Iraqi National Journal of Earth Science

www.earth.mosuljournals.com

The Geological Characteristics of Maqlub Mountain and Their Role in Developing the Karst

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Article information

Received: 16- Sep -2022

Revised: 6- Nov -2022

Accepted: 11- Dec -2022

Available online: 30- June- 2023

Keywords:
Karst
Maqlub mountain
DEM
Lineaments

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ABSTRACT

The importance of the emerged geological characteristics is that they represent the basis of the earth's surface morphology including the karst phenomenon. The problem of the study is manifested by highlighting the effect of the geological properties and their role in terms of the karst formation and whether they play a certain role in developing the chemical erosion played by the linear structures in terms of the emergence and the evolution. The study aims to understand the reflection of the tectonic situation on the formation of the area represented by a set of rocky formations that have great importance in terms of the evolution of karst, particularly the limestone within the Pila Spi Formation as they are characterized by geological weakness in the cracks and partitions and so it is considered the suitable environment for developing the karst aspects. The results of the study highlight the importance of the slope characteristics in terms of the evolution of several karst phenomena in addition to the role of porosity, permeability, and the purity of the lime that are necessary for the development of the land shapes in general and the karst shapes in particular. After analyzing the geological characteristics of Maqlub Mountain, one of the objectives of the study is accomplished, which is their effective role in the evolution of the karst aspects.

DOI: 10.33899/earth.2023.135975.1032,

الخصائص الجيولوجية لجبل مقلوب ودورها فى تطوير الكارست

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معلومات الارشفة

تاريخ الاستلام: 16- سبتمبر-2022

تاريخ المراجعة: 6- نوفمبر-2022

تاريخ القبول: 11-ديسمبر-2022

تاريخ النشر الالكتروني: 30-يونيو-2023

الكلمات المفتاحية:

كارست

جبل مقلوب

نموذج الارتفاع الرقمي

الخطيات

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الملخص

تكمن أهمية الخصائص الجيولوجية الناشئة في أنها تمثل أساس مورفولوجيا سطح الأرض بما في ذلك الظاهرة الكارستية. تتجلى مشكلة الدراسة من خلال إبراز تأثير الخواص الجيولوجية ودورها من حيث التكوين الكارستي وما إذا كانت تلعب دورًا معينًا في تطوير التآكل الكيميائي الذي تلعبه الهياكل الخطية من حيث الظهور والتطور. تهدف الدراسة إلى فهم انعكاس الوضع التكتوني على تكوين المنطقة المتمثلة بمجموعة من التكوينات الصخرية التي لها أهمية كبيرة من حيث تطور الكارست، وخاصة صخور الجير داخل تكوين البلاسبي حيث يتميز الضعف الجيولوجي في التشققات والفواصل وبالتالي فهي تعتبر البيئة المناسبة لتنمية الجوانب الكارستية. تسلط نتائج الدراسة الضوء على أهمية خصائص المنحدر من حيث تطور العديد من الظواهر الكارستية بالإضافة إلى دور المسامية والنفاذية ونقاء الجير اللازمة لتطوير أشكال الأرض بشكل عام والأشكال الكارستية على وجه الخصوص. بعد تحليل الخصائص الجيولوجية لجبل مقلوب تم إنجاز أحد أهداف الدراسة وهو دورها الفعال في تطور الجوانب الكارستية.

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Introduction

The karst system is regarded as a complicated hydro-geomorphological system that involves the investigation of the surface and ground waters, which form one natural flow system. The reaction of the water with the limestone, gypsum, and salt stones forms the various types of karst aspects including the surface and subsurface ones due to the chemical processes in addition to the geological characteristics of the area studied that have a significant impact on developing karst aspects in Maqlub Mountain. The karst phenomenon is associated with ground risks that have reflections on the infrastructure, i.e. the networks of roads, bridges, dams, and the various land uses. In addition, the karsts are important in the field of tourism and other fields. Therefore, the study is to investigate the karst in Maqlub Mountain. The importance of the study emerges from being the first detailed field study of the karst aspects and it aims to identify the geological characteristics and their role in the evolution of the karst geomorphologic aspects. The reason for choosing the subject of the study is the importance of the karst in Maqlub Mountain with its obvious existence and being one of the natural aspects that increases the importance of the area and that supports the developmental activity in it. Modern technologies, including remote sensing, are very important in the study of this type of geo-shapes, so the study aims to use these techniques in knowing the influence of geological factors on karst.

The name of the mountain derives from “The Old Man Mar Matta”, where the word "Mar" is of Syriac origin, which means the saint. The saint Matta is originally from a village in Deyar Bakr City in Turkey and he is from a rich Christian Family (Jacob 1961). He tended to a life of austerity and asceticism and so he lived in a monastery with his companions monks at his village in 361 A.D. They were inflicted by persecution and expelled from the monasteries and churches. Therefore, he fled with his companions to the bank of the Habur

River and built a small cabin, and after that, they went to the mountain and built the monastery and this monastery dates back more than 1600 years. It is regarded as the first and the most ancient monastery in Iraq, built by the pagan Assyrian king (Nineveh King) Sennacherib in the fourth century (363 A.D.). The stages of construction lasted for more than 20 years and more than 22 thousand workers participated in the construction and it was completed in (381 B.C.). The first chief of the monastery was Saint Matta, who died in 44 A.D. He lived more than 90 years and has been called the Old Man as he was very old and the word has nothing to do with the religion.

Materials and Methods

To accomplish the objective of the study, the following data are used:

1. The tectonic map of Iraq was prepared by (Fouad, 2012) is used to clasiify the situation of study area according to tectonisim.

2. The geological map, with a scale of 1/1000000 was prepared by (Sissakian and Fouad, 2015) is used to clasiify the situation of study area according to distribution of geological formations.

3. Digital Elevation Model (DEM): DEM 30 Shuttle Radar Topography Mission Arc Second Global.

4. Computer software with the tools of spatial analysis in the package ARC GIS 10.7.1.

5. Spatial of Land Sat8 for the year 2021.

6. The package PCI Geomatica Line to draw the lineaments.

7. Rock Ware 16 for rose diagrams drawing.

8. The drone (type: Mavic Air2).

Previous studies

1. Al-Omari, and Sadiq, 1997, the geology of Maqlub Mountain.
2. Amin, 2010, studied the geomorphology of Maqlub Mountain taking part in the karst morphologies.
3. Al-Khattab, 2000, studied the hydrogeology of the Maqlub Mountain within Bashiqa Region.
4. Alobadi et al., 2021, study the characteristics of carbonate rocks and the environmental conditions of some caves, in northern Iraq
5. Al-Jawadi, 2021, studied the rock slope stability in Maqlub Mountain.
6. Elias, Z., 2015, study the influence of tectonic activity on the Lower Khazir River that is crossing three mountains (Maqlub , Ain Al-Safra, and Makhmoore).

Location of the Study Area

Maqlub Mountain is located northeast of Mosul City. The area under investigation covers about 25.38 Km^2 (Fig. 1). Maqlub area is administratively affiliated with Nineveh Governorate. Bashiqa is situated to the west of the mountain and Bashiqa Mountain is located to the south of it and from the north and the northeast Wadi AlAbdali valley is located. AlKhazir River represents the southern and eastern borders of the mountain. It is situated within the latitudes (36◦ 28' 0" N – 36◦ 34' 0" N) and longitudes (43◦ 30' 0" E - 43◦ 22' 0" E). The area is classified to be under Cubin's climate classification. From the data of the climate of Maqlub Mountain that was obtained from the climate station, it is clear that the climate is semi-hot and it is called semi-dry (hot and dry in summer and cold and rainy in winter) (Al-Ansari, 2021).

The mountain has several local names, the first name is Alfaf Mountain. The word (Alfaf) means thousands due to the large number of monks and worshippers, which was several thousand in the past ages (local name) (Fig.2). There is another opinion of people who say that the word was not originally (Maqlub) but (Maqbul), which means that whoever comes to the monastery in the mountain to ask Matta to be healed or to accomplish his wish and need, his request would be accepted and he is given what he wishes, but with time there has been a replacement of the letters of the word and so it changed to give another meaning. This is evident in some Karshonic in the late times.

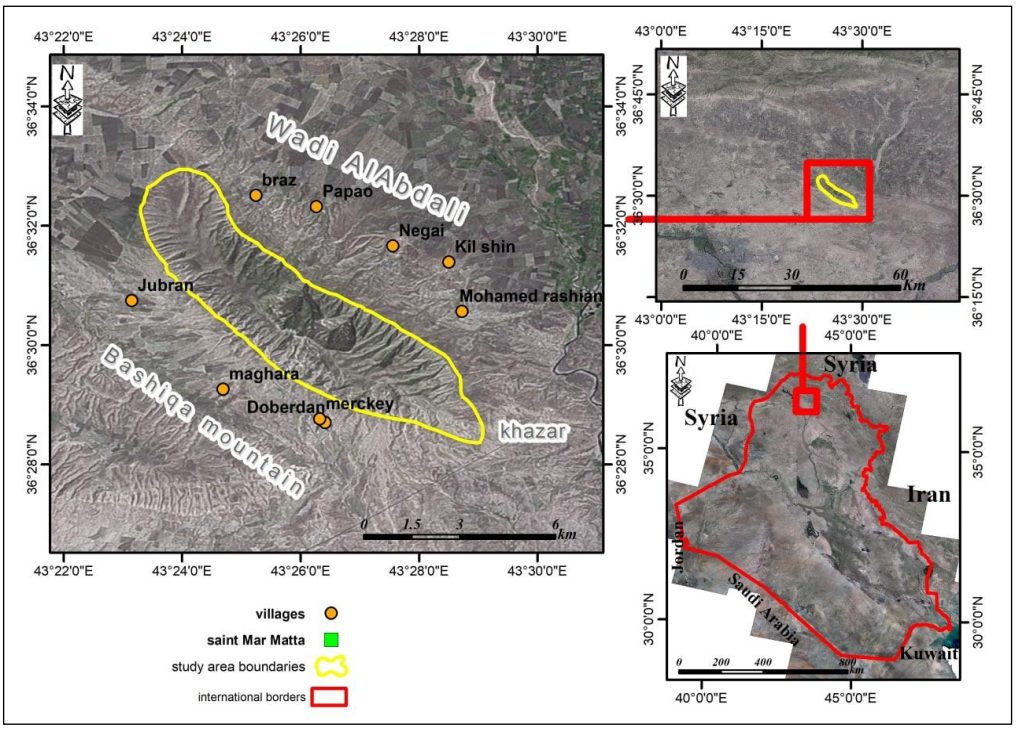

Fig. 1. Spatial image (Land sat 8) of the package Arc. GIS Online v.10.7.1.

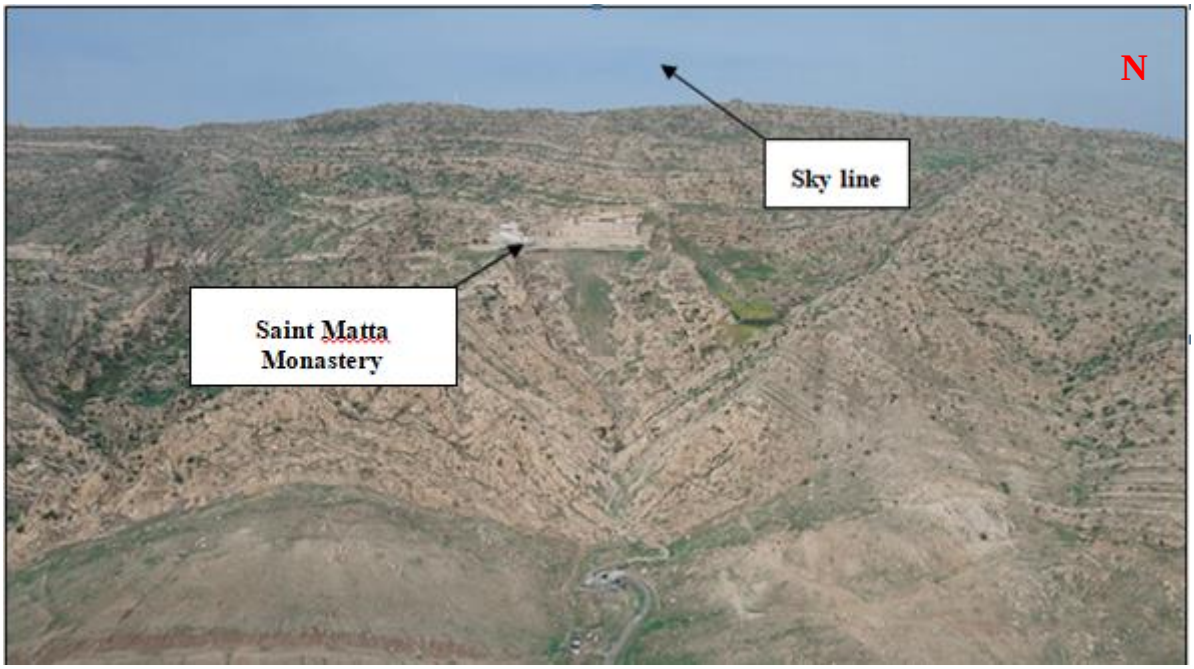

Fig. 3. The location of Mar Matta monastery in Maqlub Mountain Source: A field visit on 20/5/2022, aerial image (High oblique) taken by a drone.

Geological settings

The geological history of Maqlub Mountain is associated with the geological history of Iraq as a large part of it including the area of the study was covered with Tethys Sea and due to the tectonic movements that started in the Cretaceous age of the second geological age and reached its peak in the third geological age, especially in the Miocene and the Pliocene. These movements led to the evolution of the mountains in Iraq and Maqlub Mountain is one of them, which is tackled in the present study (Al-Omari, and Sadiq, 1997).

The geological structure is considered one of the important and dominant factors in terms of the evolution of the earth's phenomena including the karst phenomenon. Maqlub mountain is considered one the cylindrical anticlinal, which is asymmetrical due to the inclination of the southwest and the northeast parts with an average of 52°, and the northeastern part with an average of 20° (Hawa, 1985), which is called the box fold (Bakos, 1982) with an elevation of 1048 meters a.s.l. (Fig.3). Hence the name Maqlub Mountain was derived according to its structural characteristics that resulted from the intense compressive tectonic powers that came from the eastern north because of the Alps movements (Al-Omari, and Sadiq, 1997). These movements led to a change in the morphological characteristics and therefore, the western parts became steeper than the northeastern ones, as one can observe that the southwestern parts seem closer to a vertical limb due to the extreme folding because of the earth movements compression, while the northeastern part was featured with long slopes.

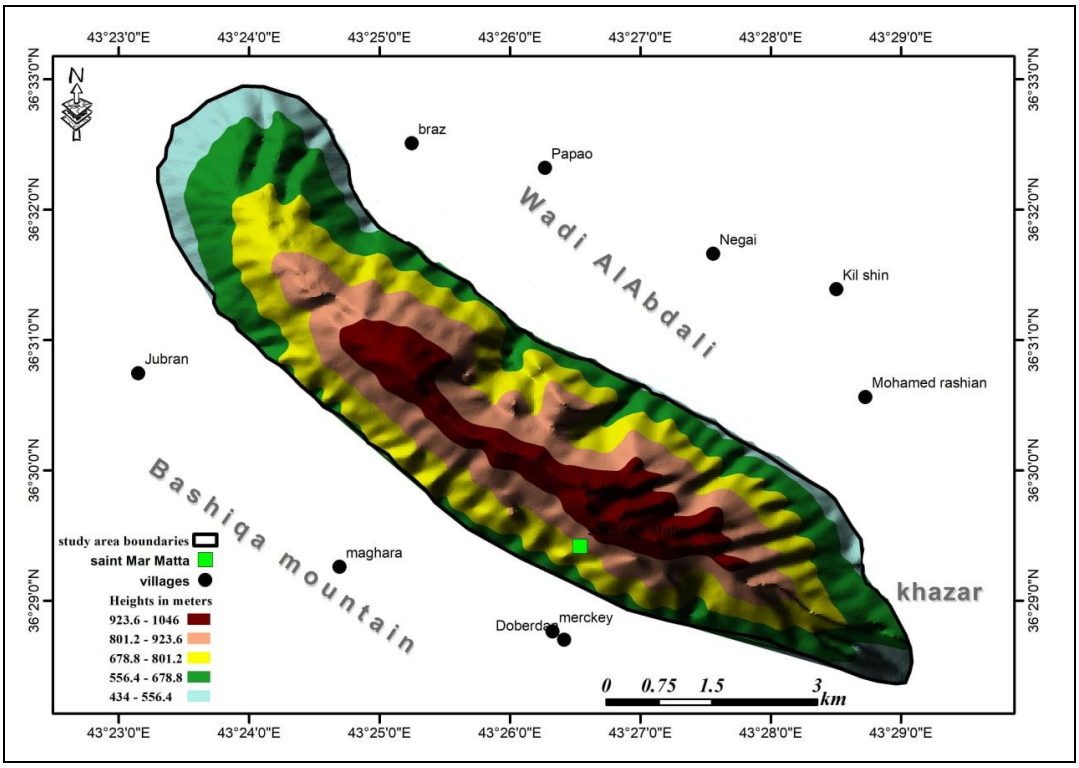

Fig. 3. Shows the elevations with TIN (3D)

Source: Depending on the Digital Elevation Model (DEM) and Arc Map.Gis 10.7.1 package.

Maqlub Mountain is located within the Foothill Zone on the Butmah-Mosul Sub zone, which constitutes a part of the unstable platform of the northern and the northeastern part of the Nubian Arab surface (Fouad, 2012) (Fig. 4). This tectonic position was reflected in the formation of the region with a group of geological formations from the oldest to the youngest (Sissakian and Fouad, 2015).

1. Kolosh Formation (Paleocene - Lower Eocene)

Kolosh Formation represents a small area at the core of Maqlub Mountain (Fig. 4 and Table 1), and its thickness is about 39 m with an area of (0.860) km^2 and its percentage doesn't exceed 3.39%. It is made up of fine sand rock with clay and various-sized chert (Bakos, 1982).

2. Gercus Formation (Middle Eocene)

Its area is (2.81) Km^2, with a percentage of 8.19% in the core of Maqlub Mountain and a thickness of 40 m (Bakos, 1982). The rocks of this formation are characterized by the domination of the red color. It consists of shale, clay rocks, and sandy marl in addition to thin belts of gypsum with the presence or the absence of gravel sand rocks. This formation is featured with its resistance to erosion and this creates a suitable environment for the evolution of the karst aspects.

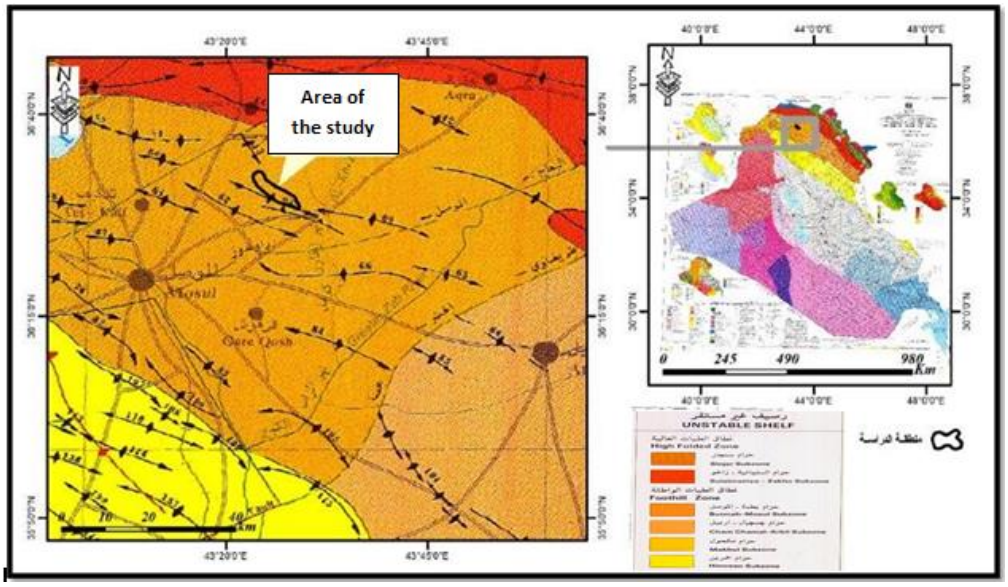

Fig. 4. The tectonic map showing the structures of the study area (Fouad, 2012)

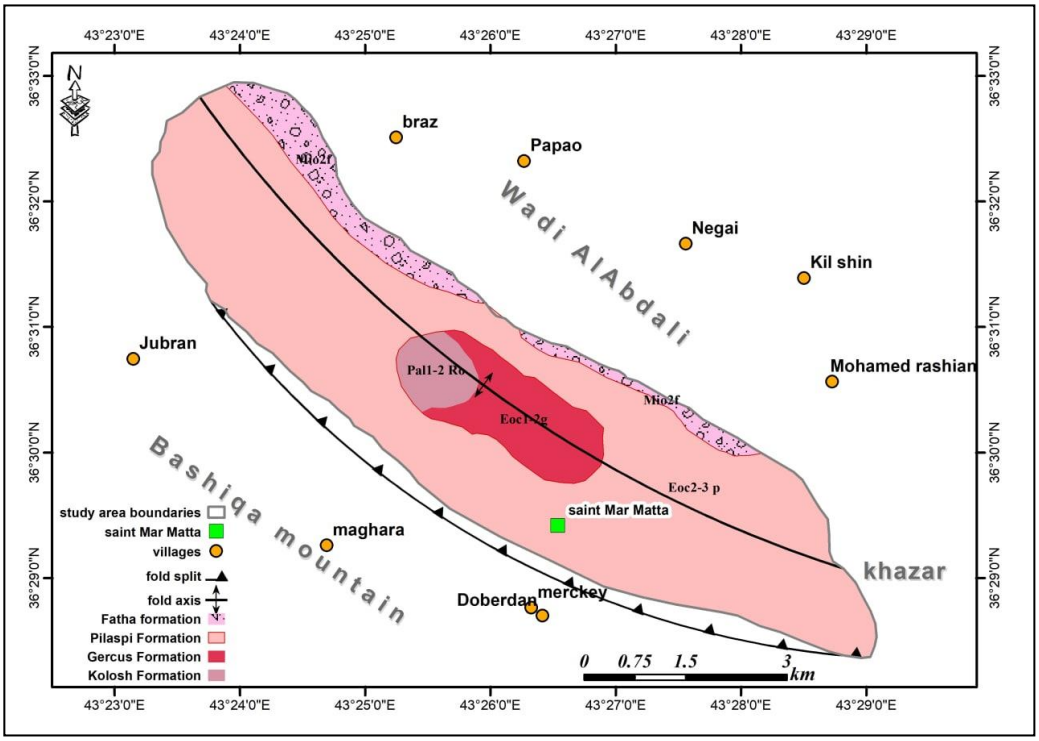

Fig. 5. The Geology of the study area (Sissakian and Fouad, 2015).

Table 1. The geological formations, the percentages, and their areas. Source: (Fig.4).

No.	Geological formations	Geological age	Area (Km^2)	Percentage (%)	Rocks components
1	Kolosh	Third	0.86	3.38	Fine sandy rocks with clay and various-sized chert
2	Gerkus	Third	2.08	8.19	Shale, clay rocks and sandy Marl, thin belts of gypsum with the presence or absence of the gravel sand rocks
3	Pila Spi	Third	20.30	79.97	well-stratified white aerated crystalized limestone with bundles of pale green of Marl
4	Fatha	Third	2.14	8.44	well-stratified white aerated crystalized limestone with bundles of pale green of Marl
	Total		25.38	100%	Includes beds of anhydrous gypsum, limestone, and clay.

3. Pila Spi Formation (Middle and Upper Eocene)

The Pila Spi rocks constitute the structure of Maqlub Mountain and its area is (20.304) Km^2 with a percentage of 79.97%. The highest thickness of the formation is about 190 m (Bakos, 1982). It is composed of well-bedded white aerated crystallized limestone with bundles of pale green marl. As for the porosity and permeability, it is impenetrable and weak due to the conditions of precipitation in the chemical environment that made it solid rocks that don't involve fossils or organic materials and don't gather the fluids unless it is cracked. Therefore, it is filled with limes due to the chemical aeration and the fullness of cracks and spaces with these solutions and so the Pila Spi represents the base of the evolution of the karst aspects in the area of the study (Buday, 1980**)**.

4. Fatha Formation (Middle Miocene)

It is exposed as a narrow ribbon that extends from the northeast parts to the southwest at the mountain foot with an area of (2.144) Km^2, a percentage of 8.45% and its thickness is about 200 m (Al-Sayegh, and Al-Nuaimi, 2004). The sulfate constitutes about 50% of the total thickness of the formation (Fig.. 3). It is composed of anhydrous gypsum with thin beds of lime and clay that are characterized by its solubility in water, which contributed to the formation of caves and karst holes (Al-Juboury and McCann, 2008).

Fig. 6.The impact of the Fatha Formation on the limestone

Source: A field visit on 17/3/2022 (to the northeast)

Lithological and petrophysical characteristics

To form the karst, certain lithological characteristics should be available as follows:

1- The Carbonate rocks

In Maqlub Mountain, the famous rocks are limestone ($CaCO_3$), and dolomite (Ca, Mg) CO_3 which are contain hard minerals compared to gypsum ($CaCO_3.2H_2O$) in Fatha Formation, and the great portion of it is represented in the Pila Spi Formation. The limestone and dolomite are well-beded, which are relatively weak as noticed in the cracks, and the bedding planes (Bodour, 2016). This phenomenon is a suitable environment to form the karst and this shows the importance of the cracks through the field visits.

2- The gypsum rocks

The gypsum rock ($CaSO_4.2H_2O$) in the Fatha Formation exists in Maqlub Mountain and it is characterized by its high potential to dissolve and chanal makes and increasing porosity from which rainwater moves slowly in the body of the rock rather than concentrating in the weak spots (Sims, 2007). Consequently, this doesn't produce but little karst aspects, the most important of which are the drains, dissolution gaps, and caves and this grants the rocks deformed karst terrains that are easily removed (Beheiry, 1979).

3- The clay rocks and marl

These exist in Fatha, Gercus, and Kolosh formations and they are regarded as impermeable rocks that play an important role in directing the movement of the groundwater vertically, and this facilitates its movement within the soluble beds (Salama, 1983). During this movement, the chemical aeration process is activated, especially the dissolution and decomposition, and this, in turn, decreases the block volume and increases the surface area from a couple of millimeters to several meters to form the gaps and cavities and other karst aspects.

4- Stratification

The sequence of the rock units that have effects on the development of the karst aspects due to the bed sequence between the dissolvable rocks with the impermeable beds, as in the Pila Spi Formation beds that are composed of a periodic succession of dolomite is a moderate to highly solid rock with brown color, The surface of the beds includes the chert nodules and cracks (Al-Dulaimi, 2006) and after the Pila Spi Formation precipitation, the precipitations of the Fatha Formation began, which are represented by marl, clay, and some other beds of limestone and gypsum as an upper separating border of the Pila Spi Formation (Al-Lahaibi, 1994).

5- Purity

The purity of the limestone affects the dissolution process. The purer the rock, the faster the dissolution is, while the decrease in purity and the increase of impurities decrease the dissolution because these impurities seal and shut the pores and cracks and hinder the movement of water inside the rock bulks, and the rocks that form the karst should be of a purity close to 80% (Stokes, et al., 2003) (Fig.4). Therefore, based on what was mentioned earlier, the solidness of the rocks represented by its mineral structure is of a great importance in the development of the karst and maintaining its marks for a longer time (Odeh, 1996), and this is because its resistance to the chemical aeration more than the rocks that are composed of minerals with less solidness. Therefore, the dissolution of the gypsum rocks is faster than the limestone because the hardness of the gypsum in Moh's scale is (2) while the of the calcite is (3) (Thabet and Al-Ashoo, 1993).

Fig. 7.The lime in the Pila Spi formation

Source: A field visit on 17/3/2022 (to the northwest)

6- Porosity and permeability

The porosity stands for the spaces connected, i.e. the size of the spaces that can be filled with the fluids, and this is called effective porosity as it is effective in terms of the movement of the fluids in the rocks (Enarah, 2016). The rocks of the area are characterized by variation in porosity; some of them are primary as in the sandy, clay, and gypsum rocks, which acquired this porosity directly when they were formed and they are of various sizes according to the type of the rock from which it was formed. Consequently, the clay rock is considered to have high porosity (more than 50%), but it is not permeable because it has a delicate capillaceous porosity and therefore it became an impermeable rock (Al-Muhsin, 2013); the impermeable beds plays a great role in the geomorphological processes and activity in terms of the evolution of the karst aspects, whereas the gypsum rocks are characterized by high porosity and therefore they are considered as permeable rocks (Salloum and Siam, 2017) as water goes freely through them (infinite permeability) (Salama, 2010). The second permeability is a structural permeability that is represented by the cracks, and stratified surfaces that are concentrated in Pila Spi Formation, and this type of rock has structural porosity. This type of porosity is featured by gradation where it doesn't help in retaining the water with the increase of the depth and this will provide an opportunity for the formation and evolution of the karst aspects (Gondie, 2004). Moreover, permeability plays an active role in directing the surface water and groundwater as it can pass the water within the parts of the rock. The evolution and development of the karst caves depend upon the permeability of the caves and the extent of dissolvent. The permeability of the rock depends upon its porosity because the porosity and permeability determine together the texture of the rock, which plays an important role in the development of the ground shapes in general and the karst aspects in particular.

Results and discussions

The lineaments are considered the mirror that reflects the movements as well as the geological events under the rocky beds. They are different in terms of length, direction, and density, and they are expressed by straight lines or slightly curved that are called lineaments, which are of a geological origin (Al-Fahdawi, 2018). These lineaments play a major role in developing the water flow routes on Maqlub Mountain that have an impact on developing the karst aspects. Several names are used to express the lineaments, such as linear trends, linear features, fractures, fracture traces, mego joints, vincula, and other names. These are all used for description and not as genetic terms or names as a weak linear characteristic for any length whether they are exposed or partially covered with surface materials (El-Etr, 1974). The density of the karst is more connected in the anticlines compared to the synclines because most of the short lineaments are concentrated in the locations of the anticline while they are few in the synclines as there is no thick cover of the newly formed precipitations (Gabriel, 1990). Lineaments are considered the most important attributes that can be observed in aerial photos and the imaging satellite, and they are shown by using the PCI Geomatica Line package and then they are obtained by using a set of analyses relevant to their lengths, density, and their direction to determine the spots of weakness, the tectonic activity and their reflection on the land aspect (Fig. 5 and Table 2), where the lineaments structures can be obtained by the steps as follows (Thannoun, 2013):

-The space Land Sat8 was used.

-Some methods of processing the aerial photos were applied to improve the quality of the natural edges and lines to distinguish them from the human lines.

-The third step is dependent on the technologies of extracting the lineaments using the values of parameters of the package PCI Geomatica Line.

-Three geographical analyses were applied to evaluate the lineaments, which represent the length, direction, and density.

-The geographical analysis of the lineaments provides a good correspondence with the arrangement of the tectonic powers that are characterized by the stratified surfaces (cracks) in Maqlub mountain.

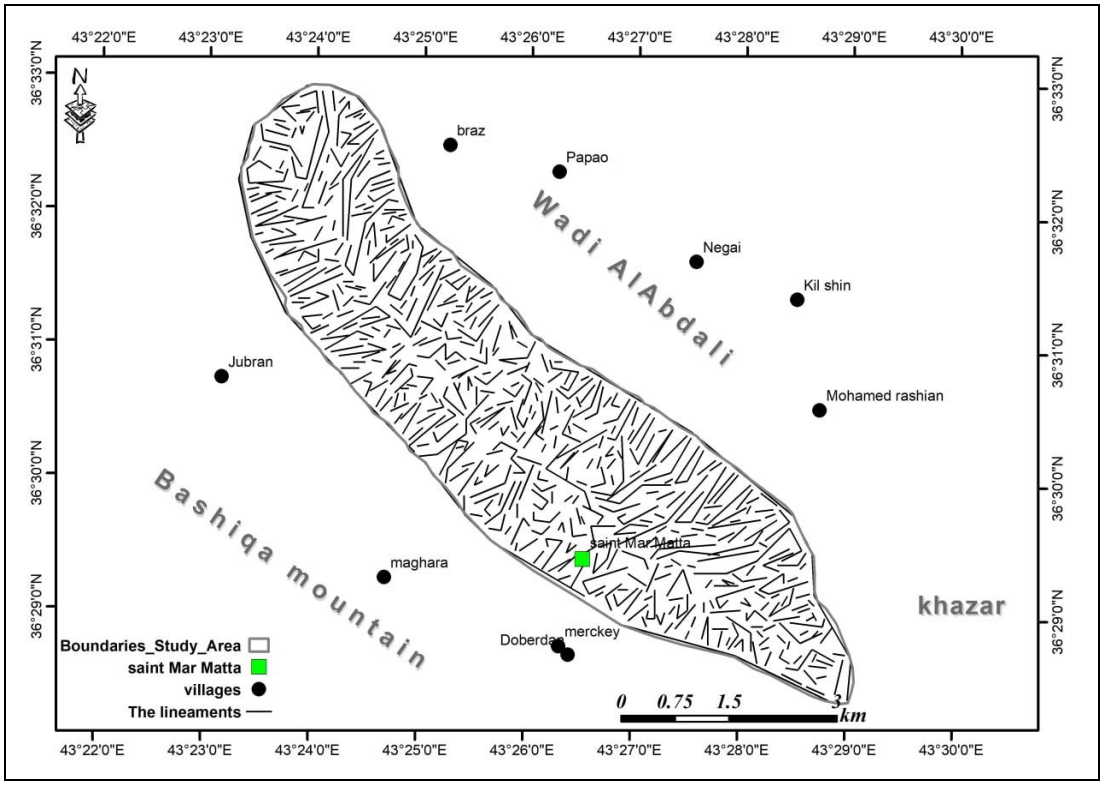

Fig. 8.The lineaments

Source: Depending on the DEM, using the PCI Geomatica Line package and the outputs of package Arc Map Gis 10.7.1

Table 2. Source: Depending on the map of the lineament. Directions and length of the lines in the area of the study

Direction	No. of lines	Length (Km)
Northeast – Southwest	105	25.46
Northwest-Southeast	266	81.99
North-South	35	8.79
East-West	277	87.48
Total	683	203.72

Through the application of the previous steps and from the Figure (5) and Table (2), it is clear that:

First: Lengths analysis

El-Etr, (1974) classification is adopted to categorize the lineaments' lengths, and according to that, the lineaments are classified in Maqlub Mountain as short lineaments, i.e. less than 2 Km and the long lineaments (2-10) Km. On the other hand, the huge lineaments that have more than (1000) Km in length were absent in the area of the study as the total length of the lineaments was (203.72) Km as shown in Table 2.

Second: The analysis of lineament directions

The lineaments are represented by geographical directions (north-south), (northeast-southwest), and (northwest-southeast), through which they are represented using Rock Work 16 package. The total of the area lines is (683) lines and the lengths of the directions in the lineaments in Mqlub Mountain vary in terms of the number and lengths of lines according to their location (Fig. 1). They are divided into the following directions:

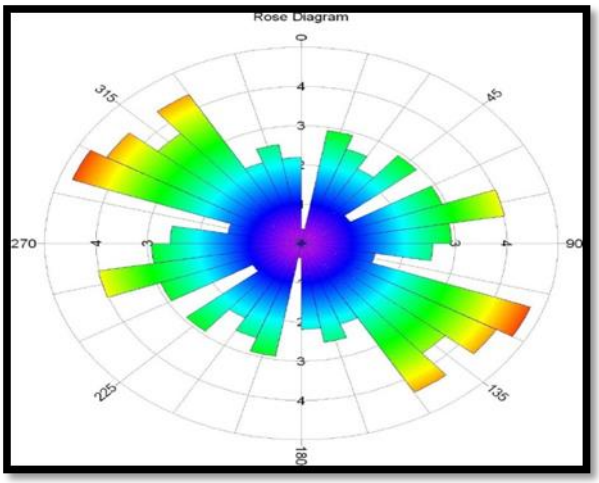

Fig. 9. Directions of lineaments in Maqlub Mountain

Source: Fig. (5) and the outputs of Arc Map Gis 10.7.1 and Rock Ware 16 packages.

The northeast-southwest direction represents the third order with the number of lines (150 lines) and their length is (25.46) Km this corresponds to the Fatha Formation in the northeast and Pila Spi Formation in the southwest, which constitutes the basis of the evolution of the karst aspects.

Northwest-southeast occurs in the second rank with the number of lines (266 lines) and a length of (81.99) Km as its similar to Fatha and Pila Spi formations, which are non-resistant to erosion.

The direction south-north, with (35) lines and a length of (8.79) Km is considered the least direction in terms of having lineaments, which concentrate on the north side and the south side of Maqlub Mountain.

The direction east-west is in the first order in terms of the number of lines in the area of the study (277 lines) with a length of (87.48) Km. These two directions represent the main foci of karst aspects formation due to the diversity of the geological structures and due to the vast number of cracks and the dissolvable lime rock and decomposition in certain climate conditions. These lineaments play an active role in the evolution of the karst phenomenon as the chemical aeration became active through them, which in turn develops several Karren lines with various directions and lengths (Fig.. 5) in addition to the activation of the notched limestone surface phenomenon (Fig..6) and other phenomena.

Notched limestone surface **Lime Carine**

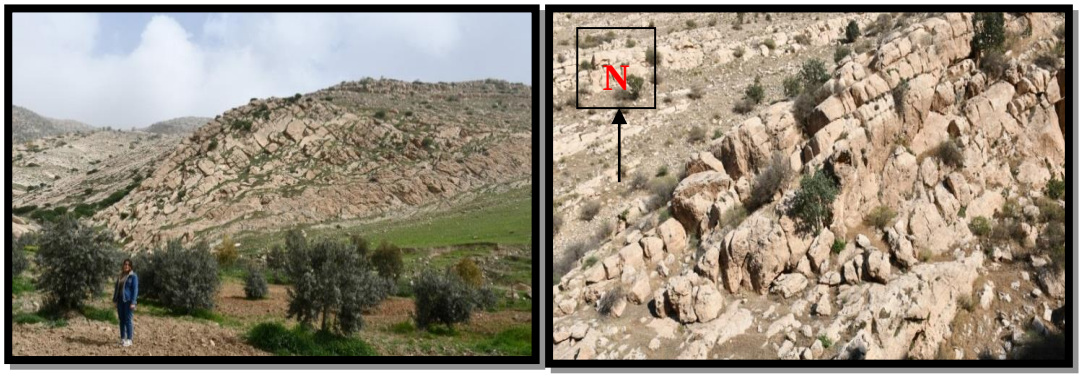

Fig. 10. Source: A field visit on 26/3/2022 (To the southwest)

Fig. 11.Source: A field visit in 11/6/2022

The slope characteristics

The slope plays an important role in the variation of the temperature, humidity, plant cover, and the movement of the surface water, which are all considered morphological factors that assist the development of aeration, especially the chemical one that is responsible for the evolution of the karst phenomenon in Maqlub Mountain.

To identify the slope of Maqlub Mountain, Zink's classification (Stam Marin, 1999) is applied and DEM is adopted with a distinguishing ability of 30 m in a GIS environment as shown in Figure (6) and table (3). The area of the study is divided into the following domains:

Surface lands: They include the lands with a slope not more than (1.9°-5°) and they represent the plains, and valleys with a slight slope and area is (4.31) Km^2 with a percentage of (17.25%). It became a convenient environment for the growth of plant cover. It involves thick transferred soil or remaining soil and the thick soil and the plant cover are considered a major source for providing the infiltrated water with carbon dioxide, which is important in the process of melting the lime rock units. The flow of water in this domain is slow to allow infiltrating to the sub-surface units through the first and second porosity and this will aerate the cracks and expand them to be the core for the evolution and development of the karst.

- **The domain of the lands with slight rolling:**

It is characterized by fewer terrains and its slope ranges between (2°-7.9°), an area of (7.06) $Km^{2,}$ and a percentage of (26.66%) of the total area of the study area. This domain is exposed in Pila Spi Formation and it is similar to the first domain.

- **The domain of the rolling lands:**

The slopes of this domain are in the range (8°-15.9°) and it is called the low hills. It spreads in large parts of the study area with an area of (7.19) Km^2 and a percentage of (28.77%). This domain is low as it is exposed to water erosion in winter and it appears as rolling and the most spread type of domain in the area of the study.

The domain of the divided barren lands:

It is called the high hills with slopes of (16°-29.9°), with an area of (5.05) Km^2 of a percentage of (20.23%) and it represents the high feet of the above in slope area of the study.

- **The domain of the extreme barren lands:**

This spot is located within specific parts of the area of the study as it is regarded as the fifth and the last category in Zink's (Stam Marin, 1999) classification with a slope of 30° and more, and its area doesn't exceed (1.77) Km^2 with a percentage of (7.09%). This domain appears in the rocky exposures outcrops of the Gercus and Kolosh formations representing very steep feet. It is concluded that the effectiveness of karst aspects in the fourth and the fifth domains decrease as these slopes lack soil and as they are exposed to water erosion due to their high speed of flow, which doesn't give a chance to surface water to infiltrate to the subsurface units.

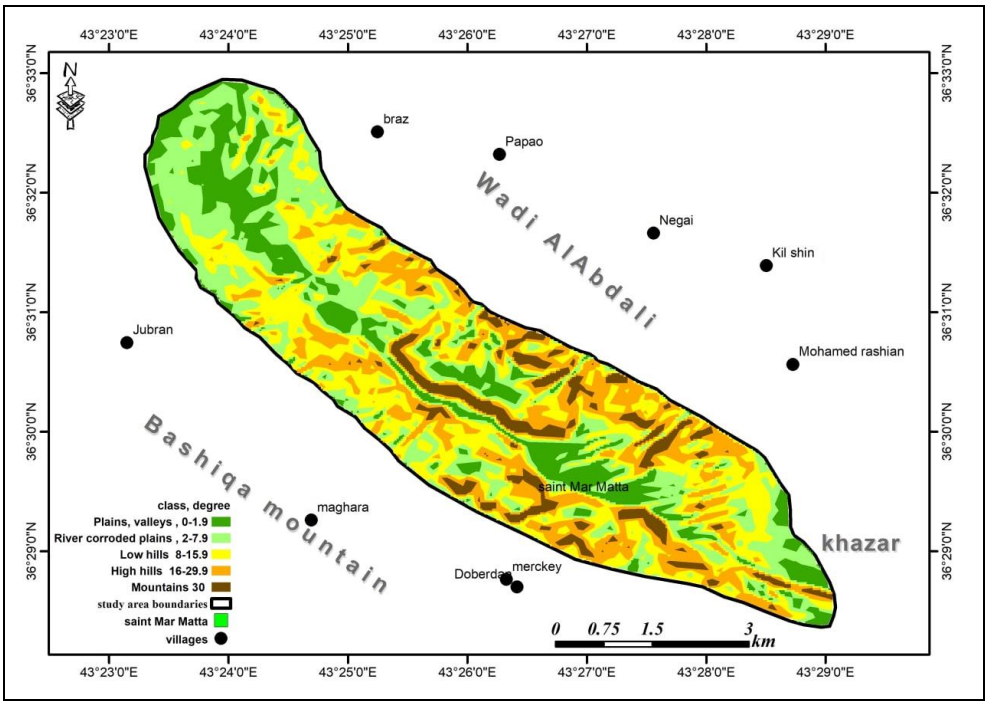

Fig. 12.The slope characteristics of Maqlub Mountain according to Zink's classification

Source: Depending on the data of DEM and the outputs of Arc Map Gis 10.7.1 package

Table 3. Types of declines and the levels of land terrains according to Zink classification
Source: Figure (1) and Arc Map Gis 10.7.1 package

No.	Shape	slope	Area (Km2)	Percentage	Category
1	Plains, valleys	0-1.9	4.31	17.25	Plain lands
2	River corroded plains	2-7.9	7.06	26.66	Slight waviness
3	Low hills	8-15.9	7.19	28.77	rolling
4	High hills	16-29.9	5.05	20.23	Divided barren lands
5	Mountains	30 and more	1.77	7.09	Extremely barren
	Total		25.38	100%	

Hill shade

Shades provide virtual lighting to the surface employing determining the quantity and the value of the light for each cell that exists in the Raster (Arc Gis Desktop v.10.7.1). The analysis of light is conducted by shedding the light or any source of lighting and after that, the effect of lighting on the adjacent cells is calculated. The grey degrees appear as virtual in the Arc GIS package and what is meant by the lighting is the sunlight, i.e. the quantity of the sunlight, the angles of lighting are in the range (0°-180°) to give the best results of condition that measuring should be clockwise. The Geographical Information System technology was used to derive the hill shade depending on DEM to determine the hill shade spots that are effective in identifying the karst aspects and their locations. Two angles of sunlight were chosen to show their importance in Maqlub Mountain as follows:

First: angle (0°-45°) of sunlight

The direction of the sunlight angles is measured clockwise from the north (0°-360°), and the elevation is the slope or the lighting source angle on the area of the study for a virtual angle (45 °) (Fig. 7). This involves all the cells with angles between (0°-45°), which represent the hill shade spots or the heights that are located in the sun shade of the northeastern parts in which the effect of the Fatha Formation is clear through the availability of sulfate on the rocks from one hand and the effect of humidity and the small portion of evaporation that led to the activation of the chemical processes from the other hand that the rocks seem to be covered with black, as observed in the field visit (Fig. 7).

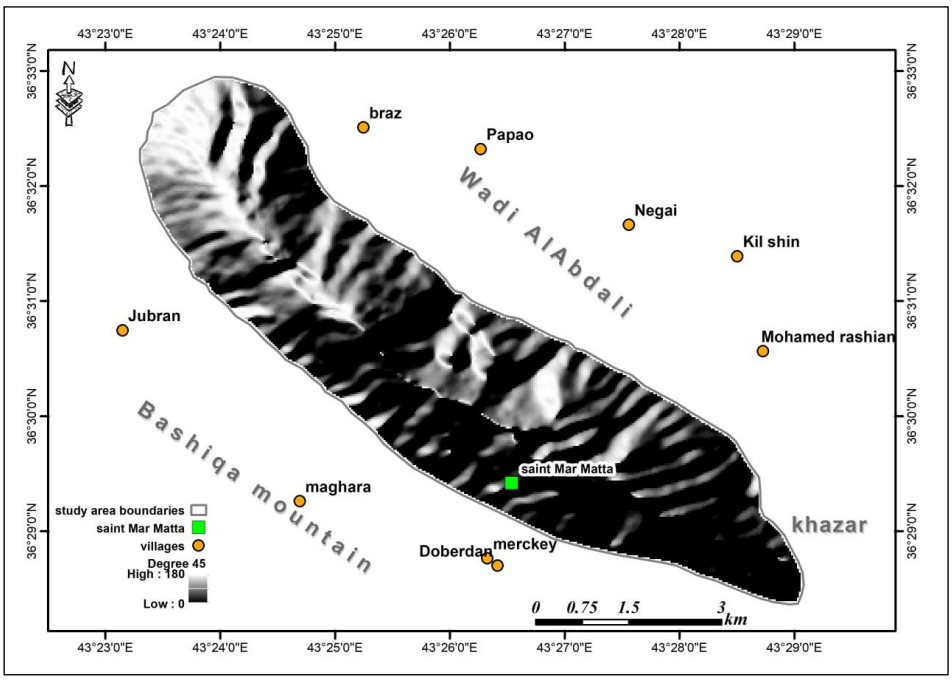

Fig. 13.The shadow of the hills (45°)

Source: Depending on the data of the DEM and Arc Map Gis10.7.1package.

Fig. 14.The impact of moisture on the rocks. Source: A field visit on 17/3/2022 (to the northeast)

Second: angles with values of (60°-225°):

From the solar ray angles with an elevation of 225°, the areas that face the sunlight and that are exposed more to the sunlight compared to the other sides were represented, and they include the eastern parts of Maqlub Mountain, the areas of the caves and other karst aspects are like the bee disks (rain traces) in addition to the notched limestone surface and others (Fig. 8).

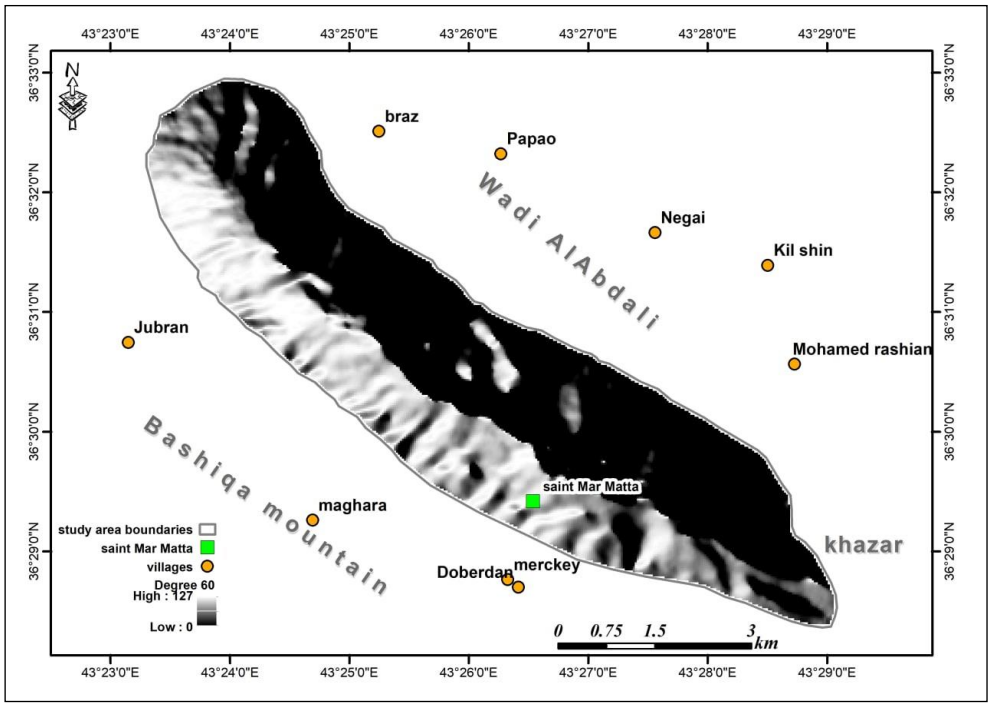

Fig. 15. The shadow of the hills (60º)

Source: Depending on the Date of the Digital Elevation Model (DEM) and Arc Map Gis10.7.1 package.

From what has been mentioned earlier, it is concluded that both the categories 45° and 60° had significant effects on clarifying the shade and light areas and they both played a vital role in the evolution and development of the karst aspects.

Conclusion

1. The Stratification of Maqlub Mountain, including the geology, is considered the main factor behind the evolution of the karst aspects and their development in the study area.
2. Rocks, especially the porous and permeable in Maqlub Mountain play an important role in forming the karst aspects.
3. The great role of the lineaments is characterized by identifying the cracks that is regarded as a source of feeding to develop the karst aspects.
4. The role of the characteristics of the slope is prominent in developing the chemical aeration processes, which, in turn, develop many karst phenomena.
5. The shades of the hill have a great impact on determining the areas of shadow and light, which are vital for the evolution and development of the karst aspects.
6. The study proved the importance of using the imaging satellite to obtain the most important results that support the study.
7. A drone of the type Mavic Air2 is used to get high-resolution photos for the area of the study.

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