Mineralogy and Petrography of Marl Sediments Within the Fat`ha Formation in Selected Parts of Northern Iraq

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ABSTRACT

X-ray diffraction analyses and petrographic study of marl samples belonging to the Al-Fat`ha Formation (Middle Miocene) from four selected localities in northern Iraq, revealed the presence of the minerals, carbonates (calcite and dolomite), quartz, plagioclase feldspars and the clay minerals illite, chlorite, kaolinite and montmorillonite. The origin and diagenesis of the non clay and clay minerals are discussed. Clay minerals, fossil contents and associated evaporite sediments revealed that the environment of deposition of marl sediments at the studied localities were hyper-saline and semi-arid marine lagoonal environment.

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INTRODUCTION

The studied area is situated in the northern part of Iraq and includes four localities belonging to the Fat`ha Formation (Middle Miocene) (Fig. 1).

Three of the localities (Makhmur, Shaikhan and Shaikh Ibrahim) are natural exposures while the fourth (Mishraq) consists of bore hole cores. The lithology consists of alternations, in cyclic fashion of marls, carbonates and gypsum. A total number of (32) samples were collected from the four localities (Fig.2).

The purpose of this work is to study the mineralogy, petrography and fossil contents of marl at the four localities. To use the results of the study for the establishment of the

origin and diagenesis of the non-clay and clay minerals and the environment of deposition of marl sediments.

MINERALOGY

In order to identify the mineral phases of marl samples of the studied localities, thin sections and X-ray diffraction analyses were carried out. Thin section studies were useful for the non-clay fraction, which mainly consists of carbonates and quartz. X-ray diffraction analyses were used for the identification of the clay minerals as well as the non-clay minerals.

THIN SECTION EXAMINATIONS

A total number of sixteen representative thin sections (four from each locality) were made and examined under the polarizing microscope.

The samples exhibited similar texture, which essentially consists of detrital rock fragments (porphyroblasts) embedded in a matrix of very fine grained clay minerals.

There are some variations between the localities in the amount and/or the size of rock fragments. They consist of carbonate (mainly calcite), quartz, chert, and plagioclase feldspars. There are also small amounts of chlorite flakes, metamorphic rock fragments (serpentinites) and some heavy minerals like zircon and tourmaline. The size of the fragments ranges from (0.01) to (0.2) mm. Hematite mixed with matrix, causing the pegmentation of red marl samples is very common.

Carbonate Minerals:

Carbonate minerals are of three types: detrital carbonates which are the most dominant; consisting of calcite, then chemical carbonates and thirdly carbonates of microfossil remains.

Detrital carbonates are very common in Shaikh Ibrahim and Shaikhan marl samples (Plates 1, 2, 3). They are rounded to subrounded grains exhibiting the
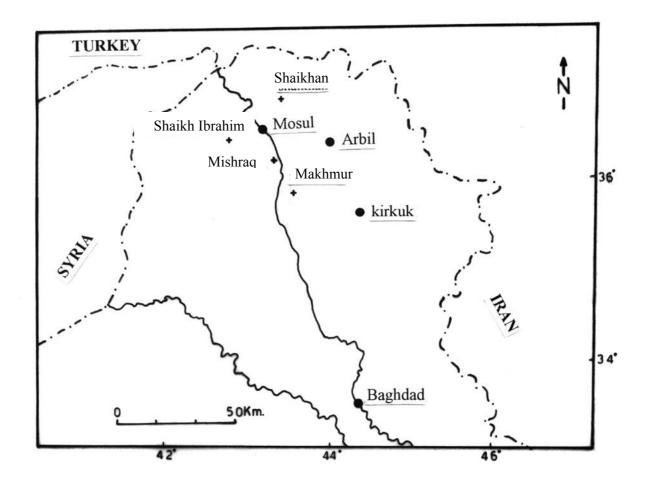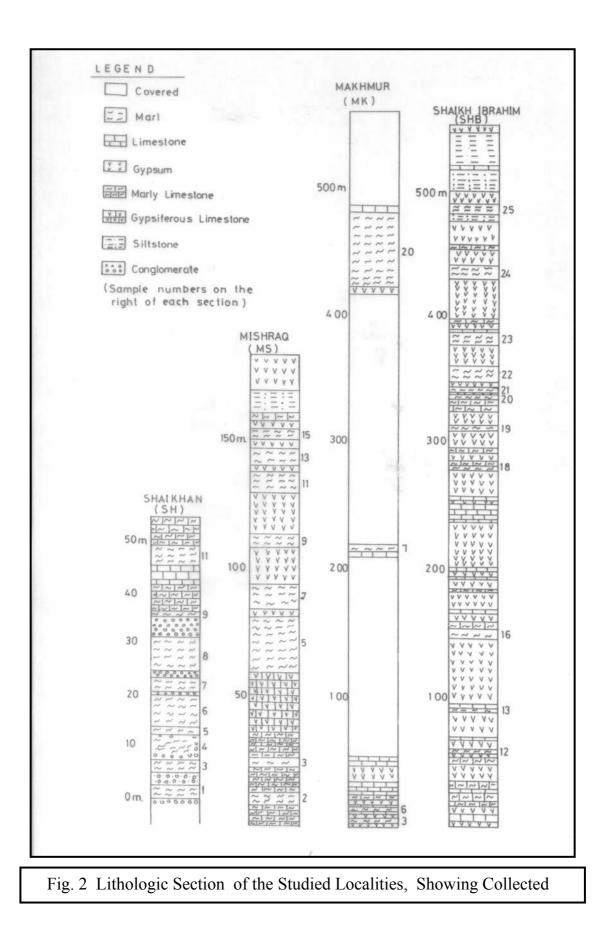
Figure (1) : The Studied Localities (+).

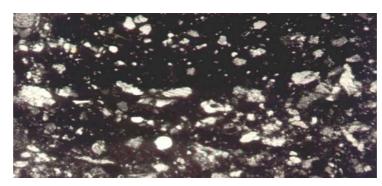Fig. 2 Lithologic Section of the Studied Localities, Showing Collected

Plate 1 : Carbonate and Quartz fragments, Carbonate
fragment in centre exhibits lamellar Twinnig
Sample: SH-8 x 100 crossed Nicols

Plate 2 : Quartz Grains Showing Reaction Rims (centre)
Bitumen (Small black spots) is very common
Sample: MS-15 x 100 crossed Nicls

Plate 3 : Plagioclase Feldspars (centre) with Lamellar
twinning and Reaction Rim.
Sample: MS-15 x 100 crossed Nicols

extreme interference colours characteristic of carbonates. Some of the grains have repeated or lamellar twinning similar to that in plagioclase feldspars, but the latter have low interference colours.

Carbonate grains are most likely to be calcite since dolomite, which is very similar to calcite, under the microscope, can not be detrital.

Quartz:

Quartz is very common detrital mineral in all the samples. It occurs in an irregular to subrounded grains, characterized by their lack of cleavage, low interference colours and wavy or complete extinction (Plates 1&2).

Some grains contain very fine inclusions (probably magnetite or titanite) which have random orientation, indicating that they are of igneous origin (Pettijohn, 1957). Also, some grains show reaction rims, due to replacement of silica by carbonate (Plate 2).

Plagioclase feldspars:

These fragments are much less abundant than carbonates. They are subhedral to angular in shape, indicating their detrital origin. They exhibit the very distinctive repeated or lamellar twinning (Plate 3).

Some show alteration to kaolinite, others look quite fresh. The plagioclase feldspars are also surrounded by reaction rims, that is they show alteration to carbonates around the edges (Plate 3).

X-RAY DIFFRACTION ANALYSIS

A Phillips (PW 1390) X-ray diffraction spectrometer, at the Geology Department, College of Science, University of Mosul, was used for the determination of mineral phases.

X-ray diffraction analysis confirmed thin section studies and revealed the presence of the following non-clay minerals (calcite, quartz and plagioclase feldspars). The original powder (bulk sample) was used to determine carbonates and quartz.

Dolomite was also identified by X-ray diffraction, but not in thin sections as detrital fragment. Hence, it must be restricted to the matrix, in the form of very fine grain crystals, of the studied samples. Overall mineralogical analysis proved that all the studied samples fall within Pettijohn (1957) definition of marl (clay minerals and quartz more than 35%. Carbonate fraction less than 65%).

The relative proportion of each non-clay mineral (carbonates and quartz) at each locality , measured from peak heights (Fig.3) is as follows:

Calcite: Makhmur > Shaikh Ibrahim > Shaikhan > Mishraq.
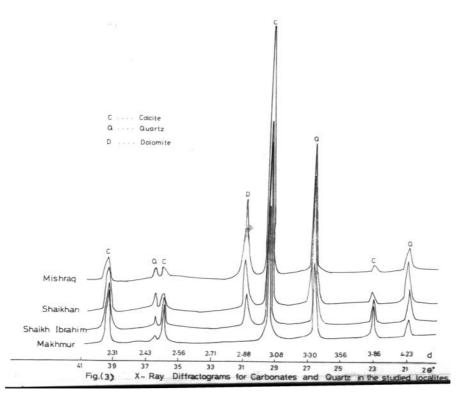Dolomite: Mishraq > Shaikhan > Shaikh Ibrahim > Makhmur.

Fig 3: X-Ray Diffracograms for Carbonates and Quartz in the Studied localities.

Thus, there is an inverse relationship between calcite and dolomite, indicating that dolomite (dolomitization) forms at the expence of calcite.

Quartz: Shaikh Ibrahim and Shaikhan (almost equal amounts)>Mishraq > Makhmur.

Plagioclase feldspars appear with the clay minerals fraction (oriented samples) at a small peak (2θ) of about (28˚) (d-3.20 Å) (Fig.4).

For the identification of clay minerals, oriented samples were treated with ethylene glycol (glycolation) (for the identification of montmorillonite), heated to (350˚) (also for the identification of montmorillonite) and further heated to (550˚)for distinguishing chlorite from kaolinite (Grim, 1968; Carroll, 1970; Millot, 1970). The details of the methods for the preparation of oriented samples, glycolation, heating and the analytical conditions of X-ray diffraction spectrometer, are given in Al-Kawaz (1980).

Peak heights (intensities) of the oriented, treated and heated samples show that illite is the most dominant clay mineral, followed by chlorite, montmorillonite and kaolinite (Fig.4).

FOSSIL CONTENTS

Some samples from Makhmur and Shaikh Ibrahim contain microfossils which include the foraminifera species *Rotalia* and *Ammonia*, and unidentifiable genera of Ostracods (Plates 4, 5 and 6) (Khalaf, 2002, personal communication).

It is interesting to note that Makhmur samples contained no dolomite (Fig.3) and the relative amount of dolomite in Shaikh Ibrahim is small. It is possible that fossil contents of other sections have been destroyed or obliterated by dolomitization.

ORIGIN AND DIAGENESIS OF NON-CLAY MINERALS

Carbonates:

From the examination of thin sections, carbonates appear to be of three origins: detrital, biogenic and chemical.

Detrital carbonate fragments constitute a significant proportions of the non-clay minerals in some sections (e.g. at Shaikhan, Plate 1). These fragments must have been derived from pre-existing sedimentary rocks (shales or limestones) that is they have been recycled. They are most likely to be calcite, since dolomite is relatively unstable and can not survive transportation.

The biogenic carbonate fraction constitutes the shells (the hard part) of microfossils. The microfossils (Ostracods and Forams) have only been found in Makhmur and Shaikh Ibrahim samples. The absence of fossils from other localities may be due to dolomitization.

The chemical carbonate fraction consists of calcite and dolomite. It represents that fraction which was deposited directly from solution due to the increase of the carbonate ion concentrations (Mg and Ca ions).
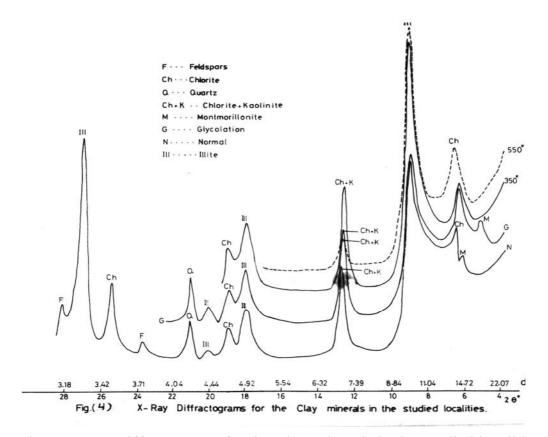

Fig.(4)   X– Ray Diffractograms for the Clay minerals in the studied localities.

Fig 4: X-Ray Diffracograms for the Clay Minerais in the Studied localities.
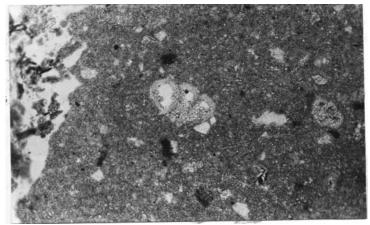
Plate (4)

Plate 5

Plate 4 and 5 : Foraminiferal Species Belonging to Either <u>Rotalia</u> or <u>Ammonia</u>.

Plate 6 : An ostracod genus Sample: SHB-17 x 100 ppl

It is evident from X-ray diffraction analyses that dolomite is restricted to the matrix, replacing calcite.

Some of the precipitated calcite was quickly dolomitized by Mg ions. Calcite could also be dolomitized during burial diagenesis by Mg-rich pore-waters (Aljubouri, 1972).

The extent of dolomitization depends on the relative concentrations of Mg ions. For example Mishraq samples, which have the highest Mg/Ca ratio of 0.53 (Al-Kawaz, 1980), are relatively more extensively dolomitized than samples from the other three localities. Dolomitization is perhaps responsible for the absence of fossils from Mishraq and Shaikhan.

Hematite, Quartz and Feldspars:

Detrital hematite was formed in the weathering zone (possibly Taurus Zagros mountains) from breakdown of mafic minerals under strongly oxidizing environments (Robb, 1949; Grim, 1951, Flores, 1990). It was transported to the basin of deposition as thin coatings on clay minerals and quartz grains (Carroll, 1958) or in colloidal solution. The only diagenetic changes were the reduction to the ferrous state in reducing environments in the presence of organic matter such as bitumen as in Mishraq, resulting in the change of colour from red or brown to green marl.

Quartz is usually the result of physical (disintegration) weathering of granitic rocks (Butler, 1953, 1954) or of any quartz-rich rock. It is relatively very stable mineral. The only observable diagenetic change in the present study is the replacement by chemical carbonate around the edge (reaction rims). This replacement is likely to be due to local change in the pH of the solution towards alkaline, where silica is unstable (Mason, 1966, p.167).

Plagioclase feldspars may have been derived from an igneous rock body. Symmetrical extinction angle measured on few possible grains gave a range of 14˚ to 19˚, which places the feldspars within oligoclase range (Kerr, 1959, p.258). This means that the feldspars were originally derived from granitic (acidic) igneous rock. The absence of orthoclase is probably due to alteration, i.e. breakdown to kaolinite and mica. Plagioclase feldspars are much less susceptible to alteration than orthoclase.

Diagenesis of plagioclase feldspars was mainly their replacement by carbonate around the edges (reaction rims) and their partial alteration to kaolinite and mica.

It is quite possible that haematite, quartz and feldspars of the present study were partly derived from pre-existing sedimentary rocks of similar composition (shales) to the present day marl sediments, or acidic igneous rock.

ORIGIN AND DIAGENESIS OF CLAY MINERALS

The important and common clay minerals in argillaceous rocks, illite, chlorite, montmorillonite and kaolinite are known mostly to occur as detrital (terrigenous) in origin. That is they are usually produced in the weathering zone of the parent rock and subsequently transported by wind, rivers or torrential rains to the area of deposition (Grim, 1953; Degens, 1965; Aljubouri, 1972, Walgenwitz, 1990).

Authigenic (i.e. in-situ formation or diagenetic) origin of all these minerals can not be ruled out but this origin usually plays a minor part in the production of these clay minerals (Burst, 1959; Hawkes and Webb, 1962; Berner, 1971).

It is envisaged that in the weathering zone, which leads to the formation of the clay minerals illite, chlorite and montmorillonite, leaching was kept to minimum by the dry-arid climate and by the absence of plants, which in the presence of water would produce strongly leaching acids. It was such an environment rather than a common source rock, produced the important detrital clay minerals (illite, chlorite and montmorillonite) in the marl sediments of the Fat`ha Formation.

A considerable proportion of detrital chlorite and illite is in the degraded form when reaching the basin of deposition. The degraded minerals would quickly adsorb the available K^+ and Mg^{2+} from solution and balance their structure. Both detrital illite and chlorite undergo no further diagenetic changes and in fact become more and more abundant as diagenesis proceeds, since other clay minerals convert to chlorite and illite (Dunoyer de Segonzac, 1970).

Montmorillonite becomes unstable under burial diagenesis, it undergoes progressive transformation by aggradation. According to Dunoyer (1970) aggradation of montmorillonite can follow two paths: (a) Dehydration and adsorption of Na^+ and K^+ ions produces illite through the mixed layer mineral rectorite and (b) Dehydration and adsorption of Mg^{2+} ions produces chlorite via the mixed layer corrensite. The cations Na, K and Mg are derived from the pore solution.

Kaolinite, on the other hand, requires neutral to acid environments, with strong leaching, i.e. with the removal of the major cations Ca^{2+}, Mg^{2+}, Na^+, K^+ and Fe^{2+} and the addition of H^+ (Degens, 1965). Kaolinite therefore can not be formed under the same environments as illite, chlorite and montmorillonite.

It is likely that kaolinite either formed in different environments from the other clay minerals, but from the same source area or it is of authigenic (diagenetic) origin; i.e. it was produced in the basin of deposition much after the arrival of the detrital clay minerals illite, chlorite and montmorillonite. Alternatively, kaolinite may have been derived from kaolinite-bearing sedimentary rocks.

Diagenetic kaolinite may be produced from the alteration of feldspars in the sediments. In the present study plagioclase feldspars which show signs of alteration to kaolinite were found in all marl sediments of the studied localities (Plate 3).

ENVIRONMENTS OF DEPOSITION OF MARL SEDIMENTS

The use of clay minerals as indicator of environments of deposition is a controversial subject. For example Weaver (1958) concluded that any of the major clay minerals can occur in abundance in any of the major depositional environments and there is no consistence between specific clay mineral and specific environment.

On the other hand, an increasing number of workers tend to belive that clay minerals can be used for the evaluation of environments of deposition. In the present study, this concept is considered appropriate.

Grim (1968) suggested that saline lake or marine environments which are alkaline, rich in Ca^{2+} and Mg^{2+} would favour the formation and conservation of illite, chlorite and montmorillonite. These detrital clay minerals brought into saline lake or marine environments, would as Grim put it ″be at home″ and undergo no degradation (break down)in their structure.

When fossils are used as environment indicators, it is not possible to use the ostracods since the generic identification was not possible. The foraminiferal genera *Rotalia* and *Ammonia* are known to inhabit brackish water (hyposaline) with salinity of less than 32‰. to hypersaline environments with salinity of more than 37‰. The depth is between (0-50) meters (shallow water) and the temperature is between (15-20° C) (warm water) (Ahmad, 1980, p.129).

Detailed studies of evaporites (mainly Gypsum) of the Fat`ha Formation (Sulayman, 1990; Aljubouri, 1993; Aljubouri and Sulayman, 1996) which are associated

with marls and carbonates in a rhythmic or cyclic deposition, may give a good indication for the environment of deposition of marl sediments. Hence, it may be concluded that marl sediments of the studied localities were deposited under hypersaline, semi-arid, marine and lagoonal environment.

CONCLUSIONS

1- Petrographic and X-ray diffraction studies revealed that marl sediments of Fat`ha Formation (Middle Miocene) of the studied localities, consist of quartz, carbonates (calcite and dolomite) and the clay minerals illite, chlorite, montmorillonite and kaolinite with minor amounts of plagioclase feldspars.

2- Thin section examinations showed that carbonates are of three origins: detrital, biogenic and chemical. Detrital carbonate is mainly calcite. Biogenic carbonate is represented by the shells (the hard parts) of fossils. Chemical carbonate consists of calcite and dolomite which is restricted to the matrix.

3- Illite and chlorite become more stable and more abundant, while montmorillonite becomes unstable, under burial diagenesis. Montmorillonite either converts to illite through dehydration and adsorption of Na^+ and K^+ ions, or converts to chlorite through dehydration and adsorption of Mg^{2+} ions.

4- Marl sediments of Fat`ha Formation of the studied localities were deposited under hypersaline, semi-arid, marine and lagoonal environment.

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