CLAY MINERAL TYPING IN THE SHALE UNITS OF THE KAISTA AND ORA FORMATIONS OF North IRAQ: IMPLICATIONS FOR DEPOSITIONAL ENVIRONMENTS

S. H. Al-Hazaa
Asst. Prof.
Dept .Applied Geology, Coll. of Sci., Universityof, Tikrit Iraq
Email: sawsanalhazaa@yahoo.com

ABSTRACT

This paper reports the results of X-ray diffraction mineralogical and Scanning electron microscopic (SEM) studies of the shale units in the Devonian-early Carboniferous Kaista and Ora formations from northern Iraq. The mineral composition is uniform throughout the studied succession, kaolinite, illite, chlorite, and palygorskite form the main clay mineral assemblage while quartz, feldspar, calcite and dolomite form the non-clay fraction of the studied shales. Kaolinite dominates over illite in the Kaista shale, whereas, illite and chlorite with common palygorskite dominate over kaolinite in the Ora shale. The clay mineral assemblage is largely of detrital origin and indicates rather cool and/or dry climatic conditions favouring mechanical erosion of the source rocks. Palygorskite is of authigenic origin in evaporative conditions mostly in the subtidal Ora shales.

Keywords: Palygorskite, Kaolinite, Subtidal, Paleozoic succession, Kaista, Iraq

مجلة العلوم الزراعية العراقية -2018: 49(4):601- 610 الهزاع

انواع المعادن الطينية في وحدات السجيل لتكويني كاييستا و اورا من شمالي العراق : استعمالها في تفسير البيئة الترسيبية

سوسن حميد الهزاع

استاذ مساعد

قسم علوم الارض التطبيقية، كلية العلوم ، جامعة تكريت

Email:. Sawsanalhazaa@yahoo.com

المستخلص

يتناول هذا البحث التحليل باستخدام حيود الأشعة السينية والمجهر الماسح الالكتروني لوحدات السجيل من تكويني كاييستا و اورا (بعمر الديفوني –الكاربوني المبكر) من شمالي العراق .التركيب المعدني متماثل الى حد ما في التعاقب قيد الدراسة وتشكل معادن الكاوولينايت ، الالايت ، الكلورايت والباليكورسكايت المعادن الطينية الرئيسية بينما يشكل الكوارتز والفدسبار والكالسايت والدولومايت المعادن غير الطينية ضمن وحدات السجيل قيد الدراسة. يشيع وجود معدن الكاوولينايت قياسا الى اللايت في وحدات السجيل لتكوين كاييستا ، بينما يشيع معدني اللايت والكلورايت والباليكورسكايت قياسا الى معدن الكاوولينايت لوحدات السجيل لتكوين اورا. مجموعة المعادن الطينية هي على الاغلب فتاتية الاصل تعكس ظروف مناخ رطب قليلا او جاف والتي تؤثر في التجوية الميكانيكية لصخور الاصل بينما معدن الباليكورسكايت هو موضعي النشأة تكون في ظروف تبخرية ضمن البيئة تحت المدية البحرية لسجيل تكوين اورا

كلمات مفتاحية: الاشعة السينية، المعادن، الالايت، كلورايت.

***Received:18/2/2018, Accepted:14/5/2018**

INTRODUCTION

Clay minerals commonly are used as indicators of changing environmental conditions and recognition of sedimentary environments because of their high sensitivity to changes in the rock composition, temperature and pH values of their surroundings (19). Original clay mineralogy depends on climate, relief, lithology of the source area, tectonic activity, among other factors (12, 8). Clay mineralogy may be used as a valuable tool for untangling the environmental conditions coeval of deposition, but with care in interpretation of clay mineralogy due to the effect of burial on clay transformation (16,18). The extent of these transformations and involved processes depends on several factors; the facies characteristics and post-depositional evolution and the original clay mineralogy (5, 4). Under shallow burial or exposure, low pH meteoric water is capable of changing the clay mineralogy by a process of meteoric flushing (1). The extent of these mineralogical changes depends on the facies (e.g. grain size and mineralogy). Understanding of facies features and paleogeographic evalution is important to discern the relative influence of the above-mentioned factors in the study of clay types and their relation to depositional environment of geological successions. The Kaista and Ora formations belong to the Devonian-early Carboniferous cycle. This cycle represents a period of continuous deposition in subsiding basin with a wide geographic distribution extended from Ora area in extreme north Iraq to the extreme west of Iraq (2). The Kaista Formation is composed mostly of sandstones with minor shales and carbonates while the Ora Formation consists of marine shales and minor carbonates. The purpose of this paper is to interpret the variations in clay mineral assemblages in the shale successions of both Kaista and Ora formations from northern Iraq and their relationships to depositional system.

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 within Iraq. 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 (Figure 1). The stable shelf is characterized 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 [8]. In the Paleozoic, much of the region was covered intermittently by shallow epeiric seas that bordered lowlands made up of portions of the Nubio-Arabian shelf (9). The areal extent of the shelf seas change in response to succeeding transgressions and regressions as the Paleozoic era advanced and their setting varied between tropical and temperate latitudes of the southern hemisphere (10). The studied formations crop out in Kaista and Harur areas, near Chalky, Khabour Valley, and in the Geli Sinat and Derashish areas northwest of Shiranish, Amadia district of extreme northern Iraq (Figure 1). The studied formations forms the main Devonian-Carboniferous succession in Iraq both in subsurface and outcrop. Generally, these formations are composed of siliciclastic-carbonate facies. The Kaista Formation is of Late Devonian to Early Carboniferous age and represents the transition between the terrestrial deposition of the Pirispiki Formation (Early Devonian) and those of shallow-marine deposits of the Ora Formation. The formation consists of heterogeneous clastics of sandstones intercalated with siltstones and calcareous shale. The Ora Formation is characterized by its shale lithofacies that intercalates with few sandstone and siltstones and some dolomitized limestone.

MATERIALS AND METHODS

Ten samples were chosen from the shale units in both Kaista and Ora formations from the type section of the two formations at extreme northern Iraq (2 from Kaista S1-2K; and 8 from Ora S1-8 O, see Figures 1 and 2).

A representative portion of each sample is manually ground to a fine powder using a ceramic mortar and pestle. The powder was packed into a recessed plastic holder and preferred orientation was minimized. The samples were analysed using a Philips X-ray diffractometer (PW3710) scanning from 4º to 60º 2θ. The generator was controlled using Philips PC-APD software. Peak identification was enabled using PDF/ICCD database and quantification using Rietveld analysis using commercial programme Siroquant (Sietronics, Australia). Analysis done at laboratories of the department of Earth Sciences, Royal Holloway University of London. Scanning Electron Microscopic analysis (SEM) was performed using cam Scan MV 2300 at the Palaeontological Institute, Bonn University, Germany.

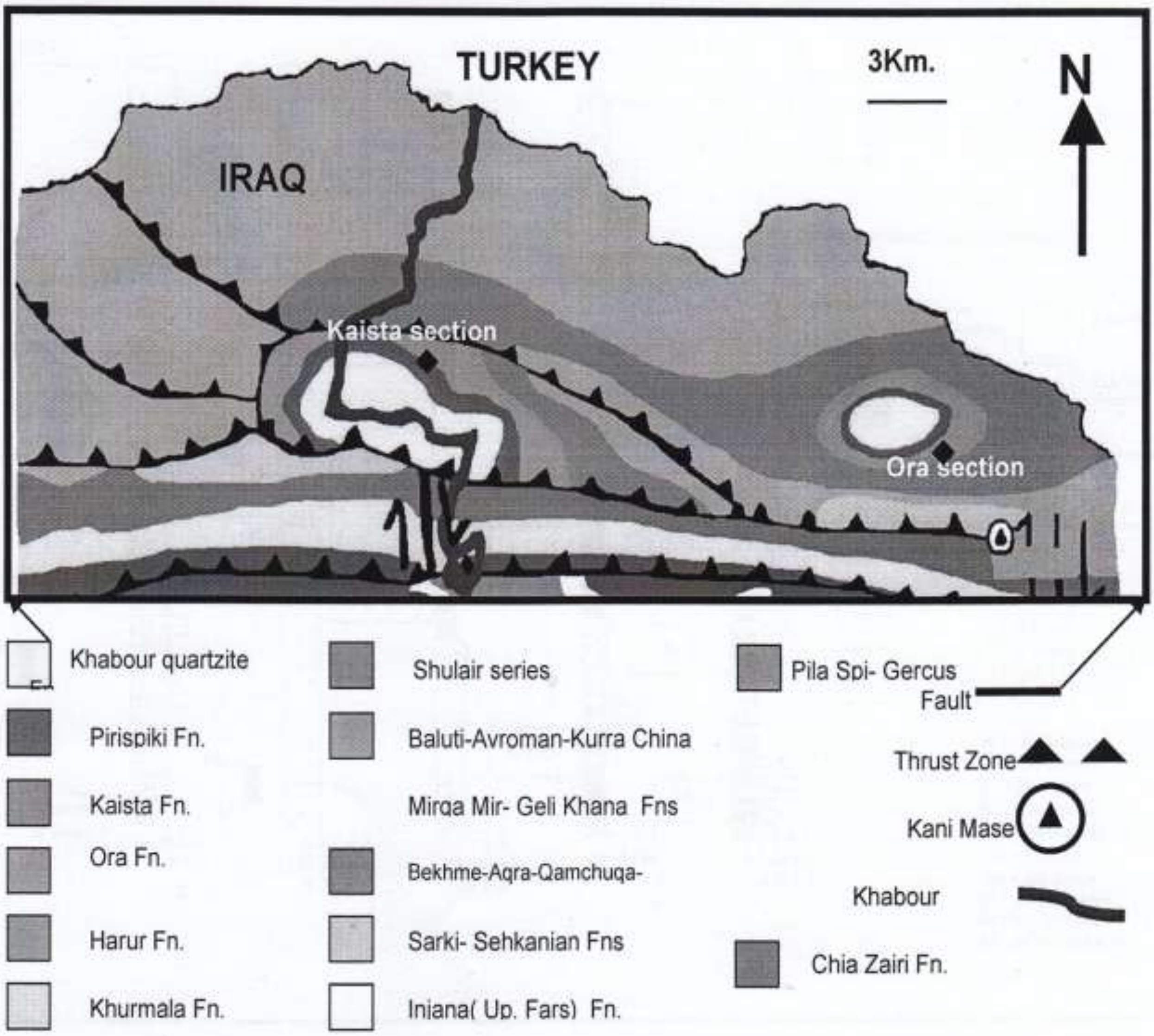


Figure 1. Geological map of the study area modified from Hassan et al. [10].

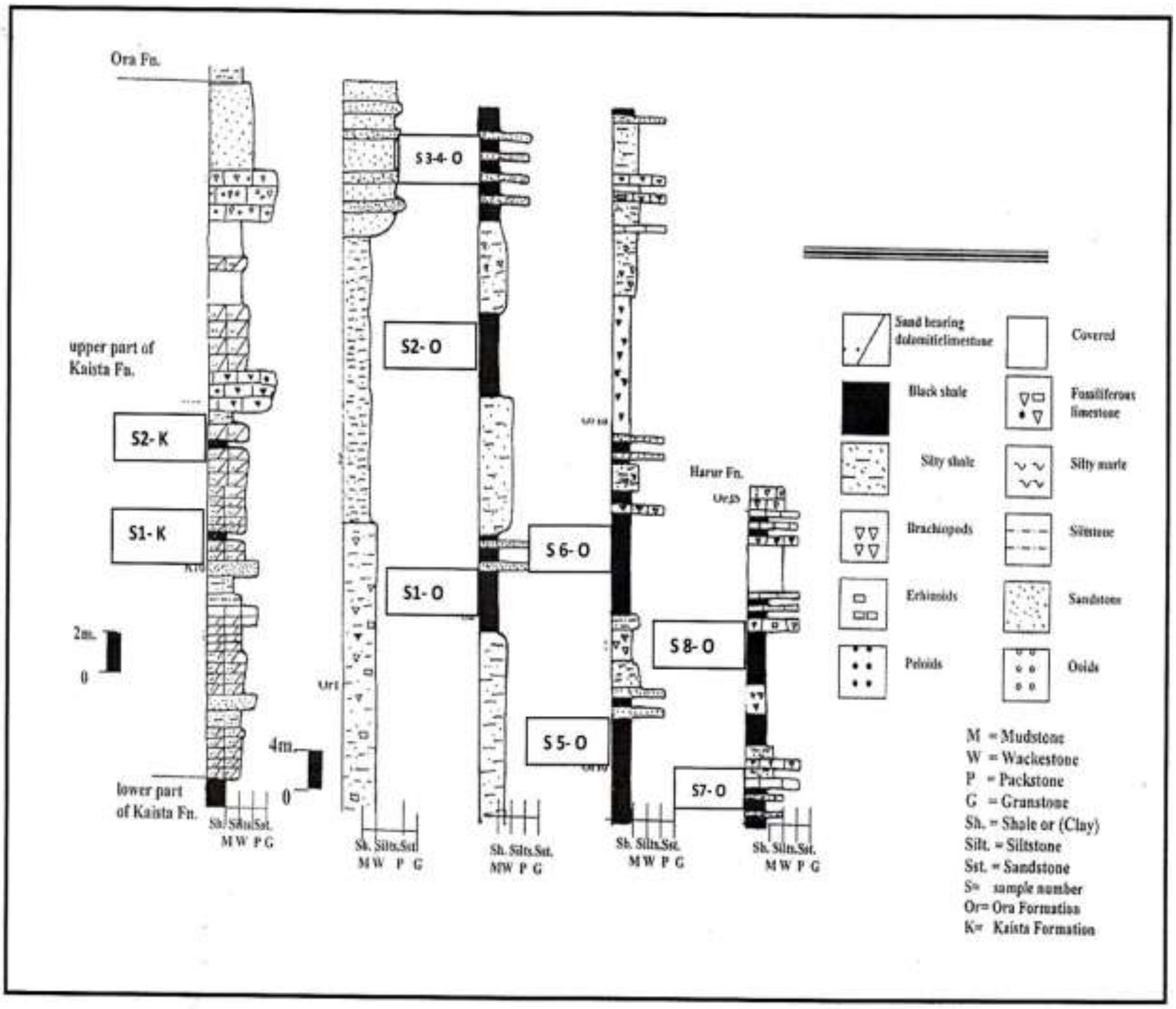


Figure 2. showing the stratigraphic section of the studied upper part of the Kaista Formation and the Ora Formation in Ora type section, Dohuk Governorate, North Iraq.

Petrology of the kaista ond ora formations

The Kaista Formation represents the transition between the continental-fluvial deposition of Pirispiki Formation and those of shallow-marine deposits of the Ora Formation. The formation consists of heterogeneous clastics of sandstones intercalated with siltstones and calcareous shale and occasional dolomitic limestone in the upper part. In their detailed study of the facies analysis and depositional environment of the Devonian to Carboniferous succession from northern Iraq, Al-Juboury and Al-Hadidy (2) have concluded that the clastic facies dominate the Kaista Formation and is represented mainly by sandstones and minor shales. Sandstones mostly are quartz arenites. The most likely source for the sediments are reworked materials from the older Ordovician Khabour and Devonian Pirispiki formations. The shale lithofacies intercalates with the sandstones and is composed of silty quartz grains as well as mica, pyrite and galuconite and occasionally contains thin dolomite laminae. The mixed fluvial-marine facies may indicates the estuary mouth sediments at the initial stages of transgression (2). The Ora Formation is characterized by its shale lithofacies that intercalates with subordinate sandstones, siltstones, and dolomitic units, and represents the transition between the mixed (fluvial-marine) clastics of the Kaista Formation and carbonates of the Harur Formation. Shale, sandstones and dolostones lithofacies form the main lithological constituents of the Ora Formation. Black fissile shale dominates and is partly changed into silty shale and partly dolomitized shale. Mica and pyrite are common with glauconite, sometimes dolomite fills cavities and fractures in the shale. Thin bedded dark grey sandstones are found as intercalations with shale and are represented by quartz arenites and micaceous silty sandstones. Some brachiopod fragments are found in the sandstones. Dolomite is found in aphanitic drusy mosaic texture with common crinoids (2). The shale, dolostones and sandstones units can be interpreted to be deposited in subtidal environment.

RESULTS AND DISCUSSION

1. X-ray diffraction mineralogical identification and interpretation

Several clay and non-clay minerals are identified in the studied shale units from both Kaista and Ora formations. Kaolinite and illite are the main clay minerals recognized in the Kaista shales in addition to non-clay minerals represented by quartz, calcite and dolomite (Figure 3)

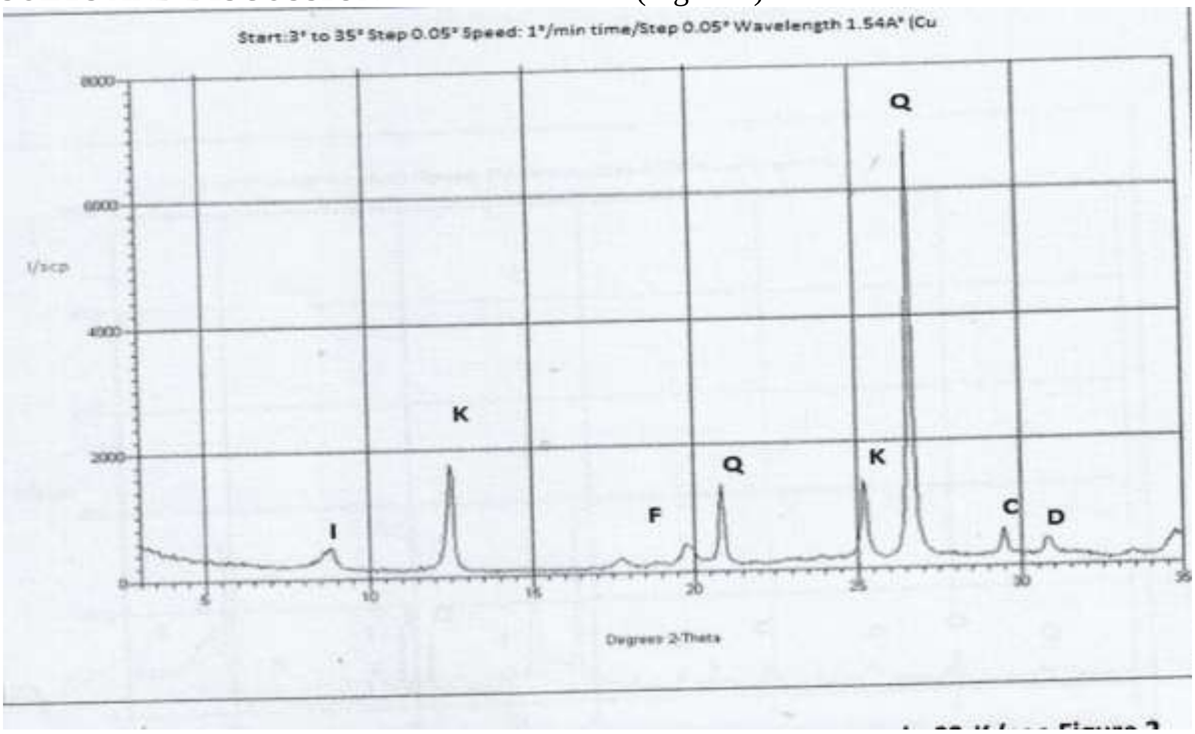


Figure 3. X-ray diffractogram of the shale from Kaista Formation, sample S2-K (see Figure 2 for location). K=Kaolinite, I=Illite, Q= Quartz, C= Calcite, D=Dolomite, F=Freldspar

In the Ora shale, illite, palygorskite,mixed layers montmorillonite chlorite dominated over kaolinite as clay minerals, whereas, quartz, feldspar and calcite are found as non-clay fraction (Figures 4 and 5).

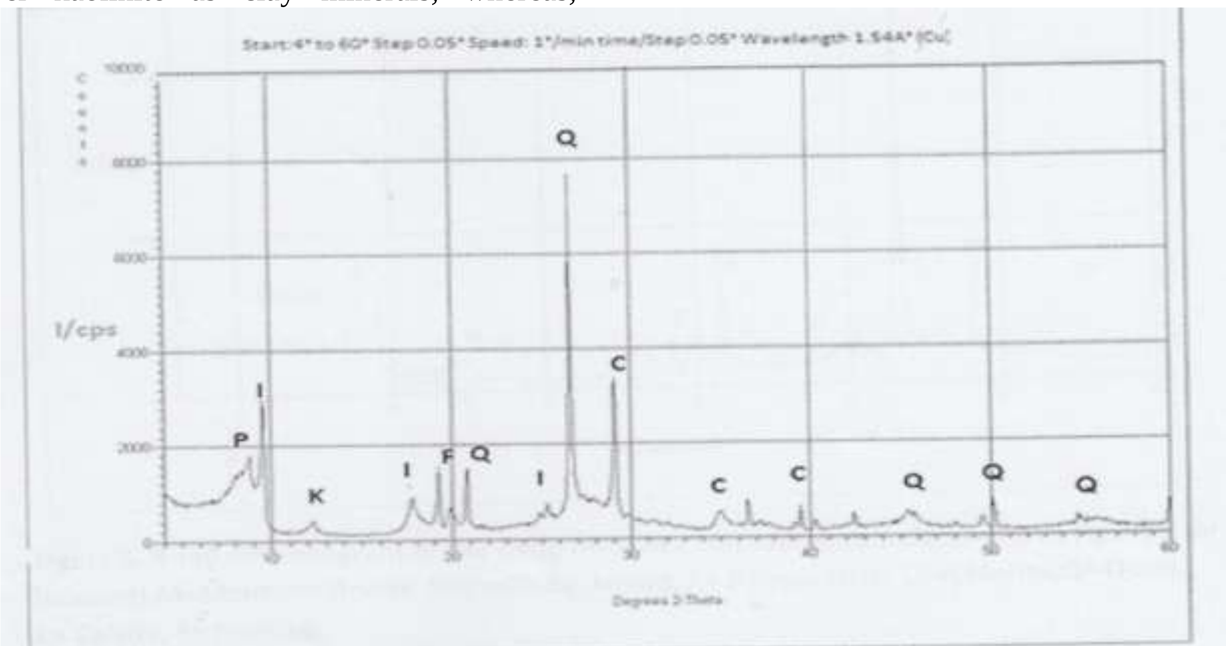


Figure 4. X-ray diffractogram of the shale from Ora Formation, sample S2-O (see Figure 2 for location). K=Kaolinite, I=Illite, P= Palygorskite, Q= Quartz, C= Calcite, F= Feldspar.

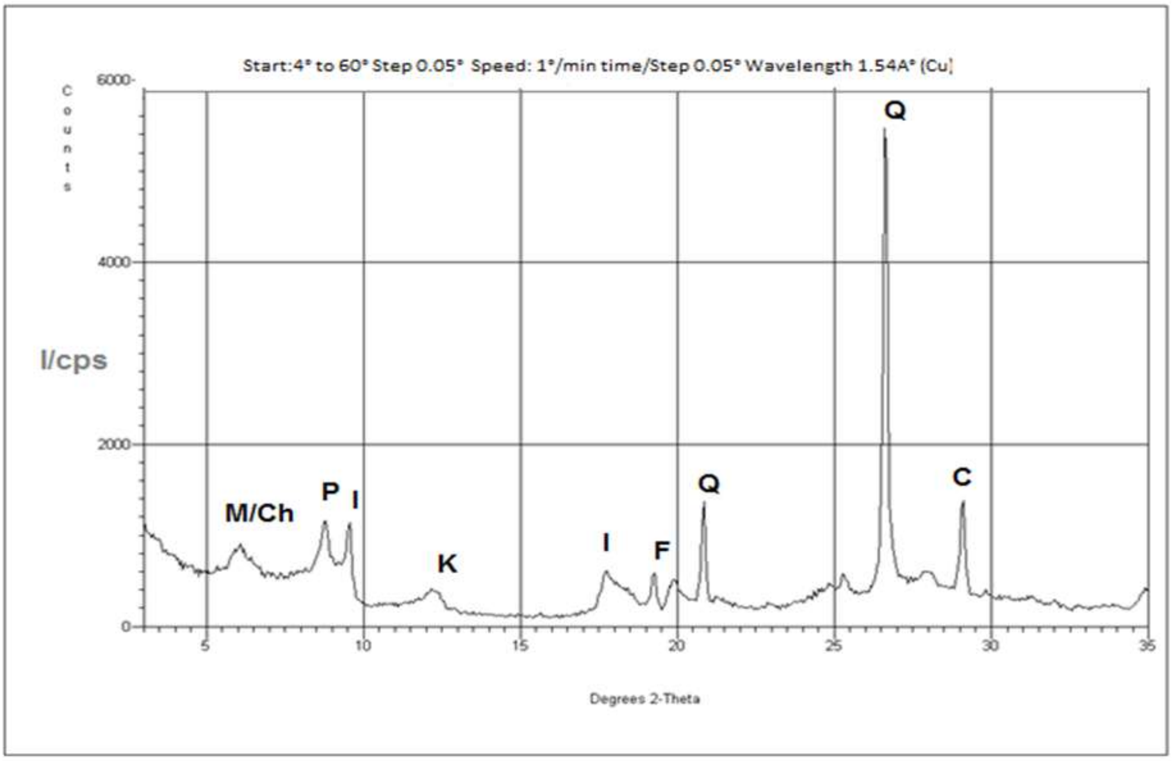
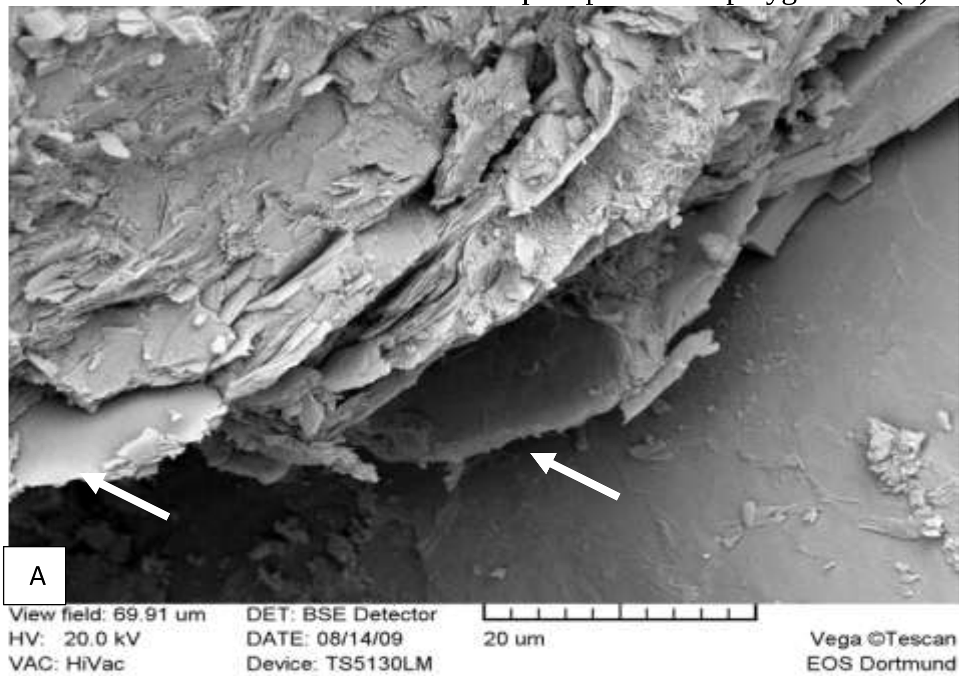


Figure 5. X-ray diffractogram of the shale from Ora Formation, sample S7-O (see Figure 2 for location).M=Montmorillonite K=Kaolinite, I=Illite, P= Palygorskite, Ch=Chlorite,Q= Quartz, C= Calcite, F= Feldspar.

2. Clay mineral morphology, Scanning Electron Microscopy: Detailed description of clay minerals habit and morphological characteristics are studied using scanning electron microscopic (SEM) imaging. A Scanning Electron Microscope (SEM) is a powerful magnification tool, which brought about major breakthroughs in understanding of depositional and diagenetic products and processes [9]. The chief advantages of the SEM are the great depth of focus, producing excellent photographs of extremely small (micron- and submicron-sized) three-dimensional surfaces. In the present work, a detailed SEM investigation for the Kaista and Ora shale units is conducted to show main shapes and habits of the clay and non-clay minerals existed in these rock units and determine their genesis of either detrital or authigenic. Kaolinite booklets and degraded kaolinite hexagonal plates are observed in the shale samples from Kaista Formation (Figure 6). Fibers and fine plates of illite are commonly seen in the studied samples especially for the Ora shales (Figures 7B and 8). Palygorskite long fibers are found in Ora shales associated commonly with dolomite (Figure 7A). Fine disc-shaped chlorite could recognized too in the studied samples (Figure 7B). Clay minerals are either of terrigenous (detrital) and/or authigenic and diagenetic in origin. Kaolinite seems to be of detrital origin derived mainly from igneous rocks rich in alkali feldspars, and to lesser extent from the reworking of older sedimentary rocks (14). The presence of kaolinite as a subsidiary mineral is an indication of relatively little leaching effect and chemical weathering in the source area (8). Hexagonal plates with pitted and degraded surfaces and eroded plates (Figures 6-8) could be interpreted as retransported and re-deposited (detrital) kaolinite (2, 17). Illite could be formed as a result of alteration of muscovite, biotite, and k-feldspar both in weathering zone and during diagenesis (11). In the present study, illite occurs as fibers or as crusts (Fig. 3d) which may indicate the altered form of illite from older feldspars or other silicate minerals. Chlorite is derived from the weathering of rocks rich in ferromagnesian minerals that contains high Mg and Fe and that is excellent in the basic igneous and metamorphic rocks (14). The above distribution of clay minerals fits with the depositional environments of the studied fuvial-marine Kaista and subtidal Ora formations. The presence of kaolinite, illite, quartz, feldspars indicates shales, sandstones and possibly magmatic and metamorphic rocks of felsic composition (granite, gneiss) as the most likely types of source rocks. Sandstones and shale are common rock types in the older clastics of the lower Paleozoic Khabour and Pirispiki formations that were derived from preexisting complex rocks including magmatic and metamorphic rocks (2, 16). Kaolinite is produced directly from the source rock and could be a product of limited chemical weathering in the source area The apparent dominance of illite over kaolinite in the Ora shales indicates that intensive mechanical breakdown of rocks prevailed in the source area. Such processes are favoured in temperate, cold and dry climatic conditions. The coexistence of palygorskite fibers with dolomite reflects lagoonal, brackish-hypersaline, alkaline waters and magnesium-rich environments that were suitable for authigenic formation of this mineral. Seasonably arid climatic conditions, in the absence of local tectonic activity, promoted elevated salinity and intense evaporation, which in turn supported the direct chemical precipitation of palygorskite (8).



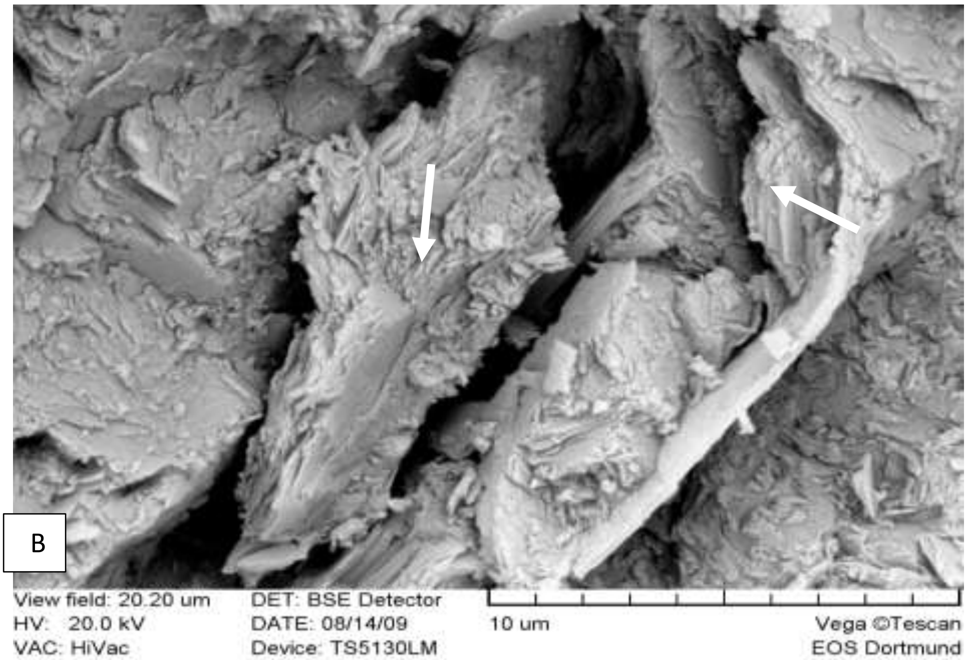


Figure 6. A-B, SEM image of the Kaista Shales illustrating common Hexagonal and booklet shapes of Kaolinite (arrows), sample S1-K (see Figure 2 for location).

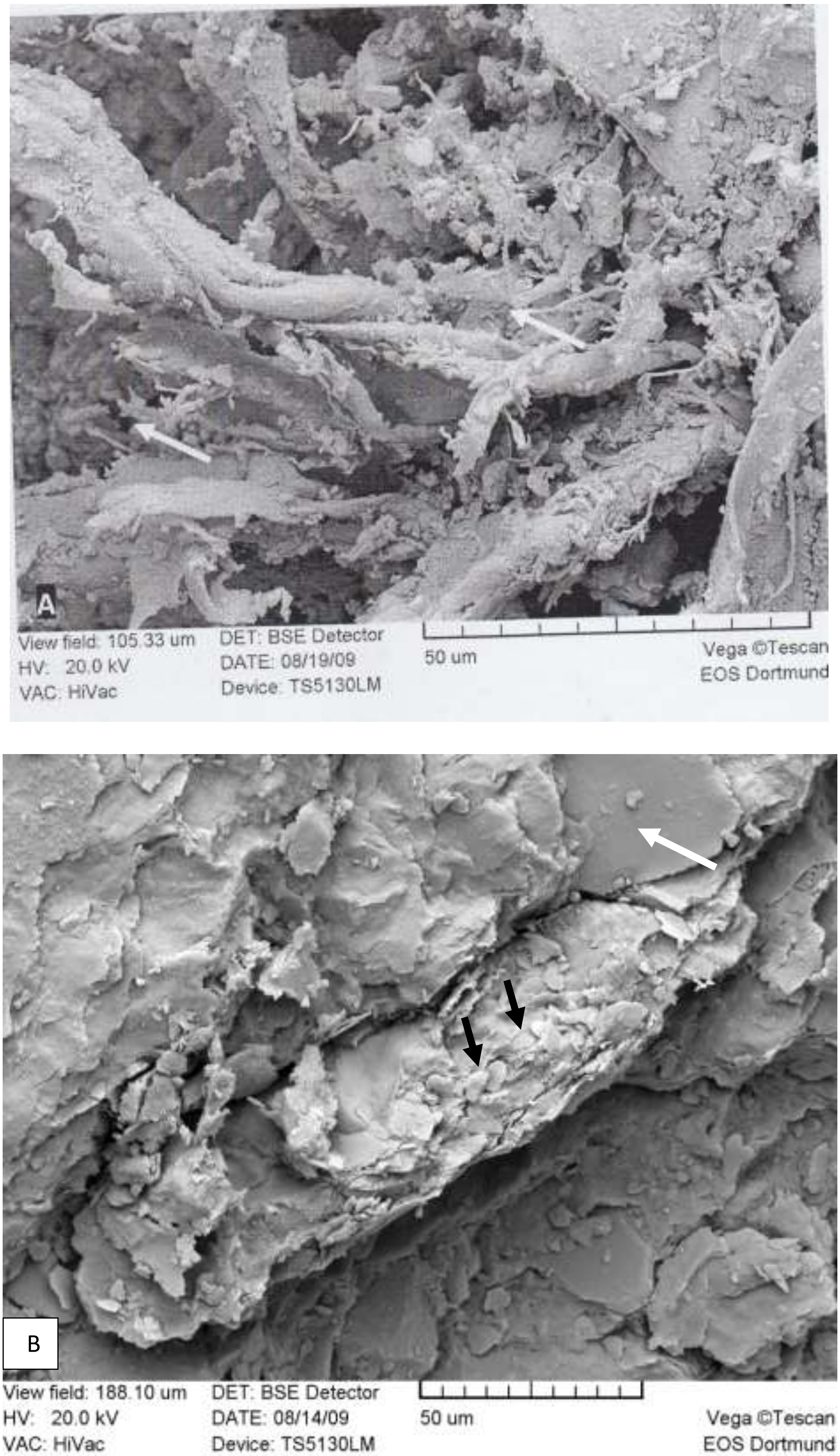
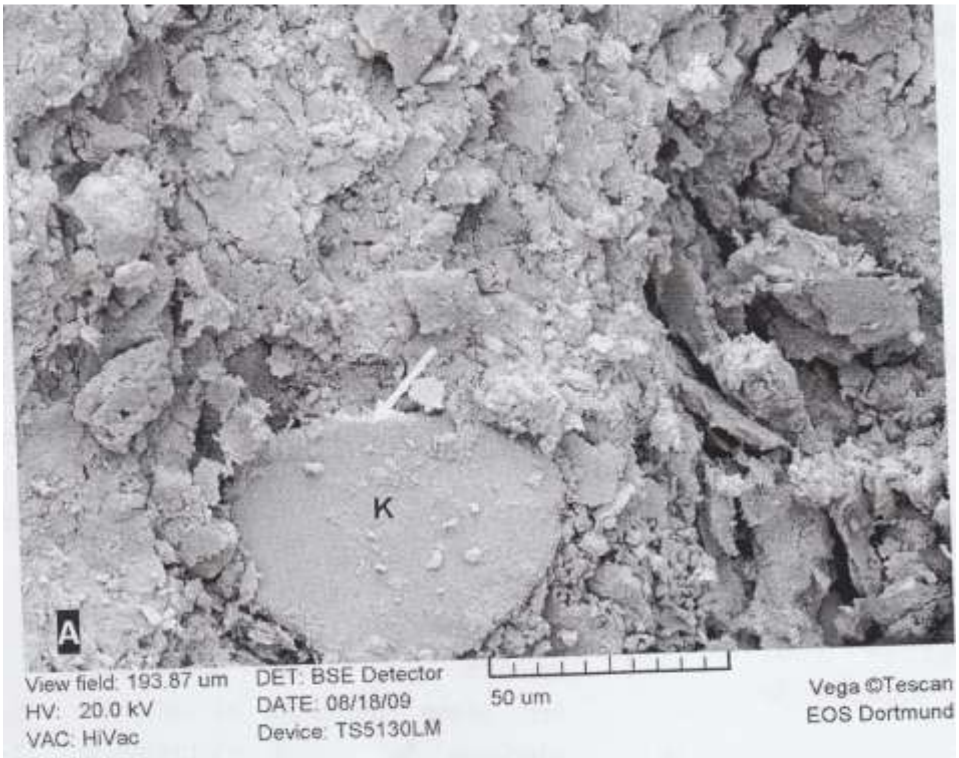


Figure 7. A- SEM image from the Ora shales , palygorskite fibers (arrows), B- Kaolinite platy hexagonal shapes (arrow) and fibrous illite (I), fine disc-shaped chlorite (black arrows) sample S3-4O (see Figure 2 for location).



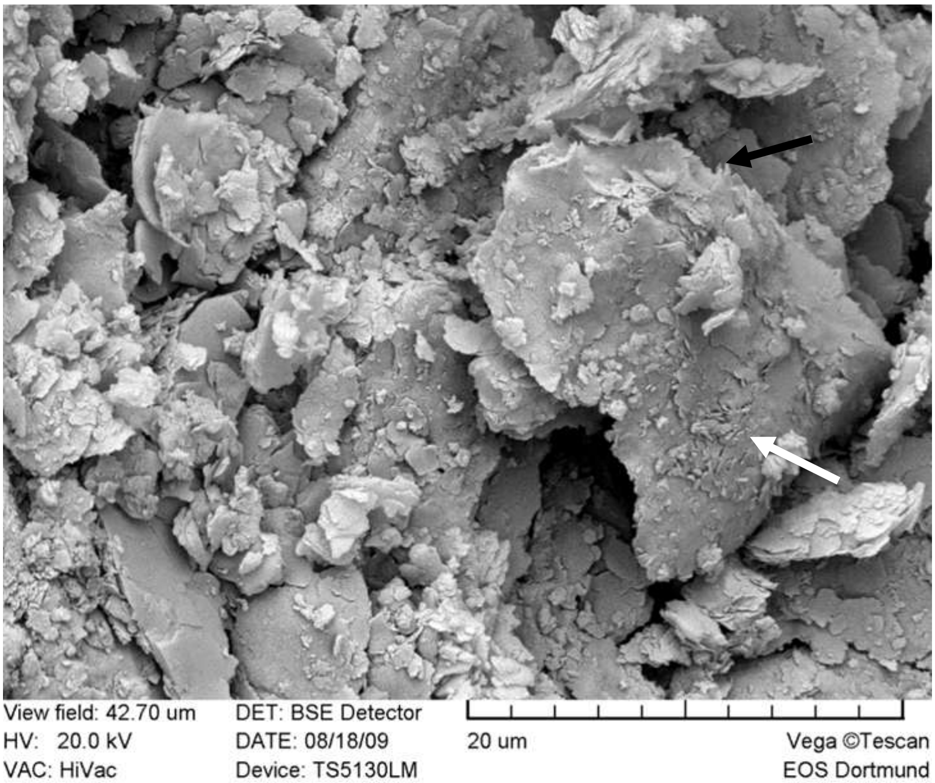


Figure 8. A SEM image from the shale of the Ora Formation illustrating kaolinite degraded plates (K) with illitization at margins (arrow), B- fine plates and fibers of illite (black and white arrows) and degraded kaolinite (K) with illitization at the margins, sample S-5O, (see Figure 2 for location).

Types of clay minerals in the shale units from both Paleozoic Kaista and Ora formations from extreme northern Iraq have revealed the presence of several mineral minerals that support in identification of the depositional environments. Dominance of kaolinite associating with detrital non-clay fractions of quartz and feldspars in the Kaista shales suggest deposition in fluvial depositional environments. While dominance of illite over kaolinite in the Ora shales indicates that intensive mechanical breakdown of rocks prevailed in the source area with temperate, cold and dry climatic conditions. Common palygorskite in Ora shales suggests seasonably arid climatic conditions, elevated salinity and intense evaporation. These conditions probably exist in subtidal environment, a suggested one for the deposition of Ora shales.

REFERENCES

1. Ahlberg, A., I. Olsson, and P. Šimkevičius, 2003. Triassic-Jurassic weathering and clay mineral dispersal in basement areas and sedimentary basins of southern Sweden, Sedimentary Geology 161(1):15-29

2. Al-Juboury A. I. and A. H., Al-Hadidy, 2001. Petrography and diagenesis of Khabour Formation, Western Iraq. Rafidain J. Science,. 12,. (2):.50-62, part2

3. Al-Juboury, A.I. and A. H. Al-Hadidy, 2008. Facies and depositional environment of the Devonian-Carboniferous succession of Iraq. Geological Journal, Wiley, Vol. 43, (2-3), :383-396.

4. Al-Juboury, A.I., and A. H., Al-Hadidy, 2009. Petrology and depositional evolution of the Paleozoic rocks of Iraq. Marine and Petroleum Geology, 26(2), : 208-231

5. Al-Sharhan, A.S., and A.E.M., Nairn, 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier, Amsterdam,pp: 843

6. Beydoun, Z.R., 1991. Arabian plate hydrocarbon, geology and potential: A plate tectonic approach, AAPG Studies in Geology, 33, pp:77

7. Buday, T., 1980. The Regional of Iraq. Vol.1, Stratigraphy & Palaeogeography. State Organization for Minerals, Baghdad, Iraq, pp: 445

8. Chamley, H. 1989. Clay Sedimentology. Springer-Verlag, Berlin, pp;623

9. Flügel, E. 2004. Microfacies of carbonate rock analysis, Interpretation and application. Springer, Berlin, pp: 976

10. Hassan, I., O., A., M., Surdashy, G., H., Sherwani, A., M., Aqrawi, and S., F., Naqishbandi, with the contribution team of Sulaimaniyah University, 2002. Lithostratigraphic Map of Northern Iraq. Scale 1:500,000, FAO library

11. Hower, J., P.M.,Hurley, W.H. Pinson, and H.W. Fairbairn, 1963. The dependence of k-Ar on the mineralogy of various particle size ranges in a shale. Geochim. et Cosmochim. Acta. 27, 405-410

12. Keller, W.D., 1970. Environmental aspects of clay minerals. Journal of Sedimentary Petrology, 40, (3) : 788-813.

13. Keller, W.D., 1978. Classification of Kaolins exemplified by their textures in scan electron micrographs. Clays and Clay Minerals, 26(1): 1-20

14. Millot, G. 1970. Geology of clays, chapman and Hall; London.pp: 429.

15. Murray, H.H. 1976. Applied Clay Mineralogy, Occurrences, Processes and Applications of Kaolins, Bentonites, Palygorskite-Sepiolites and Common Clays, Elsevier, pp:123-179

16. Singer, A., 1980. The Paleoclimatic Interpretation of Cay Minerals in Soil and Weathering Profiles. Earth Science Review, 15:303–326

17. Sinjary, W.S. 2006. Mineralogy and geochemistry of Pirispiki Formation, Northern Thrust Zone, Iraqi Kurdistan Region. MSc thesis, Salahaddin University, Erbil, Iraq, pp:157

18. Thiry, M., 2000. Palaeoclimatic interpretation of clay minerals in marine deposits: an outlook from the continental origin, Earth-Science Rev., 49, : 201-221.

19. Weaver, C.E. 1967. The significance of Clay Minerals in Sediments, In: B. Nagy, and U. Colombo, Eds., Fundamentals Aspects of Petroleum Geochemistry. Elsevier, Amsterdam, pp:37-75.