Formation in the Imbrication Zone is Aptian to Cenomanian. The followings are most foraminifera that identified in the studied samples of Balambo Formation from bottom to the top.

Aptian: *Globigerinelloides algerianus* (PL1,1 a, b); *Hedbergella luterbacheri (*PL1,2 a, b); *Globigerinelloides barri* (PL1,4 a, b); *Blefuscuiana kuznetsovae* (PL1,6 a, b). **Albian:** *Microhedbergella praeplanispira* (PL1, 3a, b); *Ticinella primula* (PL1,3a, b); *Ticinella Sp*. (PL1,5 a, b)); *Lenticulina gaultina* (PL1,7 a, b).

Cenomanian: *Rotalipora montsalvensis* (PL1,9a, b) *Ticinella aprica* (PL1, 10a, b).

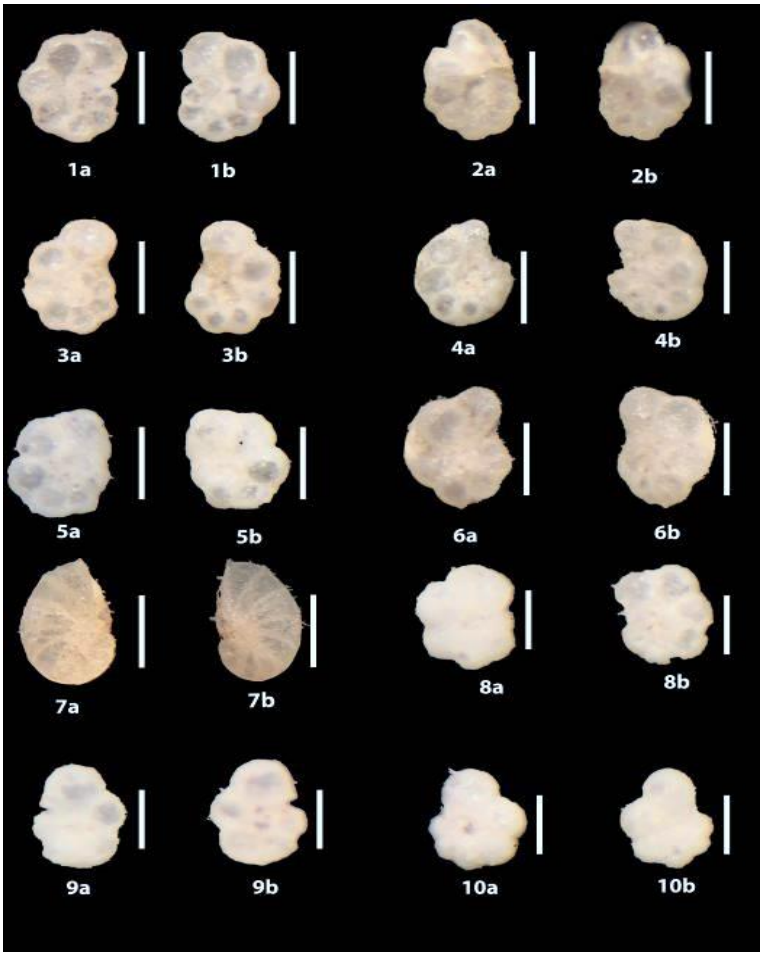

Plate 1: 1a, b) *Globigerinelloides algerianus* (Cushman and ten Dam 1948); 2a, b) *Hedbergella luterbacheri* (Longoria 1974), sample No.37; 3a,b)*Microhedbergella praeplanispira* (Huber & Leckie 2011),sample No.72;4a,b) *Globigerinelloides barri* (Bolli, Loeblich and Tappan, 1957), sample No. 37 ;5a,b);*Ticinella* Sp., sample no. 72; 6a,b)*Blefuscuiana kuznetsovae* (Banner and Desai 1988), sample No. 37; 7a,b) Lenticulina gaultina (Berthelin, 1880), sample No. 37; 8a,b) *Ticinella primula* (Luterbacher, in Renz et al., 1963), sample No.111;9a, b) *Rotalipora montsalvensis* (Mornod, 1950), sample No.111; 10a, b)*Ticinella aprica* (Loeblich and Tappan 1961)sample No.111.

Note: Scale bar is 125µm for sample (1-7) and 63µm for sample (8-10). (Sample (1-8) (a) is dorsal view, (b) is umbilical view), (sample (9,10) (a) is umbilical view, (b) is dorsal view).

3.3 Petrographic description

The petrographic study of carbonates of Balambo Formation is carried out through 79 thin sections. The petrographic constituents of carbonate samples in thin sections were demonstrated by using a polarizing microscope. In general, the carbonates of Balambo Formation consist of micrite ground mass that slightly neomorphosed. The main skeletal grains are;

fossils that include a variety of planktonic and some benthic foraminifera, radiolaria, calcisphere, ostracods, pelecypods, larva-ammonoids, small brachiopods, sponge spicules, echinoid spine, and bioclasts. Non-skeletal grains contain peloids only (Fig. 7).

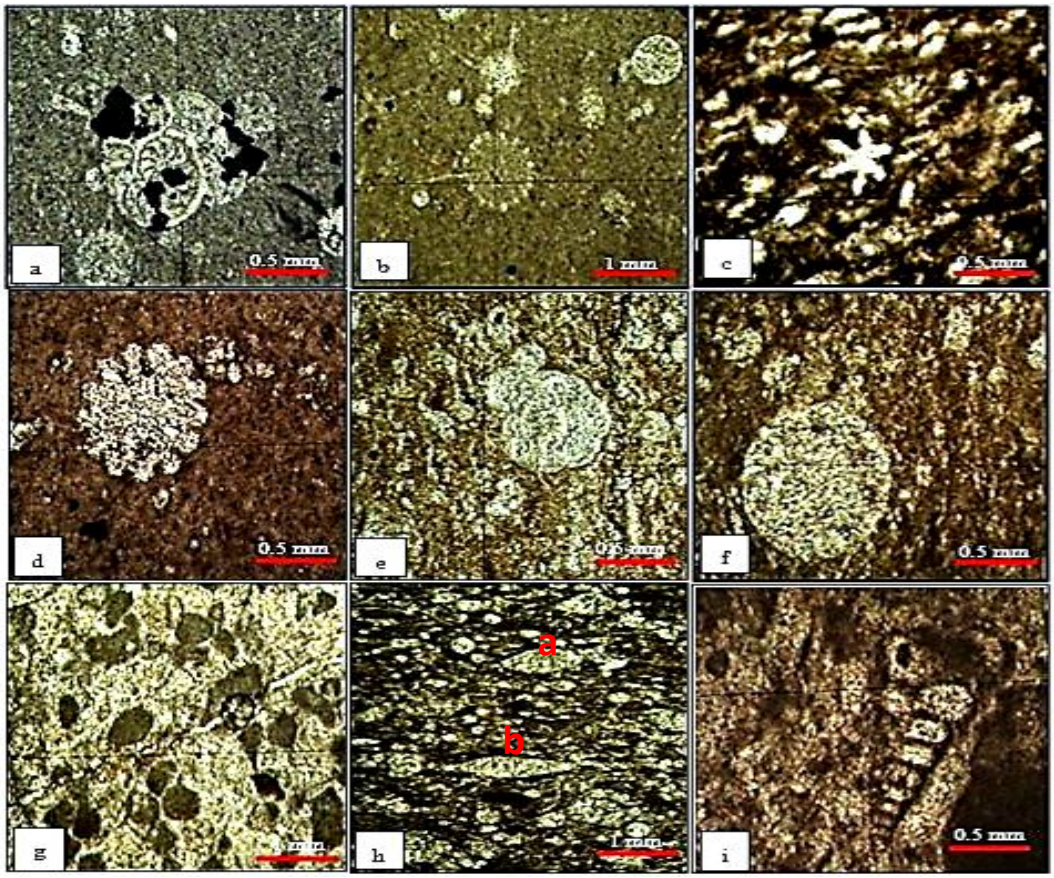

Fig. 7: Carbonate ptrographic component; a) Larva- ammonite partially replaced by cubic pyrite, Ch11, P.L. b) Radiolaria within micritic matrix. Ch1, P.L. c) Sponge spicules (Hexactine), Ch112, P.L, A.S. d) Echnoid spine within micritic matrix, Ch36, P.L, A.S. e) Ticinella sp (Planktonic foraminifera) within neomorphosed micritic matrix, Ch89, P.L. f) Unwalled calcisphere in micritic matric, Ch63, P.L, A.S.g) Fecal peloids in neomorphosed micritic matrix, Ch58, P.L.h) (a) articulate ostracods and (b) Pelecypods within micritic matrix, Ch40. i) Textularian (Benthic foraminifera with micrite envelope, within micritic matrix, Ch41, P.L, A.S. *Key: Ch, Chombarok; P.L., Plain polarized, A.S., Alizarin stained.*

3.4 Mineralogy

XRD analysis

The bulk mineralogy of eight shale and marl samples was determined by using X-Ray diffraction (XRD) analysis after the rock sample was crushed to <4 µm. The results suggested the presence of phyllosilicate with abundant calcite, common quartz, and moderate Fluorapatite with minor dolomite contents (Fig. 8). Calcite is common non clay mineral in the studied formation. It's found in high concentrations in the bulk mineralogy. Calcite's bulk fraction dominance over other minerals is comparable with the common occurrence of calcareous fossils such as bivalve, ostracod, and planktonic foraminifera. The behavior of calcite and phyllosilicates is diametrically opposed. This could explain the carbonate dilution caused by terrigenous elements derived from the land [9].

On the other hand, X- Ray diffraction analysis found that the abundant clay mineral in the examined marl and shale samples is illite. Precipitation of illite occurs in oxygenated pore fluids [11]. In addition, Illite is thought to originate from detrital grains formed from reworked sedimentary rocks and muscovite that has weathered multiple sedimentary cycles and alteration of feldspars [10], [12]. Because there is no detection of smectite in the examined samples of Balambo shale and marls, It is suggested that all smectites were transformed to illite during diagenesis. Physical erosion of mica-bearing parent rocks produced the illite-rich shales and marls. Ancient mudrocks and shales are primarily composed of illite clays. It could possibly come from the weathering of potash feldspar-rich igneous rocks like andesites and rhyolites [13]. Physical erosion of mica-bearing parent rocks produced the illite-rich shales and marls. The occurrences of Illite with quartz indicate substantial detrital input in dry areas [13]. In addition the occurrence of illite in the Balambo Formation in Chombarok section indicates a hot, arid climate during the Aptian-Cenomanian in the Imbrication zone, Northeastern Iraq.

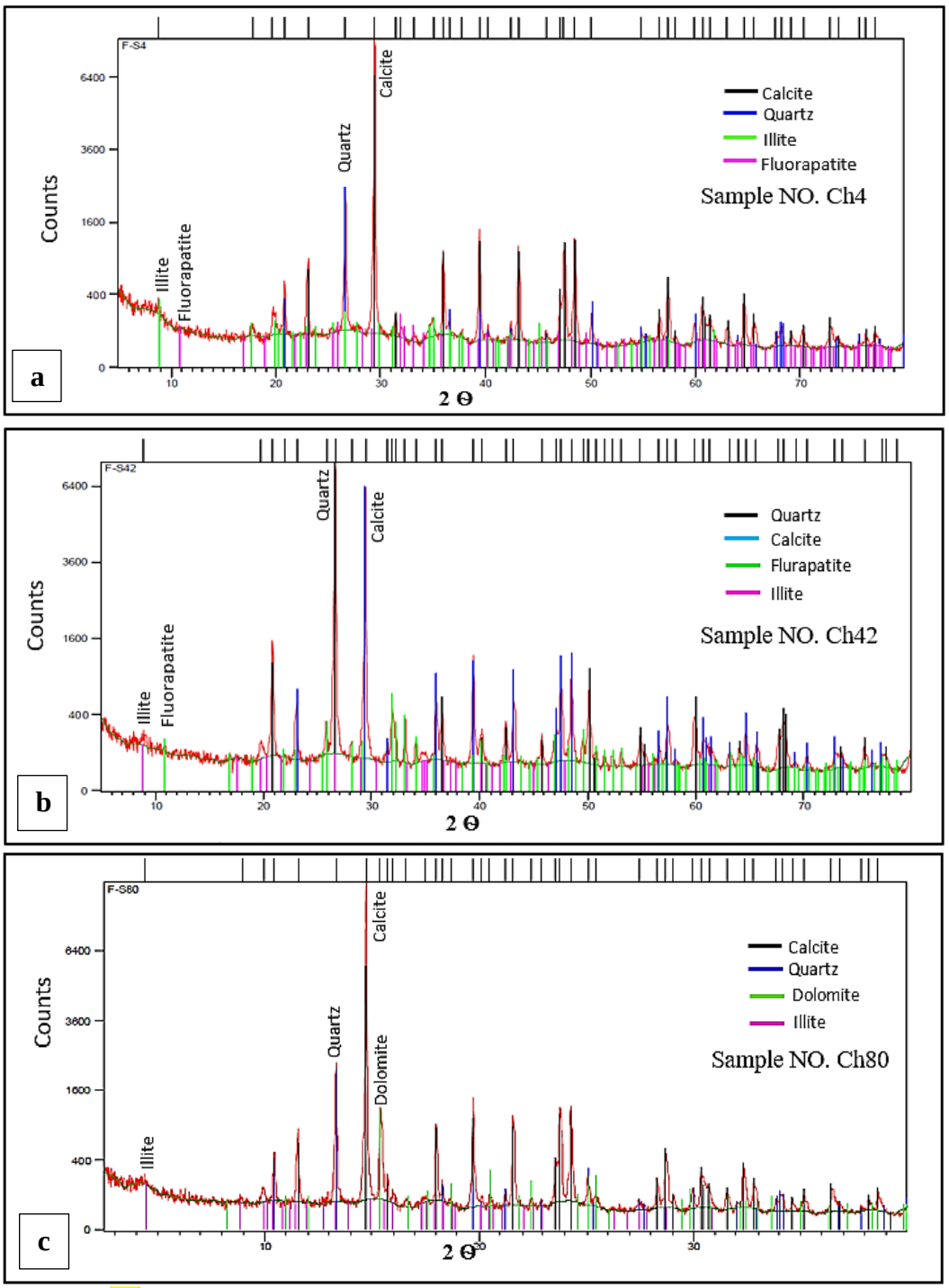

Fig. 8: a-c) X-ray diffractograms of the studied samples of the Balambo Formation, Chombarok section, Imbrication Zone, NE-Iraq. *Key. Ch. Chombarok*.

Discussion

The Balambo Formation is part of the Upper Tithonian-Lower Turonian Megasequence AP8 of [16] was deposited in a large deep basin in the southern Neo-Tethys during most of Cretaceous period. The Balambo Formation consists of an alternation between thin –medium and thick beds, yellowish brownish in weathered surface and black to dark gray in fresh of limestones, marly limestones, with thin- medium beds of grayish black marl and shales. Thin bands of black chert with abundant nodules and lenses are seen all over the studied formation.

The microscopic study of carbonate samples depends on 79 thin sections that show common deep marine biotas like; a variety of planktonic and some benthic foraminifera, radiolaria, calcisphere, ostracods, pelecypods, larva-ammonoids, small brachiopods, sponge spicules, echinoid spines, and bioclasts. Non-skeletal grains contain peloids only. Depending on field observations (lithological description) and petrographic analysis, two lithofacies that build the

Balambo Formation can be observed; marly limestone-marl and cherty limestone lithofacies.

In general, from the previous studies the age of Balambo Formation was assigned to be Valanginian – Turonian. [3] first assigned the age in its type section as Turonian at the top and Valanginian (probably Upper Valanginian) at the bottom by the evidence of assemblages of diverse foraminifera and ammonite faunas. Biostratigraphical study and age determinations of Balambo Formation were carried out by using marine fossils (benthonic and planktonic foraminifera) to determine relative age range. While, according to an assessment of foraminiferal assemblages within the examined samples of Balambo Formation, different types of planktonic and benthonic foraminifera can be identified and used for the biostratigraphical study and age determination. Based on the standard geological ranges of the observed planktonic and benthonic foraminiferal species, the age of Balambo Formation has been determined as Aptian to Cenomanian.

The results of X-ray diffraction (XRD) analysis for marl and shale samples of Balambo Formation demonstrated the presence of phyllosilicate (illite) with calcite, common quartz, and moderate Fluorapatite with miner dolomite in the upper part of formation. Calcite is the common non clay mineral in the sediments under study. While, Illite is abundant clay mineral within the studied samples. Illite is the major component of shales. Also it can be found with chlorite, kaolinite, smectite, and quartz [16]. The Precipitation of illite occurs in oxygenated pore fluids [11] On the other hand, the Illite is thought to originate from detrital grains formed from reworked sedimentary rocks, detrital feldspars and muscovite that has weathered multiple sedimentary cycles [10], [12]. Illite with quartz indicates substantial detrital intake in dry areas [14]. The occurrence of illite in the Balambo Formation in Chombarok section indicates a hot, arid climate during the Cretaceous period in the Imbrication zone, Northeastern Iraq.

4. Conclusions

The Balambo Formation at the studied section from Imbrication Zone of NE Iraq is composed of 450 m, of alternation between thin - medium and thick beds, of yellowish-brown and black to dark gray limestones, marly limestones, with thin to medium beds of grayish black marl and shale. Thin bands of black chert with abundant nodules and lenses are also seen all over the studied succession. The petrographic study of carbonate rocks of Balambo Formation shows a variety of deep marine biotas such as; planktonic, radiolaria, calcisphere, ostracods, pelecypods, larva-ammonoids, brachiopods, sponge spicules, echinoid spines, and bioclasts. and some shallow water benthic foraminifera, Non-skeletal grains contain peloids only. From the field studies and petrographic analysis, the Balambo Formation was made from two main lithofacies; marly limestone-marl and cherty limestone lithofacies that rhythmically interbedded. Using the extraction method and according to an assessment of foraminiferal assemblages within the examined marl and shale samples of Balambo Formation, different types of planktonic and benthonic foraminifera can be identified and used for the biostratigraphical study and age determinations. Based on the defined planktonic foraminifera, the assigned age of Balambo Formation in the Imbrication Zone is Aptian to Cenomanian as upper Balambo age. The results of X-ray diffraction (XRD) analysis for bulk mineralogy of selected shale and marl samples suggested the presence of phyllosilicate with abundant calcite, common quartz, and moderate Fluorapatite with minor dolomite content. Illite is dominant clay mineral in the Balambo Formation and indicates a hot, arid climate during most of the Cretaceous period in the Imbrication zone, Northeastern Iraq.

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الطباقية و المعدنية لتكوين بالمبو (الابتين– السينومانيان) قرب قرية جومباروك, نطاق التداخل, أقليم كوردستان العراق

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الملخص

تم دراسة الطباقية والمعدنية لتكوين بالامبو (الابتيان– السينومانيان) في منكشف سطحي قرب قرية جومباروك في نطاق التداخل, شمال شرق العراق. يتكون التكوين من 450 متر من طبقات الرقيقة والمتوسطة والسميكة من الحجر الجيري والحجر الجيري الصلصالي الاصفر البني والاسود الى الرمادى المتداخل مع الطبقات المتوسطة و السميكة من الصلصال والطين ذات اللون الرمادى والاسود مع أحزام رقيق وعقد وألسنة من الصوان الاسود على طول التكوين. من خلال المشاهدات الحقلية ودراسات البتروغرافية تبين بأن تكوين بلامبو يتكون بشكل رئيس من سحنتين صخاريتين هماسحنة الحجر الجيري الصلصالي– الصلصال وسحنة الحجر الجيري الصواني. أعتمدت الدراسة البتروغرافية للصخور الكربونيتية على 79 شريحة رقيقة و تبين بأنه صخور الكربونتية للتكوين يتكون من الارضية المكرتية مع مختلف من الحبيبات الهيكلية مثل الفورامنيفيرا الطافية و قليل من القاعيات و الراديولاريا وكوريات الكلسية والاوستراكودا و رأسيات القدم والامونويد وبطنيات القدم الصغير وأبر الاسفنجيات و أشواك نجوم البحر مع الفتاتات الحياتية. أما الحبيبات غير الهيكلية تشمل على الدمالق فقط. بأستخدام طريقة الاستخلاص للمجاميع الفورام الطافية لنماذج الصلصال والاطيان تم تحديد عمر التكوين ب (ألابتيان الى السينومانيان) كما عمر بالامبو العلوي. أضهرت نتائج تحليل الاشعة السينية لمعدنية الكل لنماذج المختارة من الاطيان والصلصال بتواجد المعادن الفيلوسليكيت مع كل من المعادن الكالسايت والكوارتز والفلوروأبتايت والدولومايت بنسب مختلفة. تعتبر ألألايت من المعادن الطينية الشائعة في التكوين البالامبو ويعتقد وجوده دلالة على المناخ الحار والجاف السائد خلال معظم فترات العصر الكريتاسي في نطاق التداخل في شمال شرق العراق.