Mineralogy of agate gemstone in Quaternary deposits, Southeastern Basrah, Iraq

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Mineralogy of agate gemstone in Quaternary deposits, Southeastern Basrah, Iraq

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Abstract

A mineral-geological study was conducted for the dispersion agate that spread on the surface of the Dib-dibba desert within the border of Basrah Governorate -Southern Iraq. The collected stones were studied using polarized microscopy, XRD and EDX- SEM techniques to determine their mineral and chemical composition. Five types have been distinguished: white, colloidal, banded, cluster, and fleshy. It is believed that these stones are part of the gravels that are included in the components of clastics Dibdibba Formation, it forming resulting of the erosion of the igneous and metamorphic rocks that related to Arabian Shield, which were moved by torrential waters and seasonal floods to long distances and cumulated in that area. Several mechanical operations affected these stones like crushing, sorting, and polishing which contributed to their appearance and exposure on the surface of the earth**.**

Keywords: Agate, Gemstone, Mineralogy, Petrography, Dibdibba Formation, Iraq.

1. Introduction

Agate is one of the well-known and common semi-precious stones in the world, which is char-acterized by specifications that distinguish it from other stones, such as hardness, luster, colors, and special shapes. Agate is an expression that does not describe a specific mineral, but it is called a group of different forms of silica, especially chalcedony, which is one of the types of cryptocrystalline quartz, with a waxy luster, transparent or translucent, and is characterized by white, gray, brown or black colors. Agate belongs to the hexagonal crystallization systems; the specific weight is between (2.60 - 2.65) while the refractive index is between (1.544 - 1.553) and its hardness ranges between 6.5 -7. It chemically consists of silicon dioxide SiO_2 with various impurities of iron or manganese oxides and sometimes some nickel as it may be surrounded by water or gas bubbles [1]. Chalcedony is formed as a result of aqueous solutions in the voids and cracks in the host rocks, primarily igneous rocks [2]. Some types of chalcedony are distinguished by the presence of bands or layers that alternate in colors between white and black, or white and red, giving attractive shapes such as onyx and sardonyx. The importance of chalcedony lies in the use of its various types as semi-precious stones, the most famous of which are red agate, brown agate, onyx, sardonyx, and tree agate. The Arabic word "Akeek" is of Arabic origin, meaning "the thing that cracked", due to the cracking rocks hosting it. As for the word "Agate", which means agate, it is of Latin origin, and it derives from the name of the River "Achates" on the island of Sicily, Italy.

Agate is found in several countries in the world, the most important of which are Yemen, Aus-tralia, America, Brazil, Uruguay, the Czech Republic, Germany, Italy, India, China, Mexico, Thailand, Sri Lanka, South Africa, New Zealand, Zaire, and Armenia [3]. Agate is a semi-precious stone, and it is either in the form of chalcedony, which is translucent - translucent or opaque, in this case, it is called jasper. This stone is a beautiful stone that enhances positive energy and improves mood in humans, and is characterized by its warm colors, such as light yellow and dark red-green, and purple, which gives the impression of optimism and satisfaction. This stone has many uses, in-cluding in the manufacture of ornaments and jewelry, as well as in the manufacture of antiques, furniture pieces, thermal insulators, and it is used in laboratories for the manufacture of agate grinding mortars [4]. There are many sellers and hobbyists of gemstones in the local market in Iraq who offer large quantities of stones as agate stones, which were collected from different de-sert areas in western and southwestern Iraq, while the largest number of these stones form pieces of different rocks of quartz, flint, and others minerals. This study aims at diagnosing the main types of agate found in the Al-Dibdibba desert area in southwestern Iraq, determining their types, shapes, and areas of gathering, as well as determining their sources and conditions of existence in this region (Fig.1).

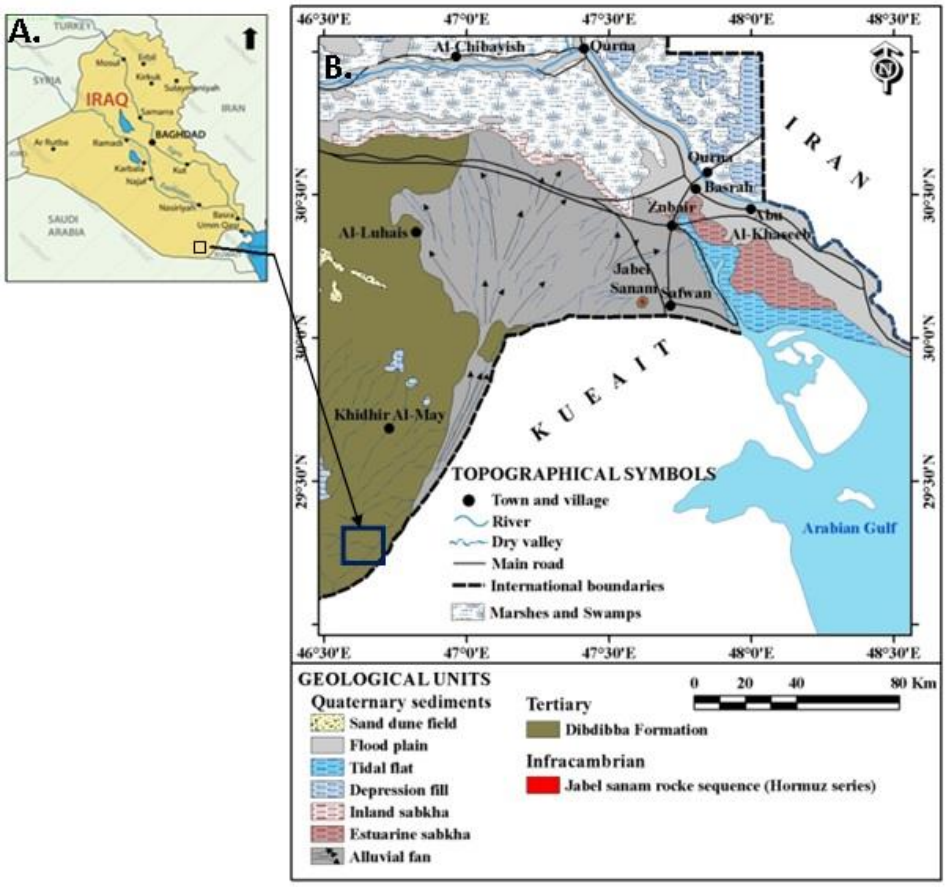

Fig.1. A- Iraq map with the location of the study area (Black rectangle), B- Geological map of the study area and sample's location. [5].

2. Geological Setting

The study area is located in the farthest part of the Al-Dibdibba desert in the Iraqi-Saudi-Kuwaiti triangle within the coordinates (29° 35′ 35.1N, 46° 45′ 32.8E) (Fig.1), where there is the largest concentration of gravel and stone deposits due to its proximity to the source in Saudi lands.

The Quaternary and Dibdibba sediments covered the Basrah desert, this desert is characterized by a flat surface with a maximum dip reach of 7°, it is desiccated by wide and shallow valleys, that created by erosion or fault escarpment, which represent the highest hills in the region with maximum high reach to 50m. Karst features also occur with varied shapes and sizes, and are characterized by a circular view, the contour elevation is increased from northeast to southwest [6]. The important geomorphological feature of the study area is Al-Batin alluvial fan (Fig.1). Al-Batin fan is composed of sandy gravel, gravely sand and gypcrete, interbedded with lenses of silty and sandy clay, the presence of heavy minerals like zircon and rutile suggests that these deposits were derived from of Arabian shield [5]. Tectonically, the Southern Desert is located at the Stable Shelf of the Arabian Platform, it is invalid of the tectonic folds [7]. While Fouad (2015) [8] determine the desert within the inner platform, started by Anah- Abu Jir longitudinal fault. Another features existence there, these are the Al-Batin lineaments. Stratigraphically, the latest Neogene and Quaternary consider the last deposits that covered of the studied area, started with fresh water deposits of Zahrah Formation and varied clastics of Dibdibba Formation that evaluated to denudational sediments of Quaternary age [9]. The desertification was effective during the late Quaternary period (36000Y.BP) until the present time [10]. Dibdibba Formation is exposed in the

Southern Desert, beginning to Tar Al-Najaf until to Zubair city, the first description of this formation by Owen and Nasr (1958) [11], in the type locality of oil well Zb-3, the total thickness is 355m, contains different types of clastics, such as poorly sorted of sand, pebbly sand and gravels, with varied colors, the important minerals are composed of grey quartz, feldspar, and rock fragments. The origin of these deposits are acidic and intermediate igneous rocks, with a rare percent of metamorphic rocks, limestone, and chert [12].

The study area is characterized as a broad, flat desert in general, where the large geomorphological features disappear, except for some common desert structures such as sand dunes, which are characterized as longitudinal dunes of low height and extending for long distances consisting of sand and dust grains. Other desert sedimentary structures are formed, the most important of which are the ripple marks (Fig. 2A, B), as well as the traces of various animals and reptiles (Fig. 2A) and the Nepak forms. The most prominent other geomorphological forms were the grooves and channels made by torrential rains and monsoons (Fig.2C, D), which are of different shapes and lengths, straight or zigzag and branched. These grooves are loaded with pieces of stones, pebbles and various muds that were transported by torrential water and rain from long distances. It is believed that the speed of its water currents was very high, which can be deduced from the sizes and weights of those pebbles, whose weights sometimes exceed 1 kg. These grooves are deep, sometimes exceeding 1 m in depth, which sometimes reveals parts of gravel sequences that date back to the Dibdibba Formation (Fig. 2E) and recent sediments (Fig. 2F)**.**

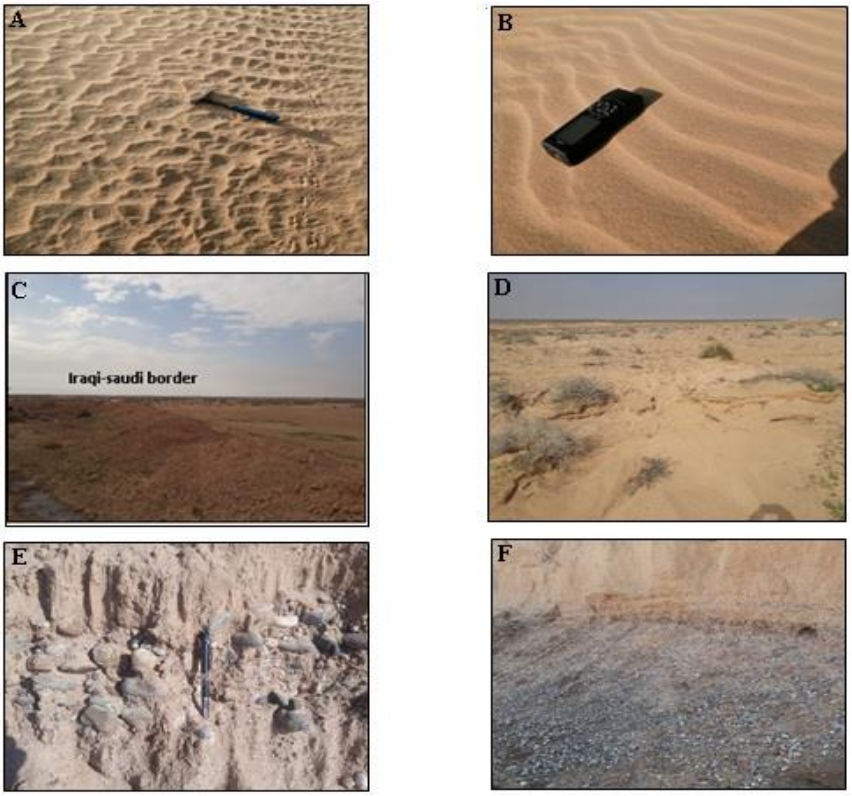

Fig.2. The main geomorphological features (**A** and **B**: ripple marks with animals' trials), (**C.** and **D.** grooves and channels made by torrential rains), also sediments distribution patterns in the study area (**E**. gravels of Dibdibba Formation, **F.** mixed gravel of recent sediments with Dibdibba deposits).

3. Methodology:

More than 70 samples of these stones of different sizes and shapes were collected within the sediments of the Quaternary age; In addition, some of outcrops belong to Dibdibba Formation. The fieldwork was carried out during March 2021, immediately after the end of the rainy and torrential season, where frivolous gravel deposits are clearly exposed above the surface of the ground. 72 samples of agate stones of various shapes and sizes were collected, their sizes ranged between 1-5 cm^3, and later 14 of them were isolated after laboratory examination, as it was found that they were pieces of different igneous and sedimentary rocks. Five types of agate stones were distinguished depending on their colors and their external and texture characteristics. Thin sections of these types were made to study them under a polarized microscope to diagnose them and determine their microscopic textures. These types were also examined using an X-ray diffraction technique in the Research Department of the Ministry of Science and Technology / Baghdad to diagnose them mineralogically. In addition, 4 samples of these stones were analyzed using SEM-EDX technology in SEM laboratory in Physics Department/ Science College/ Basrah University to determine the general chemical components of these stones**.**

4. Results and discussion

4.1 Mineralogical and textural characteristics

Large quantities of gravels and stones of different sizes and shapes are spread in the study area (Fig. 2F), 72 samples of these stones that could be agate stones were collected (Fig. 3a), and after examining these samples in the laboratory, some samples that turned out to be pieces of igneous and sedimentary rocks or minerals of quartz, chert, and others. The remaining samples, which were pieces of agate, were classified into different types after studying their natural, morphological and textural characteristics, as shown in (Table.1). Agate stones are divided into two main groups, the first being chalcedony, which is usually transparent to semi-transparent and has varying colors such as white, brown, red, blue, purple, green, and others. The second type is jasper as opaque stones that do not allow light to pass through. These stones also have a variety of colors and shapes, including brown, yellow, banded, etc. with a conchoidal fracture and smooth surfaces. These two types of agate were distinguished in the region, and jasper stones were the common ones. Their colours ranged between brown, yellow, white and gray, and sometimes with different textures and appearances (Fig.3b). Two types of chalcedony stones have been identified, the first type is translucent white (Fig. 3c) characterized by its medium transparency and vitreous luster, and the second type was called the colloidal type because it resembles a hardened gel (Fig. 3d) and has a dark brown color gradient to yellow and with a waxy luster. On the other hand, three types of jasper agate have been distinguished, which are the banded agate, which has reddish-brown colors gradient in the form of fine lines (Fig.3e). The second type was called the fleshy agate because of its leathery or fleshy appearance and greasy texture (Fig.3), while the last type was characterized by the cluster appearance (Fig.3g) in the form of spots or lobes separated by dark sinuous lines and brown, yellow and white colors.

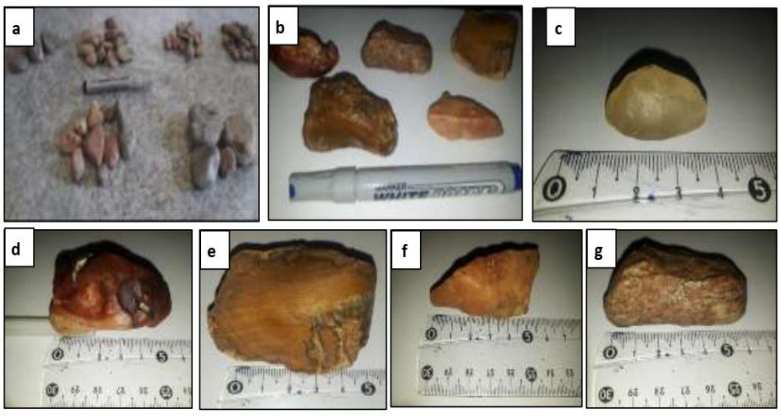

Fig. 3. Types of agates (a) The collected samples (b) Identified agate types (c) White agate (d) Colloidal agate (e) Banded agate (f) Fleshy agate (g) cluster agate.

Table1. Types and initial properties of collected stones.

Type of samples	No.	Colours
Igneous & metamorphic gravels	14	White, light brown, light purple, gray, lined an banded gray
Quartz and chert	8	White, gray
Agate (chalcedony)	38	White, brown, light red, lined white
Agate (jasper)	12	Brawn, buffy, light pink, light red
Total	**72**	

Agate stones were distinguished under the polarized microscope as being composed of hidden crystalline or microcrystalline quartz microllites (poly-crystalline quartz) (Fig.3a), and sometimes they were fibrous and fine in appearance and sometimes they took a radial shape (Fig.3b), which is one of the features of chalcedony minerals under the microscope [13]. Some may contain silica veins or iron oxides, especially the cluster type, which can be followed by the effect of crack-filling solutions (Fig.3c).

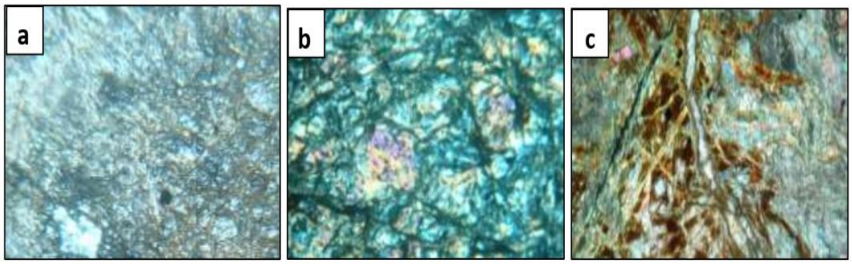

Fig. 4. (a) Microcrystalline quartz microllites in colloidal agate. **(b)** Fibrous and radial texture of quartz grains **(c)** Silica and iron oxides cluster agate type. (All images 40X. X.P.L.)

4.2 Micro-mineralogical analysis

X-ray diffraction analyzes were performed for powders of chalcedony-type chalcedony and jasper. The precise mineral analysis of selected samples of agate species showed that the main mineral component in them is quartz (Fig. 4,5) [14], and it is believed that it is the main phase in these minerals, as no other phases may be associated with it, such as terdymite or cristobalite [15].

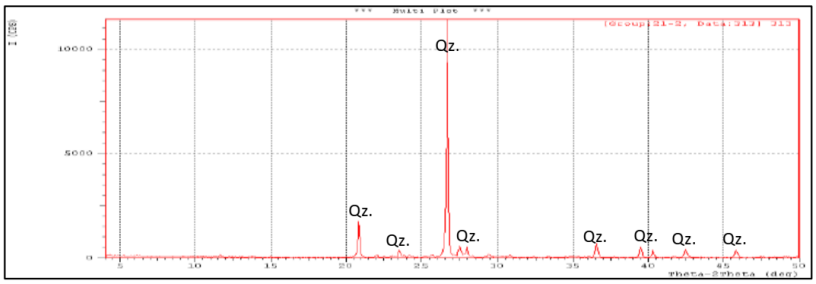

Fig. 5. X.R.D chart of White agate (chalcedony)

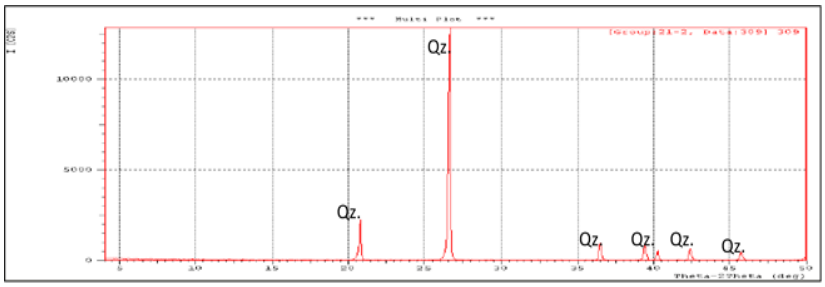

Fig. 6. X.R.D chart of Fleshy agate (Jasper) showing composition and type of quartz in agate sample.

Microscopic study and electron microscopy SEM images of the studied agate by examining the geomorphology of the surface grains. The main internal structure of these stones consists of quartz minerals in various forms. The chalcedony grains are characterized by fibrous or flaky shapes (Fig. 6, 8), while they are irregular and colloidal appearance in Jasper stones (Fig.7) [3]. The semi-quantitative chemical analysis of the various pieces of agate shows that it consists of basic quartz components with minor components of some elements, primarily Fe, which is included in the composition of hematite or goethite minerals that fill the gaps and cracks between the mineral grains, which are sometimes in relatively high concentrations (Fig.6) [1, 5], which gives agate stone is a distinctive brown or red color, and is sometimes in the form of successive lines with different concentrations of this element. Several researchers have suggested that agate bands form as a result of crystallization from hot aqueous fluids [15]. The combination of elements such as Al, Fe and Mn observed in the jaspar samples (Fig. 6) supports the metamorphic or metasomatic origin of the formation of these stones [2, 16].The presence of sulfur and calcite (Fig.7, 8) in some samples may be attributed to the gypsum matrix or gypsum accumulations on the surface of the mineral grains. A concentration of Ti was observed in some agate stones (Fig.9) and this supports that they are derived from distant source rocks such as the acidic igneous rocks of the Arabian Shield [17], because this element is present in this type of rock and has the ability to remain in the granules of clastics minerals despite its long-distance transmission [18].

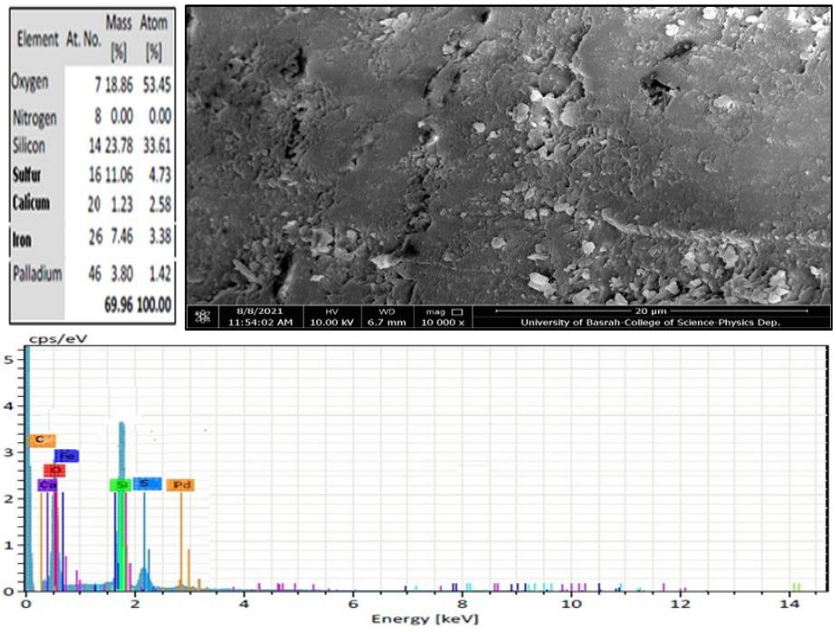

Fig.7. SEM-EDX of colloidal agate (DA1) showing the granular and flaky morphology of the surface and its chemical composition.

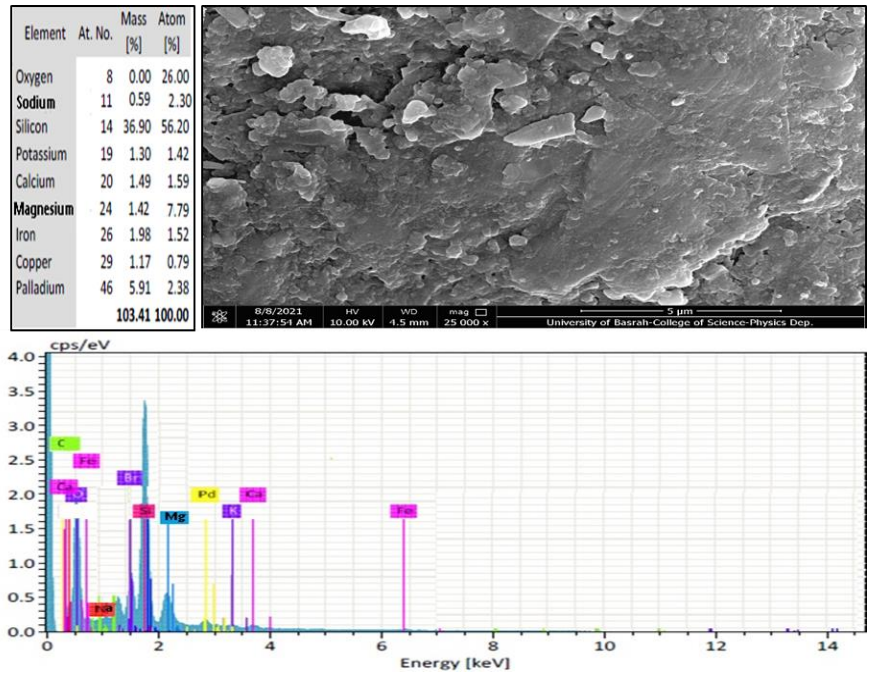

Fig. 8. SEM-EDX of agate (DA.3) showing the flaky and fibrous morphology of the surface and its chemical composition

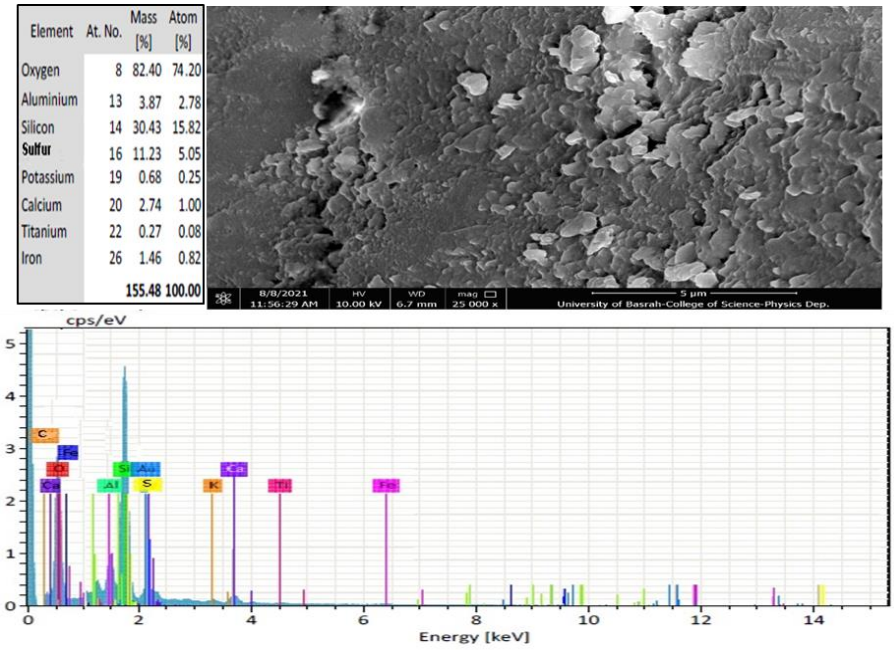

Fig. 9. SEM-EDX of agate (DA1) showing the morphology of the surface and its chemical composition

The fluvial plain, which formed the deposits of the origin of Dibdibba Formation sediments, is huge sediment deposited by strong currents. These currents transported huge amounts of clastic sediments from exposed rocks in the Arabian Shield region of Saudi Arabia during the Pliocene-Pleistocene [19, 20, 21] formed Al-Batin alluvial fan (Fig.10). It consists of sand and gravel of igneous and metamorphic rocks and variable forms of white quartz, agate, chert, and other minerals [9].

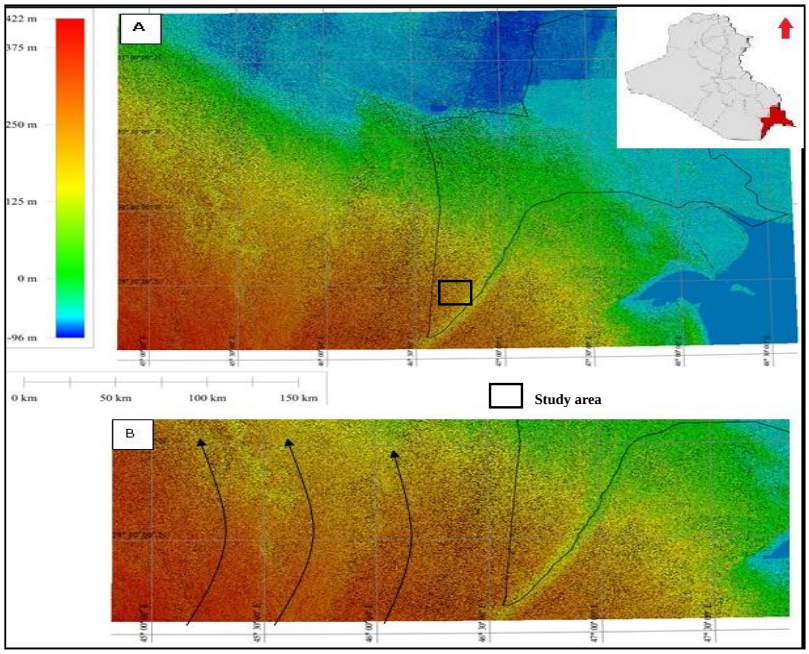

Fig. 10. A. Satellite image for Al-Batin alluvial fan in Southern desert, **B.** magnified scope to the studied area showing the direction of fan arms and sediments.

5. Conclusions

The Dibdibba agate in southern Iraq is characterized as poly or crypto-crystalline quartz, it consists of various forms of quartz minerals such as chalcedony and jasper, which differ in their colors according to the chemical impurities they sometimes contain, especially the elements iron, magnesium, and others. It's believed that these stones were transported from distant areas (Arabian shield) if no veins or outcrops were found that could be a source for these stones in that area, and their texture and morphological specifications support that. It is believed that these stones resulted from silicate bodies that were associated with the igneous and metamorphic rocks that make up the rocks of the Arabian Shield or resulted from later metamorphic, metasomatic, or sedimentary processes in the source rocks.

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