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Sedimentary and mineralogy characteristics of late quaternary sediments, Garmian area, Kurdistan Region, NE Iraq

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Abstract

The quaternary sediments have been studied in four sections; Garmian area, Kurdistan Region, North East Iraq, which are multi-features, multi-sources, and variable lithological compositional characteristics. The grain size granulometry was used and identified, gravel, sand and mud. Gravel-sized particles are partially producing a greater amount than sand and mud size in both sections (Sar-Qallah-1 and Salih-Agha). Statistical parameters such as (mean, mode, sorting, skewness and kurtosis), have shown that the sediments are very poorly sorted, very fine skewed and platykurtic. Petrographic studies of sediments under polarized microscope investigated that these sediments are predominately consisting of (chert and carbonate rock fragments), with the existence of few amounts of igneous and metamorphic rock fragments, feldspar and monocrystalline quartz. These fragments types are an indication of multiple source rocks originate from Ophiolites and thrust sheets from the Penjween area (North Iraq). Various types of heavy minerals are identified; opaque (hematite and pyrite), and nonopaque minerals (pyroxene, amphibole, epidote and zircon). X-ray diffraction technique is used to interpret clay mineralogy which indicates that chlorite and palygorskite are the main clay mineral with the presence of non-clay minerals such as quartz and calcite.

Keywords: Clay; minerals; quaternary; rock fragments; source rocks.

1. Introduction

The quaternary period is globally characterized by a series of glaciers interspersed with relatively warm periods (Elias & Mock, 2013). The marine oxygen isotope record investigations of stratigraphical position of quaternary found four major glaciation periods north hemisphere (Raymo, 1997), long core studies revealed the climatic developments and delta structures later time in the same area (Krenmayr, 1996 in Van Husen, 2004). Worldwide quaternary deposits have glacial sedimentary characteristics (Péwé,1975a; Krenmayr, 1996 in Van Husen, 2004), rarely with glacial characteristics have been found in the Middle East, Iraq, and the region, most of which are fluvial and alluvial clastic sediments. Most of the Iraqi territory is covered by quaternary deposits that incorporate various environments fluvial, delta, lacustrine, and Aeolian in the Mesopotamia plains and Foothill Zone. Recently Abdula *et al*., (2020) recorded the indicators of Pleistocene in High Folded Zone-North Iraq that show the existence of the glacial period. The characteristics of quaternary sediments in north Iraq indicated sandy, and silty dominant grains, rich heavy minerals, and high presence of light minerals (muscovite) (Al-Kaaby & Albadran, 2020). However, clay-silt particles dominant has been recorded in Bahr Al-Najaf depression with unstable heavy minerals (amphibole and pyroxene) (Benni *et al*., 2012). The Garmian region, as a plain terrain covered by multi-origin sediments that occurs valleys fill, river bed deposits (Figure 1). These sediments are composed of gravel, sand and mud, which are resulted from weathering and erosion of older rocks. This study aims highlighting the sedimentary features of quaternary deposits such as sedimentary texture, properties of minerals and source of rocks.

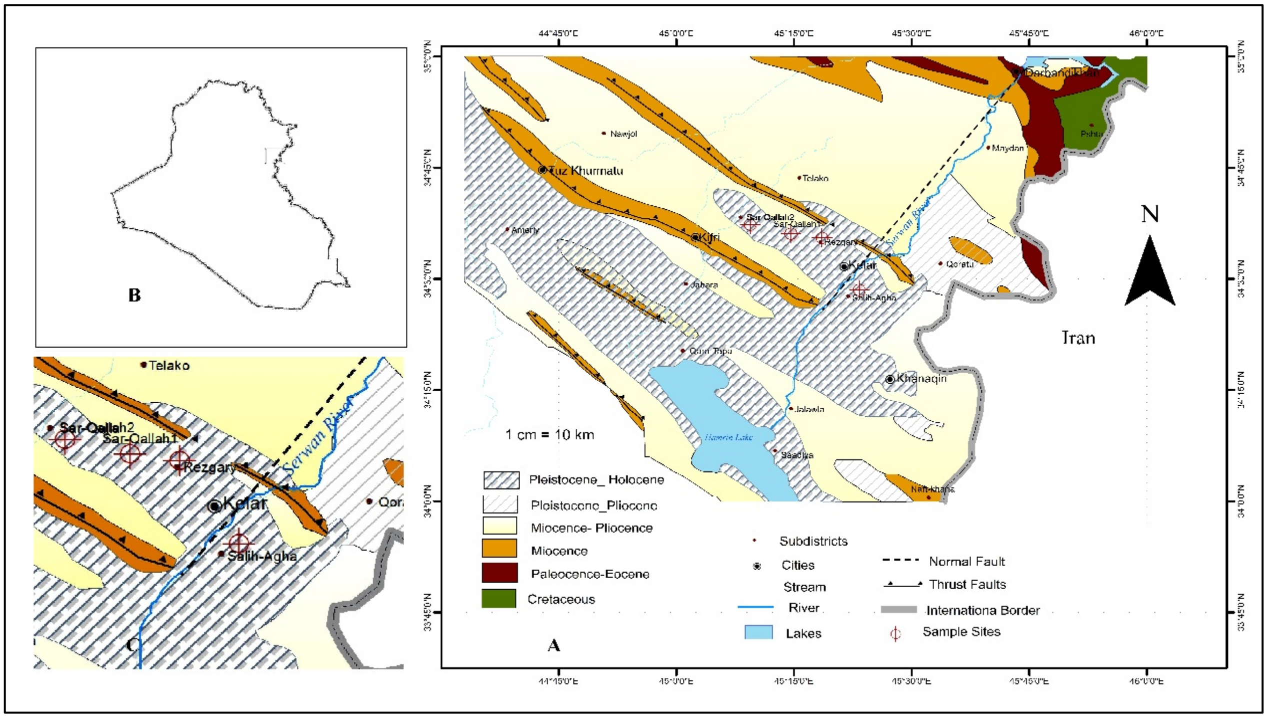

Fig. 1. Geological map of the Garmian area, Kurdistan region, North East of Iraq (after Iraq Geological Survey, 1986).

2. Geological Setting

The Garmian area, located in the northern portion of Iraq, about 80 Km South of Sulaymaniyah city, and represent a part of Zagros Low Folded Thrust Zone (Lawa *et al.,*2013; Omar *et al.,* 2015) (Figure 1).

The Quaternary deposit in the study area forms a discontinuous sheet above the pre-quaternary deposits. The later represent either by Miocene–Pliocene fluvial siliciclastic sediments involving Bai Hassan and Mukdadiya formations or by the Miocene deltaic clastic deposits of Injana Formation which underlain by mixed lagoonal facies of the Fatha Formation (Lawa & Ghafur, 2015). Accordingly, the Neogene deposit shows rapid shallowing upwards associated with the last phase of Alpine tectonic activity (Omar *et al.,*2015). Tectonically, the area is a part of the Foothill Zone, Chamchamal-Hamrin subzone within Arabian Plate (Jassim & Goff, 2006), and bordered by the High Folded Zone from the northern side, and stable shelf from the Arabian plate. The area is including one of the main normal faults adjacent to Sirwan River starting from the Darbandikhan Lake basin in the north ending at the north of the Hamrin Lake basin in the South (Lawa, 2004). Kent (2010) suggested the studied area tectonically part of simply folded zone or is part of the Low Folded Thrust zone (Lawa *et al*., 2013). Intensive uplifting and folding of sedimentary complex sequence are the result of a few alpine orogenic phases. Consequently, numerous large anticlines and synclines have been formed. In the studied area Quaternary sediments with the rock of Miocene Pliocene age cutting by the Sirwan River flows (Sissakian & Al-Jiburi, 2014).

3. Methods

The two main methods have been done in the studied area: firstly, field work which included, 27 samples were collected from unlithified sediment in the Garmian area. Secondly, granulometric analysis was carried out by the conventional method and approximately 50Kg weight of each sample was sieved were taken in each location (Table 1). The statistical parameters of graphic like median (Md), mean (Mz), sorting (σ_I), skewness (SK_1), and kurtosis (KG_1) were determined using the equation of (Folk, 1980) (Table 2). While we prepared (15) thin sections from collected samples for petrographic analysis by polarizing microscope. Separation heavy minerals from light minerals have been done by using bromoform liquid ($CHBr_3$) with a specific gravity (2.89) (Carver, 1971). This study also used X-Ray diffraction technique was done in Laboratory Ministry of Science and Technology, Baghdad- Iraq for analysis and identified the clay mineral composition for the Sar-Qallah-2 section.

Table 1. Grain size distribution in Salih-Agha and Sar-Qallah-1 sections, (Wentworth, 1922; Folk *et al.*,1970)

Salih-Agha				Sar-Qallah-1			
Sieves (mm)	Weights (Kg)	%	Accumulative ratio	Weights (Kg)	%	Accumulative ratio	Particles
> 64	8.6	16.93	16.93	6	19.99	19.99	Cobble
31.5	5.75	11.32	28.25	2	6.66	26.65	Pebble
22.4	4.32	8.5	36.75	1.8	6	32.64	
16	3.6	7.09	43.84	1.8	6	38.64	
11.2	4.75	9.35	53.19	2	6.66	45.3	
8	3.32	6.54	59.72	2.98	9.93	55.23	
5.6	2.5	4.92	64.65	2.2	7.33	62.56	
4	2.2	4.33	68.98	1.52	5.06	67.62	
2	3.43	6.75	75.73	2.24	7.46	75.08	Granule
1	3.16	6.22	81.95	1.54	5.13	80.21	Sand
0.56	3.65	7.19	89.13	2.92	9.73	89.94	
0.256	2.76	5.43	94.57	1.9	6.33	96.27	
0.125	1.51	2.97	97.54	0.8	2.66	98.93	
0.063	0.92	1.81	99.35	0.2	0.67	99.6	
< 0.0063	0.33	0.65	100	0.12	0.4	100	Silt + Clay
	50.8	100		30.02	100		

Table 2. Results of Statistical parameters of (Salih-Agha and Sar-Qallah-1) sections.

Sections\Phi Φ	95	84	75	50	25	16	5
Salih-Agha	2.1	0.2	-1.1	-3.5	-5.4	-6	-6
Sar-Qallah-1	1.8	0.4	-1	-3.2	-5.5	-6	-6
		Salih-Agha	Description	Sar-Qallah-1	Description		
Statistical	Mean	-3.1	Coarse	-2.93	Coarse		
	Sorting	2.77	VPS	2.78	VPS		
	Skewness	0.28	VFS	0.2	VFS		
	Kurtosis	0.77	Platykurtic	0.71	Platykurtic		

4. Lithology

Sissakian & Saeed (2012) mentioned that most of the Iraqi territories are covered by sedimentary rocks and quaternary deposits, and they classified them into 18 types depending on their lithological units. The lithology of quaternary deposits studied in four different locations (Figure 2). The column stratigraphy of the sediments was taken only in Rzgari which penetrated all vertical thickness in this subsurface section, while the three other sections have studied on the surface. In general, quaternary deposits in the Garmian area are rich in coarse grain particles (boulder and gravel dominant characteristic) (Table 1), except in the mud layers that appeared in Sar-Qallah-2, and the lower part of the Rzgari location. The accurate lithological characteristics of each section showed as the following:

Sar-Qallah-1 Section: These quaternary deposits are about 6m thick and consist of a mixture of friable gravel, sand, and mud that are exposed along the major valley that runs towards the Sirwan River. The coarse clastic, which is comprised of polymictic boulders, cobbles, pebbles, and gravels represent the majority and is more than 75%, while the sand ratio is about 24.52%, and less than 2% silt and clays.

Sar-Qallah-2 Section: This section is located on one of the seasonally flooded tributaries of Sirwan River from the right flank and it's about 20m thick, consist mainly of light reddish color mud, occasionally shows variation from clay to silty clay and siltstone. The mud bed contains some vertical cracks and small clusters of bedding layers (Figure 3A).

Salih-Agha Section: It is located on the left bank of the Sirwan River, about 5m in thickness and composed of a mixture of gravel and sands with a few lenses of mud, this is somewhat similar to the Sar-Qallah-1 section and as well as many of mixed sequences pebbles (Figure 2). Due to the weathering and erosion processes and the nature of the river environment, there is no united lithology appearing in the Rzgari and Sar-Qallah-2 sections.

Rzgari borehole: This subsurface section is about 120m thick and penetrated the quaternary column sediments within Rzgari borehole, which is drilled for water supply for domestic purposes (Figure 3B). The lithological component in this borehole mostly reflects an alternation between the Sirwan River terraces and flood plain deposits due to the meandering of the river course.

The coarse grain clastic intervals consist of cobble, pebble and gravels of multi-origin (sedimentary, igneous and metamorphic) rocks, most probably derived from the weathered and eroded parts of Penjween Ophiolites and Zagros Fold Thrust Belt (Stevanovic & Markovic, 2003). Occasionally, lensoidal sandy bodes are cutting across the coarse clastic. The fine clastic intervals represent by pinkish-red to reddish-brown mud and are about 20m thick in the lowermost part of the well.

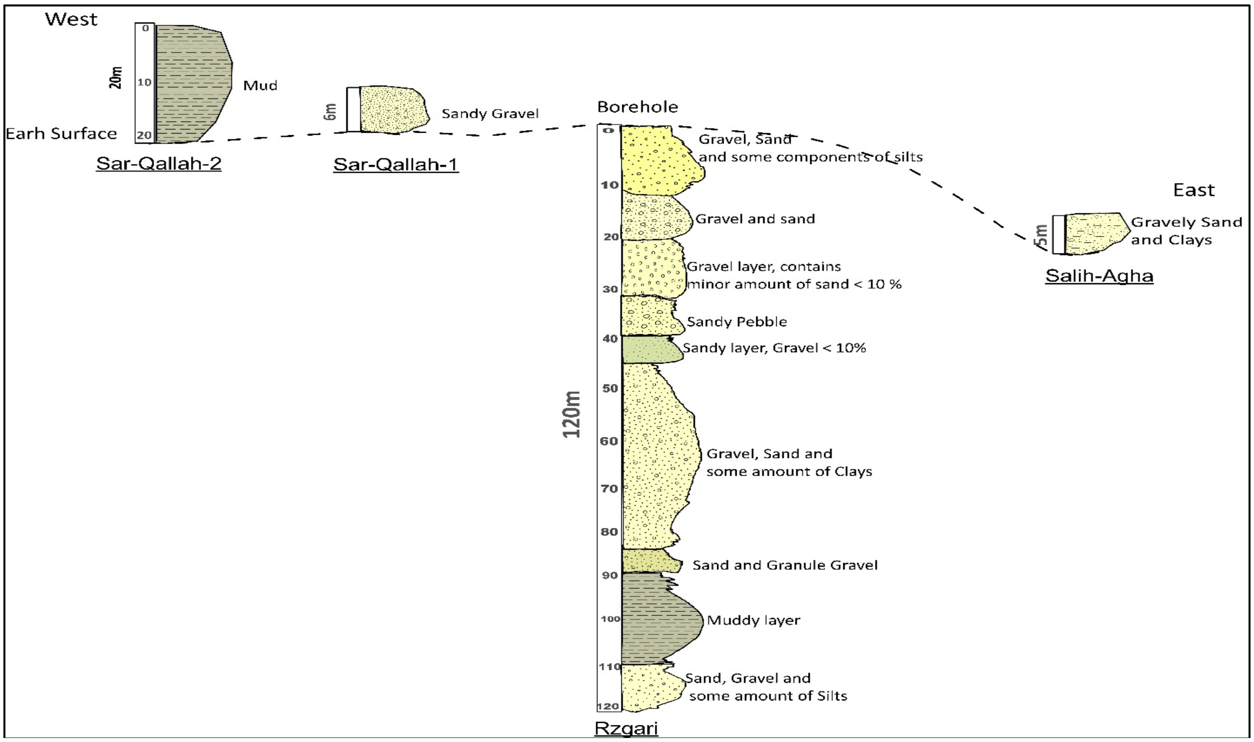

Fig. 2. Stratigraphic column of lithological unites in the Quaternary deposits in the studied area.

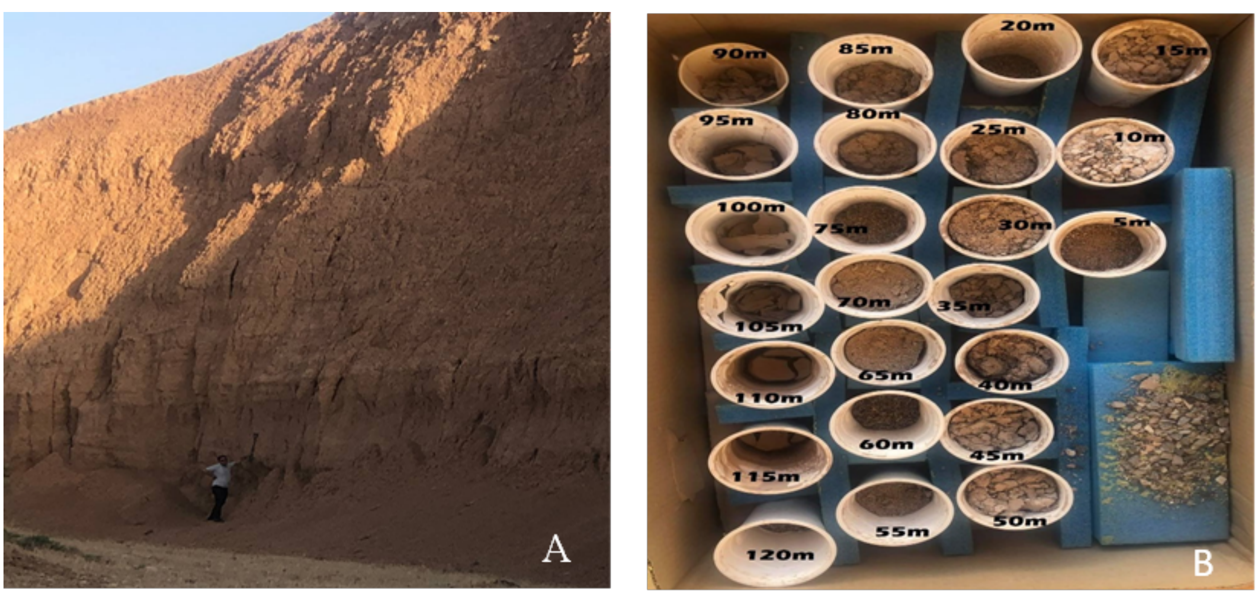

Fig. 3. (A) Sar-Qallah-2 section showing the pure mud layer alternated with thin silty layers, (B) Rzgari section, the samples were taken during well drilling, in cooperation with the Directorate of Groundwater Exploration in Garmian (10/02/2021).

5. Results

5.1 Grain size analysis

The scales (Wentworth 1922; Folk *et al*., 1970) are considered the main scales that are widely practically used to describe and analyze grain size particles of sedimentary rocks. Three major types of fractions have been recognized, gravel, sand, and mud (Table 1). Sedimentary analysis for the quaternary deposits in the Garmian area is based on two sites, which are reflecting the variations of the sedimentation. They are analyzed by the sieve method. The gravel-sized partial is the largest part, composed approximately (75%) of the sediment in both (Salih-Agha and Sar-Qallah-1) sections of different sizes including Cobble, Pebble, and Granule. Particle's form is elongated and plated, most of gravel-sized particles are low sphericity (blades and rods), and are sub-rounded to sub-angular (Power, 1953). The majority of the particles have a frosted and polished surface (Ture 4). Sand, silt, and clay-sized particles are about (25%). The range of sands is (22-23%) distributed between VC (very coarse sand), (5-6%), C (coarse sand), (7-9%), M (medium sand), (5-6%), F (fine sand), (2-3%), and VF (very fine sand), (1-2%). In addition, the silt and clay portion are less than (1%).

The studied samples have been analyzed by statistical parameters. The results are shown in (Table 2). In general, the sediments in both sections (Salih-Agha and Sar-Qallah-1) are very poorly sorted (VPS), very fine skewed (VFS), and Platykurtic. According to (Figure 4 and Table 2), the large size of the particles indicates the high flow and the strong current energy, and then carrying fewer coarse grains in the sediments mentions turbidity phenomena during sedimentation. The sorting value is acquiring from the standard deviation value. The high value of standard deviation is an indicator of poorly sorted. The sorting value of (Salih-Agha and Sar-Qallah-1) sections is very high, which versus very poorly sorted. This is a sign of high current energy and velocity. The skewness value of the samples ranged between (0.20-0.28), which implies a dominance of coarse grain size. The positive skewness of the sediments is a reflection of high transportation energy during the sedimentation. Kurtosis is a measurement of curve peakedness. The significance of kurtosis is to measure the extreme values of tails. The samples were showed that the type of Platykurtic in both locations is (0.77- 0.71).

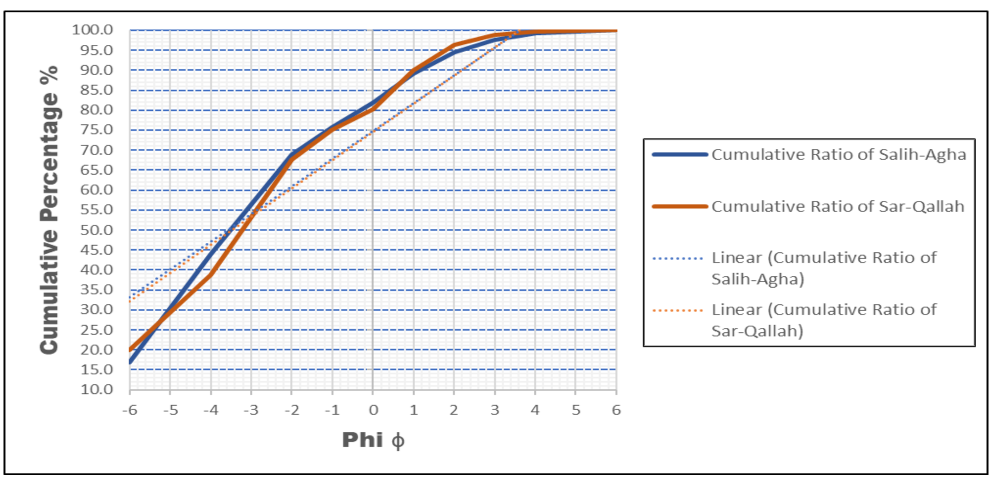

Fig. 4. Relationship between grain size (*phi*) and cumulative percentage of (Salih-Agha and Sar-Qallah-1) sections.

5.2 Petrography and mineralogy

The mineralogical composition of the studied samples was identified under a polarized microscope to determine their lithology and studying the parent rocks.

The petrographic study can be referred to lithic rock fragments, these are the predominant constituents of the quaternary deposits include sedimentary, igneous, and metamorphic rock fragments which are existing in different amounts. Lithic sedimentary fragments are the majority constituent of more than (%95) of quaternary deposits and represent by chert, radiolarian chert, and carbonate rock fragments. Here are brief characteristics of each component:

- The chert rock fragments occur as angular to subangular in shape, and they are more common than another type of sedimentary rock fragments that observed from all studied sections (Rzgari, Sar- Qallah-1, and Salih- Agha) (Figure 5a). Chert is hard, composed of microcrystalline or cryptocrystalline quartz (silica) (Knauth, 1979). Chert is of biological origin (organic, radiolarian), also may occur inorganically as a diagenetic replacement or a chemical precipitate (Bates & Jackson 1984). These fragments may be derived from the radiolarian chert beds of Qulqula Group which exposed in the thrust zone and far for 70-80 km from the studied area (Buday & Jassim, 1987). (Jassim & Goff, 2006) mention that radiolarian chert is the common composition of Qulqula Group and exceed 2000 meters in thickness.
- Carbonate lithics are the main constituent within the studied samples that occur as subangular to subrounded, mostly represented by micritic crystalline calcite, ferroginous detrital limestone, and detrital limestone (Figure 5b). The different types of carbonate rock fragments are indicated carbonate source rocks (Al-Juboury, 1994). The coexistence of these detrital is derived from Avroman Formation appear in northeastern Iraq. The fragments of chert and carbonate are very common in the study samples with an average (%92).
- Radiolarian chert rock fragments that occur as angular to subrounded and about (%3) was identified. A homogeneous sedimentary rock that is predominately composed of microscopic radiolarian organisms (Figure 5c). This fragment is derived from radiolarian chert beds and which are considered as a weathering product of the Cretaceous Qulqula Radiolarites series, NE Iraq that is adjacent to the Sanandaj- Sirjan Zone of Iran (Al- Juboury *et al*., 2009).
- Occurrence of igneous rock fragment as subangular is usually rare, with a value (%2) (Figure 5d). The existence of this fragment is indicating Penjween Ophiolites Complexes parent rocks from Thrust Zone.
- Metamorphic rock fragment is represented by minor constituents of serpentine fragments about (%1). The source of these fragments is from Ophiolites Complexes, which are exposed in the Nappe Zone (thrust and folded) cover the area of northern and northeastern Iraq.
- Monocrystalline quartz is less abundant in the studied samples with a value (%1). It is subangular with medium grain sizes (Figure 5e). It is composed of single crystal, non-undulatory (uniform extinction), and derived from volcanic igneous rocks.
- The feldspar grain is (plagioclase) less abundant accounting only (%1). Feldspar grain is elongated shape as a fresh (Figure 4f). The shape of fresh grains of feldspar is indicating the relatively short distance of transportation and might be a sign of rapid erosion in the source area (Boggs, 2006).

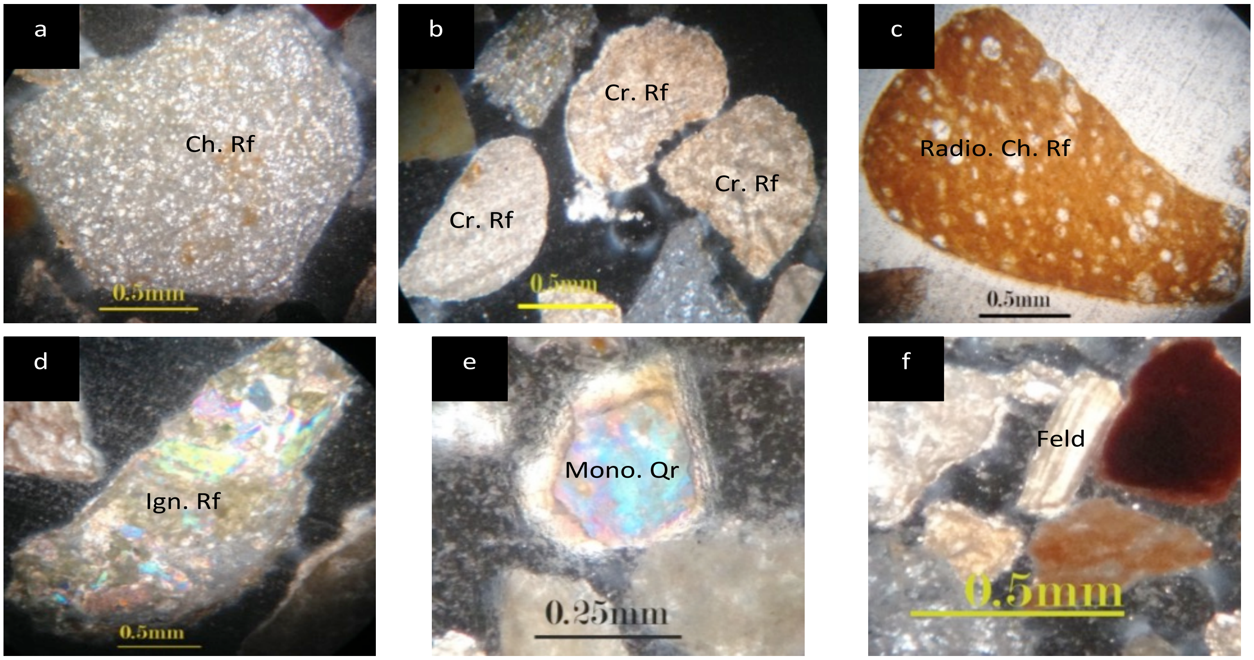

Fig. 5. (a) Chert rock fragment (Ch. Rf), Salih- Agha, XP, (b) Carbonate rock fragments (Cr. Rf), Sar-Qallah-1, XP (c) Radiolarian chert fragment (Radio. Ch. Rf), Rzgari, XP, (d) Igneous rock fragment (Ign. Rf), Rzgari, XP, (e) Monocrystalline quartz (Mono. Qr), Sar-Qallah-1, XP, (f) Feldspar grain (Feld), Salih- Agha, XP.

The mineral composition of the studied samples indicated that the area is exposed to deformation, which is caused to uplifting and erosion by orogenic (Alpine orogeny) in northeastern Iraq. The coexistence of different types of fragments indicated various rock types from the Thrusted Zone. Boggs, (2006) mentioned that the parent rocks are more reliable than individual minerals, where they could be derived from different source rocks.

5.3 Heavy minerals

Individual of heavy mineral is separated from unlithified sediments, after light grains have been removed by floatation on heavy liquids (Bromoform). The heavy minerals analysis is very important, it can give some useful indications of events in the source area and their provenance. Huang, *et al.,* (2018) mention that petrography, heavy mineral assemblages and geochemistry composition are a powerful and useful tool for detecting provenance in difficult situations. Webster *et al.,* (2003) documented that the identified heavy minerals are not affected by mineralogical composition only, it is affected also by other factors that occurring during sedimentation.

More than (20 grains) were used for identification. These minerals were identified by using a polarized microscope. The results are showing opaque minerals (hematite and pyrite), and nonopaque minerals (pyroxene, amphibole, epidotes and zircon) (Figure 6). Pyroxene and amphibole minerals are common types of heavy minerals that occur in the studied samples with an average (%95). These minerals grains as occur angular to subrounded. Aziz & Sadiq (2020) stated that the presence of opaque grains, pyroxene, amphibole and, epidotes that derived from mafic to ultramafic igneous rocks and zircon grains are indicator of derivation from metamorphic and earlier igneous source. The variety of heavy minerals in quaternary sediment reflects the multiple sources of rock types, represented by the igneous, metamorphic and sedimentary rocks.

5.4 Clay minerals

Using the X-Ray diffraction technique for interpretation and determining clay mineral composition. The mineralogical composition of clay samples in (Sar-Qallah-2) were identified and interpreted by X-Ray analysis that represented by non-clay minerals (quartz and calcite). The percentage ratio of the minerals was calculated by the semi-quantitive method. X-ray chart shows that quartz minerals have the highest percentage about (%45.8) than calcite minerals (%39.0) (Figure 7). In addition, the clay minerals represented by chlorite and palygorskite that having different values. Chlorite minerals have the highest percentage with an average (%60.55) than palygorskite (%39.44) (Figure 8). The origin of chlorite mineral is derived from erosion of igneous and metamorphic rocks which are rich the ferromagnesian minerals that contain high Fe and Mg (Velde, 1992). The second mineral ratio in the study samples is palygorskite, it is formed from erosion of mafic volcanic igneous rocks and also it appeared in the semi-arid and arid climate (Grim, 1968).

Clay minerals that formed by weathering and erosion processes took place in source rocks caused some minerals alteration to clay minerals (Grim, 1968; Millot, 1970). The difference in clay minerals assemblage probability is caused by changes in climate or sediment source (Al-Jaberi, 2017). The non-presence of kaolinite mineral in the studied clay samples indicated that the occurrence of a low amount of acidic igneous rocks and arid climate in the source area because kaolinite is formed from the weathering of acidic igneous rocks in a moisturizing climate (Millot, 1970).

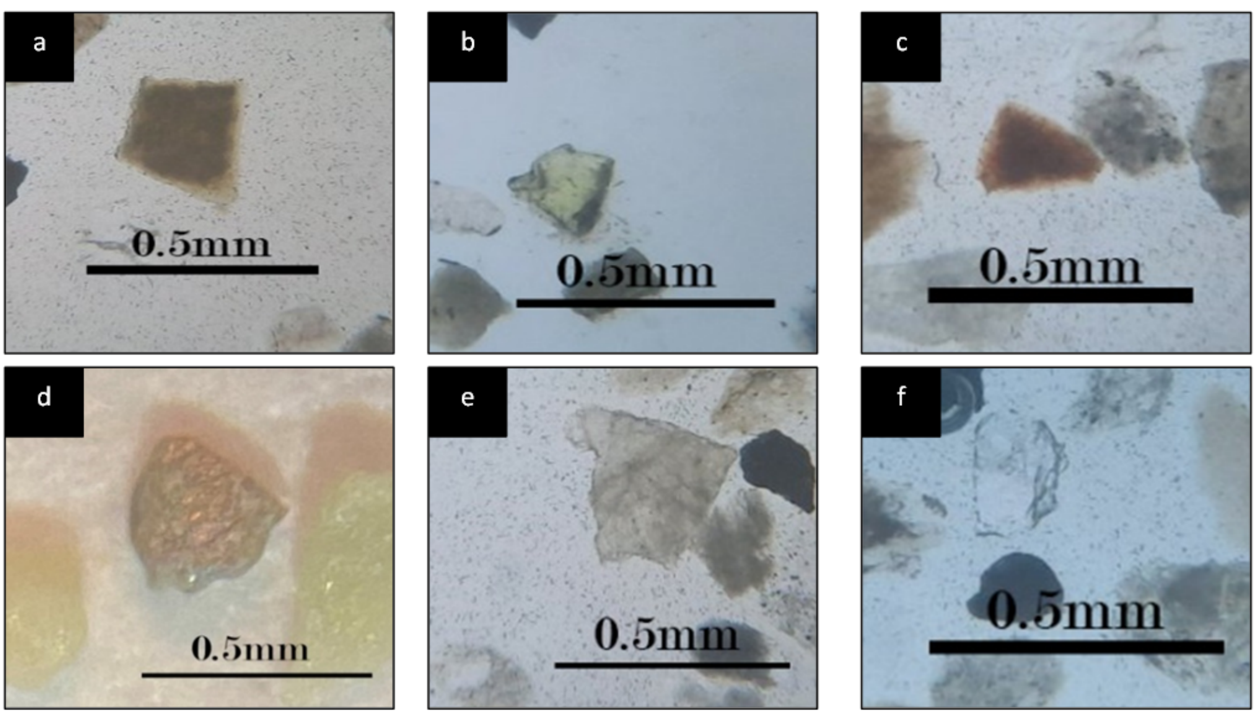

Fig. 6. (a) Amphibole, Sar-Qallah-1, ppl, (b) Epidote, Salih- Agha, ppl, (c) Hematite, Sar- Qallah-1, ppl, (d) Pyrite, Salih- Agha, ppl, (e) Pyroxene, Sar-Qallah-1, ppl, (f) Zircon, Salih- Agha, ppl.

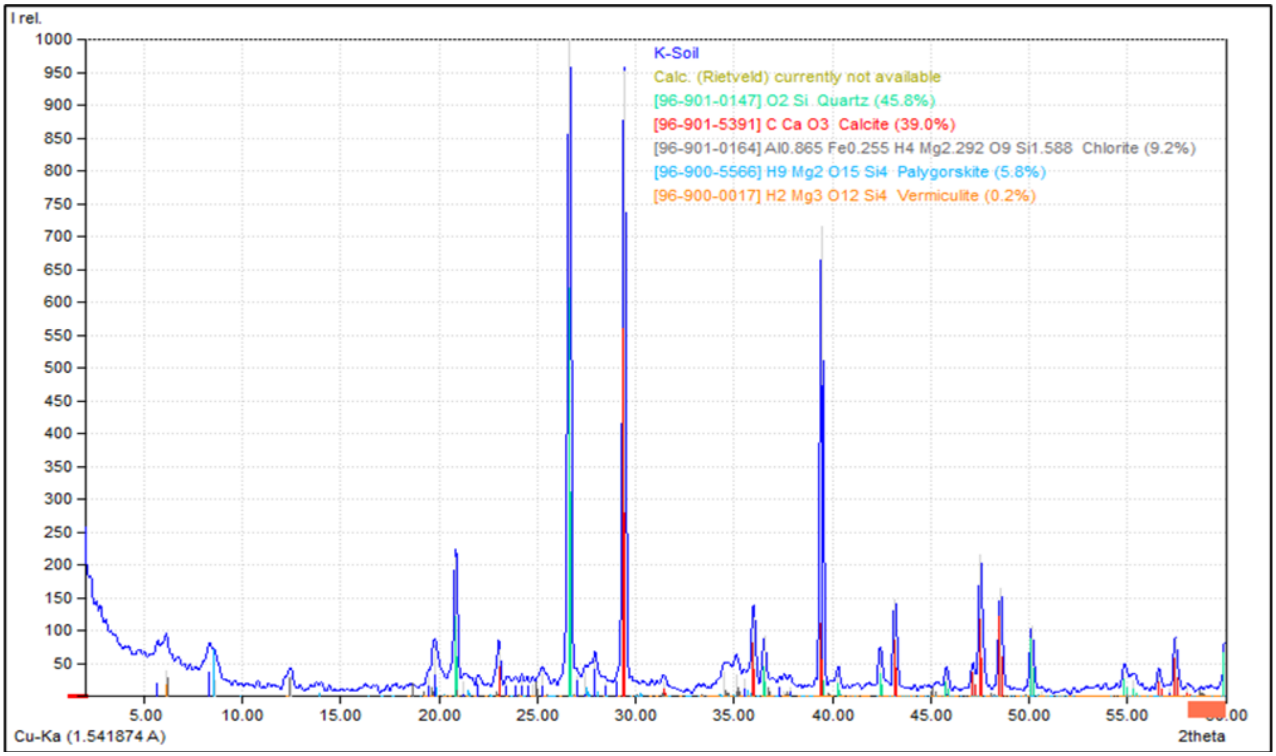

Fig. 7. X-Ray diffractograms of clays mineral samples of (Sar-Qallah-2) section.

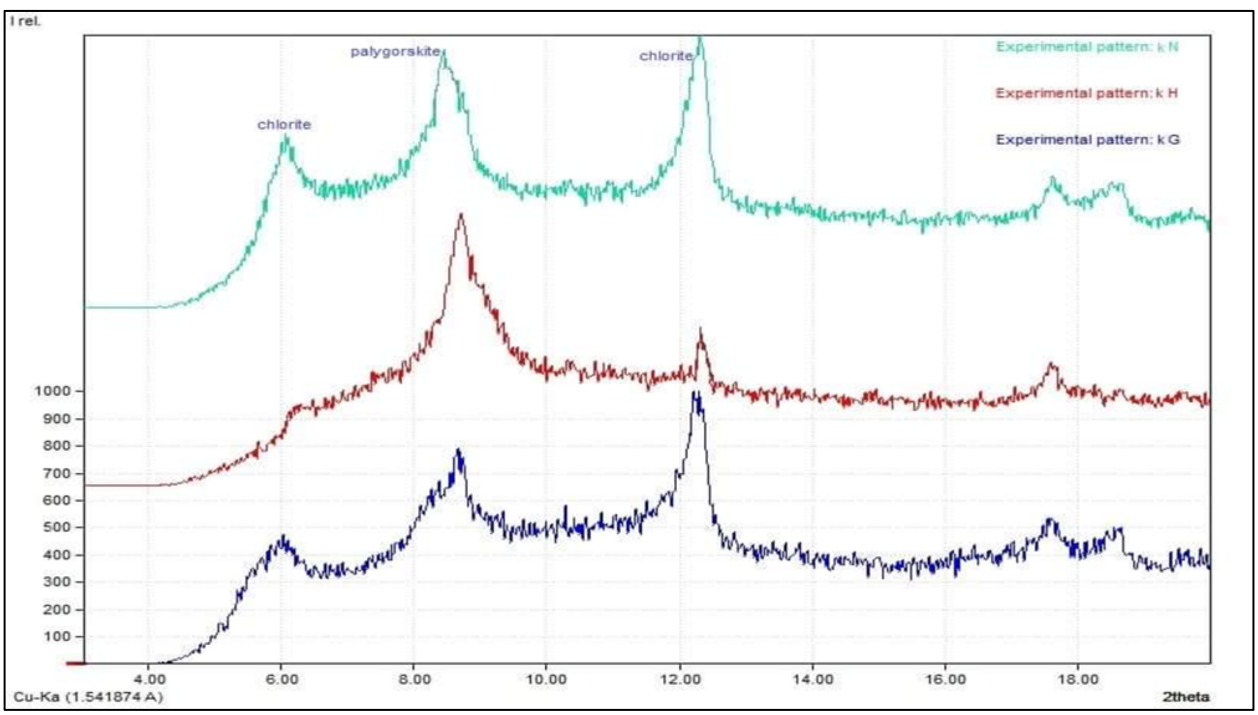

Fig. 8. X-Ray diffractograms of clay minerals samples of (Sar-Qallah-2) section.

5. Conclusions

Some significant points have been concluded as following:

1. The grain size analysis of the studied samples was identified, the gravel size partially is greater amount than sand and mud size in both sections (Sar-Qallah-1 and Salih-Agha). Based on statistical parameters such as (mean, sorting, skewness and kurtosis), it is obvious that the results of the sediments are very poorly sorted, very fine skewed and platykurtic.
2. The petrographic study of Quaternary sediments shows different compositional types of lithic rock fragments and represented essentially by sedimentary rocks (mainly carbonate and chert) followed by radiolarian chert and then by, igneous, and metamorphic rock fragments.
3. The huge distribution of chert and carbonate rock fragments within quaternary deposited indicated closeness to the source area.
4. The predominant opaque heavy minerals such as hematite and pyrite with nonopaque minerals are like pyroxene, amphibole, epidote and zircon, almost reflect different source rock types.
5. The clay minerals are represented by chlorite and palygorskite types, the quartz and calcite are the common in non-clay minerals.
6. The clay minerals are derived from erosion of igneous and metamorphic rocks in the semi-arid and arid climate.

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