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SEDIMENTOLOGY OF SINJAR LIMESTONE FORMATION, SULAIMANIAN AREA, NORTHEASTERN IRAQ

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ABSTRACT

Sinjar Limestone Formation of Eocene age is composed of allochthonous and autochthonous limestones. Petrographic and geochemical characteristics of the rocks of this Formation show the occurrence of phosphatic rocks in two horizons which are separated by 43 feet thick nonphosphatic limestone beds.

The study also reveals that the phosphatic rocks are recycled sedimentary deposits from the near-by source. No effects of phosphatization was observed in the associated rocks.

Five phases of sedimentation representing different physicochemical controls have been established on the basis of petrography, chemistry and the fossils present in them.

INTRODUCTION

The present article deals with the sedimentological investigation of Sinjar Limestone Formation exposed in Kinjinnah, Bazyan and Dukan areas of Sulaimaniah county in northeastern Iraq (*Fig. 1*). Attempt has been made to reconstruct the depositional environment of the formation which is composed of allochthonous and autochthonous limestones. The investigation also seems to ascertain the degree of mineralogical correspondence between Sinjar Limestones and the intertonguing Kolosh Formation on the basis of clastics.

Besides the studies of the physical properties, field relationships, structural continuity of Sinjar Limestones and the associated rocks, the petrographic invetigation of the samples collected and the quantitative estimation of the acid insolubles were also made. The petrographic evidences and acid insolubles are expected to help in the determination of the degree of mineralogical correspondence between the beds of Sinjar Limestone Formation intertonguing with the associated Kolosh Formation. Efforts have also been made to trace the possible provenance of the clastics present in the rocks and to study the diagenetic changes. Chemical analysis of the representative samples of the Sinjar Limestone Formation has been made to study the variations in Ca and Mg concentrations of the beds under varying geochemical conditions of the depositional basin.

GENERAL GEOLOGY OF THE AREA

Reference to the geology of Sinjar Limestone Formation is found in the reconnaissance geological reports since 1959 but no attention was paid to the petrographic investigations of this formation which is composed of varieties of limestones. Studies

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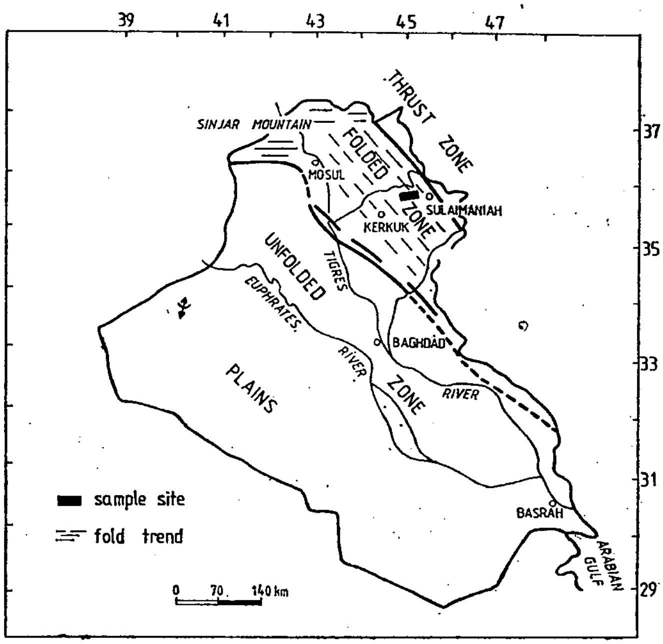

Fig. 1. Tectonic map of Iraq showing location of sample site

on the stratigraphic aspects and the microfacies of Sinjar Limestone Formation has been made by AL-SIDDIQI (1968). AL-KUFAISHI (1977) made a geochemical study of some of the core samples from Sinjar Formation and concluded that no relationship exists between the microfacies of the formation and the trace elements concentration. The author could also establish non-reefal origin of the facies and decreasing effects of dolomitization with depth on the basis of Ca/Mg ratio and the strontium contents.

The formations exposed in Kinjinnah, Bazyan and Dukan areas are Sheranish, Tanjero clastic, Sinjar and Kolosh, and the Gercus of Upper Cretaceous, Paleocene and Miocene ages respectively (VAN BELLEN, 1956). Tanjero Clastic Formation is contemporaneous of Sheranish Formation and Kolosh Clastic Formation intertongues with Sinjar Limestone Formation.

Sheranish Formation is composed of blue marl at the upper part and thinly bedded marly limestone at the bottom. Fresh surface of the marl looks dark blue but on weathering the colour changes to a typical pale blue. The rocks are considered to be of transgressive sequence of Upper Campanian age.

Tanjero Clastic Formation is contemporaneous of Sheranish Formation and underlies Sinjar Limestone Formation in the areas of present investigation. It is composed of silty marls, siltstones, sandstones, conglomerates and sandy or silty organic reef and shoal types of limestones. The non-calcareous clastics are dominated by chert and green rock detritus. The clastics comprise the pebbles and fine grained detritus of different Mesozoic limestones, green rock fragments and radiolarian cherts.

Sinjar Limestone Formation of Paleocene/Eocene age is well exposed in the type locality near the village of Mamissa in the Sinjar Mountains at Latitude 36°22′33″

N and Long. 41°41′23″ E after which the formation is named. In the type locality the formation is 577 ft. thick limestone showing elements of algal reefal facies, a lagoonal miliolid facies and a shoal nummulitic facies. It is usually recrystallized hard and yellow in colour. It overlies the Sheranish Formation unconformably and is marked by a complete faunal and facies changes. In this locality Jaddalah Formation overlies the Sinjar Limestone Formation unconformably and is marked by ravinement and glauconite concentration.

In other localities such as Kin-Jinnah, Bazyan and Dukan which are under the present study, Sinjar Limestone Formation underlies Gercus Formation unconformably instead of Jaddalah Formation and overlies the Tanjero Clastic Formation. The rocks of Sinjar Limestone Formation are composed of varities of limestones which differ in texture from coarse friable to fine dense hard and compact states with varying contents of fossils. Generally the microfossils are more abundant in the upper part of this formation. The colour varies from light grey to brown yellow and mottled. The effects of physical and chemical weathering are non-uniform. Some of the beds which are compact and hard stand out in relief with steep escarpments, while others which are brown yellow or mottled show intense effects of physical and chemical weathering probably due to their higher argillaceous contents which make them soft and give different colours in presence of organic matter and iron oxides.

Kolosh Clastic Formation interfingering with Sinjar Limestone is composed of shales, coarse and fine sandstones of dark and green colours. Thin layers of marl are also found. The formation is highly heterogenous in lithology and is rapidly variable both horizontally and vertically. It is deposited by turbidity currents (BANAT *et al.*, 1981).

Gercus Formation of Miocene age is contemporaneous of Jaddalah Formation. It is composed of reddish brown maroon coloured shale and sandstones of different grades. It overlies the Sinjar Limestone Formation in the area of study instead of Jaddalah Formation.

Structurally the area forms a flank of a major anticline trending NW and SE in the Zagros folded mountain belt of Iraq. The main highway connecting Sulaimaniah and Baghdad is across the strike of the beds in the western flank of the major anticline. The topography of the area is moderately rugged because of variable lithological characteristics of the limestones, shales and sandstones of different formations present in the area. Gentle to steep escarpment slopes with interstream highs are common features in this area.

METHOD AND MATERIAL

The localities mentioned earlier were selected for detailed sampling of Sinjar Limestone Formation, the top of the underlying Tanjero Clastic Formation and the bottom of the overlying Gercus Formation. Samples were also collected from Kolosh Clastic Formation which interfingers with Sinjar Limestone Formation. The samples collection was based on the differences in colour, texture, structure, algal characters, compactness, thickness of beds, types of weathering, response to acid test and other characteristics observable in the field, in order to get proper representation of the varying conditions during deposition of the rocks. To facilitate the study of the degree of correspondence between the beds of Sinjar Limestone Formation, special consideration was given to the study of samples collected from the contact zones of the beds. Qualitative estimation of insoluble residues has been made to facilitate the study of the degree of correspondence with the associated rocks.

The limestone beds of Sinjar Formation show variable thicknesses and shades in colours on the weathered and fresh surfaces. In hand specimens light grey, yellow and brown are the dominating colours with patches and streaks of reddish brown, pink, white and black (Table 1). In some of the beds, the effects of argillaceous content and organic matters are well pronounced. Mottled appearance is more pronounced in phosphatic beds which have been discovered by the senior author of the present paper. The details of the phosphorite is discussed in a separate paper already published (MALLICK and AL-FADHLI, 1980).

TABLE 1

Lithostratigraphic details on a section from Sinjar Limestone Formation, Sulaimaniah area, Iraq

Bed №	Thickness of bed in ft.	Lithology
SK—22	19	Mottled (brown and white) coarsely crystalline limestone.
SK—21	17	Light brown crystalline limestone.
SK—20	12	Light brown hard and massive limestone with white streaks.
SK—19	39	Light brown massive limestone with black specks.
SK—18	13	Light green, dense and massive limestone.
SK—17	37	Dark brown argillaceous limestone showing recrystallization effects.
SK—16	51	Light grey with pink streaks dense and hard limestone.
SK—15	17	Mottled hard and massive argillaceous limestone.
SK—14	20	Mottled clastic argillaceous limestone.
SK—13	18	Reddish brown hard and compact clastic limestone.
SK—12	19	Yellow clastic argillaceous limestone.
SK—11	8	Light brown dense and hard limestone.
SK—10	17	Dark brown massive limestone with sub-conchoidal fracture.
SK—9	16	Mottled clastic hard limestone.
SK—8	2	Light brown and banded hard limestone.
SK—7	5	Reddish brown hard clastic limestone.
SK—6	10	Mottled argillaceous fossiliferous limestone.
SK—5	21	Light brown argillaceous clastic limestone.
SK—4	6	Mottled argillaceous clastic limestone.
SK—3	6	Light grey hard argillaceous clastic limestone.
SK—2	10	Light grey hard clastic limestone with argillaceous patches of brown colour.
SK—1	7	Light grey argillaceous limestone with black specks.

The development of weathering features like honeycomb, spongy and plain surfaces are common in Sinjar Limestone Formation, signifying non-uniform condition during deposition with respect to sedimentation and tectonism in the area. The Formation is more argillaceous in the lower part than the upper. Honeycomb and spongy weathering is quite common. Uneven development of escarpments and escarpment slopes as common features are probably due to variable lithology and compactness of the rocks in the beds, wide range of textural varieties are observable in hand specimens and the thin sections of the rocks.

The limestones are mainly allochthonous and, therefore, the textural variations seem to be very much related to lithology of the limestones of this formation. The variation in autochthonous limestones of this formation is not very much. Banded algal structures are quite pronounced both in hand specimens and the thin sections of the limestones.

The thim sections from the rock samples of the overlying Gercus and the underlying Tanjero Formations were examined to study the similarities in the shapes of the grains and the mineralogy of the non-carbonate contents of Sinjar Limestone beds. Special attention was paid to the study of similar and oissimilar non-calcarlous minerals in the beds of the limestones in relation to the associated beds. Due emphasis was given to the study of the samples collected from the contact of the consecutive beds to facilitate the study of non-carbonate minerals present due to transition or intermixing, if they were laid down in the same cycle of deposition with some degree of fluctuations in the depositional basin or there were some pronounced changing conditions of deposition due to inter-play between tectonism and sedimentation.

PETROGRAPHY

In megascopic study the shales, marls, siltstones and the sandstones of Tanjero Formation appear greenish grey in colour. The texture is fine to medium. In this sections, quartz grains and grains of limestone fragments which are generally crystalline are common. Relatively fresh grains of alkali feldspars and the flakes of muscovite and biotite are also present. The grains of the minerals in the limestone are angular to subrounded in shape. Fossils are not common in the upper part of Tanjero Formation which has unconformable contact with Sinjar Limestone Formation. Perhaps the provenance of Tanjero clastics was not far from the depositional basin and the sedimentation rate was relatively higher than the sinking of the basin of deposition which helped in preserving the morphology of the grains without much modifications.

The lowermost bed of Sinjar Limestone Formation in unconformable contact with the top of Tanjero clastics is fine grained, massive and fairly hard to break. Black specks probably of organic matter are common.

The thin section of the rock reveals an aggregate of argillaceous pellets and fragments embedded in calcareous matrix. The pellets range in size from 1 mm to 3 mm and amount to about 15%. The argillaceous fragments are angular to subrounded, 1 to 5 mm in diameter and their amount is about 20%, obliterated microfossils showing micritization are also present. Some of the fossils although micritized can be seen with partly preserved characters. Micritization and presence of sparry calcite in matrix and concretions having cluster of argillaceous pellets and fragments are easily observable in thin sections *(Fig. 2)*. The pelleted argillaceous limestone beds are repeated in the sequence. The effects of micritization and the cluster of calcite grains are not uniform in all the argillaceous limestones. Fossils are rare and algal structures are observable. Argillaceous patches can also be seen. The mud supported limestones both the ooids and the massive with irregular patches of sparry calcite show variable degree of micritization and appear quite different from the pelleted limestone beds. The fossils are not visible in the mud supported limestones *(Fig. 2d)*. Perhaps the sparites are the fossil fragments which have been completely replaced and recrystallized.

Where ever the ooids have developed into larger sizes of 0.6 mm to 1.0 cm, the sparites in association with them are also larger in sizes and more in abundance. Micritization and sparry calcite can also be seen within concritions producing concentric pattern due to the presence of organic and argillaceous matters at the time of deposition of the rocks. The non-pelleted limestones appear relatively less argillaceous

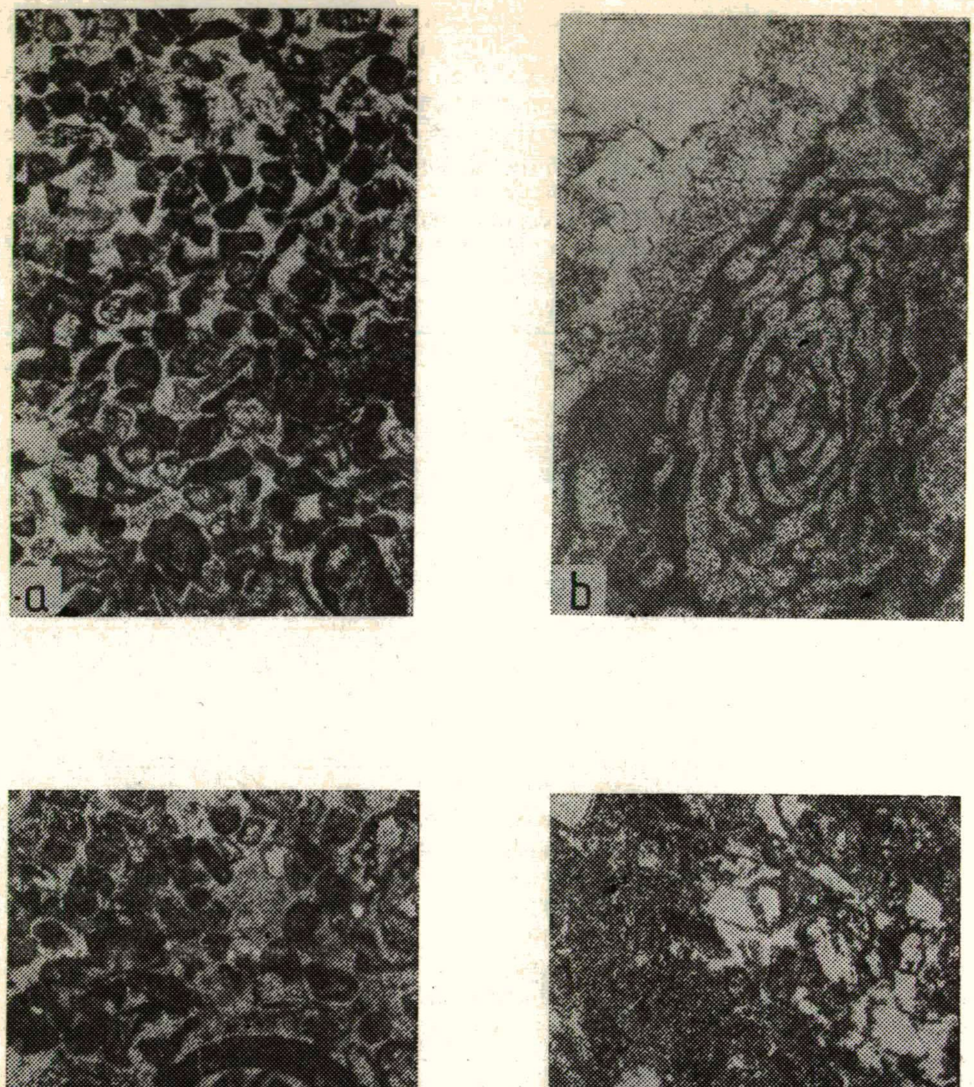

Fig. 2

and contain fragments of fossils, angular grains of quartz, calcites and few argillaceous fragments showing micritization effects. Some of the thin sections of the rocks from Sinjar Limestone Formation show an aggregate of well packed uneven grains of variable mineralogical compositions.

The bed overlying the lowermost bed of Sinjar Limestone Formation appears more algal and argillaceous and contains rounded to subrounded grains of limestones. The grains show varying degree of recrystallization with seggregation of argillaceous and organic matters within their bodies. Smaller fragments appearing as sparry calcite in the algal matrix are common *(Fig. 3)*.

The upper part of Sinjar Limestone Formation is relatively more fossiliferous and the fossils are well preserved in their outlines and internal structures. Tubular larger fragments of fossils in association with the smallers in the calcareous matrix are common. The smaller fragments are mostly replaced by calcite and appear as fragments of calcite in argillaceous matrix *(Fig. 4)*. The larger fragments of fossils also show diagenetic effects, and therefore, they appear to be composed of sparry calcite with black specks of argillaceous matter but the structure of the fossils is recognizable.

The occurrence of tube like structures with pelloids, argillaceous angular fragments and sparry calcite probably indicates that mud feeding animals were present in the shallow depositional basin. The outer wall of the tube gives indications of micritization and the presence of sparites. In such types of rocks the percentage of pellets is about 2 and the matrix is calcareous. No effects of dolomitization could be observed in these rocks. The rocks with calcareous matrix, well preserved fossils and algal lumps of variable sizes occur in all over the area under present study.

The overlying bed of the same formation shows a marked change in the matrix from calcareous to argillaceous in which well preserved microfossils and fossil fragments are present. The effects of replacement in the fossils and fossil fragments are well pronounced but the internal structures are not disturbed.

The top of Sinjar Limestone Formation in contact with the bottom of the overlying Gercus Formation is hard lithic limestone. The thin section reveals the presence of lumps, pellets and intraclasts embedded in calcaro-ferruginous matrix. Micritization is well pronounced both in the lumps and the intraclasts.

The bottom of Gercus Formation in immediate contact with the top of Sinjar Limestone Formation is highly ferruginous and clastic. In thin section of the rock, rounded to subrounded grains of orthoclase, microcline, perthite, limestone, and quartz are identifiable. Mostly the grains range in size from 0.5 to 2.0 mm. Fine grains of quartz are also observable in the matrix.

Fig. 2. Photomicrographs from phosphorite deposits, Sulaimaniah area, North Eastern Iraq. a) An aggregate of argillaceous intraclasts, pellets and microfossils embedded in calcareous matrix. Micritization observable specially in the central parts of the microfossils. Pressure solution effects are also visible. ×50.4, polarized light. b) Ooid showing concentric structure with micrites, sparry calcite, collophane and dahllite, visible. Sparry calcite developed due to pressure solution effects is also observable. ×50.4, polarized light. c) Lump, intraclast and pelloids embedded in calcareous matrix. Micritization prominent. Collophane and dahllite and pressure solution effects can be seen. ×50.4, polarized light. d) Lathic limestone containing peloids and intraclasts. The intraclasts probably of fossil fragments are completely recrystallized and firmly embedded in calcaro-argillaceous matrix. ×50.4, polarized light

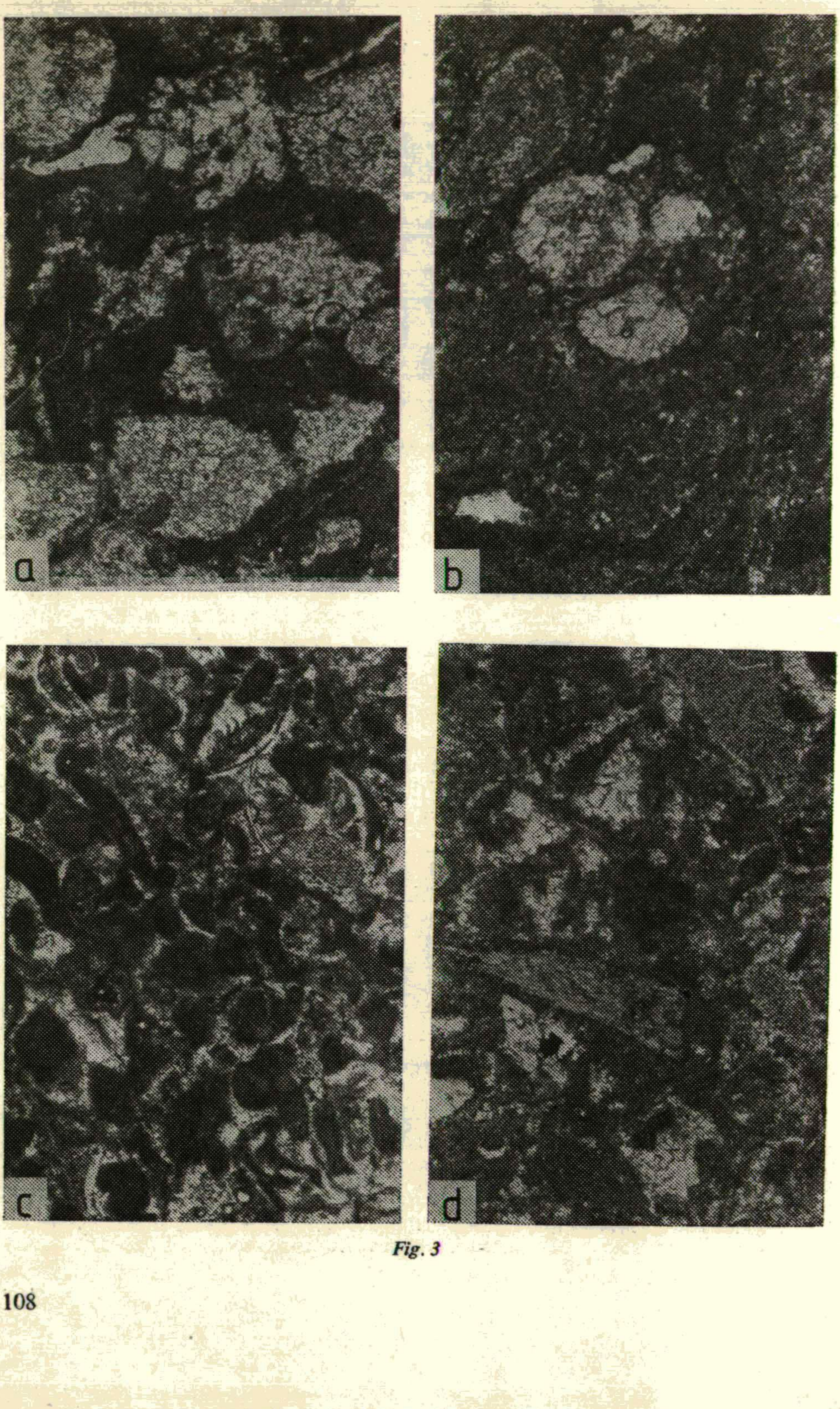

Fig. 3

MAJOR CHEMICAL CONSTITUENTS OF THE ROCKS

Quantitative estimations of calcium, magnesium, silicon, phosphorous and acid insolubles were made to study their relative concentrations in the beds of Sinjar Limestone Formation which appear different in physical and compositional characteristics. The graphs have been plotted with the assumption that the magnesium concentration in the nearshore water or in shallow seas is more as compared to the offshore deep-sea water and reverse is true for Ca. Any change or abnormal concentration of either of the elements would be an indication of varying physico-chemical conditions giving rise to enrichment or depletion of the elements through replacement and diagenesis. This assumption may not be rigorously true in all cases due to complexity in the local condition of the region during deposition and diagenesis but it would be helpful in over all appraisal of the conditions fairly satisfactorily.

The concentration of phosphorous, silica and acid insolubles were determined to describe the degree of correspondance if any, between the major constituents of the rocks. The graphs plotted represent a cross section of the major chemical constituents of the rocks of this formation in the area.

The plots of concentrations for Ca and Mg appear to show antipathic relationship with each other except in sample Nos. 9, 14 and 15 *(Fig. 5)*, and their concentrations appear in accordance with the assumption described earlier. It is inferred from the graphs that geochemical conditions in the depositional basin were not consistent and caused an appreciable range of variation in the concentration of Ca and Mg or the beds during deposition.

The plot of Ca/Mg ratio versus Mg concentration shows a fairly good inverse relationship in general *(Fig. 6)* but it is not possible to conclude any sytematic change in the depth condition of the basin of deposition from the bottom to the top of the formation or *vice versa*. The cluster of points definitely indicates two different populations characterized by low and high ratios. The population having higher Ca/Mg ratio represents the deeper marine condition than that which has lower concentration. The Ca/Mg ratios between 13.5 to 16.5 appear to separate the population of shallower and relatively deeper marine water deposits or at least it shows fluctuations or possibly break in the depositional cycle.

Since the numbers with the points indicate to the beds of Sinjar Limestone Formation in ascending order i.e. from bottom to top, it is hard to interpret gradual increase or decrease in the depth conditions. The random enrichment and depletion of Ca and Mg in the beds of the formation may be because of the interplay of tectonics and sedimentation at the time of depositions. As the area is not far from the subduction zone of Afro-Arabian and Iranian plates which were very active during Paleocene, the above interpretation appears quite logical. The possibilities of heterogenous concentration of Ca and Mg in the beds of the formation due to selective diagenesis under changing geochemical conditions in the depositional basin and afterwards cannot be ignored.

Fig. 3. Photomicrographs from non-phosphatic beds of Kinjinnah and Bazyan areas, North-eastern Iraq. a) Intraclasts in ferro-calcareous matrix. Micritization prominent in intraclasts probably due to recrystallization of the calcareous fragments. ×50.4, crossed Nicols. b) Banded algal structure with ooids and fine shell fragments. Micritization prominent. Matrix calcaro-carbonaceous. ×50.4, polarized light. c) Ferro-argillaceous pellets, intraclasts, fossils and fossil fragments in calcareous matrix. Fossils and fossil fragments are micritized. Pressure solution filled the intergranular spaces with sparite. ×50.4, crossed Nicols. d) Skeletal limestone with argillaceous intraclasts. Effects of micritization and pressure solution prominent. Sparry calcite is also present. Matrix argillo-calcareous. ×50.4, polarized light

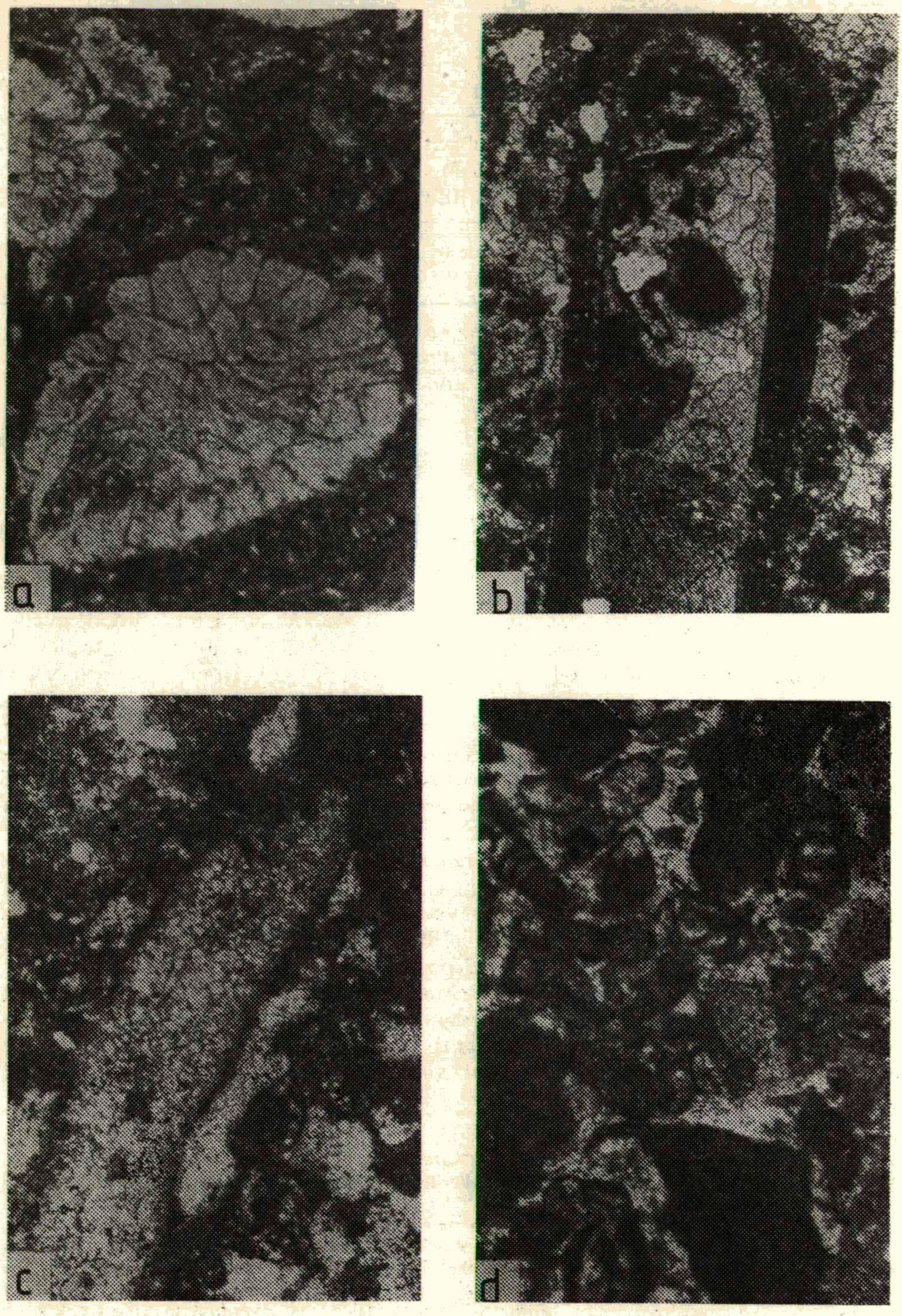

Fig. 4

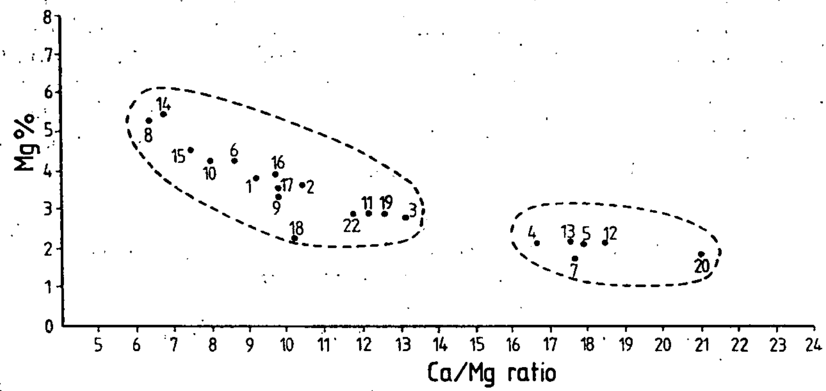

Fig. 5. Enrichment and depletion of calcium and magnesium in the rocks of Sinjar Limestone Formation

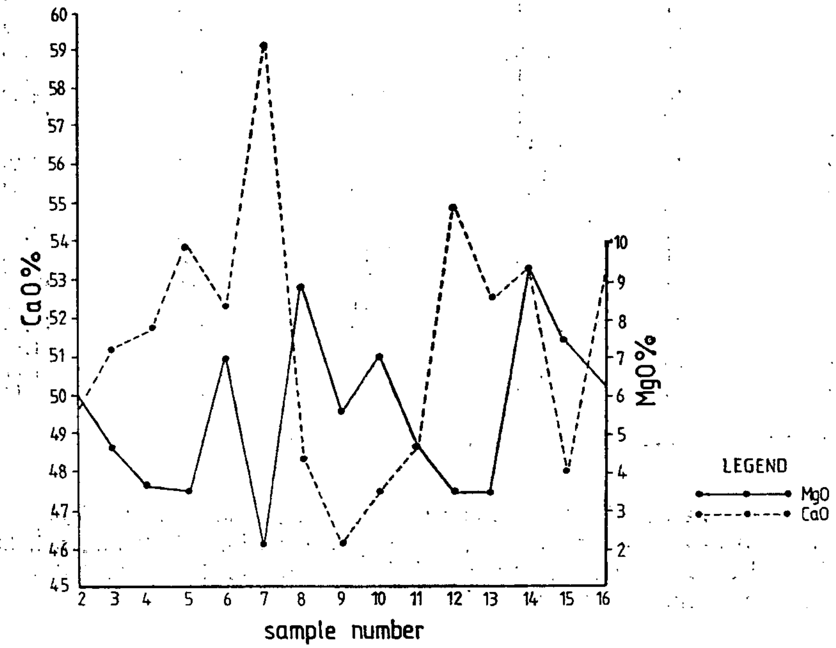

Fig. 6. Variation of Mg with Ca/Mg ratio in the rocks of Sinjar Limestone Formation

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Fig. 4. Photomicrographs from non-phosphatic beds associated with the phosphorite beds, Sulaimaniah area, Iraq. a) Fossils and fossil fragments embedded in argillo-calcareous matrix. Peloids as black speeks and micrites in the ground mass. ×50.4, crossed Nicols. b) Argillaceous pellets, intraclasts and fossil fragments within tubicular part of a mud-feeding organism and around it. Micritization and pressure solution effects prominent. Sparry calcite and dolomite observeable. ×50.4, crossed Nicols. c) Micritized obliterated fossils and intraclasts in argillo-calcareous matrix. Primary pores filled with sparry calcite due to pressure solution effects. ×50.4, crossed Nicols. d) Lathic intraclasts fossils and fossil fragments in calcareous matrix. Micritization more prominent in fossil fragments than in the intraclasts. ×50.4, crossed Nicols.

The cluster of points showing to the population with higher Ca/Mg ratio represents to phosphatic limestone beds of Sinjar Limestone Formation with the exception of samples No. 14 and 2 which are in the cluster of the other population representing non-phosphatic rocks. No relationship could be observed in the concentration of silica and phosphorous. The contents of acid insolubles and phosphorous in the phosphatic beds suggest some positive correspondence which may be because of argillaceous contents of the rocks (Table 2).

TABLE 2

Chemical characteristics of the beds of Sinjar Limestone Formation Kanijinnah section Sulaimaniah area, Northeast Iraq

Bed №.	Thickness in ft.	Ca/Mg ratio	SiO_2%	P_2O_5%	AIR %
SK—1	7	9.26	1.24	ND	3.80
SK—2	10	10.44	3.80	ND	4.10
SK—3	6	13.12	2.37	1.77	5.4
SK—4	6	16.89	1.22	3.60	5.61
SK—5	21	17.91	2.93	4.60	7.79
SK—6	10	8.79	0.33	ND	3.82
SK—7	5	37.90	0.49	1.46	2.95
SK—8	2	6.41	0.69	ND	1.73
SK—9	16	9.89	1.64	ND	4.98
SK—10	17	8.01	5.39	ND	15.30
SK—11	8	12.19	0.27	ND	3.04
SK—12	19	18.46	0.98	2.29	4.59
SK—13	18	17.67	0.85	3.17	4.82
SK—14	20	6.89	0.33	5.95	6.38
SK—15	17	7.58	3.56	1.36	7.30
SK—16	51	9.76	0.19	ND	1.35
SK—17	37	9.89	3.78	ND	10.60
SK—18	13	10.23	0.31	ND	2.20
SK—19	39	12.64	2.29	ND	16.24
SK—20	12	20.89	1.69	ND	1.84
SK—21	17	64.32	0.29	ND	1.21
SK—22	19	11.82	0.98	ND	2.13

N.B: AIR stands for Acid Insoluble Residues and ND for non detectable.

The concentration of P_2O_5 shows positive correspondence with MgO in those samples which have angular to subangular argillaceous intraclasts and pellets embedded in calcareous matrix. This relationship has developed most probably due to dolomitization of the calcareous matrix.

ACID INSOLUBLE RESIDUES

Quantitative estimation of insoluble residues was made according to the procedure described by IRELAND (1936). The clay fraction was amonge the major components of the acid insoluble residue. The non-clay minerals in the insoluble residue were gypsum, anhydrite, quartz and grains of alkali feldspars. The grains were angular to subangular with sharp edges. No relationship could be found between the percentage of insoluble residue, the thickness of the beds and the concentration of CaO and MgO of Sinjar Limestone Formation. However, the concentration percentage of insoluble residue shows radical variation from one bed to the other probably due to pronounced fluctuation in the source of supply of the clastics or due to varying turbidity conditions in the basin of deposition (Table 2). It is also possible that the energy conditions responsible for contributing clastics were inconsistent. The intertonguing of Kolosh Clastic Formation with Sinjar Limestone Formation also reveals inconsistency either in the energy condition responsible for the deposition of clastics or fluctuation in depth of the basin of deposition which caused present geometry of Kolosh Clastic Formation and Sinjar Limestone formation. Perhaps the basins of deposition of these contemporaneous formations were separated by barriers and so whenever the energy conditions were changed and the depth of the basins were affected they gave rise to interfingering of the two formations having clastic and nonclastic characteristics. The radical variation in the percentage of the insoluble residues of the beds may be attributed to the same conditions. The ratios of Ca/Mg in the beds of Sinjar Limestone Formation also confirm the tendency of increase and decrease in depth of the basin of deposition. No correspondence could be established between the concentration of insoluble residues and the enrichment or depletion of Ca and Mg (Table 2).

DISCUSSIONS

The occurrence of angular to subangular grains of limestones, quartz and relatively fresh grains of alkali feldspars in Tanjero Clastics of Upper Cretaceous age lying below Sinjar Limestone Formation indicates the condition of more supply of sediments from near-by source and slower rate of subsidence of the basin of deposition.

In view of the characteristics observed it is concluded that the sedimentological cycle, physico-chemical conditions and the environments of deposition were changing during the deposition of Sinjar Limestone Formation of Paleocene age. The occurrence of varying percentages of clay fraction and the non-clay fraction in insoluble residues having minerals like quartz, alkali feldspars, anhydrite, gypsum etc. in the beds of Sinjar Limestones Formation show some degree of similarities with Tanjero Clastic Formation. Most probably the supply of sediments which formed Tanjero Clastic Formation did not stop completely but it was very slow and nonuniform. It is considered that the weak energy condition helped mixing the clastics into the sea water which was enriched with calcium to precipitate limestones along with variable contents of fine clastics, algal material and fossils of fossil fragments. The presence of algal material, fossils and fossil fragments indicate shallow warm water condition of deposition of the limestones.

It is hard to think about restricted shallow basin and the reworking of the upper part of Tanjero Formation to be the source of insolubles in the beds of Sinjar Limestone Formation because the constituents of the insolubles are not limited only in the lower beds of the Formation but are present in all the beds from lower to the upper part of the formation in varying percentages. No relationship could be found between the thickness of the beds and the contents of insolubles. Thus it appears reasonable to conclude that the supply of clastic was independent of the conditions in the depositional basin and the amount changed with respect to tectonic conditions and the rate of weathering in the source area.

The presence of micropellets of variable sizes with characters of reworking and argillaceous angular to sub-angular fragments in micritic matrix are sufficient indications of shallow basin of deposition, getting supply of argillaceous matter from the near-by source through weak energy condition. The absence of any orientation in the long axis of the elliptical pellets does not encourage to think about the diagenetic origin of the pellets in the limestone beds. On the contrary the association of lumps with randomly oriented pellets help in interpreting shallow turbid water condition in the basin of deposition. Thus it appears reasonable to describe the origin of the pellets as a result of coagulation of clays from turbid water of the basin and deposited with the limestone. Differential aggradation of clays both during sedimentation and diagenetic stages resulted in variable sizes of the pellets.

The algal structures in the limestones with fossils and fossil fragments and the clastics indicate warm and shallow water conditions possibly littoral or shoal conditions, having intrabasinal barriers wich gave rise to contemporaneous deposit of Kolosh Clastic Formation, mainly composed of marls, siltstones and carbonaceous shales. The possibilities of contribution of clays and clastics from the provenance of Kolosh Clastic Formation due to fluctuation in depth of the depositional basin and the height of the intrabasinal barriers at the time of deposition of the two formations cannot be neglected. The intermixing of the sediments across the barriers due to fluctuations in the depth of depositional basins appears reasonable explanation in favour of the observation made during the present investigation.

Relative abundance of microfossils like nummulites, miliolids and less percentage of argillaceous matter in the upper part of Sinjar Limestone Formation indicates a period of relative stability in depositional basin with respect to turbidity and favourable ecological conditions for the growth of life in clear water. Corals are found in the lower part of Sinjar Limestone Formation where argillaceous matter, clastics and pellets are common. Fossils and fossil fragments are obliterated and replaced due to the processes of diagenesis. However, some of the fossils are preserved with internal structures and their characteristics but micritized.

The presence of micro-pellets with some degree of orientation in aragonite and calcite matrix is an indication of diagenetic changes in loose textured and moderately hard limestones. Calcareous intraclasts with pellets having obliterated outlines are good indications of diagenesis. Selective micritization in the fossil fragment further confirm to the differential effects of diagenesis. Micritization of ooids has resulted concentric internal structure pattern probably due calcareous and organo-argillaceous composition of the ooids.

The clastics and the ooids embedded in lithic and organic matrix show no effects of solution pressure but indicate highly porous texture of the limestones. The calcitic fragments irregularly distributed in the rock samples are present as angular or rounded grains and are probably the remains of fossil fragments subjected to diagenesis. The aggregate of recrystallized clastics and fossil fragments along with non-crystalline sediments of argillaceous nature indicate that the diagenetic forces were active on aragonitic components quite prominantly.

Sparry calcite fillings in micro-fossils and mud-feeding animals are the results of diagenesis in the limestones. The phosphatic limestones show pronounced effects of diagenesis in the matrix and not in the pellets probably due the presence of collophane and dahllite which are not very sensitive to the diagenetic forces.

Variable contents of acid insolubles in different beds of the Formation irrespective of thickness and top and bottom further support the hypothesis of fluctuation in the depositional basin and the barriers which gave rise to the lithosomes of Kolosh elastics and Sinjar Limestones. Likewise, variable Ca/Mg ratio in the beds of Sinjar Limestone is also an indication of periodic changes in the geochemical and tectonic conditions mainly of epirogenic origin during deposition.

The absence of facies like Aaliji Limestone Formation and Jeddala Formation from the areas of present study further supports the hypothesis that the depositional basin trending northwest and southeast was having barriers and non uniformities with respect to depth conditions, energy conditions responsible for the supply of clastics and the rate of subsidence of Zagros Basin in which contemporaneous formations of different lithologic characteristics were deposited. The reasons could also be attributed to the tectonic frame work of this region during Upper Cretaceous, Paleocene and Miocene ages, beeause during these periods the regions was facing uplift from the north-east and sinking of the basin in the south-west along the margin of the Arabian shield which resulted the present Zagros Mountains (SAMIMI, 1977). The active slow subduction of the Arabian Shield along the northwest and southeast margins of the Zagros Mountains and the presence of Arabian Gulf as a remain of Zagros Basin are satisfactory proves to confirm the above arguments.

In view of the characteristics observable in the rocks of the Formation, it appears reasonable to conclude that there were at least five phases of sedimentation with varying physico-chemical conditions. These phases of sedimentation from bottom to top of the Formation were *i)* deposition of sugary limestone with very little percentage of fossils, *ii)* deposition of phosphatic beds, *iii)* deposition of non-phosphatic clastic limestones with fossils, *iv)* deposition of phosphatic beds, *v)* deposition of highly fossiliferous limestones.

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