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Variation of the Modal Percentages of Epidote in Recent Sediments from Selected Localities in Northern Iraq

Mohsin M. Ghazal
Department of Geology
College of Science
Mosul University

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ABSTRACT

The metastable detrital epidote in northern Iraq is one of the non-opaque heavy minerals found in the Recent sediments of Tigris River and its tributaries, in addition to other rivers and valleys. The petrography revealed that the detrital epidote minerals are dominantly epidote (synonym pistachite), and less abundant zoisite and clinozoisite. Generally, the detrital epidote in the fluviatile sediments constitutes high frequency in most of the selected localities, with an average of 22%. Some localities, especially Lesser Zab River has the highest content of 42.6%, whereas the lowest content is found in Gomel Al-Khazir of 2.5%. By comparing the average of the detrital epidote determined in this study with those averages given by other workers, it seems to be approximately similar to that in the Recent sediments of the main channels of Tigris River (24.4%) and Shatt El-Arab (25.8%), but of lesser value compared with that of Euphrates River (33.7%). The greater difference is noticed in the average content of detrital epidote when compared with that of Aqsu and Adhaim Rivers (66.7%). The present study has determined also the main factors controlling the deposition of detrital epidote together with other heavies. The discussion of the provenance of the detrital epidote revealed that they are most probable products of disintegration of metamorphic rocks essentially, or from metamorphosed igneous rocks, both rock types are of Zagros- and Taurus Ranges in Iraq and Turkey respectively. Moreover, the recycling of the older formations (Kolosh, Tanjero, Injana, Mukdadiya and Bai Hassan) and river terraces, which have had relatively high content of detrital epidotes as documented by many authors.

تغاير النسب المئوية لمعدن الأبيدوت في الرواسب الحديثة من مواقع مختارة في شمال العراق

الملخص

معدن الابيدوت الفتاتي شبه المستقر هو أحد أنواع المعادن الثقيلة غير المعتمة التي وجـدت فـي الرواسب الحديثة لنهر دجلة وروافده فضلا عن انهار ووديان أخرى في شمالي العراق.

أظهرت الدراسة البتروغرافية بأن معادن الابيدوت الفتـاتي هـي معـدن الابيـدوت (المسـمى

بيستاجايت) بنسبة غالية، ثم معدن الزويسايت والكلاينوزويسايت بوفرة أقل. عموماً، يشكل معدن الابيدوت الفتاتي في الرواسب الفيضية المحددة في الدراسة الحالية نسبة عالية في أغلب المواقع المختارة بمعدل 22%. وجدت أعلى نسبة في بعض المواقع خصوصاً في نهر الزاب الأسفل وهي 42.6%، بينما كانت أقل نسبة في نهر كومل الخازر وهي 2.5%. لدى مقارنة معدل الأبيدوت الفتاتي المحدد في الدراسة الحالية مع معدلاته المحددة من قبل باحثين آخرين، فإنه يبدو مشابهاً تقريباً لمكوناته في الرواسب الحديثة في الأنهار الرئيسة في العراق، مثل نهر دجلة (24.4%)، شط العرب (25.8%)، وبنسبة أقل من نهر الفرات (33.7%)، والفارق الكبير لوحظ مع رواسب نهري آق صو والعظيم (66.7%). وقد حددت الدراسة الحالية العوامل الرئيسة المسيطرة على ترسيب الأبيدوت الفتاتي مع المعادن الثقيلة الأخرى. وأظهرت مناقشة المصدرية لهذا المعدن بأن الاحتمال الأكبر أنه ناتج من تفكك الصخور المتحولة الحاوية للأبيدوت أو من الصخور النارية المتأثرة بالتحول. هذه الصخور موجودة في كل من نطاقي زاكروس في شمال شرق العراق وطوروس في تركيا. علاوة على ذلك، جاء الأبيدوت من إعادة التجوية من التكوينات القديمة (كولوش، تانجيرو، انجانة، مقدادية، باي حسن) والمساطب النهرية، والتي تحتوي نسبياً على قيم عالية من الابيدوت الفتاتي كما هو موثق من قبل عدة باحثين.

INTRODUCTION

The detrital epidote minerals have been seen to constitute good, sometimes high percentages among the heavy minerals of the clastic sand fractions of the fluviatile Recent sediments of Tigris River and its tributaries as well as some other rivers or valleys in Northern Iraq (Philip, 1968; Berry et al., 1970; Jawad Ali, 1977 and 1984; Hussein, 1980; Al-Juboury et al., 1999 and 2001a; Al-Mi`amary, 2001). Moreover, the detrital epidote has been also reported in river terraces as high frequency, and in older formations such as Kolosh, Tanjero, Injana, Mukdadiya and Bai Hassan Formations (Philip, 1968; Jawad Ali, 1977 and 1984; Hussein, 1980; Jawad Ali and Khoshaba, 1980; Al-Juboury and Amin, 1989; Al-Juboury et al., 1999,2001a.and 2001b).

The detrital epidote has been mentioned with other heavy minerals in previous works with no individual comprehensive study about this mineral. However, epidote has been mentioned by many authors to constitute the higher frequency among the non-opaque minerals in Recent sediments and older formations.

The aim of the present study includes a petrographic identification, recognition using XRD technique, distribution and provenance of the metastable detrital epidote. In addition, a comparison with other works on Recent sediments of Tigris, Euphrates, Shatt El-Arab, Aqsu and Adhaim Rivers in Iraq.

Twenty-seven samples were collected as representative selected localities in northern Iraq (Fig. 1A).

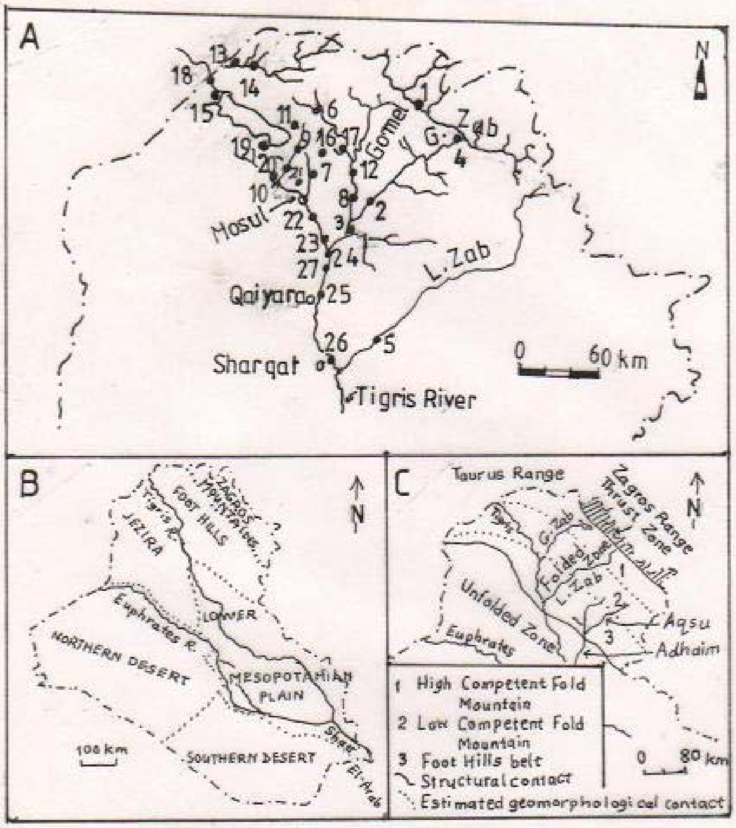


Fig. 1: A-Map of northern Iraq showing sample locations (see Table 1).
B-Physiographic provinces of Iraq (Buringh, 1960).
C-Tectonic and geomorphological divisions of Iraq (Dunnington, 1958 and Bolton, 1958)

GEOLOGY OF THE STUDY AREA

The area of the present study (northern Iraq) is part of the Folded Zone according to the tectonic and structural framework given by Dunnington (1958). It is situated in the High-, Low-Competent Fold Mountain and Foot Hills belts according to the geomorphological divisions given by Bolton (1958). The study area is lying in the Foot Hills and Jezira Provinces of Iraq according to the physiographical provinces given by Buringh (1960) (Figs. 1B and1C).

The general geology of northern Iraq could be described briefly as there are two main types of mountainous folds, the Zagros-trending Mountains and the Taurus–trending Mountains. The former type consists of NW-SE trending parallel ridges of folded Upper Paleozoic and Mesozoic age limestones and a Nappe Zone of metamorphosed Lower Paleozoic rocks along the borders with Iran at northeastern Iraq. In addition, the Foot Hills Province consists mainly of Upper Miocene and Pliocene coarse detrital sediments, which are gently folded along the same trend of the Zagros Mountains. The latter type of folds has an E-W trend ridges parallel to the Taurus range in the northwestern Iraq.

The Tigris River starts from the Taurus Mountains in Turkey and travels a distance of 1718 km. It forms in the Iraqi territories the boundary between the Jezira and Foot Hill provinces until its junction with the Lesser Zab River. Three major tributaries in Iraq drain the Foot Hills and Zagros Mountains, they are the Greater-, Lesser- Zab and Diyala Rivers. Other shorter tributaries drain also the same area, which are of special importance in this work, the Aqsu and Adhaim Rivers (Fig. 1C).

METHOD OF SEPARATION

The heavy minerals separation is carried out by washing the samples on a 0.38 mm sieve in order to remove the finer material. The sieved portion , therefore retained on a set of sieves representing a range of size from medium to very fine sand (0.25-0.063 mm). The carbonate fraction has been already removed by dilute 10% hydrochloric acid before sieving. About 10 grams of the sandy portion was separated into heavy and light fractions using bromoform (Sp. Gr. 2.9).

MINERALOGY AND PETROGRAPHY

Mineralogy:

In general, the epidote group comprises three essential monoclinic minerals, clinozoisite, epidote "synonym pistachite" and allanite "synonym orthite". The latter is characterized by containing rare earth elements such as Ce and La (Hatch et al., 1972; Hulbert and Klein, 1977). The orthorhombic polymorph of clinozoisite is called zoisite. There are common varieties such as piemontite (Mn-epidote), thulite (Mn-zoisite), withamite (poorly Mn-piemontite), tanzanite (gem quality, blue crystals). All minerals of epidote group are Ca-rich hydrous sorosilicates of complex $(SiO_4)(Si_2O_7)$ structure. Their hardness ranges between 5.5-7, and specific gravity between 3.25-4.2 (Kerr, 1959; Hatch et al., 1972; Hurlbut and Klein, 1977; Deer et al., 1978; Barker, 1983). The detrital epidotes are either transparent (colors of yellowish to pale green), or translucent (gray to black color). The well crystalline forms are prismatic and elongated parallel to the b-axis, or columnar. Some grains are rounded to subrounded.

X-ray Diffractometry

The detrital epidote of the present study has been recognized by using XRD-technique with a Philips 1730 Diffractometer (Cu∝ radiation, Ni filter). The diffractogram (Fig.2) performed on heavies of three localities (Barzan, 1; Faida, 11 and Alqosh, 16). This figure shows that epidotes are recognized at an angle of 2θ=30.90° and smaller peaks at 2θ=37.6°.

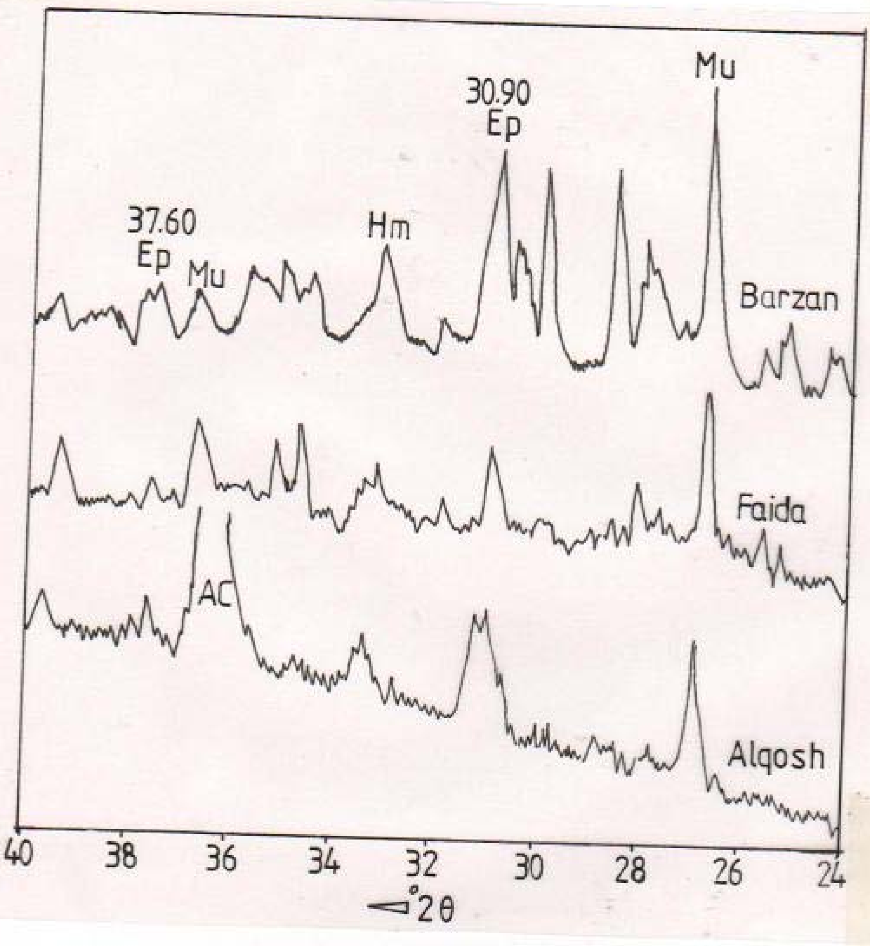


Fig.2: Diffractogram of heavy minerals in the Recent sediments at localities Barzan, Faida and Alqosh. Ep=Epidote, Mu=Muscovite, Hm=Hematite and AC=Aluminian Chromite.

Petrography:

Thin section examination shows that detrital epidote minerals are generally colorless especially those of low iron content, or yellowish to pale green for those of more iron content which is also characterized by slight pleochroism under plane polarized light. One perfect cleavage is clear. The interference colors are of high orders, but sometimes anomalous where the interference color seems bluish to brownish such as zoisite. The sections parallel to b-axis display parallel extinction, while the sections perpendicular to b-axis display maximum extinction up to 30 degrees. The detrital epidote minerals are seen in the present study being dominantly epidote (synonym pistachite), then less abundant zoisite and clinozoisite. The dominant epidote is of pistachio-green color, rounded to subrounded and equidimentional grains. Zoisite and clinozoisite are subangular grains with bluish interference color. Different types of epidote grains are illustrated in plate (1).

DISTRIBUTION OF DETRITAL EPIDOTE

Table (1) displays the modal percentages of the metastable epidote as a heavy mineral in the Recent sediments of the present study. The percentage of the detrital epidote ranges between 2.5% at Gomel Al-Khazir and 42.6% at Lesser Zab River, with an average of 22.026%.

The relative low frequencies of epidote found in Greater Zab River (6.8%), Khabour (7.5%), Gomel Al-Khazir (2.5%) and Sehaila (9.6%) can be ascribed simply to absence of one or more of the most important factors causing the enrichment or the differential accumulation of heavies. Such factors are:

(1) The appropriate distance of transportation giving enough time for disintegration.

(2) The morphology of the river, i.e. the meandering, causing a decrease in water velocity, then deposition due to gravity.

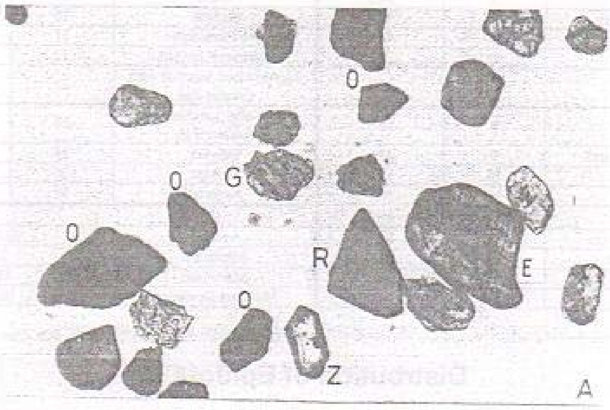
(3) The probability of selective deposition of the more spherical grains, especially in fast flow of water.

(4) The topography, i.e. gentle slope of area of travelling river, causing relative slow flow of water.

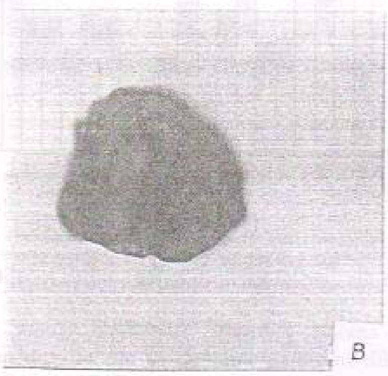
(5) The high frequency of the transported epidotes depending on their provenance.

Otherwise, the above mentioned factors would give rise in frequencies of detrital epidotes or even enrichment such as in Lesser Zab River (42.6%) (Tabble 1 and Fig.3).

PLATE (1)



(A) Heavy minerals in the Recent sediments of Tigris River (Locality Hammam El-Alil). E=Epidote (synonym pistachite, brown). G=Garnet, R=Rutile, Z=Zircon (bipyramid), O=Opaques. Plane polarized light (4X).



(B) Anhedral epidote grain of green color in very fine-grained sand (Locality Greater Zab). Plane polarized light (20X).

Table 1: Modal percentages of detrital epidote in sand fraction of the Recent sediments of Tigris River and its tributaries and valleys in northern Iraq.

Locality	Sample No.	Epidote%	Locality	Sample No.	Epidote%
Barzan	1	27.6	Gomel Al-Khazir	17	2.5
Kalak	2	31.8	Sehaila	18	9.6
Gwair	3	34.5	Wana	19	20.3
Greater Zab	4	6.8	Badosh	20	20.6
Lesser Zab	5	42.6	Al-Rashidiya	21	15.2
Zawita	6	12	Hammam El-Alil	22	20.1
Khoser	7	32.1	Tigris before junction with Greater Zab	23	20.3
Khazir	8	28.7	Tigris after junction with Greater Zab	24	31.3
Wadi Al-Malah	9	35.6	Qaiyara	25	31.5
Helaila	10	17.2	Sharqat	26	27.3
Faida	11	16.7	Nemrud	27	12.6
Kanilan	12	30.3			
Feshkhabour	13	21.4	Average	22.026	
Khabour	14	7.5	Minimum	2.5	
Tigris before Lake	15	24.5	Maximum	42.6	
Alqosh	16	14.1	Standard Deviation	10.11	

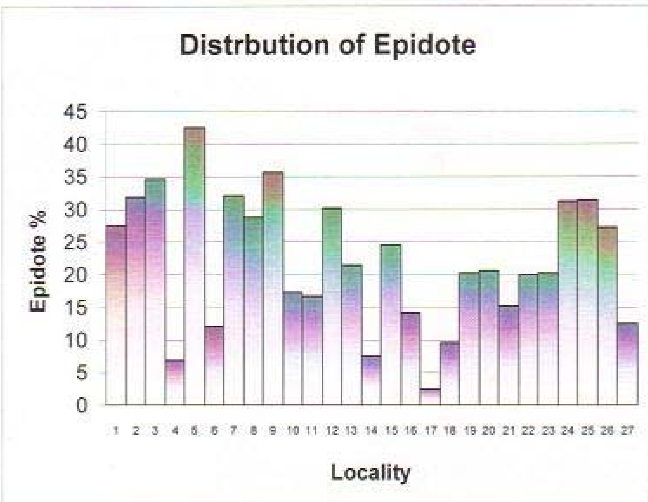


Fig. 3: Percentages of the detrital epidotes in the studied localities.

The non-opaques are epidote, pyroxene, amphibole, garnet, zircon, tourmaline, rutile, kyanite, staurolite with subsidiary amounts of olivine, sphene, spinel as well as flaky-minerals such as biotite, chlorite and muscovite (Philip, 1968; Berry et al., 1970; Hussein, 1980; Al-Juboury et al., 1999 and 2001a).

The metastable minerals found in the river terraces are epidote, garnet, staurolite and kyanite (Al-Juboury et al., 2001b). The representation of the average percentages of epidotes of the present study in comparison with the averages of epidotes given by Philip

(1968) for the main channel of Tigris-, Euphrates-, Shatt El-Arab-, Aqsu and Adhaim Rivers are shown in figure (4).

It is noticed by this representation that the average of the present study (22.026%) is rather near to the values of the averages of epidotes of the main channel of Tigris and Shatt El-Arab Rivers (24.4% and 25.8% respectively). The average content of epidote in the Euphrates River (33.7%), which is more than in the Tigris River most probably due to the supplying of the source area, the topography of the area (gentle slope) and the morphology of the Euphrates River (meandered).

The markedly increase of the frequency of epidote in Aqsu and Adhaim Rivers (66.7%) is ascribed by Philip (1968) to that Adhaim River and its tributaries that drain the Folded Zone of Iraq. This zone consists mainly of Qandil metamorphic calcareous rocks as a part of the Qandil-Gimo sequence in the ophiolitic complex of Albian-Cennomanian age (Aswad, 1999), and also to the recycling of the older formations especially Bai Hassan (formerly Upper Bakhtiari) Formation of Pliocene age. Another possible reason of this enrichment is the more probable selective transportation of less spherical amphibole and pyroxene grains due to steeper slope of Aqsu River.

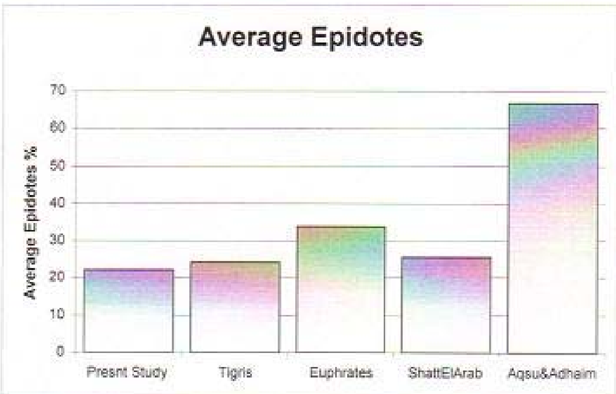


Fig. 4: Comparison of the average epidotes of the present study with other rivers in Iraq (Data from Philip, 1968).

PROVENANCE OF THE DETRITAL EPIDOTE

The epidotes are normally found in both igneous and metamorphic rocks. In igneous rocks, the primary epidotes develop essentially in pegmatites and less in granitic and other igneous rocks. The process of formation of such primary epidotes is due to the latest stage of magmatic crystallization known as deuteric readjustment of calcium-rich plagioclase component (anorthite) as shown by the following reaction (Barker, 1983):

$$\underset{\text{Anorthite}}{3CaAl_2Si_2O_8} + H_2O + \underset{\text{Calcite}}{CaCO_3} = \underset{\text{Epidote}}{2Ca_2Al_3Si_3O_{12}} + CO_2$$

Also in spilites, the epidotes form due to metasomatism during seafloor metamorphism (Barker, 1983). Epidotes occur also in association with porphyry ore deposits as alteration product in the wall rocks surrounding plutons (Lowell and Guilbert, 1970; Guilbert and Lowell, 1974).

The most dominant growth of epidotes is in the metamorphic rocks. The epidotes are stable in wide range of regional metamorphic facies, from low-grade pumpellyite-actinolite facies to intermediate-grade amphibolite facies. Characteristic associations of actinolite-albite-epidote-chlorite occur in the upper grade of the greenschist facies (Turner and Verhoogen, 1960; Turner, 1981; Best, 1982). The epidotes also occur in thermal metamorphic facies especially in albite-epidote-hornfels facies (Miyashiro, 1973). The process of epidotization of calcic plagioclases or other Ca-Al minerals is explained by the effects of metasomatism. Epidotes are formed as a product of plagioclase, pyroxene and amphibole. The epidotes are common in metamorphosed impure (siliceous Al dolomitic) limestones with Ca-rich garnets, diopsides, idocrase and calcite (Hurlbut and Klein, 1977; Best, 1982).

In northeastern Iraq, the epidotes occur in the metamorphosed igneous and metamorphic rock sequences as documented by many works; for example in Walash volcanics in Haj Omran and Sidekan (Al-Cholmaky, 2002), in spilites of Walash volcano-sedimentary group (Aziz, 1986), in ophiolitic volcanic and subvolcanic metamorphosed basic rocks of the Iraqi Thrust Zone in Penjwin and Mawat (Al-Hassan, 1982; Aswad and Ojha, 1984; Aswad et al., 1993; Al-Samman et al., 1996), in basaltic seafloor alteration and in clastics of upper part of Naupordan metamorphic group and in metamorphosed Walash and Qandil groups (Aziz et al., 1993a and 1993b).

The detrital epidote in the older formations in Northern Iraq, especially the clastic units were compiled and documented by many authors as follows:

1. In the Quaternary Tigris River Terraces, Northern Iraq, the detrial epidote forms a mean of 41% (Al-Juboury et al., 2001b).
2. In the Pleistocene Adhaim River Terraces, the detrital epidote forms an average of 62.3% (Philip, 1968).
3. In the Late Miocene Injana (formerly Upper Fars) Formation, the detrital epidote forms an average of 44.2% (Philip, 1968).
4. In the Pliocene Mukdadiya (formerly Lower Bakhtiari) Formation, the detrital epidote forms 22% (Jawad Ali and Khoshaba, 1980). In the same formation but at Injana area, the detrital epidote forms 41.6% (Philip, 1968).
5. In the Upper Cretaceous Tanjero Formation and in the Paleocene-Lower Eocene Kolosh Formation, the detrital epidote is reported by Al-Jubory and Amin (1989).

It is clear now that the provenance of the detrital epidotes in the Recent sediments of the present study is mainly the metamorphic sequences of Northeastern Iraq as well as the metamorphosed igneous rocks in both Iraq and Turkey, as well as the recycled detrital epidote from the older formations and river terraces.

SUMMARY AND CONCLUSION

The detrital epidote of the Recent fluviatile sediments of Tigris River and its tributaries, in addition to other rivers and valleys in northern Iraq has been studied in selected localities lying in Folded Zone.

The essential minerals of the epidote group found as detrital is the pistachio-green epidote, others are zoisite and clinozoisite, which are less abundant. The epidote is rounded to subrounded and equidimensional, and the zoisite and clinozoisite are subangular and characterized by masked bluish interference color. The average of the detrital epidote of the present study (22.026%) is found to be more or less similar to the average of the same mineral of other rivers in Iraq like Tigris River (24.4%) and Shatt El-Arab River (25.8%), and less than the average in Euphrates River (33.7%). The large difference in averages is noticed when compared with Aqsu and Adhaim Rivers (67.7%) of much more detrital epidote content.

The minimum frequency of detrital epidote is found at Gomel Al-Khazir River (2.5%), while the maximum frequency is found at Lesser Zab River (42.6%). The factors controlling the high frequency or enrichment of the detrital the distance of travelling rivers; the topography, the morphology of rivers summarizes epidote and other heavies; the probable selective deposition of the more rounded grains and the quantity of transported epidote grains depending on its provenance.

The detailed discussion of the occurrence of epidotes in metamorphic and metamorphosed igneous rocks in both Zagros and Taurus Ranges in Iraq and Turkey, in addition to the presence of detrital epidote in older formations and river terraces, leads to conclude that the detrital epidote minerals are products of disintegration of the mentioned rocks.

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