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Heavy Mineral Distribution and Clay Mineralogy of Injana Formation at Zawita and Daigala Northern Iraq

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ABSTRACT

This study deals with the minerology of Injana Formation (Late Miocene- Pliocene) at Zawita and Daigala sections, north of Iraq. A total of 13 samples are collected from Injana Formation. The heavy minerals assemblages include opaque minerals, orthopyroxenes, clinopyroxenes, zircon, rutile, epidotes, garnet, amphiboles, tourmaline, chlorite, biotite, kyanite, muscovite and staurolite. The source rocks of these assemblages of heavy minerals are mafic igneous and metamorphic rocks principally as well as acidic igneous and old sedimentary rocks. The ZTR indices indicate the Injana sandstone is mineralogically immature .The tectonic origins of Injana Formation is characterized as lithic recycled of recycled orogeny .The mudstone consists of mixture of clay and silt percentage variable. The major clay minerals are chlorite, kaolinite, illite and smectite. The non-clay minerals are calcite, quartz and subordinate feldspars. The mineralogy of the clay fraction of Injana mudstone leads to be climate arid to semi-arid

Introduction

Injana Formation indicate the beginning of the clastic sediment deposition by the effect of Alpine Orogeny during the continant-continant collision of Arabian craton with the Anatolian and Iranian microcontinents. It extends as parallel to Taurus – the Zagros Mountain series and extends further northeast-southwest. The Injana Formation is widely exposed in Iraq. It consists mainly of sandstone and mud stone.

Zawita section located in High Folded Zone and Daigala section located in the Low Folded Zone. Injana Formation have been studied by many author such as, [1] to appear gathering of heavy mineral and presence main of clay mineral, [2] showed presence of heavy mineral. The aim of this research is to establish the origins and details of the source area of the sediments of the Injana Formation at Zawita and Daigala sections. This carried out by heavy and clay minerals.

Geological setting

The Injana Formation (Upper Fars Formation) is a part of the tectonostratigraphic megasequence of the Arabian Plate 11(Ap11) (Latest Eocene to Present Day). This megasequence lasted 34 my and is defined as the package of sediments lying between the unconformity marking both the onset of Red Sea rifting [3] and the first continent-continent collision between Arabia and Eurasia [4], and the present day topographic surface. The tectonostratigraphic megasequence comprises the Zagros foreland basin sediments deposited following the inversion and followed erosion of the earlier northeast passive and active margins. Red Sea rift sediments deposited following the thermal uplift, doming and rifting along the length of the Red Sea axis. This tectonostratigraphic megasequence thus represents the recent foreland Basin history of the Arabian Plate, with sediments firstly infilling the long narrow Zagros foredeep margins, and then prograding southeastwards down the foredeep [5]. The lower contact between the underlying Fatha Formation and the injana formation (previously known as the Lower Fars Formation) is conformable, placed in the field at the top of the uppermost limestone horizon of the Fatha Formation which is overlain by a thick red and subordinate grey mudstone beds. The upper contact of formation with the Muqdadiya Formation (previously known as the Lower Bakhtiari Formation) is transitional; its upper limit is marked by the first consistent appearance of pebbly sandstone. During the Late Miocene - Pliocene time major thrusting occurred during the collision of the Neo Tethyan terranes and the Sanandaj-Sirjan Zone with the Arabian Plate. This event resulted in the uplift of the High Folded, northern thrust Zones and the NE parts of the Balambo-Tanjero Zones and Mesopotamian Zones. The major foredeep formed in the Rutba-Jazera and Salman Zones is uplifted. During the late Miocene and especially the Pliocene, the High Folded Zone was uplifted with increasing intensity. The products of erosion are deposited in the nearby molasse basin characterized by the conglomerates of the Bai Hassan Formation (previously named Upper Bakhtiari). In the SW the uplifted stable shelf was the source of the terrigenous clastics deposit to the NE of the euphrates boundary fault (Dibdibba Formation)[6].The Injana Formation in both section consists principally of repeated fining upwards succession nested above each other ingeneral coarsening upwards in the sand . Located Zawita section in high folded zone in unstable zone and Daigala section located between the boundary interval high folded zone and low folded zone.

Methodology

Thirteen samples were collected from Injana Formation, representing sandstone and Mudstone (4samples from sandstone from Zawita area and 3 samples from Daigala area (heavy mineral) and 6 samples from claystone both from Zawita and Daigala areas (XRD)). Seven samples of sandstone are chosen to analyze heavy minerals (4 samples from Zawita and 3 from Daigala samples). The traditional heavy liquid approach is used to separate the heavy minerals; [6] . The heavy minerals to used grain size between(0.125mm-0.063mm)to separate utilizing Bromoform of density 2.89, placed on slide of glass and point counted using 300-500 grains per slide following the method of Fleet (1926: in [6]). The six mudstone samples are investigated by x-ray diffractometry from type (X-Ray Diffractometer (XRD-6000) shimadzn-Japan) in Nanotechnology &Advanced Materials Research Center in University of Technology. Four glass smears for each sample of separated clay fraction (2µm) are prepared according to the method given by [7]. The preparation of glass smears by adding hexametaphosphate solution (calgon) with clay to become suspension solution then pipet the clay suspension onto beaker containing a glass slide. The end step placing the beaker in an oven at 60 Cº and allowing the distilled water to evaporate and the clays to settle on the four slides, which were later treated as bulk, normal, heating at 550 Cº and ethylene glycol. The X-ray – Diffract meter specification of D2 phaser volat, cover tube, 30 Kv, 10 MA, 1.5418 nickel filter.

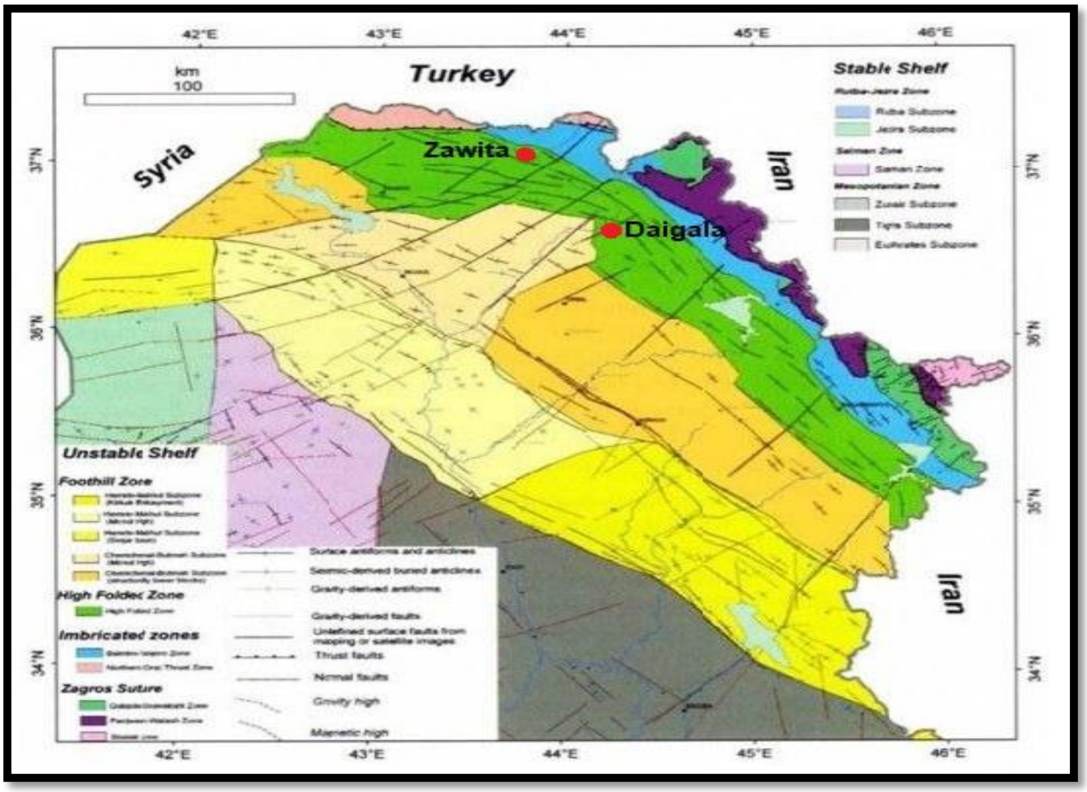

Fig. 1: Tectonic map of the studied area shows the location of the studied sections[6].

Result and dissction

Heavy minerals -Two categories of heavy minerals are identified in Injana sandstones, depending on their transparency :transparent and opaque minerals, Table -1 and Figure-1. The main components, which the opaque minerals with range 32.8%to44.6% (average38.7%) in Zawita area and 39.5-41.5% (average 40.5%) in Daigala area sandstone. The stable and unstable transparent heavy minerals assemblages , on average ,look like this: chlorite 9.95% in Daigala sandstone and 8.9% in Zawita sandstone, epidotes 5.15 % in Daigala sandstone and 5.9% in Zawita sandstone, garnet 5 % in Daigala sandstone and4.05% in Zawita sandstone, zircon 2.65 % in Daigala sandstone and 2.25% in Zawita sandstone, hornblend 6.45% in Daigala sandstone and 6.55% in Zawita sandstone, tremolit 1.3% in Daigala sandstone and 2.05% in Zawita sandstone, glaucophane 0.75% in Daigala sandstone and 1.05% in Zawita sandstone, clinopyroxenes 4.95% in Daigala sandstone and 3.75% in Zawita sandstone , orthopyroxenes 2.75% in Daigala sandstone and 3.65% in Zawita sandstone, biotite5.5% in Daigala sandstone and4.8% in Zawita sandstone, muscovite 5.35% in Daigala sandstone and 5.4% in Zawita sandstone, tourmaline 3.15% in Daigala sandstone and 3.3% in Zawita sandstone, rutile 3.15% in Daigala sandstone and3.8% in Zawita sandstone , (kyanite and staurolite) 1.35-1.75% in Daigala sandstone and 2-2.1% in Zawita sandstone and other (quartz and feldspar) 0.45% in Daigala sandstone and 0.6% in Zawita sandstone .In short, the average heavy mineral composition in the two sections under study differs noticeably. The average percentage of epidote and garnet in Daigala and Zawita sandstones is about equal. In contrast, the average of orthopyroxene in the Zawita sandstone is more that of the Daigala sandstone on average, whereas the percentage of opaques, amphibole group, chlorite, clinopyroxene and zircon are comparably high . The stability of the heavy mineral assemblages ranges from extremely stable to unstable .Additionally, they can be subrounded, prismatic or euhedral and unhedral.

Table 1: Injana heavy minerals distribution and average in sandstone at Zawita and Daigala sections

Formation	Injana			
Section	Zawita		Daigala	
Minerals	Range	Average	Range	Average
Opaques	32.8 – 44.6	38.7	39.5 – 41.5	40.5
Chlorite	7.9 – 9.9	8.9	7.4 – 12.5	9.95
Orthopyroxene	2.1 – 5.2	3.65	2.3 – 3.2	2.75
Clinopyroxene	2.7 – 4.8	3.75	4.5 – 5.4	4.95
Hornblende	4.5 – 8.6	6.55	5.6 – 7.3	6.45
Glaucophane	0.9 – 1.2	1.05	0.3 – 1.2	0.75
Tremolite	1.5 – 2.6	2.05	1.1 – 1.5	1.3
Biotite	2.4 – 7.2	4.8	4.9 – 6.1	5.5
Muscovite	4.3 – 6.5	5.4	4.4 – 6.3	5.35
Zircon	1.2 – 3.3	2.25	2.4 – 2.9	2.65
Tourmaline	2.2 – 4.4	3.3	2.7 – 3.6	3.15
Rutile	3.3 – 4.3	3.8	2.6 – 3.7	3.15
Garnet	3.7 – 4.4	4.05	4.6 – 5.4	5
Epidote	5.3 – 6.5	5.9	3.8 – 6.5	5.15
Staurolite	1.8 – 2.4	2.1	1.4 – 2.1	1.75
Kyanite	1.8 - 2.2	2	1.2 – 1.5	1.35
Other	0.3 - 0.9	0.6	0.3 – 0.6	0.45

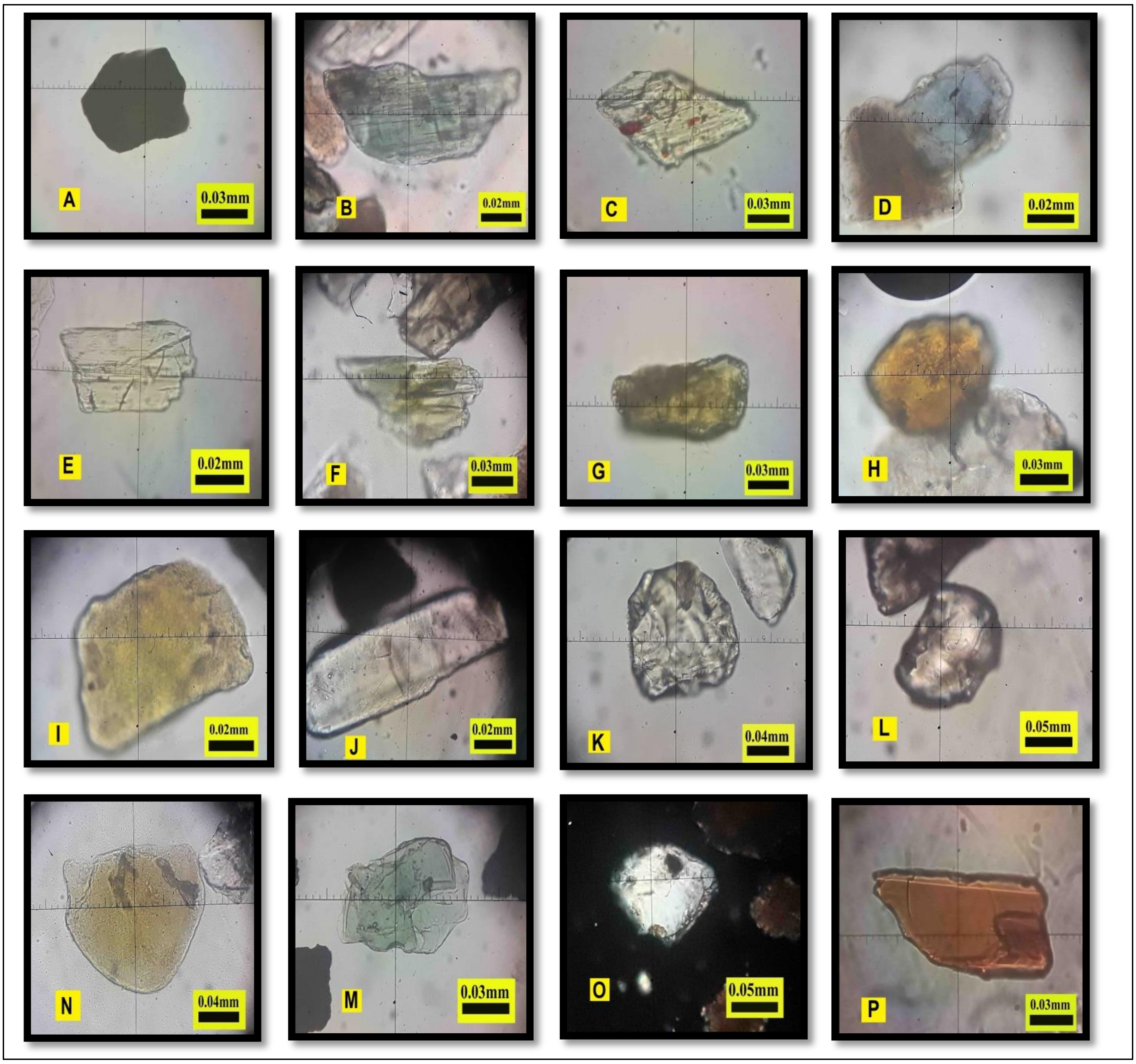

Fig. 2: Heavy minerals Photomicrograph of Daigala and Zawita sandstone: A- Opaque minerals, B- Amphibole (hornblende), C- Amphibole (Tremolite) , D- amphibole (Glaucophane),E- Orthopyroxene, F- Clinopyroxene, G- Epidote ,H-Staurolite ,I- tourmaline, J-Kyanite, K- Garnet, L- Zircon,N- Biotite, M- Chlorite, O-Muscovite, P- Rutile.

Mineralogy of the Mudstones: X-ray diffractograms reveal that the non-clay minerals are dominantly quartz, calcite and feldspar. The clay minerals are chlorite, kaolinite, mica and illite. Identification of each mineral type was based on the following cumulative criteria: non - clay minerals: this group includes: Calcite (C)- Calcite is identified by reflections at 3.03Å. It is a major mineral component in the clay fraction of Injana mudstone. This is in direct agreement with carbonate percentages in sandstones. Quartz (Q)- Quartz ranks second abundant mineral all studied samples of Injana mudstone. It is identified by reflections at 7.02Å.In some samples, the (003) and $(1\bar{1}1)$ peaks of illite and kaolinite interfere with the (101) major peak of quartz, resulting in an increase in the estimated relative abundance of quartz. Feldspar (F)- Feldspar identified in the range 3.22-3.18 Å in several samples. Exact grouping of these minerals is not possible due to its low percentage in the clay fraction of the mudstones. The presence of both calcite and quartz as major and abundant components is very well related to the sandstone mineralogy, a fact stressing the similar and common source rocks. Clay minerals: this group includes:- Chlorite(Ch)–the (001) peaks of Chlorites range from 14º - 14.4Å depending on the species. Ethylene glycol doesn't change Peak locations, although when heated to 550 ºC (001),the chlorite peak may drastically increase whereas Fe – chlorite and its possible for the higher order peaks to weaken [8]. The chlorite minerals are frequent constituents of igneous rocks that have undergone hydrothermal alteration, such as low-grade green schists. Ferromagnesian minerals and common constituents of argillaceous rocks in both detrital and authigenic forms [9]. Kaolinite(K) - Kaolinite group are identified by 7 Å (001)and 3.58 Å (002) peaks in sections studied which upon heating 550 ºC disappear [10]. All of the kaolinite groups members are formed largely through the hydrothermal weathering or alteration of feldspars in acidic environment. Illites (I) -Illites are identified by 10 Å (001) reflection. Illite group which along with other clay minerals, weather silicates, chiefly feldspar and mica, to produce the major clay minerals in argillaceous rocks. Mixed-layered clay - Interpretation of XRD spectra from mixed-layer clay cannot be satisfactorily achieved with conventional XRD methods, as mixed layered species are present in physical mixtures that include the simple clay types. Accordingly multiple analyses are needed as well as computer generated XRD patterns to discriminate the clay layers. In some situations, the creation of swelling minerals from non-swelling minerals or vice versa may include the formation of Mixed-layer clays, which can occur during weathering and involve the removal or uptake of cations, hydrothermal alteration, or removal of hydroxide interlayer and in some cases, may represent an intermediate stage in the formation of swelling minerals from non-swelling minerals or vice versa [11]; and [12]. The presence of mixed - layer clay minerals in the samples under study are basically of detrital origin. In such cases, due to weathering chlorite to may from regular and randomly interstratified mixed-layered clay minerals most likely smectite/illite following a typical weathering sequence:

The abundance of the clay minerals indicates that basic igneous and metamorphic rocks as well as recycled sedimentary rocks seem to be major contributors to the formation of clay minerals in the source area. The formation of illite and chlorite is taken to represent condition where intensive leaching of the cations is prevented and hence represent arid to semi-arid climate. The presence of illite indicates acidic igneous and metamorphic source rock in dray environment with high alkaline, as well as old sedimentary source rock. The presence of kaolinite indicates acidic igneous source rock in tropical and acidic condition, in addition old sedimentary source rock. The clay minerals assemblage appears to be of detrital origin given by the source location with minimal evidence of digenesis or transformation during transportation in the investigated samples .Depending on the above, the clay mineral of Injana is derived mainly from acidic igneous and sedimentary and less dominance metamorphic .The presence of clay minerals in the examined area suggests that the regions current predominance of dry to semi- arid climate was the environment their formation they were likely formed at the source places.

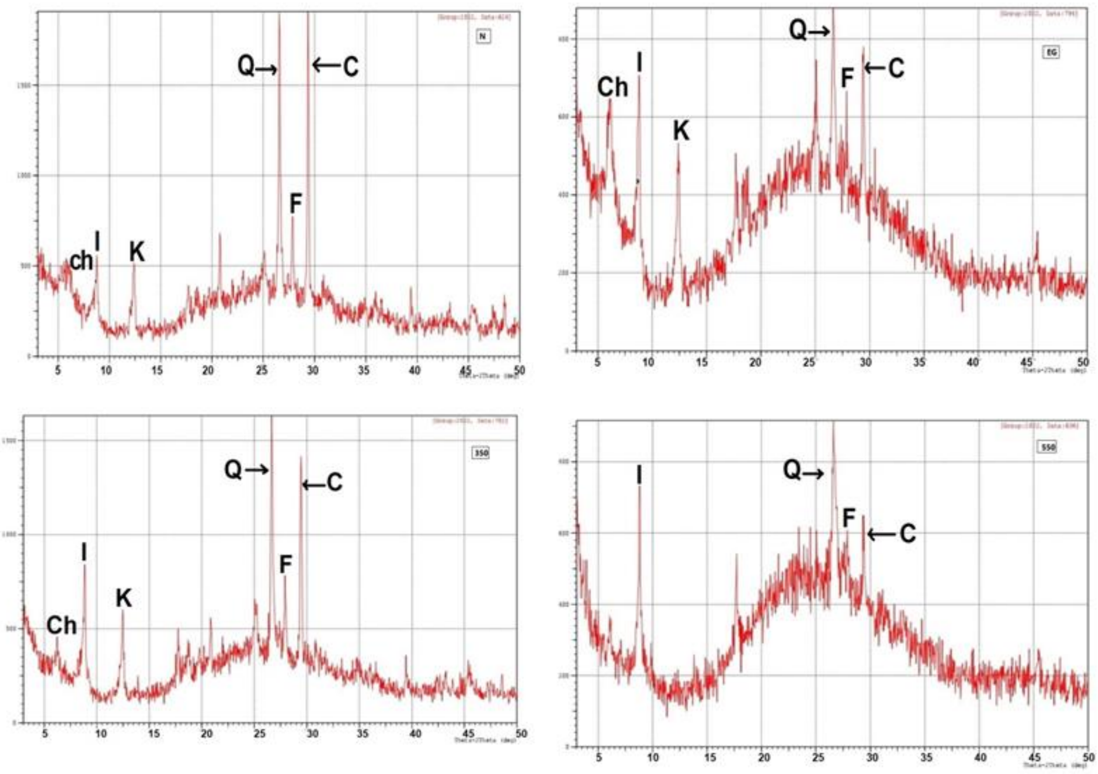

Fig. 3: X-ray diffractograms show the clay mineral components of the sample K3 in Daigala section representing: Q=Quartz, F=Feldsper,Ch=Chorite, C=Calcite, I=Illite ,K=kaolinite,.

Provenance

To ascertain the provenance and tectonic setting of the source location, the heavy minerals analysis is. The presence of opaques in this study comes from mafic igneous and metamorphic rock mainly, as well as acidic igneous and reworked sedimentary rock. Pyroxene is abundantly dispersed in the basic igneous rocks[13], glaucophene characteristic of metamorphic rocks such as gneiss and schist [14], hornblende is common in mafic igneous and metamorphic rocks [15], while tremolite-actinolite are metamorphic provenance [16], biotite is formed from acidic igneous and metamorphic rocks [17], [18], zircon occurs in acid and intermediate igneous rocks, and its euhedral structure indicate the presence of acid igneous rock [19]. Epidote, chlorite, garnet, amphibole (glaucophane and tremolite-actinolte), staurolite and kyanite are indicating metamorphic source [19]. A provenance of metamorphosed argillaceous sediments of high grade schist and acidic igneous rock is characterized by the presence of rutile [20]. Tourmalines Presence points to granitic pegmatites and acidic igneous origins [20]. Presence rounded or subrounded grains are indicative of reworked sedimentary provenance ,including certain opaques, zircon, and tourmaline [16].According to the findings of the study of heavy minerals for the examined samples of the Injana Formation, the source rocks are ultra-basic ,basic and metamorphic rocks, essentially, along with modified reworked sedimentary rock and acidic igneous rocks.

Conclusions

Different types of heavy minerals suggest different source rocks when they are present. The two sandstones under study have a noticeable variance in the amount of heavy mineral species present, which show that their sources are slightly different. Compared to other heavy minerals, which are said to mostly come from mafic igneous and metamorphic origins, the heavy minerals assemblages contain avery high percentage of opaques, additionally to sources of acidic igneous rock and reworked sediments. The proximit shows the presence of unstable heavy minerals, New York, 618p. y sources rock. The ZTR indices indicate the Injana sandstone is mineralogically immature. The mineralogy of the clay fraction of Injana mudstone leads to be climate arid to semi-arid.

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توزيع المعادن الثقيلة والمعادن الطينية لتكوين إنجانة في زاويته وديكلة شمالي العراق

ساره علي العامري ، لفتة سلمان كاظم

قسم علوم الارض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

تناول البحث الحالي دراسة معدنية لتكوين انجانة (المايوسين الأعلى) في مقطعي زاويتة وديكلة في شمال العراق. تمت نمذجة (13) عينة من التكوين في كلا المقطعين. تجمعات المعادن الثقيلة تضم المعادن المعتمة كمكون رئيسي، اورثوبايروكسين ، كلاينوبايروكسين، زركون، روتايل، ابيدوت، كارنت، امفيبول ، تورمالين، كلورايت ، بايوتايت، كيانايت، مسكوفايت وستوروﻻيت هذه التجمعة تشير الى انه المعادن الثقيلة مشتقة بصورة رئيسية من صخور نارية قاعدية وصخور متحولة بالإضافة الى الصخور النارية الحامضية والرسوبية القديمة .وتميزت بكونها غير ناضجة معدنيا. والاصل التكوتوني للتكوين إنجانة يعود الى الاورجيني المعاد .أما المعادن الطينية الرئيسية هي الكلورايت والكاؤلينات والالايت والسمكتايت، اما المعادن غير الطينية هي الكوارتز والكالسايت والفلدسبار. وأشارت الى ان المناخ جاف الى شبه جاف.