Mineralogy and Geochemistry of Serikagni Formation, Sinjar, Iraq

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Abstract

Serikagni Formation (lower-middle Miocene) was studied at four outcrop sections within Sinjar Anticline, Para (the western plunge),Jaddala, Sinjar, (Southern limb), and Noaniaa (Northern limb) of Sinjar Mountain ,which is part foot hill zone of northwest Iraq. This Formation is composed of Globigerinal limestone, marly limestone intercalated with marl, deposited in quiet deep marine environment.

Mineralogical investigations by using XRD; as well as the Petrographical analyses by using Polaroid microscope were done. Geochemical analyses included the total digestion of the samples for the purpose of analyzing of the major constituents (CaO, MgO and I.R.) ,the secondary constituents (SiO_2, Al_2O_3, Fe_2O_3, Na_2O ,K_2O , and trace elements (Sr, Mn, Cu, Zn, Co, Cr, Pb) in the rock samples and of the extract of the soluble residue were accomplished.

The calcite is the predominant mineral which is mostly of micrite types as well as spary calcite. Dolomite is observed in some rocks which were formed by the process of dolomitization of micrite. The insoluble residue (I.R.) has negative correlation with the carbonate percentages in the rock formation as observed by the XRD analyses. Clay minerals show low occurrence. The Palygorskite, Montmorillonite and Sepiolite are the predominant clay minerals in Serikagni rocks.

Geochemical differences can be noticed between the limy and marly facies constituting the same formation. Differences are also observed between the geochemistry and mineralogy of the four studied localities such as the relatively more pure limestone in Jaddala and Para sections than Sinjar and Noaniaa sections which indicate the higher percentages of marly limestone. This is believed to be due to the geographic location of these sections within the main depositional environment, as well as the consequences of sea level fluctuation.

Key words: Mineralogy, geochemistry, diagenesis, Serikagni Formation, Sinjar, Iraq

الخلاصة

درست اربع مكاشف صخرية لتكوين السريكاكاني(المايوسين المتوسط الأسفل) في طية سنجار المحدبة وهذه المقاطع هي: بارا (الغاطس الغربي للطية), جدالة وسنجار(الطرف الجنوبي للطية) ونعينيعة (الطرف الشمالي للطية) في جبل سنجار.

إن التركيب المعدني لهذا التكوين هو الصخور الجيرية الكلوبيجرانية والصخور الجيرية الطفلية التي تتداخل مع صخور الطفل والتي ترسبت في بيئة البحر العميق الهادئة. تمت دراسة مهدنية الصخور بإستعمال المجهر الضوئي المستقطب وطريقة الأشعة السينية. XRD.

لقد تم إجراء التحاليل الكيميائية على الصخور بعد إجراء الهضم الكلي لمعرفة المركبات الرئيسة وهي:

Sio_2 ,Na_2o, Fe^2o^3, Al_2o_3, K_2o . إضافة الى العناصر النادرة التالية:Zn, Mn, Cu, Sr, Co, Cr, Pb

أظهرت النتائج ان معدن الكالسايت هو المعدن الشائع ولوحظ معدن الدولومايت في بعض الصخور حيث تكون بفعل عملية الدلمتة لأطيان الكاربونيت من المكرايت. لقد بينت نتائج الرواسب المتبقية بإنها ذات تناسب عكسي مع نسبة المعادن الكاربوناتية كما اظهرتها نتائج الأشعة السينية , وان المعادن الطينية كانت بنسبة محدودة وهي من نوع الباليكورسكايت والمونتموريلونايت والسيبيولايت. لوحظت الإختلافات الجيوكيميائية والمعدنية بين السحنات الكاربوناتية والطفل ضمن المقاطع المدروسة الأربعة حيث دلت النتائج ان الى ان صخور مقطعي الجدالة وبارة تتكون من صخور كاربوناتية نقية قليلة الشوائب لتتميز عن المقطعين الأخرين في سنجار ونعينيعة التي دلت على وجود نسبة من الطفل ضمن الصخور الكاربوناتية ويعتقد ان هذا الإختلاف ناتج من الموقع الجغرافي لهذه المقاطع ضمن بيئة الترسيب إضافة الى تأثيرات تذبذب مستوى ماء البحر كتقدم او تراجع بحري.

الكلمات المفتاحية:معدنية, جيوكيميائية,عمليات تحويرية,تكوين سريكاكني, تكوين سنجار.

Introduction

The geochemistry of carbonates through their elemental analyses is stressed, and many studies are being carried on this subject. It has been shown by many workers that these elemental analyses can be a useful tool for the interpretation of the original depositional environment, and for correlation purposes.

The Serikagni Formation(lower-middle Miocene) whose type locality is situated near the village of Para, at Sinjar Mountain, located at latitude (36° 20′ 30″) north ,and longitude (41° 29′ 00″). Sinjar Mountain (east – west direction) is located within Nineveh governorate about 100 km west of Mosul city, (Figure 1). The Serikagni Formation rocks were composed mainly of Globigerinal limestone, marly limestone intercalated with marl, with 150 m thickness, (Figure 2), (Bellen *et al*., 1959). All workers whom have studied the Serikagni formation agree that it has been deposited under marine environment according to the fossil content and lithofacies characteristics. It is believed that the source area from which the sediments of Serikagni formation were derived are the Pre-and Early Miocene, carbonate rich rocks of the north and northeast of Iraq and surrounding area. The presence of small grains of detrital quartz suggests that other rock units rich in such constituents have also contributed, in supplying sediments to the nearby sea where Serikagni formation rocks were deposited. Conditions in the source area in one hand, and at the site of deposition of Serikagni formation, in the other hand, were also not homogeneous as indicated by facies change from more calcareous rocks to more marly once, as well as the accompanied gradual modification on the geochemistry and mineralogy of these rocks. Physiographically, it forms a distinct rock unit within Sinjar Mountain as a southern part of the Foot hill zone that characterized by dense sedimentary basins, thick sediment sequences, and with various sedimentary facies. Tectonically, it is a part of Unstable Shelf in Iraq, (Jassim and Goff, 2006). Many researchers had been recommended or used the geochemical studies in solving geological problems, especially those relating to the environments of deposition, (Banat and Al-Dyni, 1981, Kettaneh & Sadik 1989). Therefore, the use of chemical elements is a useful tool to interpret the depositional environment of sedimentary rocks and their origin as well as their diagenesis, (Al-Kufaishi & Al-Aasm, 1978, Siegel 1961; Al-Sayegh, 1972). The formation has been studied from paleontological, stratigraphic and sedimentological point of view by many authors such as , Al-Hashimi and Amer, 1985,and Al-Ani,2005, but no one has been studied this formation from the mineralogical and geochemical point of view. This study is a further contribution to the petrography, mineralogy, and geochemistry, (major and some trace elements content) of Serikagni Formation. It covers four sections, the first near the village of Jaddala, the second near the village of Sinjar at the Southern limb, the third near the village of Noaniaa at the Northern limb, and the forth near the village of Para at the western plunge of Sinjar Mountain, northwest Iraq **,** (Figure 1). The studied four sections were sampled, the Jaddala section (95m thickness), the Sinjar section (92m thickness), where the formation has unconformable contact with overlying Jeribe formation. The third section is Noaniaa section (13 m thickness), and the forth section, Para (19 m thickness) near the village of Para, where the Serikagni Formation has gradational contact with the overlying Dhiban Formation. The Serikagni formation (deep marine environment), has unconformably underlying by Jaddala Formation, due to the Oligocene regression in all of these sections, (Bellen et al., 1959, Jassim and Goff, 2006).

Due to the lacks of detailed geochemical and mineralogical studies on Serikagni Formation in the Sinjar area, the aim of this research was to determine the geochemical and mineralogical characteristics of Serikagni Formation through four sections selected in the Sinjar Mountain, (Jaddala, Sinjar, Para and Noaniaa). Also, this research aims, to investigate whether these geochemical and mineralogical characteristics of Serikagni Formation rocks can give better identification of the diagenetic and environmental aspects of Serikagni Formation.

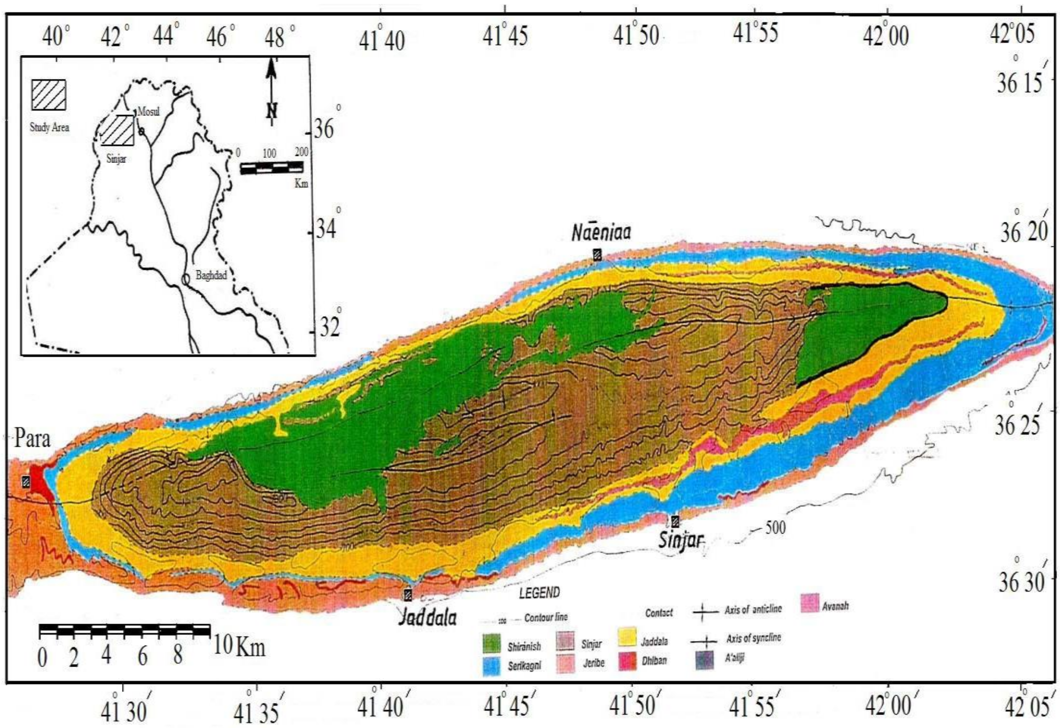

Figure 1: Location and geological map of Sinjar mountain,(After Maala,1977)

Materials And Methods

Total of one hundred and five samples were collected from the selected four stratigraphic sections, (Para 22 samples, Sinjar 35 samples, Jaddala 31 samples and Noaniaa 17 samples). The collection of samples was made with reference to lithologic, and textural variations, also the color was considered an important factor during collection of samples. The mineralogical and geochemical analyses were described as follows:

1- Mineralogical investigation was done by using XRD; total of 16 samples, (4 samples from each section) were analyzed, to determine the mineralogy of the bulk samples and the insoluble residue (IR), (Hassan, 2005).
2- The clay fractions were separated from the Serikagni rocks for 8 samples (2 samples from each section). Pipette analysis was used in the separation of clays and oriented slides were prepared. Normal, heated (350 °C and 550 °C) and glycolated oriented slides of these separated clays were run by XRD for their full identification, (Hassan, 2005).
3- Petrographical analyses by using Polaroid microscope were done, (18 samples were chosen and thin sections were prepared).
4- Geochemical analyses included the partial digestion of the 19 samples by using diluted acetic acid for the purpose of analyzing the constituents of the trace elements (Sr, Mn, Cu, Zn, Co, Cr, Pb,) were determined by AAS , of the extract of the soluble residue.

5- Geochemical analyses (total of 44 samples, 11 from each section) included the total digestion of the samples by using diluted HF acid for the purpose of analyzing the major constituents CaO, MgO and I.R. ,the secondary constituents SiO_2, Al_2O_3 ,Fe_2O_3 ,Na_2O ,K_2O , as well as P2O5 and TiO2 and trace elements Sr, Mn, Cu, Zn, Co, Cr, Pb in the rock samples of Serikagni Formation, Sinjar Mountain.

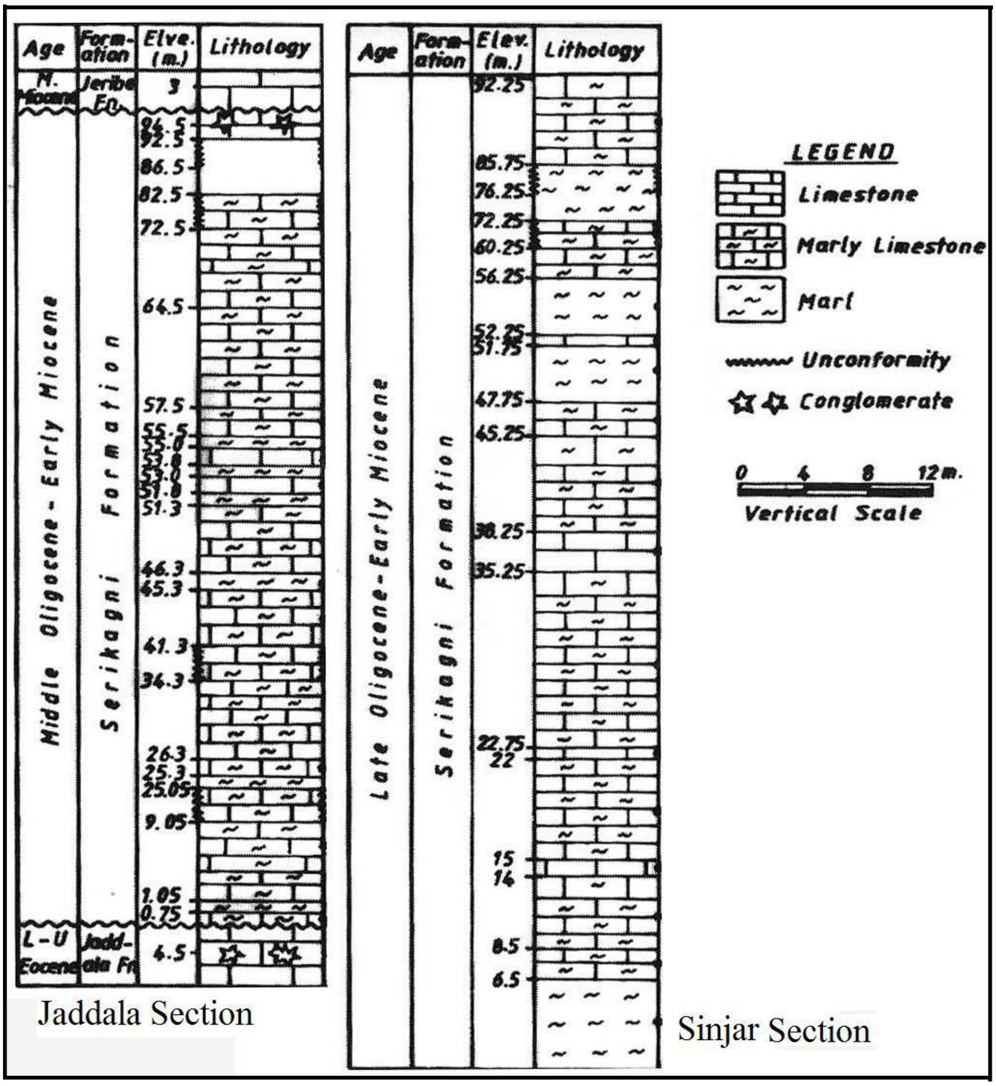

Figure 2: Lithological log at Jaddala and Sinjar sections, of Serikagni Formation, Sinjar Mountain, (After Hassan, 2005)

Results And Discussion

The geochemical and mineralogical analyses results of the major constituents (CaO, MgO and I.R.) ,the secondary constituents (SiO_2, Al_2O_3 ,Fe_2O_3 ,Na_2O ,K_2O , and trace elements (Sr, Mn, Cu, Zn, Co, Cr, Pb) in the Serikagni Formation rock samples are shown in tables 1,2, 3 and 4.

The results for the four sections show that the main components are represented by CaO, MgO and I.R. Their concentrations within the four sections were depending on the diagenetic processes, such as dolomitization. The calcite is the predominant mineral which is mostly of micrite types as well as spary calcite which was resulted from the recrystalization of fossil chambers. The calcite may reach maximum of 97.1% in pure limestone rocks and reach 60.4 % as minimum amounts in the impure limestone rocks. The calcite followed by different proportions of dolomite that reach maximum of 11% and 1.6 % as minimum amounts within the rock formation, (Table 1). Dolomite as rhombs can be observed in subordinate amounts in some rocks which were formed by the process of dolomitization of micrite and the existence of micro crystals of dolomite reflect the early dolomitization.

The main components correlation coefficients varied within the four sections due to the variation in the diagenetic processes such as dolomitization and the minor changes in the environment of deposition of the Serikagni Formation. The secondary components indicated by SiO2, Al2O3, Fe2O3, Na2O, and K2O varied in concentrations within the four sections. Silica is present as detrital grains of quartz and chert fragments as well as very small rounded bodies with separated outlines which look very much like radiolarian fossils. Clay minerals, pyrite, and glauconite occurred as insoluble residue, (Table 2). Glauconite as rounded to oval shaped grains, green colored were observed especially at the lower contact zone. Oval shaped; light brown isotropic phosphate grains can be seen in few samples, the chemical analysis of P2O2 reflect that it range from 0.02% to 0.3%.

Table 1: The of the carbonate % range (indicated by calcite and dolomite %) with the range of quartz % of the studied four sections (Jaddala, Sinjar, Noaniaa and Para) of Serikagni Formation,

Section name		Quartz %	Carbonate Minerals%	
Jaddala Section	Minimum	1%	80 %	
	Maximum	2%	88%	
			Calcite%	Dolomite %
	Minimum		75.3 %	1.6%
	Maximum		94.9%	5%
Sinjar Section	Minimum	2%	78%	
	Maximum	5%	95%	
			Calcite%	Dolomite %
	Minimum		70.7%	1.9%
	Maximum		87.1%	11.5%
Noaniaa Section	Minimum	1%	70%	
	Maximum	3 %	87%	
			Calcite%	Dolomite %
	Minimum		60.4%	2.8%
	Maximum		91.8%	6.6 %
Para section	Minimum	1%	78%	
	Maximum	2%	87%	
			Calcite%	Dolomite %
	Minimum		65.3%	2.4%
	Maximum		92.2%	7.6%

The insoluble residue (I.R.) range from 1.0 to 31.0 % with an average 15.4% , which has negative correlation with the carbonate percentages in the rock formation as observed by the XRD analyses.

Clay minerals show low occurrence and as traces within the Serikagni Formation and the results had indicated that the clay minerals Palygorskite; Montmorillonite and Sepiolite are the predominant minerals in Serikagni rocks, while mixed layer of Illite-

Montmorillonite is the subordinate clay in some rocks especially within the lower calcareous facies, Kaolinite appear in trace amount. Montmorillonite is the abundant clay within the marly facies within lacks Illite but contain traces of Kaolinite.
Pyrite is exist as macroscopic concretionary form as tiny microscopic to submicroscopic grains.

The major constituents CaO, MgO and I.R.

The results of the CaO show that it ranges from 45.2% to 48.7% with average concentrations of 46.8%. The lowest concentrations of CaO were determined in Noaniaa section. While the results of the MgO show that it ranges from 0.3% to 2.4% with average concentrations of 1.3%. The lowest concentrations of MgO were determined in Jaddala section, (Table 2).

Ca and Mg are controlled by carbonate and gypsum minerals precipitation, most sites Ca and Mg are well correlated, probably due to co-precipitation of both elements into dolomite, or more likely, in a solid solution of Mg with calcite or aragonite, (Durfor, and Becker, 1972).

Also, the results of the analyzed rock samples at Sinjar and Noaniaa sections reflect a relative increase in silica concentrations comparing with Jaddala and Para sections, which is believed to be due to the geographic location of these sections within the main depositional environment, (Table 2).

Table 2: represent the averages and ranges of the CaO, MgO, and I.R. % of the studied four sections (Jaddala, Sinjar, Noaniaa and Para)

		Jaddala Section	Sinjar Section	Noaniaa Section	Para Section
CaO %	Range	42.7 - 54.3	39.7-55.1	34.0 -51.0	33.0 - 49.0
	Average	48.7	46.4	45.2	46.7
MgO %	Range	0.35 -1.1	0.42 - 2.4	0.3 - 1.5	0.3 - 1.2
	Average	0.92	1.6	1.32	1.31
IR %	Range	1.5- 20.5	1.0 - 31.0	10 -30.0	6.7 - 23.6
	Average	11	16	20	14.4

Moreover, the results of the insoluble residues analyses reflect that their range in the pure limestone rocks is 1.5 - 3.6% and their range in the impure limestone rocks (marly limestone and marl) is 5.5- 31%.

The amounts of the insoluble residue may reflect the humid climate occurred during the deposition of the Formation. The analyzed samples at Jaddala section reflect the lowest amount of the insoluble residue concentrations comparing with the other studied sections.

Also, the results indicated that their variation within the studied sections reflect the geographic location of each section within the depositional environment, such as the Jaddala section (Jaddala WT. % of IR min= 1.5 % max=20.5% Mean= 11%) and the Para section (Para WT. % IR min=6.7% % max=23.6% Mean=14.4%), had relative lower values of IR that represent relatively basinal and deeper part of depositional environment for Serikagni rock formation. While Sinjar section (Sinjar WT. % IR min=1.0% % max=31.0% Mean= 16%) and Noaniaa section (Noaniaa WT. % IR min=10% % max=30.0% Mean=20%) represent the shallow near shore depositional environment and this may marked the distance of these sections from the shore line. Consequently, the Serikagni formation rocks were classified according to Barth et al., 1939 in Pettijohn, 1975, as shown in figure 2. The Jaddala and Para sections reflect that they composed of relatively more pure limestone than Sinjar and Noaniaa sections which indicate that they composed of higher percentages of marly limestone.

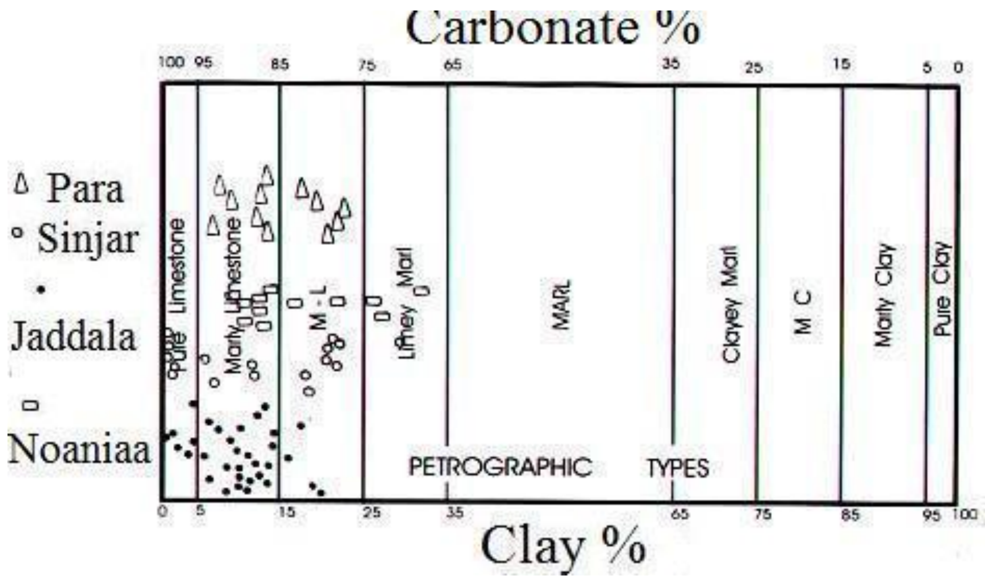

Figure 2: The Serikagni formation rocks classification according to their insoluble residue % within the four studied sections, (after Barth et al., 1939 in Pettijohn, 1975 and Al-Ani, 2005)

The secondary constituents

The secondary constituents representing by SiO2, Al2O3, Fe2O3, Na2O, and K2O varied in concentrations within the four sections, (Table 3), as follows:

SiO2 % in Serikagni rocks range from 7.4 % to 12.4 % in an average of 10.4%.

The silica amount is considered small in comparison with their values in carbonate rock, (Table 5). However and as mentioned before the silica and clay minerals represent the insoluble residues which are of importance in reflecting the shore line with their higher values and the deep marine depositional environment with their lower values, (Kettaneh & Sadik 1989).

Al2O3 % in Serikagni Formation rocks is ranging from 1.7% to 2.6% in an average of 2.2%. These amounts are considered small in comparison with their values in carbonate rocks, (Table 5). Moreover, Aluminium content is mainly controlled by the clay content. The lowest aluminium contents are found in Jadala section that contain higher carbonate contents such as ,dolomites and limestone, (Windom et al, 1989).

Fe2O3 % is ranging in Serikagni rocks from 0.4% to 0.8% in an average of 0.6%. These amounts are considered small in comparison with their values in carbonate rocks, (Table 5). Iron cycling is biogeochemically driven by abiotic and biotic reactions. Although the oxidation rate of iron is instantaneous (Stumm and Lee, 1961), most aquatic sediments are anoxic due to bacterial degradation of organic matter. Therefore, Fe^{2+} is produced in situ and is often associated with sulphide, precipitating as pyrite (Todorova et al., 2005). Total iron concentration is a critical biogeochemical property of the sediments. Because of the large adsorption capacities of iron, its accumulation in sediments impacts (1) concentrations of other ions,(2) sorption of trace elements such as Cd and As (Carroll et al., 1998), (3) decomposition of organic matter (Tessier et al., 1996), and (4) ecosystem nutrient cycling (Burdige, 1993, Olivie-Lauquet et al., 2001). Migration of Fe^{2+} from anoxic conditions to oxic /anoxic boundaries as a result of resuspension of bottom sediments produces Fe-hydrous oxides, which incorporate organic matter and inorganic oxide particles that scavenge both heavy metals and organics (Taillefert et al., 2000). The value of Fe2O3 in Noaniaa section is higher than in the other studied sections.

Na2O is ranging in Serikagni Formation rocks from 0.22% to 0.45% in an average of 0.3%. These amounts are considered small in comparison with their values in carbonate rocks, (Table 5).

Sodium is the most abundant of the alkali elements and constitutes 2.6 percent of the Earth's crust. Compounds of sodium are widely distributed in nature (Weast, 1973). Weathering of salt deposits and contact of water with igneous rock provide natural sources of sodium, (Ontario Ministry of the Environment, 1981). Most sediment contains sodium in the range of 0.1 to 1 percent, mainly as silicate minerals such as, Amphiboles and Feldspars. The concentration of the sodium is observed in Serikagni Formation rocks to be higher in Noaniaa section.

K2O is ranging in Serikagni Formation rocks from 0.3% to 0.5% in an average of 0.43%. These amounts are considered small in comparison with their values in carbonate rocks, (Table 5). K^+ is commonly found in sedimentary rocks and released slowly upon dissolution of rocks (Potassium Feldspars and Mica minerals). K^+ is strongly held by clay particles in the sediment.

In addition, TiO2 and P2O5 were analysed in this study. The results indicated that TiO2 % in Jaddala, Sinjar, Para sections are ranging from less than 0.006% to 0.012 %, while in Noaniaa section ranging from 0.006% to 0.037 %. Infact , there is a positive relation between TiO2 % and I.R.% where the TiO2 determined by very fine grains transported with fragments of Rutile or Illeminite and the clay and silt size product of weathering . The amount of TiO2 depends on the intensity of weathering processes, (Al-Ani, 2005). Accordingly, it is believed that Noaniaa section rocks were deposited in relatively shallower deposition environment that effected with sever weathering processes. While, the results were indicated that P2O5 % in Jaddala, ranging from 0.03% to 0.39%, Sinjar, ranging from 0.03 % to 0.19% Para, ranging from 0.02 % to 0.15%, while in Noaniaa section ranging from 0.07% to 0.2%.

Infact, there is a positive relation between P2O5 % and I.R. % where the P2O5 determined by very fine grains transported with the clay particles as product of weathering.

Table 3: represent the averages of the SiO2, Al2O3, Fe2O3, Na2O and K2O % of the studied four sections (Jaddala, Sinjar, Noaniaa and Para)

Average %	Jaddala Section	Sinjar Section	Noaniaa Section	Para Section
SiO2	7.4	11.3	12.4	10.5
Al2O3	1.7	2.3	2.6	2.2
Fe2O3	0.6	0.4	0.8	0.6
Na2O	0.24	0.22	0.45	0.3
K2O	0.5	0.3	0.5	0.41

The trace elements

The results of the trace elements concentration are shown in table 4 and discussed below:

Mn in Serikagni rocks is ranging from 23.0 to 162 ppm in an average of 91.8 ppm. These amounts are considered small in comparison with their values in carbonate rocks, (Table 5). Mn is one of the important elements in the study of carbonate rocks due to its relation with the environment of deposition which comes from the ability of Mn to replace Ca in the space lattice. Accordingly the study of Mn may concern the indication of the physico-chemical conditions of sea water during deposition. The reduction environment which took place directly after deposition create a suitable conditions that high amount of Mn could replace Ca in the space lattice of calcite and these conditions are available in deep sea environment. Accordingly the little amount of Mn in the Serikagni rocks indicates absence of such conditions, suggesting general shallow depositional environment, (Maani, 2009).

Mn is one of the most abundant trace elements in the lithosphere, and its common range in rocks from 350 to 2000 ppm. Its highest concentrations are usually associated with mafic rocks. Mn forms a number of minerals in which it commonly occurs as the ions Mn^{2+} , Mn^{3+} , or Mn^{4+},but its oxidation state +2 is most frequent in the rock-forming silicate minerals (Kabata-Pendias, Henryk Pendias ,2001).Under oxic conditions, Mn forms oxides, which can be important reservoirs for trace metals, especially Co, Zn and Cr, ((Friedman, 1968 ,Tonkin et al. 2004).

Sr is ranging in Serikagni rocks from 710 to 794 ppm in an average of 743 ppm.

The amount of Sr is considered to be within the range in comparison with its average in carbonate rocks, (Table 5), however, this amount is acceptable because the rocks of Serikagni formation were deposited in relatively shallow environment, (Veizer and Demovic, 1973). Moreover, the amount of Sr concentration is could be due to diagenetic aragonite – calcite transformation process which was acted intensively in Serikagni formation where the X-Ray diffraction diagrams showed absence of aragonite. The chemical similarity of strontium to calcium, having similar ionic radius and the same valence, means that strontium tends to behave similarly to calcium in most systems (Simon, 2003).

According to Veizer, and Demovic,1974, and Simon, 2003, there are many factors that control the Sr content in carbonate rocks such as age, salinity, clay mineral content and depositional environment, in addition to, the kind of diagenetic process, mechanism of aragonite –calcite transformation. The depositional environment is also played its role in modifying the amount of Sr. Its role comes through their effects on the amount of insoluble residues, where this amount reflects the nature of the basin and water agitation, and source rocks, (Hassan, 2005).

Cu is ranging in Serikagni rocks from 6.9 to 12.64 ppm in an average of 9.8 ppm . These amounts are considered to be within the range in comparison with their values in carbonate rocks, (Table 5).

Copper, like lead, is a chalcophile that forms discrete sulphide minerals (Achterberg et al. 1997) or may associate with pyrite (Huerta-Diaz et al. 1993; Schoonen ,2004) .

Zn is ranging in Serikagni rocks from 16.25 to 20.0 ppm in an average of 17.9 ppm. These amounts are considered to be within the range in comparison with their values in carbonate rocks, (Table 5).

Zinc is a chalcophile element that forms distinct sulphide phases under anoxic conditions (Bostick et al., 2001). The relatively highest concentration value is determined in the Sinjar section.

Co is ranging in Serikagni rocks from 37.0 to 40.0 ppm in an average of 38.5 ppm. These amounts are considered higher in comparison with their values in carbonate rocks, (Table 5).

Cobalt is a siderophile, frequently found in association with Fe. In anoxic sediments, Co can form a discrete phase (CoS) or may be associated with disulphides including pyrite and marcasite (Schoonen ,2004). In oxic or suboxic sediments, Co typically associates with oxides, including both Fe and Mn oxides (Davison, 1993).

Cr is range in Serikagni rocks from 14.2 to 31.0 ppm in an average of 19.3 ppm . These amounts are considered higher in comparison with their values in carbonate rocks, (Table 5).

Chromium, like Mn, is a lithophile element and is generally not associated with sulphides (Huerta et al., 1998, and Morse and Luther, 1999). The Co and Cr or the acid soluble can be used as energy index indicators. They exist in or on clay minerals and organic matter which are generally more abundant in the quieter, lower energy marine environment, (Till, 1979). This assumption applies well on the situation concerning the depositional environment and the facies variation of Serikagni formation. The geochemistry of Serikagni rocks showed increase of Ca, I.R. and Sr, towards the more limy facies, while the most other elements, i.e. MgO, SiO_2, Al_2O_3, Fe_2O_3, Na_2O, K_2O, Mn, Zn, Co, Cr, Pb and Cu varies between the limy and the marly facies.

Pb is ranging in Serikagni rocks from 30.6 to 34.6 ppm in an average of 32.5 ppm. These amounts are considered higher in comparison with their values in carbonate rocks, (Table 5). Under anoxic conditions Pb, which is a chalcophile element, forms distinct sulphide phases (Morse and Luther 1999). Pb may be present as a discrete phase (i.e. Cerrusite, $PbCO_3$), or more likely, exists in solid solution with or sorbed to aragonite or another carbonate phase (Kersten ,& Forstner ,1986).

Table 4: represent the averages of the Sr, Mn, Cu, Zn, Co, Cr, and Pb (in ppm) of the studied four sections (Jaddala, Sinjar, Noaniaa and Para)

Average in ppm	Jaddala Section	Sinjar Section	Noaniaa Section	Para Section
Sr	794	727	710	742
Mn	162	23	97	86
Cu	6.7	12.6	9.7	10
Zn	16.3	20	17.3	18
Co	40	39	37	38
Cr	14.2	30.6	31	26
Pb	32.5	30.6	35	32.3

Conclusion

In conclusion, it is believed from the results of this study, that the geochemical analyses are essential in reflecting the minor changes of the environment of deposition of the Serikagni Formation. The results may marked the events in the depositional environment of Serikagni Formation, such as the transgression periods that may represented at the early and late deposition stages of the Formation and the regression period that may indicated within the middle depositional stage of the Formation, this finding is suggest some sort of more oxidizing environment such as shallower marine conditions or some sort of continental effect during early stages of deposition, (Al-Taee, 2003).

In addition , comparing the results of this study with other authors findings such as, Rankama and Sahama,1950 ,Turekian and Wedepohl,1961,Hawekes and Webb,1962 , Horn and Adams,1966 and Kettaneh and Sadik,1989, reflect that the Al2O3 , Na2O and K2O constituents represent higher concentrations in Serikagni Formation which could be due to the occurrence of clay minerals within the Serikagni Formation. Also the results indicate that SiO2 and Fe2O3 concentration are with the range comparing with its range in known carbonate rocks which is believed to be due to the minor changes in the deposition environment and the nature of the dolomitization solutions.

The existence of sulfides (pyrite) and glauconite indicate prevalence of reducing conditions during the deposition of Serikagni formation under quiet marine environment. Pyrite was probably formed as a result of convolution , alteration ,and changes of the existed minerals within the sediments to more stable forms during diagenesis (Berner, 1971). Iron was brought to the basin of deposition of Serikagni formation from nearby continental mass to the northeast as detrital grains and iron rich minerals as well as iron absorbed on detrital clay minerals.

The trace elements Co, and Cr, or the acid soluble can be used as energy index indicators, they exist in or on clay minerals which are generally more abundant in the quieter, lower energy marine environment. This assumption applies well on the situation concerning the depositional environment and the facies variation of Serikagni Formation.

In addition , comparing the results with that of Rankama andSahama,1950 ,Turekian and Wedepohl,1961,Hawekes and Webb,1962 , Horn and Adams,1966 and Kettaneh and Sadik,1989 , that the Co , Cr, and Pb constituents represent higher concentrations in Serikagni Formation which could be due to the occurrence of clay minerals within the Serikagni Formation. Also the results indicate that Sr, Cu and Zn concentrations are within the range of other known carbonate rocks, while the Mn concentration is lower than that of known carbonate rocks. However, such a result is believed to be due to the minor changes in the deposition environment and the nature of the dolomitization solutions, (Tables 1,2,3,4, and 5).

The over all geochemistry of the average values of rocks are representing different facies of the Serikagni formation from the four studied localities.

However, due to the marly nature of parts of the formation, distinct variations are expected. Geochemical differences can also be noticed between the limy and marly facies constituting the same formation. The marly facies is richer in all major elements except Ca, K, and I.R. and in all analyzed trace elements.Magnesium as a major element plays an important role in the chemistry of the analyzed sediments probably due to the large amount of fine dolomitic detritus.

Differences are also observed between the geochemistry and mineralogy of the four studied localities such as the relatively more pure limestone in Jaddala and Para sections than Sinjar and Noaniaa sections which indicate the higher percentages of marly limestone. Also, the relative increase of silica concentrations at Sinjar and Noaniaa sections comparing with the lower concentration at Jaddala and Para sections, which is believed to be due to the geographic location of these sections within the main depositional environment, as well as the consequences of sea transgressions that recognized at the lower and upper part of Serikagni formation and the sea regression that determined during the middle part of the formation.

In addition, TiO2% and P2O5% were indicated a positive relation with I.R.% where the TiO2% and P2O5% determined by very fine grains transported and the clay and silt size product of weathering . Accordingly, it is believed that Noaniaa section rocks and to less extent Sinjar section rocks were deposited in relatively shallower deposition environment that effected with sever weathering processes. Actually, these conditions are similar in general to the effect of the deposition during the regression of the sea throughout the middle part of the Serikagni formation depositional environment, (Al-Ani, 2005 ,and Hassan, 2005).

Table 5: comparison of the averages of the SiO2, Al2O3, Fe2O3, Na2O and K2O % and Sr, Mn, Cu, Zn, Co, Cr, and Pb (in ppm) of the this study with other authors results

Element\ Research	Al2O3 %	Fe2O3 %	Na2O %	K2O %	SiO2 %	Sr ppm	Mn ppm	Cu ppm	Zn ppm	Co ppm	Cr ppm	Pb ppm
Rankama& Sahama,1950	0.43	0.45	0.037	0.27		425-765	385	20.2	50?	<0.3	2	5-10
Turekian& Wedepohl,1961	0.79	0.54	0.054	0.324		722	1420	4	20	20	11	9
Hawekes& Webb,1962	-	1.3	-	-		-	1300	5-20	4-20	0.2-2	5	5-10
Horn& Adams,1966	1.66	1.17	0.053	0.287		730	1086	5	16	13	7	17
Kettaneh & Sadik,1989	1.04-1.9	0.63-0.85	0.08-0.12	0.6-1.24	5.7-11.4	403-538	-	11-22	16-21	-	-	4-32
This study	2.2	0.6	0.3	0.43	10.4	743	91.8	9.8	17.9	38.5	19.3	32.5

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