Paleoenvironmental Indicators of Clay Minerals in Miocene Sediments, Northern Iraq

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ABSTRACT

Clay mineralogy of the Miocene successions taken from northern Iraq constitute an important paleoenvironmental indication for the evolution of these sediments. Palygorskite is a common mineral especially in the lower Miocene sediments of Euphrates formation and the upper detrital part of the Fat'ha Formation belonging to the middle Miocene. Scanning Electron Microscope (SEM) study indicated that this mineral, was formed authigenically by neoformation in suitable chemical conditions within the evaporitic environments. Other minerals (kaoloinite and illite) have been most probable formed in detrital system and were preserved in those evaporitic conditions. Common kaolinites in the Injana clastic Formation (Upper Miocene) as well as its habit in SEM images are indicators for its detrital origin in such continental sediments.

Words: Clay Mineralogys, Miocene Sediments, Palygorskite, Kaolinite.

الدلائل البيئية القديمة للمعادن الطينية في ترسبات الميوسين شمال العراق

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الملخص

إن لدراسة المعادن الطينية في تتابعات الميوسين في شمال العراق أهمية كبيرة في معرفـة البيئـة الترسيبية القديمة، وأثرها في تطور ترسيب هذه الترسبات. يمتاز معدن الباليغورسـكيت بكونـه الأكثـر شيوعا ولاسيما في ترسبات الميوسين الأسفل لتكوين الفرات والجزء الفتاتي العلوي لتكوين الفتحة مـن الميوسين الأوسط. أظهرت نتائج دراسة المجهر الماسح الالكتروني لأشكال هذا المعدن بنشأته موضـعياً عند توافر الظروف الكيميائية المناسبة له في البيئات التبخرية. أما بقية المعادن (الكاؤولينيت والاليـت) فقد تكونت على الأرجح من أصل فتاتي وحفظت ضمن تلك البيئات. يمتاز الكاؤولينيت الأكثر شيوعاً ضمن فتاتيات تكوين إنجانه من الميوسين الأعلى بوجوده ضمن أشكال سداسية منتظمة ممـا يعكـس الأصـل الفتاتي ضمن تلك الرواسب القارية الأصل.

الكلمات المفتاحية: المعادن الطينية، ترسبات الميوسين، الباليغورسكيت، الكاؤلينيت.

Introduction

Clay minerals and their relative abundance may record information on climate, eustasy, burial diagenesis, or reworking.

Distribution of clay minerals in sediments is affected by the detrital input to the sedimentary basin. Mica, chlorite, associated quartz and feldspars constitute typically of terrigenous species (Chamley, 1989). These clay minerals develop generally in areas of steep relief active Mechanical erosion limits soil formation, particularly during periods of enhanced tectonic activity (Millot, 1970).

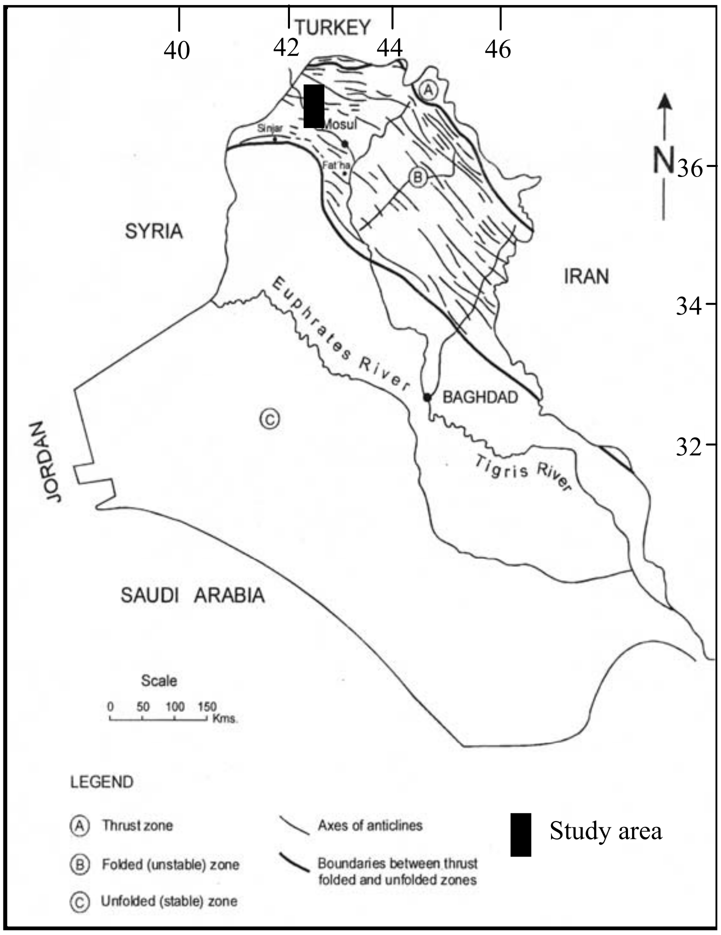
The Miocene sedimentation of northern Iraq is characterized by the marine nature and was started by deposition of Early Miocene carbonates and evaporates of Serikagni, Euphrates, Dhiban and Jeribe formations within shallow epicontinental seas and lagoons in marginal basins. Marine conditions became progressively more restricted, with many small seas and lagoons sporadically replenished with normal marine water. These gave rise to the shallowing-upward cyclic deposition of evaporites in Middle Miocene (Lower Fars, Fat'ha Formation), (Numan, 1997). In the marginal parts of Fat'ha basin the clastics dominate and are represented by fine sandstones and silty claystones occupying the upper two-thirds of the sequence of the upper unit of the formation and characterized by red coloration. These clastics were interpreted to be deposited in fluvial –dominated deltaic system (Al-Naqib and Aghwan 1993; Al-Juboury et al. 2001).

The deposition of fluviatile Injana (Upper Fras) Formation in the foreland basin of Iraq in the Upper Miocene marked the end of marine conditions in northern Iraq. This formation is a clastic sequence of medium to coarse sandstones, siltstones and claystones and deposited in fluvial- tidal environment (Al-Banna, 1982; Al-Juboury, 1994).

The studied Miocene sediments representing the Euphrates (Lower Miocene), Fatha (Middle Miocene) and Injana (Upper Miocene) formations were selected from northern Iraq to study their clay mineral contents in order to give an idea about the paleoenvironmental aspects of these clay minerals on the evolution of these important successions of formations in northern Iraq.

Geological Setting

The regional geology of northern Iraq consists of the Zagros mountains Range with an NW-SE structural trend in the northeastern part, and Taurus mountain Range with an E-W structural trend in the north and northwestern parts. The structural framework of Iraq was divided by Bolton (1958) into Thrust Zone, Folded Zone and Unfolded Zone (Figure, 1).



Figure(1) Tripartite tectonic subdivision of Iraq (Modified after Bolton, 1958).

The folded zone contains three tectonic zones which are, from west to east: the Mesopotamian zone (Quaternary molasses and buried structures), the Foothill zone (Neogene molasses and long anticlinal structures separated by broad synclinals), and High Folded zone (Paleogene molasses and harmonic folded structures). These longitudinal tectonic zones are segmented into blocks bounded by ENE-WSW (shifting to NE-SW) transverse faults with both vertical and horizontal displacement (Jassim et al., 1999). The transverse blocks have been active, at least, since the late Cretaceous and greatly affected the sedimentary facies of the Cretaceous and Tertiary sequences (Numan, 1997).

Stratigraphy

The stratigraphy of Iraq is strongly affected by the structural position of the country within the main geostructural units of the Middle East region as well as by the structure of the country itself. Iraq lies in the border area between the major Phanerozoic units of the Middle East, i.e., [between the Arabian part of the African Platform (Nubio-Arabian)] and the Asian branches of the Alpine tectonic belt. The platform part of the Iraqi territory is divided into two basic units, i.e., a stable and an unstable shelf. The stable shelf is characterised by a relatively thin sedimentary cover and the lack of significant folding. The unstable shelf has a thick and folded sedimentary cover and the intensity of the folding increases toward the northeast (Buday, 1980).

Euphrate Formation of (lower Miocene to early middle Miocene) and is composed of shelly, chalky, well bedded recrystallized limestones. Marl beds are interlaminated between the carbonate beds throughout the formation (Bellen, et al., 1959).

Litho- and biostratigraphic distribution may reflect an environment ranging from reef to back- reef into shallow shelf lagoon and the adjacent plateform deposition for the Euphrates Formation.

The Fat'ha Formation was deposited in a cyclic fashion of marl, limestone and gypsum (Bellen et al. 1959). Detrital sediments such as sandstones and siltstones persist within its upper member. In addition, thickly bedded alteration of nodular gypsum and marl are dominant as well as the frequent presence of red and reddish brown to green marl within the upper member. The clastic – nonclastic ratio increases radically within each individual cycle as the formation goes younger (Al-Naqib and Aghwan, 1993).

Injana Formation is basically a clastic sequence that consists of fining upwards cyclothems of carbonate-rich sandstones, siltstones and marlstones. The main geological formations of northern Iraq are illustrated in Figure (2).

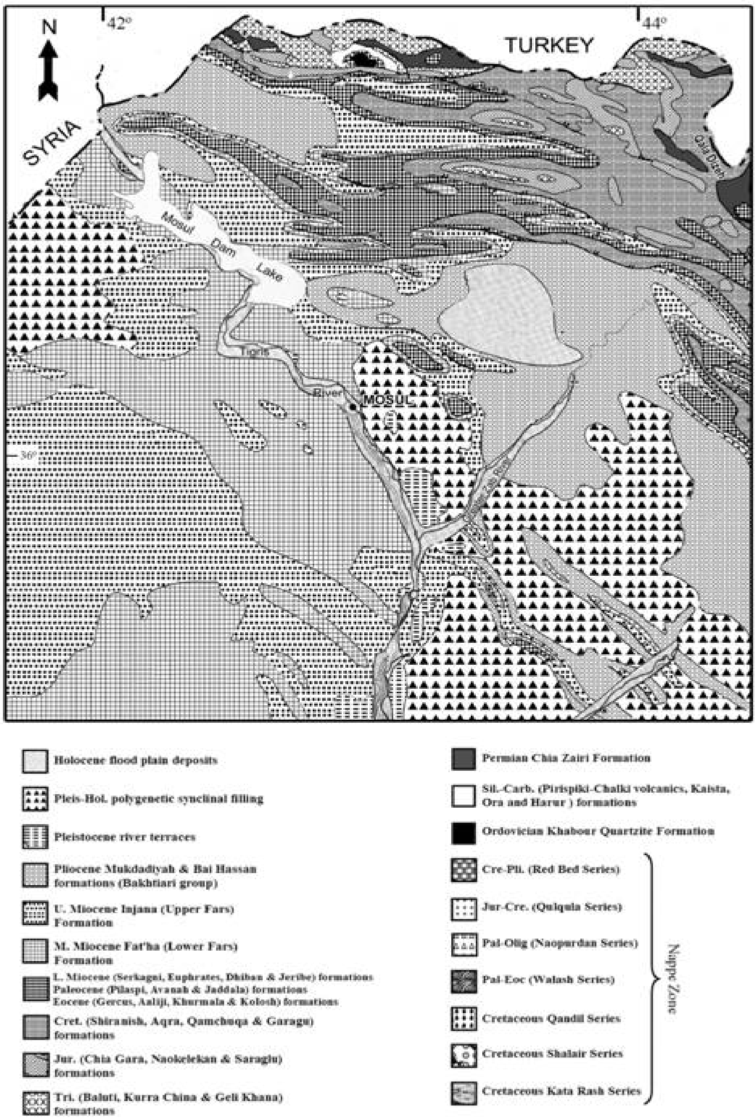


Figure (2) Geological map of northern Iraq showing the geologic formations of the Ordovician to Recent (modified from the Geological map of Iraq, 1986).

Marine conditions became progressively more detached with plenty of lagoons that occasionally replenished with sea water and gave rise to the cyclic deposition of the evaporites of the Fat'ha Formation in the Middle Miocene. Deposition on the platform ceased after the early Miocene. The deposition of fluviatile Injana Formation (formerly Upper Fars Formation, Al-Rawi, *et al.,* 1993).

Structurally, the area of study lies in the foreland basin in the late Miocene marked the end of marine conditions in Iraq and molasses deposition prevailed from this time onwards.

Methodology

The clay fraction of different rock types was concentrated before they are analyzed by x-ray diffractometry techniques. Samples were dissociated in water, then calcium carbonates was removed in 1/5 N hydrochloric acid. The fraction smaller than 2µm was decanted according to Stock's law and oriented pastes were made on glass slides. A Philips PW 1130 diffractometer (Ni-filter, Cu k α radiation) was used to make the x-ray diffraction scans at 2Ø°/ min. on air-dried, glycolated and heated samples. The semiquantitative evaluation is based on peak heights and areas according to the method of Biscay (1965). SEM analysis was performed using Cam Scan MV 2300 at the Paleontological Institute, Bonn University, Germany.

Results

Clay minerals separated from the marl beds of the Euphrates Formation reveals that palygorskite is the most abundant clay mineral followed by trace amounts of illite, chlorite and kaolinite. The main types of clay minerals which were found in the clastics of the Fat'ha Formation include respectively palygorskite, illite, kaolinite and chlorite.

In the sediments of Injana Formation, the principal clay minerals present include; kaolinite, illite, palygorskite, chlorite and chlorite-smectite mixed layers, The X-ray diffractions pattern of the represented clay minerals are represented in Figure (3).

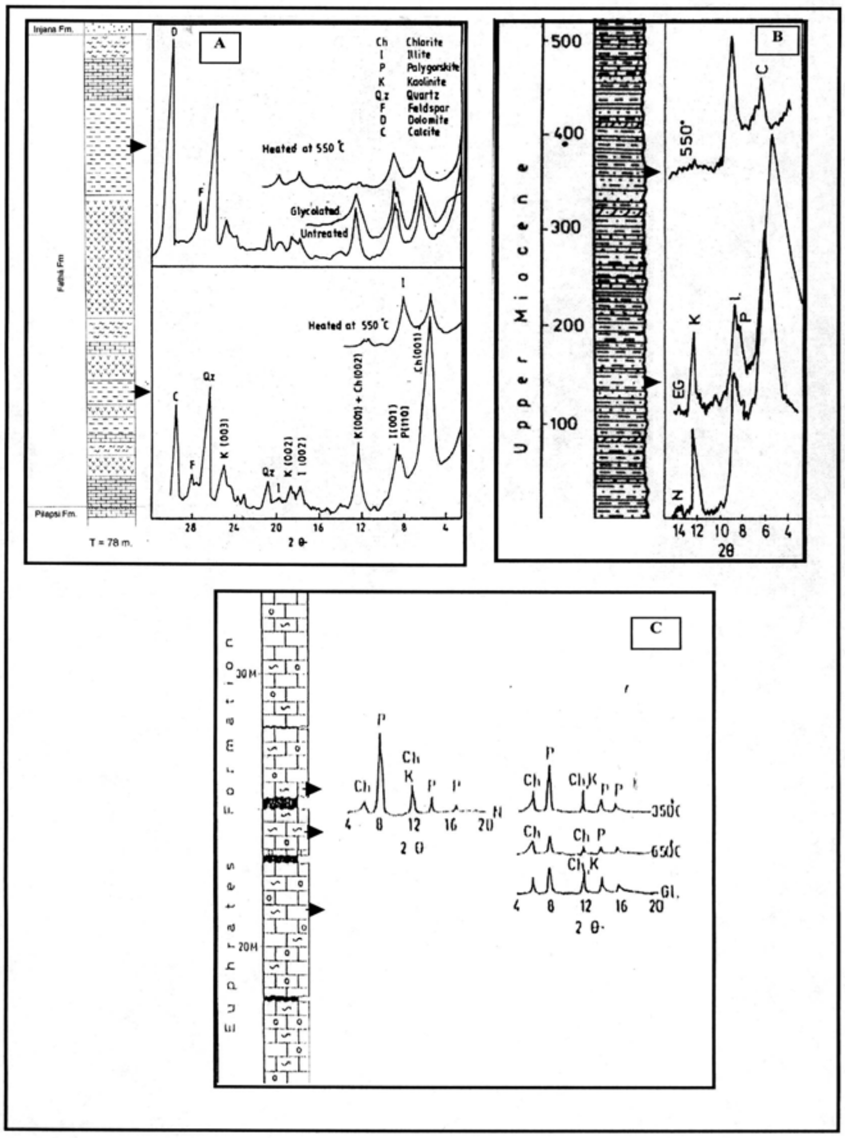


Figure (3) Representative X-ray diffraction patterns of the studied samples. (A) Fat'ha Formation; (B) Injana Formation; (C) Euphrates Formation. N=normal treated,EG= Ethylglycolated samples, 550º=heated to 550ºC, black arrows indicate sample locations.

Discussion and Conclusions

Palygorskite is a fibrous clay mineral and is commonly associated with dolomite and other Mg- rich minerals. Chamley (1989) has shown that palygorskite derives from chemical precipitation in evaporative basins. He summarized the conditions for palygorskite formation as "alkaline conditions in restricted basins subject to marine transgression, limited water exchange, warm and humidity, contrasted climate and strong evaporation". It seems that these conditions are suitable for the formation of palygorskite as neoformed clay mineral in restricted back-reef and lagoons of the marl beds of the Euphrates Formation. SEM photomicrographs show palygorskite as long and small fibers as well as in botroydal framboidal shapes indicating their authigenic source (Figures, 4 & 5A).

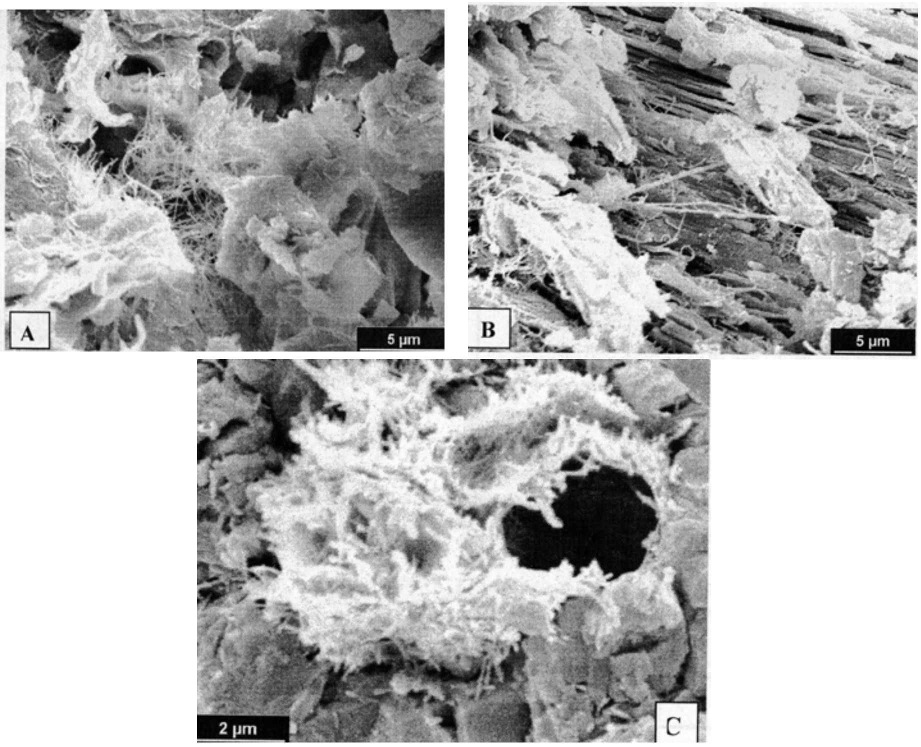


Figure (4). Scanning electron microphotographs showing; A, Palygorskite fibers and illite flakes; B, Long palygorskite fibers; C, Palygorskite fibers filling cavity.

Increased kaolinite contents in marine sediments resulted either from increased runoff, which could be caused by sea level falls, or from increased rainfall (Robert and Kennett, 1994). Scanning electron images show the well defined pseudo-hexagonal plates of the studied kaolinite especially those taken from the Injana continental samples (Figure 5B).

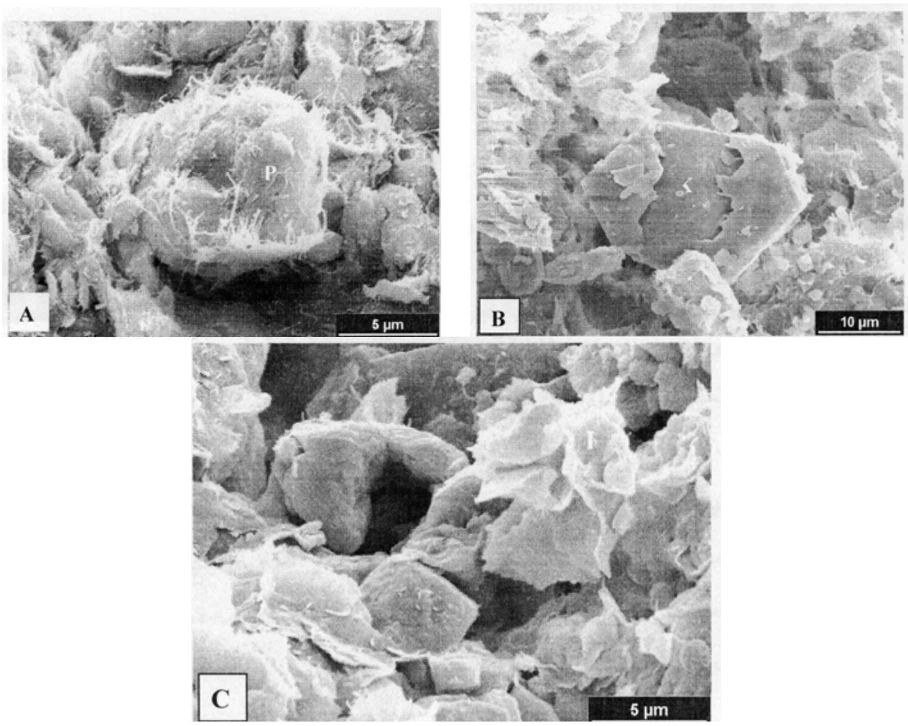


Figure (5): A, SEM images for A, Palygorskite framboidal shape (P); B, Kaolinite hexagonal flake (K); C, White illite flakes (I)as well as calcite and quartz grains.

Weaver (1960) stated that kaolinite is dominant in sediments of fluviatile environments, indicated environments of the Injana Formation and the upper clastic unit of Fat'ha Formation.

Illite is a common mineral in the studied samples. This mineral develops from the weathering of igneous rocks that are rich in potassium feldspars (Keller, 1970). Furthermore, Engelhardt (1977) has concluded that illite may be derived from reworked sedimentary rocks and from muscovites that sustain for many sedimentary cycles. These sediments may exist in the older Tertiary and Cretaceous successions from northern Iraq. The studied illites generally show illite as white flakes in carbonate cemented sandstones (Figure, 5C).

In conclusions, clay mineralogy of the studied Miocene successions gave an important indication for the paleoenvironmental aspects of these successions. It is believed that most of the clay minerals are detrital in origin, except palygorskite which is formed by authigenesis in evaporitic environments. Palygorskite is common in the Early Miocene Euphrates rocks and in the clastics of the upper unit of Fat'ha Formation. Marl beds of the Euphrates Formation were deposited in lagoonal, quite saline environment, a suitable one for the neoformation of palygorskite (Al-Juboury and Kassim, 1997). The upper clastic unit of Fat'ha Formation was deposited also in restricted, evaporitic lagoonal conditions which promote the authigenic formation of palygorskite (Al-Juboury et al. 2001). Other minerals are detrital in origin from the older successions and were preserved in the rocks.

Finally, I recommend to study the industrial importance of the clay minerals in Miocene clastics since they form an important mineralogical constituents of these successions.

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