

Research Article

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Investigating the limestone quarries as geoheritage sites: Case of Mardin ancient quarry

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Abstract: Abandoned quarries are valuable as a tourism element, as they exhibit the building material of the buildings built in the geographical area they are located in as historical objects. However, in order to determine how the quarries can be used for tourism purposes, it is necessary to determine the constraints on the choice of solution in spatial arrangements. The aim of this study is to investigate how the ancient limestone quarry of Mardin, which is a natural and cultural geological heritage, can be used for tourism and to develop suggestions. Within the scope of the study, in order to examine the possibilities of how an idle quarry located in Mardin province in Turkey can be used for tourism, the constraints in the selection of the post-use solution will be determined. In order to determine whether the Mardin quarry is accessible and safe to visit, various field studies were carried out in the study area, laboratory experiments and analyses. The caves were scanned with a 3D laser scanner, and its plans and sections were obtained. The findings were evaluated and suggestions were developed for the use of the ancient limestone quarry for tourism.

Keywords: quarry, Mardin limestone quarry, geoheritage, tourism

1 Introduction

Areas with abandoned quarries are an important tourism element both regionally and nationally [1]. These areas can function as tourist attractions, as they allow the building materials and technical infrastructure used in structures of a society to be examined as historical objects [2]. The later use of quarries for tourism purposes shows that old quarry sites are not just degraded areas, but can provide added value to the land and act as a catalyst for the development of a region [3]. In this context, these areas need to be associated with society in order to contribute to the United Nations National Sustainable Development Goals and also to contribute to wider social benefits such as promoting tourism in the region [4,5].

Studies on associating abandoned quarries with the society with tourism activities and reintroducing them to the society are a point emphasized in the literature [6–10]. Dino et al. [11] investigated the usability of The Carrara, an abandoned quarry in Italy, for tourism purposes, and stated in the results of the study that the historical quarries could be turned into open-air museums through which hiking trails pass. Germinario et al. [12] emphasizes that the spatial actions organized in the historical quarries contribute to the tourism of the region and increase local employment in the Euganean Quarry in Italy. Baczyńska et al. [1] argue that more tourists can be attracted to the region by spatial arrangements and additional activities (hiking, cycling, and horse riding) to be made in the Quarries in Śląża Region in Poland. Fort et al. [13] stated that it is important for tourism that the excursion routes created in the abandoned quarries of the Madrid Region in Spain exhibit the characteristics of the stones and building materials used in the structures located in the geographical environment. Pe'rez-Monserrat et al. [14] emphasize that the geo-monumental roads created in the quarries in the Spanish Madrid region have tourism value as they show what kind of heritage value that geographic region has and encourage a closer relationship between peoples and their cultural heritage.

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Another factor that makes the abandoned quarries a tourist attraction point is that the quarries are landscape areas formed by the natural habitats of many valuable flora and fauna species after excavation [15–21]. After excavation in the quarries of the Śląża Region in Poland, surface waters and many valuable vegetation were formed. In this context, items have been created in the area to appeal to the five senses. By using other stimuli such as the pleasant sound of water, the visuals of plants, insects, and other animals, the area has been turned into a tourist attraction [22]. The area formed after the excavation of “Pierwosów” quarry in Polish has been arranged as recreation areas where you can fish, walk, and organize integration meetings in the open air. On the routes created, people are informed about the geological structure of the stones with unique colors and structures, and the existing fauna and flora species [23]. In addition, it is emphasized that the interesting morphological forms formed after the processing of the rocks after excavation in the quarry sites are another point that contributes to the revival of the tourism industry [23–30]. The use of the land forms of the abandoned quarries in various karst areas in Europe as well-arranged recreation areas is one of the best examples in this area [31,32].

In most studies investigating the use of abandoned quarries for tourism purposes, it is emphasized that the suitability of these areas for geotourism purposes should be determined by various studies [33–37]. It is stated that human health and environmental safety should be considered as the most important issues in the applications to be made in the use of natural stone quarries for tourism purposes [38,39]. Beranová *et al.* [40] stated that in order to identify sites suitable for geotourism purposes, a combination of old maps and current orthophoto maps should be used, and quarries should be evaluated according to potential use value (visibility and accessibility) criteria. Raška *et al.* [41] showed that the quarry-related features, which indicate the geological and mineralogical characteristics of the sites, make it possible to examine the surface dynamics of the site after quarrying.

In determining how the quarries can be used for tourism purposes later, it is necessary to determine the constraints in the choice of solution in spatial arrangements [3]. The aim of this study is to investigate how the ancient quarry of Mardin, a potential that needs to be protected for geological heritage, can be used for tourism and to develop suggestions. The quarry is currently abandoned and therefore conservation and restoration recommendations are needed to raise awareness of its potential use. Various field studies, surface geology studies, and

geophysical measurements were made in order to determine the restrictions for public use. In the next stage, analytical drawings of the caves were obtained by using orthophotos obtained from terrestrial laser scanning. In the last stage, suggestions were developed for tourism purposes by evaluating all the findings and considering the determined restrictions.

1.1 History and importance of the study area

Mardin stone, a Micritic limestone, has been used since the Artuqid period (twelfth to fourteenth century AC). The use of this stone is common in buildings of historical value in terms of cultural heritage built in the urban site of Mardin Province. It has been determined that this stone was used in important monumental structures such as Ulu Mosque (twelfth century), Virgin Mary Church (nineteenth century), Kasımiye Madrasa (fifteenth century), Deyrulzafaran Monastery (fifth century), and traditional residences in the urban protected area in Mardin [42]. In this context, Saraçoğlu ancient stone quarries and caves, which is the main quarry where the Mardin stone is extracted, is seen as a potential geotourism area that is currently in an idle state. Saraçoğlu neighborhood ancient stone quarries and caves are called “Mardin Caves” among the people. In addition, the land is located in the southern part of the Mardin urban site, interacts with the active settlement areas to the north of the ancient quarries, and is also located within the boundaries of the site management plan (Figure 1). This land was taken under protection by the Diyarbakır Cultural Heritage Preservation Regional Board with the decision dated 18.12.2014-2823 and registered as 1st Degree Archaeological Site as a Cultural Heritage.

1.2 Presentation of the study area

The study area is located in the center of Mardin Province, at 37°18′ north latitude and 40°44′ east longitude. It is surrounded by Artuklu district in the center, Kızıltepe in the southwest, Mazıdağı in the northwest, Savur in the north, Ömerli in the northeast, and Nusaybin in the east. The caves, located in the Savurkapı neighborhood of the Artuklu district of Mardin, in the 1st degree protected area, are present on sloping land in the southeast of Mardin and are currently either closed or used as barns. There are



Figure 1: Ancient quarries and caves and surrounding development.

reinforced concrete structures, a cemetery, and a highway in the upper parts of the region, which is described as an archaeological site and an ancient stone quarry. The project area is currently idle. Since the caves were used as quarries in the old period, their static strength decreased. Reinforced concrete structures are positioned around the cave, which is partially used by the local people. This area is thought to have a great potential for cave tourism for the region [43] (Figure 2).

We do not have clear data about the history of this area, since no surface research and archaeological excavations have been carried out in the quarries and rock tombs in this area. However, it is estimated that the area has been inhabited since the early periods and has continued its functionality until a certain period [44]. When the ancient settlements in its vicinity are examined, it is understood that the area has been a functional area since the Roman-Byzantine-Middle Ages, including the early

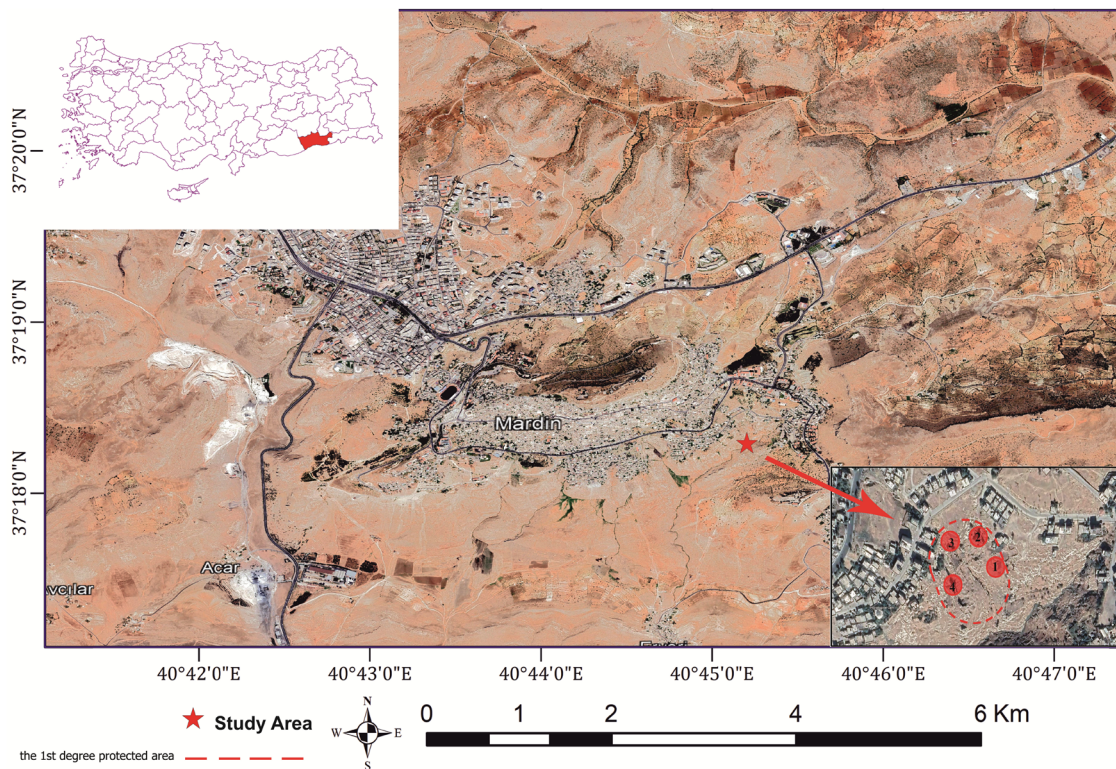


Figure 2: Location map of the study area.

periods. The existing natural origin Saraçoğlu caves offer the opportunity to see the life styles of our predecessors internalized with nature as we enter them, and see their arrival to the present day. In addition, considering the functional uses and settlements of the cave culture, comparisons can be made with some caves in the province of Mardin. The crushed stone finds in the Tarin Cave, located on the Tur Abdin mountain range between the Upper Tigris Valley and the Upper Khabur Region, are dated to the early stages of the Pre-Pottery Neolithic Period and the Paleolithic Age [45]. Except for crushed stone tools, no other human remains were found in and around the caves. The Pottery Neolithic Age crushed stone tools found around the cave suggest that this period, which is mostly defined by the mounding context in Southeastern Anatolia, may have been experienced as a different model in and around the caves located in more mountainous areas in the region. In addition, other crushed stone remains found in deep valleys or cave terraces in the same region support a denser settlement in the Late Epipaleolithic and Neolithic Ages.

According to the information obtained from the Mardin museum, the area, which is described as an ancient stone quarry and historical caves in the Savurkapı neighborhood of the Artuklu district of Mardin, is expected to be visited by approximately 5 million tourists in 2023. In this context, bringing the abandoned protected area to tourism will contribute to the region economically.

1.3 Geology, hydrology, and geomorphology of the study area

Mardin is located in the Southeast Anatolian region, on the Syrian border, in and around Nusaybin. In this area, only the Eocene aged Midyat group, which belongs to the Southeast Anatolian autochthon, and generally consists of carbonates, crops out. In the region affected by the compression regime in the north-south direction during the Miocene, anticlines and synclines with an approximately east-west trending axis and southward thrusts developed due to the emplacement of the Bitlis Pötürge-Malatya nappes on the Southeast Anatolian autochthon. The Southeast Anatolian autochthon, represented by platform-type rock units developed in the Precambrian-Quaternary interval, is found in the region. The mountainous part, which covers approximately 370 km² (43%) of the district's lands, is in the northern part, extends in the east-west direction and forms a very large mass at an average height of 600 m from the plain. The altitude rises

above 1,000 m in some parts. The highest point of the district is the Mardin threshold, where the Mardin castle is located, with 1,204 m meters. Mountains are often bare. Since most of it is calcareous, cracks and crevices have formed. Surface waters are drawn to the bottom of the cracks and rise to the surface in the plateaus close to the plains. Oak trees are found at the heights of Artuklu district, Mazıdağı, Savur, Ömerli, and Yeşilli in clayey and calcareous soils. The calcareous parts of the mountains eroded rapidly and turned into plateaus. These plateaus are covered with lava that comes to the surface in places. The plain section, which covers the remaining 490 km² (57%) of the district's territory, is an extension of the Mesopotamian plain. The fertile Mesopotamian plain extends to the Syrian state border. The plain is suitable for irrigated agriculture with the accumulation of streams and streams in winter and the water extracted from artesian wells. In the Northern Mesopotamian Plain, a climate with cool winters and hot and dry summers, also defined as the "Degraded Mediterranean Climate," is observed. It can also be called the land where the steppe desert came to life [46].

There are four caves in the study area. Located on a sloping land southeast of Mardin, these caves are located in a limestone area where karstification processes form natural karst caves (Figure 3).

Cave 1 is currently used by local people as a barn for domestic animals. The width of the entrance of the cave is approximately 16 m and its height is approximately 5 m. It is divided into rooms. According to the information obtained from the local people, the reinforced concrete structures in the upper part continue to the lower parts. There are damages such as rusting, cracks, etc., on the cave surfaces. Access to Cave 2 is provided from the rooms in Cave 1. Minimal stalactites began to form in the upper parts of the cave due to the water leaking from the cracks. Cave 2 has a mouth width of approximately 21 m and has three rooms. It is known to be connected with Cave 1.



Figure 3: Mardin ancient quarries and caves.

Cave 3 has 2 entrances. The large mouth is about 16 m wide, and the small mouth is about 12 m wide and 8 m high. There are cavities in the upper elevations of Cave 3. There are two rooms at the lower level of the cave. According to the information obtained from the local people, 4 caves are connected to each other through the rooms and it is said that there is a transition from the rooms of Cave 3 to the castle, but it was closed in time. Cave 4 is the last cave according to the excursion route of the area. There are 2 entrances to Cave 4. This area, which has a height of approximately 19 m, is divided into branches at the upper elevations. Again, according to the information obtained from the local people, it is suggested that it merges with Cave 3 (Table 1).

2 Methods

The aim of this study is to investigate how the ancient limestone quarry of Mardin, which is a natural and cultural geological heritage, can be used for tourism and to develop suggestions. In this context, field studies, surface geology studies, geophysical measurements, and laser scanning and orthophotos work steps were followed.

2.1 Field studies

As a first step in the field studies, ancient quarry caves were investigated *in situ*. Based on observational findings, ancient quarry caves, which are a potential geo-tourism destination, were evaluated by following the geo-site assessment model (GAM) evaluation methodology. GAM consists of three indicators as main values such as scientific/educational value, scenic/aesthetic value, and protection value. The second indicator group of the GAM is functional and touristic values [47].

Table 1: Length/depth of cave passages

Cave no.	Width length of cave entrance (m)	Depth of cave	Min and max height of the ceiling (m)
1	16	5 m	915/940
2	21	6 m	916/939
3	16	8 m	920/937
4	14	7 m	914/930

2.2 Surface geology studies

In order to determine how the physical properties of the rocks in the caves will affect human health, temperature, relative humidity, and air flow, measurements were made in the caves. Measurements were recorded once every hour (24 recordings per day). However, more detailed or annual measurements are required in the implementation project. Measurements were made to determine the temperature, relative humidity, air flow, and surface water of the caves. Temperature measurements in the cave were carried out using automatic temperature meters. Measurements were made outside the caves, 5–10 cm above the ground, in other parts of the cave except the entrance. Relative humidity measurements in the caves were carried out for 1 day using automatic relative humidity meters. Relative humidity meters are the same as the device that makes temperature measurements. This instrument is dual-channel and can record both temperature and relative humidity data at the same time. Measurements were made outside the caves, at the entrance 5–10 cm above the ground.

Within the scope of laboratory tests, point loading and determination tests were carried out on the rock samples taken from rock surfaces in order to classify the rocks in the study area and determine the strength parameters (compressive strength and bearing capacity) and the results were evaluated. Ten samples were collected from the rocky surfaces and uniaxial compressive strength of samples were determined. Bearing capacity of the rocks were calculated.

2.3 Geophysical measurements

Nine multi-electrode resistivities were taken in the study area. AGI brand, 8-channel, 84-electrode resistivity and IP measurement device was used in the field. In the study area, dipole-dipole gradient method was applied in nine profiles and different expansions to the extent that the working conditions would allow [48]. The variation in resistivity with depth was investigated. Thus, structural discontinuities, lithology, thickness of the layers, and groundwater situation were examined by using resistivity differences. Studies with 2D and 3D Electric Tomography techniques have been interpreted separately for each cave. Three resistivities were applied for Cave 3, and two resistivities for other caves.

2.4 Laser scanning and orthophotos

The section where the caves are located was scanned with a terrestrial laser scanner device and orthophotos were prepared.

In order to understand the relationship of the caves with the environment and their connection with each other, transverse and longitudinal sections were taken from the orthophotos. In the next stage, the project stage, all rooms should be scanned with a laser scanner in detail and work should be done together with the application details.

In order to obtain the plans and sections of the caves, a laser scanning device (Faro focus laser scanner) was used in the section where the caves are located, and 3D point clouds were obtained in the scanning process. 3D images of the caves were obtained using the 3D point clouds obtained in the laser scanning process using the software called PointCab Origins 4.0. Using this software, orthophotos (upright photos) of the caves were produced by taking sections from the desired places on the 3D images of the caves. Orthophoto images are digital images in which the errors that occur due to curvature, rotation, and height difference are corrected and transformed into vertical projections [49]. Orthophoto images that can be created from point clouds obtained from laser scanning data are very useful products for architectural documentation. Since the orthophoto images obtained are to scale, the exact dimensions of the caves can be obtained. Thus, orthophoto images can be used as a base in architectural drawings. Orthophoto images obtained from point cloud allow measurement of plans and sections with millimeter precision in the office environment [50,51].

AutoCAD program was used in the process of creating the drawings of sections and plans. Before starting the drawing process, orthophoto images produced in PointCab Origins 4.0 software were transferred to the AutoCAD environment. It can be transferred to AutoCAD environment in TIF file format with tif or tiff extension, which is the common data format of AutoCAD software. By using the scaled orthophoto images obtained, the plan and section drawings of the caves were obtained with the Autocad program.

3 Results

3.1 Geological characteristic of study area

First of all, the ancient quarry caves, which are a potential geotourism destination, were evaluated by on-site observation, following the GAM assessment methodology. In the first indicator group of the geosite evaluation model, various geofeatures have been observed in the area where the fixation quarries obtained in the scenic/aesthetic subgroup

are located, exhibiting the ways in which the stones were cut as a result of the historical processing of rocks for stone extraction.

Although the rock units observed in the study area are claystone in certain areas, most of them consist of limestone units. Based on experimental study results, in the samples taken from the study area, an off-white-colored carbonate intercalated porous, weathered, cracked, and fractured limestone unit was observed (Figure 8). Filling material has been seen in some caves. According to the definitions made on the samples, porous, weathered, cracked, and fractured limestone units with dirty white carbonate intercalation belonging to the Adiyaman Group were encountered.

Normal seasonal air currents were observed in the Caves 1–3. But there is a small passage in Cave 4 that gives a constant stream of cool air. Since both the land conditions and the constructions on the land do not allow the work, it could not be determined how far the passage in question continued.

3.2 Surface and groundwater

There is no surface water in the study area. However, since the caves are currently idle, illegal reinforced concrete structures have been positioned around them. In the neighborhood consisting of these illegal reinforced concrete structures located on the upper part of the archaeological site, the sewer pipelines are directly given to the area from the upper parts of the caves. Sewage waters have formed a stream bed in the area over time. Sewage waters flow in the 2nd and 3rd caves and precautions should be taken for this.

Table 2: Bearing capacity of rocks

Cave no.	Sample no.	Uniaxial compressive strength (kgf/cm ²)	Bearing capacity (kgf/cm ³)
1	1	171	3.52
	2	238.5	4.92
2	3	205.5	4.24
	4	267	5.51
	5	139.5	2.87
3	6	106.5	2.19
	7	247.5	5.10
	8	124.5	2.57
4	9	133.5	2.75
	10	244.5	5.04

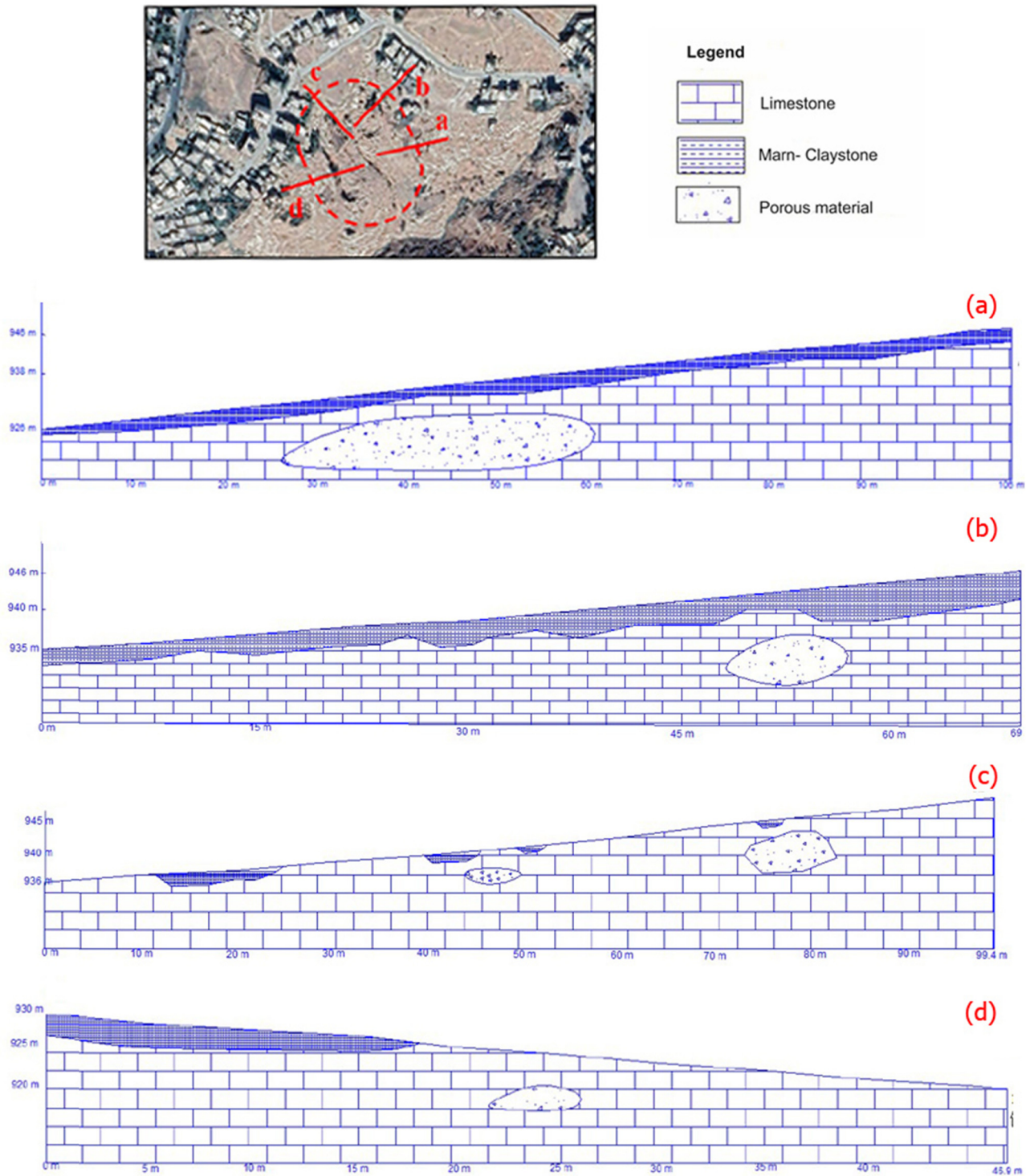


Figure 4: Sections showing the geological structure in the caves obtained from the geological map: (a) section of 1st cave, (b) section of 2nd cave, (c) section of 3rd cave, and (d) section of 4th cave.

As a result of the geophysical measurements carried out in this study, no groundwater was encountered, and probably a phreatic zone occurs at lower elevations. Therefore, there is no groundwater that may adversely

affect the structure. The groundwater level is deep, and groundwater can rise and fall during seasonal periods with heavy rainfall. Groundwater seasonally occurs in the caves. In this case, the caves are in the epiphreatic zone.

Necessary precautions should be taken by taking this situation into consideration while preparing the project.

In order to determine the strength properties of the caves, the point load index test was performed on the rock samples taken from the caves and it was concluded that the lowest strength value was in Cave 3 with a value of 2.19 kgf/cm^3 . According to these results, no bearing capacity problem is expected in any of the caves, including Cave 3 (Table 2).

Sections showing the geological structure in the caves obtained from the geological map are shown in Figure 4.

It was observed that the filling material (limestone) was randomly filled on the floor of the 2nd and 3rd caves (Figure 5). In the study area, carbonate minerals were crystallized inside the cave. Calcite minerals were formed in small areas on cave ceilings and walls. In addition, minimal stalactites began to form in the upper parts of the cave due to the water leaking from the cracks.

Since groundwater is not observed in the study area, liquefaction is not expected. Soil problems such as settlement and swelling are not expected at the entrance and for the interior filling material of the caves in the study area. However, when the application project is made, samples should be taken from this area and removed from the environment if needed. Karst cavities were encountered in the caves in the study area (Figure 6). It is recommended to make a suitable drainage system in the caves so that the system is not affected by precipitation and leachate. No landslides were observed in the study area.

3.3 Orthophotos, maps, sections, and main objects

In order to understand the relationship of the caves with the environment and their connection with each other, transverse and longitudinal sections were taken from the orthophotos. Figure 7 shows the orthophotos of the caves.



Figure 5: Filling material randomly distributed in the study area.



Figure 6: Karst cavities.

By using the scaled orthophoto images obtained, the plan and section drawings of the caves were obtained.

Section A-A shows the cross section of the entrance of Cave 4 (Figure 8). This part provides the entrance to the Cave 4. There are rooms on the upper levels of this cave, both inside and on the façade. In addition, there are reinforced concrete structures in the upper parts of the cave. Like the other 3 caves in the archaeological site, the entrance part of Cave 4 also provides an opportunity to enter the cave with a flat ground.

Section B-B gives information about the entrance of Cave 2 and its relationship with the dried stream bed. In the ceiling parts of the cave, stalactites began to form as colonies due to cracks and leaks. This cave, which is divided into five rooms within itself, is the only cave actively used for animals (Figure 9).

Section C-C cuts the entrances of Caves 1 and 2 in parallel and gives information about the relationship of these caves with each other. The rough topography shows that architectural elements such as stairs, ramps, etc., should be resolved in the next step in terms of circulation. From the photographs shown in the sections and annexes, traces of cut stones are evident on the surfaces that indicate that the caves were used as quarries (Figure 10).

Section D-D cuts the Cave 3 from the middle part of the entrance and gives information about the topography of the cave. There are rooms in the upper elevations of the Cave 3, which shows the greatest variation in the ground elevations of the cave. On the ground, there are pits and partially hilly areas. It is thought that at the entrance of this cave, a large green rock mass was torn from the surface due to the cracks-crevices and tectonic movements (Figure 11).

Section E-E describes the relationship between the entrances of Caves 2 and 3. Some of the sewer pipes

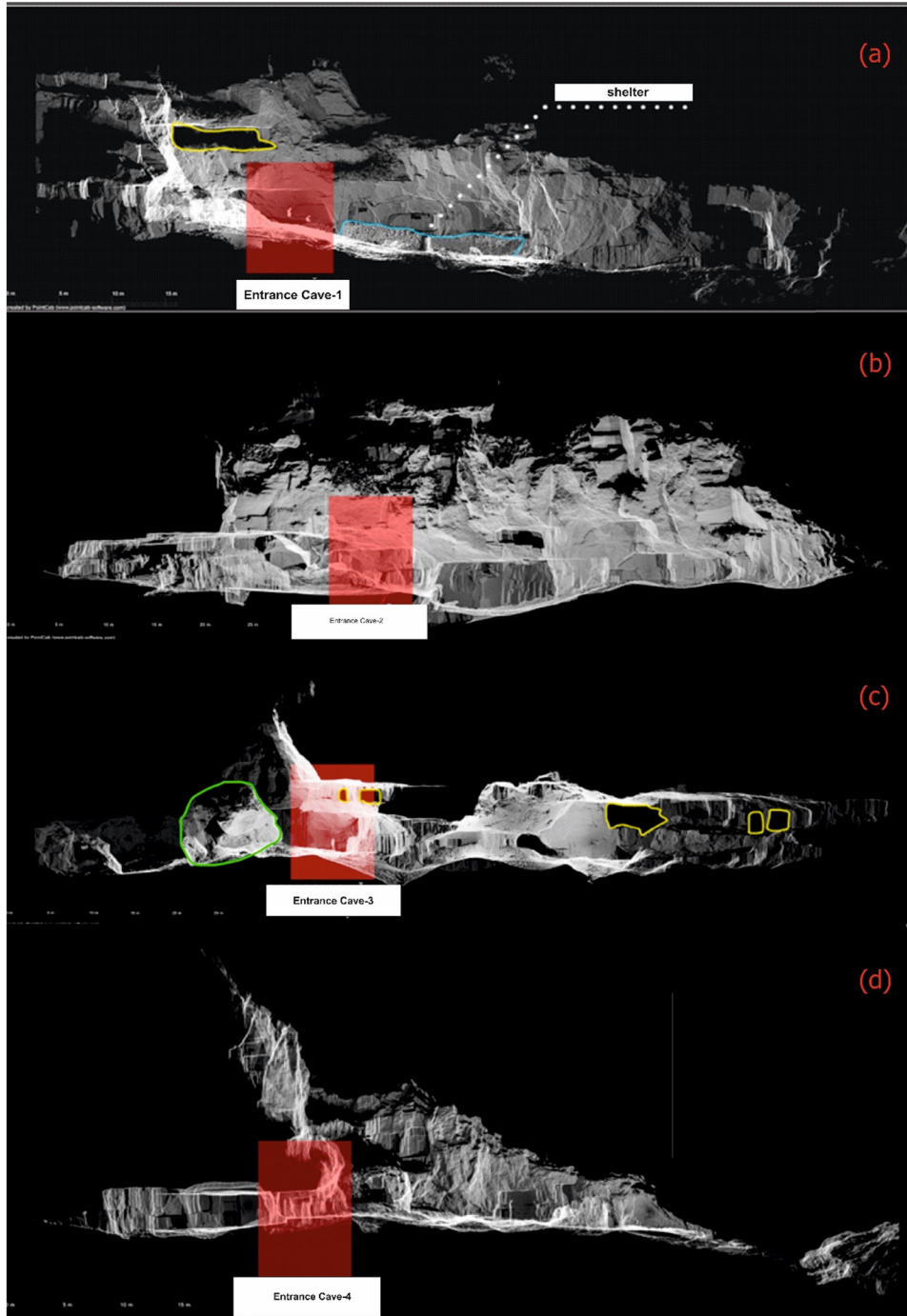


Figure 7: Orthophotos: (a) section A-A (1st cave); (b) section C-C (2nd cave); (c) section D-D (3rd cave); and (c) section G-G (4th cave).

flow into the gap on the walls of Caves 2 and 3 and merge with the dried stream bed. Due to the dirty water flowing in the area, algae have formed on the surfaces. Relevant analyses were made in order to remove the sewer infrastructure system without damaging the area, and a recommendation was made regarding the sewer infrastructure system in the conclusion part of the study (Figure 12).

Section F-F passes parallel to the entrance of Cave 4. This cave is the farthest of the 4 caves with respect to the entrance point to the area. The entrance to the cave is provided through the mouth 2. The entrance part is met with a large area and gives direction with 2 tunnels (one of which is closed) and 1 room. Cold air flows through the open tunnel (Figure 13).

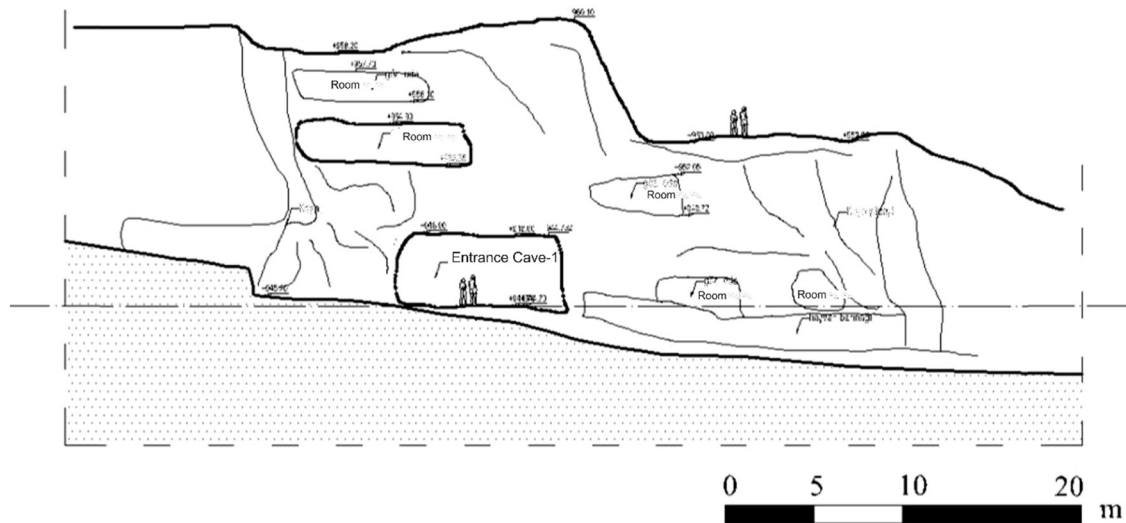


Figure 8: Architectural Measured Drawing of section A-A.

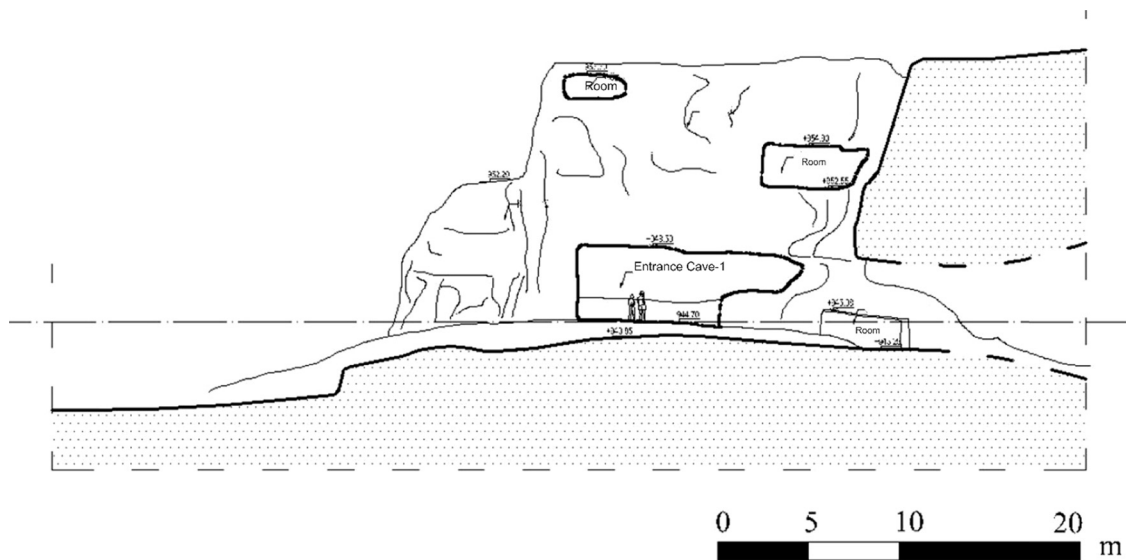


Figure 9: Architectural measured drawing of section B-B.

Section G-G cuts Cave 4 longitudinally. Consisting of 2 mouths, this cave has 1 chamber (room) and 2 tunnels (one of which is closed). The open tunnel opens to a wide and high area as a result of a distance of approximately 10 m and leads to small-large and continuous chambers within that area (Figure 14).

Section H-H includes the entrance part of Cave 2 and cuts it parallel to the long side of the cave. It has been determined that there is a tunnel (pass) in this cave, which has a wide and high mouth (Figure 15).

3.4 Challenges and obstacles for tourist development

In the observational determinations made by fieldwork, a karst landscape consisting of various visual forms was encountered in the area where the quarries are located. Geofeatures, which were formed as a result of the removal of rocks during quarrying in history, were observed inside the caves. In addition, minimal stalactites began to form in the upper parts of the cave due to the water leaking from the

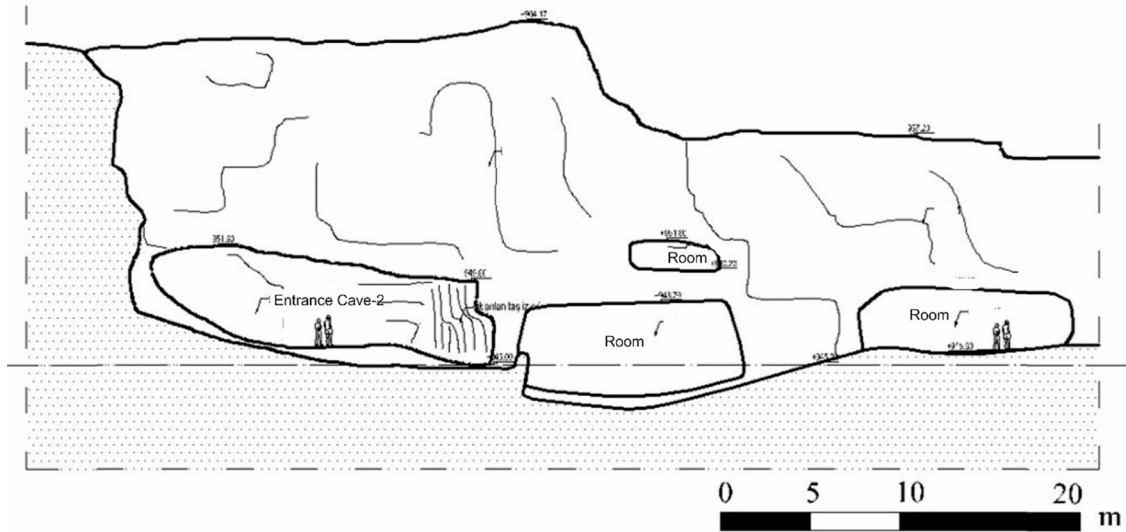


Figure 10: Architectural measured drawing of section C-C.

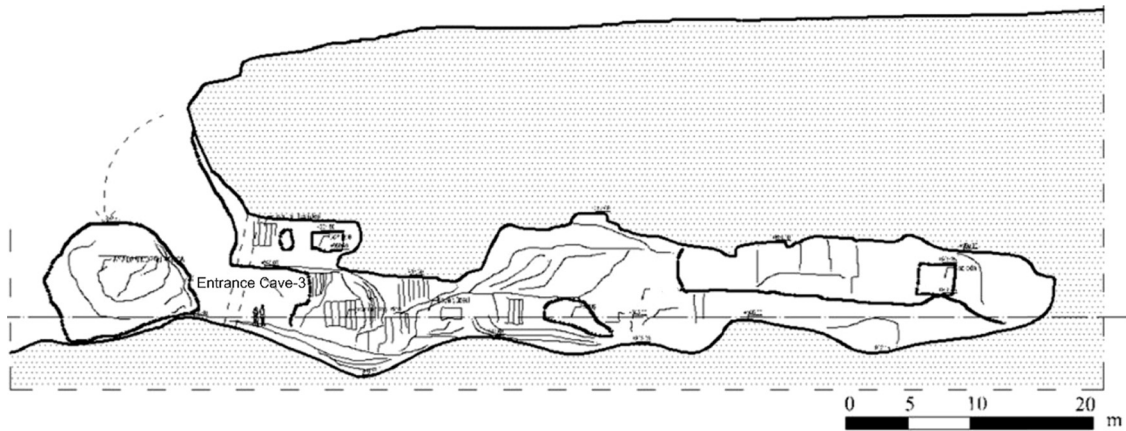


Figure 11: Architectural measured drawing of section D-D.

cracks. These findings show that the area can be turned into a tourist attraction by using stimuli such as the visuals of geofeatures. In this context, it is recommended to organize hiking trails for outdoor visitors. These routes must allow them to explore the karst geosites in the open area and geo-historical elements displaying traces of quarrying and minimal stalactites on the inner surfaces of the caves [52].

In addition, in the visual determinations made, during the evaluation of the region as a tourism area, elements that would adversely affect the visual silhouette were encountered. Since the caves are currently idle, illegal reinforced concrete structures have been positioned around them. Therefore, there is a need for improved geographical protection in the karst landscape. In this context, these illegally constructed reinforced concrete structures should be removed as they negatively affect the

visual silhouette of the area. In addition, in the neighborhood consisting of these illegal reinforced concrete structures located on the upper part of the archaeological site, the sewer pipelines are installed directly leading to the area from the upper parts of the caves. Sewage water has formed a stream bed in the area over time. In order to remove the waste water from the project area, dam should be built and the waste water should be transferred to the waste water collection center specified in the project.

As a result of the experimental studies carried out in the ancient stone quarries, it was observed that there were karstic cavities in the caves. Since the cavities are dangerous, it is foreseen to build walking paths to the entrances of existing caves 1–4. Filling areas in existing caves should be emptied and cleaned. Deteriorations on the cave surfaces (plantation, darkening, rusting, etc.)

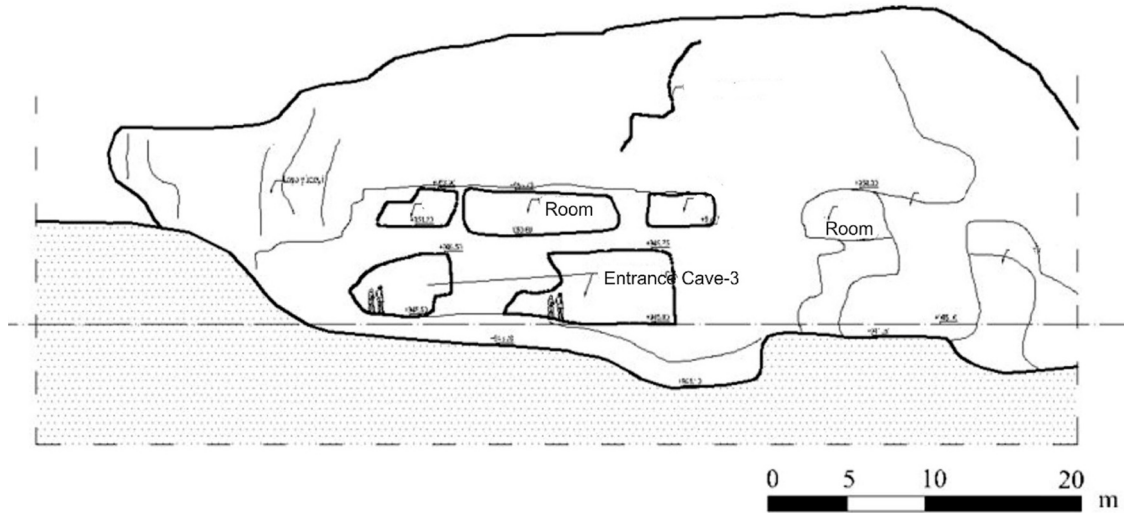


Figure 12: Architectural measured drawing of section E-E.

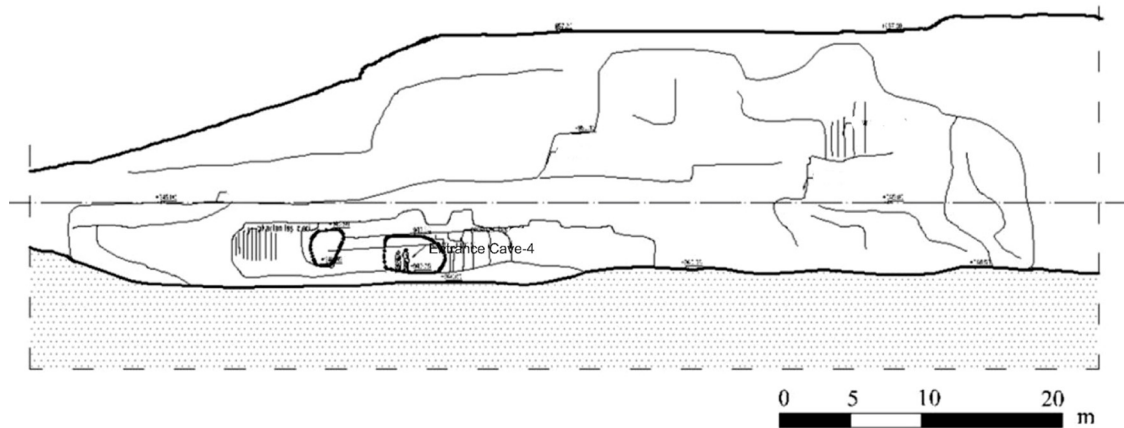


Figure 13: Architectural measured drawing of section F-F.

should be cleaned by technical methods. After the necessary repair and cleaning works are carried out in the interiors of the caves, it is recommended to organize this area as a permanent exhibition area and multifunctional areas mostly for training, workshops, and conferences.

In the studies carried out in the study area, an off-white-colored carbonate intercalated porous weathered, cracked, and fractured limestone unit formed as a result of the Adıyaman Group weathering was observed. Since the caves were used as quarries in the old period, their static strength decreased. In this context, the fractured cracked areas in the cave should be examined in detail in the project. According to the data obtained in line with the first examination, it is recommended that the trips be made in groups of maximum five people, since it can be dangerous to visit the caves in crowded groups. It has

been observed that there is filling material (randomly filled) remaining from the later or previous works in the cave at the bottom of the 2nd and 3rd caves in the study area. In the application project of the structure of this filling, it is recommended to study in more detail if a travel route is made for the guests inside the cave.

As a result of the geological and geophysical studies carried out in the investigated parcel, the groundwater has not been encountered, and probably a static level occurs at lower elevations. The groundwater level is deep. Therefore, there is no groundwater that may adversely affect the structure. Groundwater may rise and fall during seasonal periods with heavy rainfall. Project implementers should take this into account and take the necessary precautions. There is no surface water that can be considered as surface water in the study area.

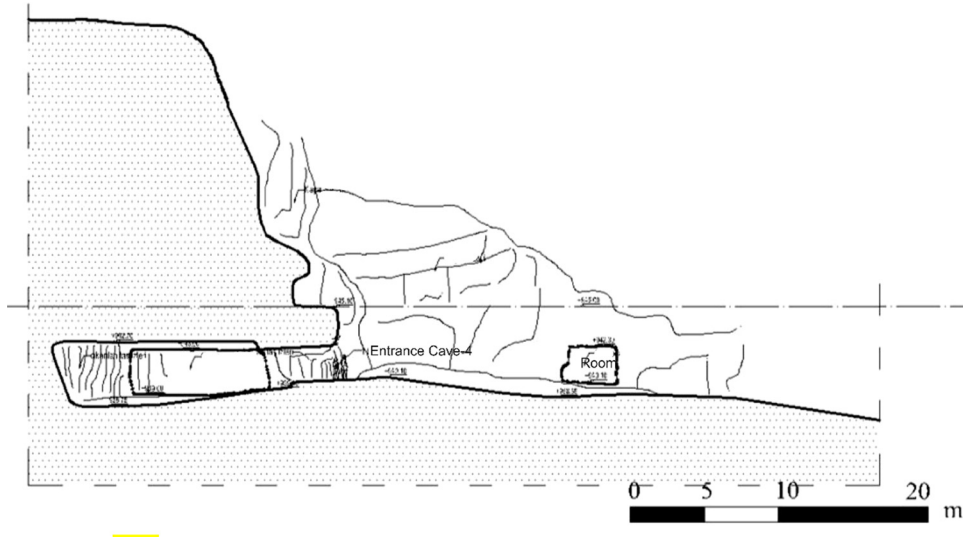


Figure 14: Architectural measured drawing of section G-G.

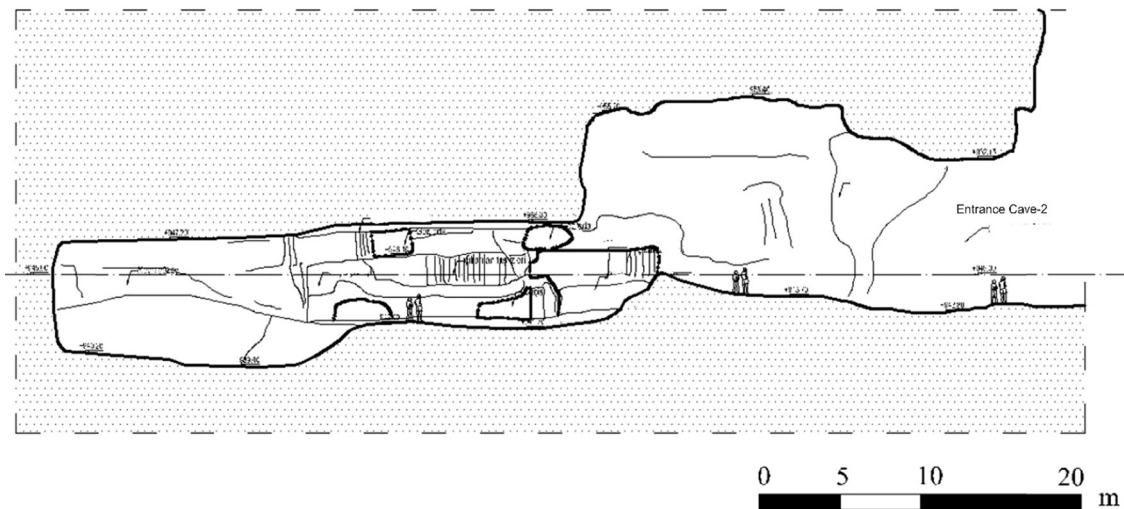


Figure 15: Architectural measured drawing of section H-H.

No landslides were observed in the study area. Soil problems such as settlement and swelling are not expected at the entrance of the caves in the study area and for the filling materials inside. Karst cavities were encountered in the caves in the study area. The geological structure in the study area offers suitable features in terms of foundation ground. The rock shows a positive structure in terms of unit bearing capacity and stability. It is recommended to make a suitable drainage system in the caves in the study area so that the system is not affected by precipitation and leachate.

4 Discussion

The first finding of this research is that in the area where the quarries are located, a karst landscape from various visual forms is encountered. Geofeatures formed as a result of the extraction of rocks from quarries were observed inside the caves. In addition, minimal stalactites began to form in the upper parts of the cave due to water leaking from the cracks. This finding supports the finding that the reported obtained in various studies in the literature can be a tourist attraction center with the landscape formed

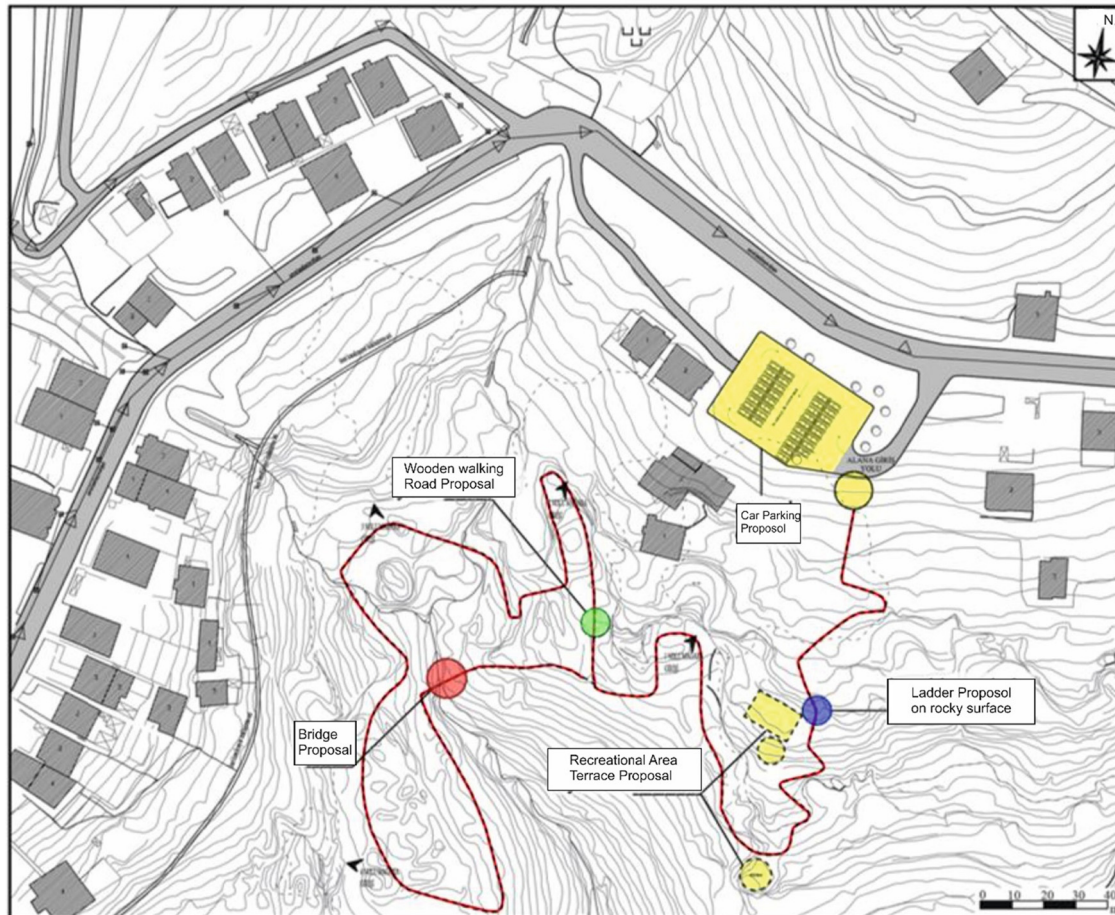


Figure 16: Suggestions for the project.

after the excavation in this geographical context [15–23]. In addition, the geofeatures (stalactites, karst scene) formed as a result of the processing of the rocks in the quarry areas have been determined as another point that will contribute to the revival of the tourism sector in the region. This finding supports the finding that the geofeatures formed as a result of processing the rocks after excavation in the quarry sites mentioned in various studies in the literature are a point that contributes to the revival of the tourism industry [23–33].

As a result of the geological and geophysical studies in the study area, no groundwater was encountered, probably a static level occurs at lower elevations. Soil problems such as settlement and swelling are not expected for the entrance of the caves in the study area and for the filling material inside. The soil in the study area offers suitable features in terms of foundation ground. The rock shows a positive structure in terms of bearing capacity. It is recommended to make a suitable drainage system in the caves in the study area so that the system is not affected by precipitation and leachate. Since there is no

groundwater level in the filling material in the study area, the fortification will not have a negative effect during the excavation. Fractured structures inside the cave should be examined in detail in the application project. Another factor is that the filling areas in the existing caves should be emptied and cleaned. Deteriorations on the cave surfaces (plantation, darkening, rusting, etc.) should be cleaned by technical methods. In order to remove the waste water from the project area, dam should be built and transferred to the waste water collection center specified in the project. All these findings support the fact that human health and environmental safety should be considered as the most important issues in the applications to be made for natural stone quarries, which is emphasized in various studies in the literature, in this geographical context [37,39].

The results of this study support the finding of the study by Beranová et al. [40] that plans and sections of the quarries can be obtained by using the current orthophoto maps of the abandoned quarries in order to determine suitable sites for geotourism purposes. In addition, the examination of the geological and mineralogical

features of the fields made it possible to examine the surface dynamics of the field after quarrying, as in the study results of Raška et al. [41]. As a result of the geological studies carried out in ancient stone quarries, it has been observed that there are karstic voids in the caves. Since the gaps are dangerous, walking paths should be built to the entrances of the all-existing caves. According to this result, various spatial arrangements should be made in order for the area to be used for tourism purposes. This finding supports the idea that historical quarries, which are mentioned in various studies in the literature, can become touristic areas with the spatial actions organized and that these areas can contribute to the tourism of the region and increase local employment [1,11–14]. In this context, there is a need for areas such as parking area, resting area, and observation terrace for visitors to the area.

In this direction, it is thought that the parking area may be suitable for the flat area located at the upper level of the area. In the flat area under the parking area on the upper level, a resting area can be built from demountable (steel–wood) material suitable for the texture of the archaeological site. Stairs in some parts of the area and bridge areas with removable materials in some parts are proposed, and 2 units, which are described as observation terraces on the periphery of the determined walking axis, and located at a high elevation with panoramic view of the area, are proposed. Resting areas and parking areas should be built to meet basic needs for visitors. In order to reach the caves, walking paths, observation terrace, and bridge should be constructed as specified in the project. It is thought that all these spatial activities to be carried out in the study area can ensure the usability of the historical quarries for tourism purposes (Figure 16).

5 Conclusion

In this study, suggestions have been developed on how the ancient quarries of Mardin can be used for tourism by obtaining plan-sections with the help of field studies, surface geology studies, geophysical measurements, orthophotos obtained from laser scanning and evaluating them together. Research results show that Mardin quarry area can provide a sustainable valuable resource for touristic visits. Within the scope of the findings obtained in the study, it is seen that the abandoned quarries can be an important tourism element both nationally and internationally. It is thought that with the later use of the researched area for tourism purposes, the old quarry sites are not only

degraded areas, they can provide added value to the land and act as a catalyst for the development of a region. By making improvements that correspond to the results of the research, it is thought that the region can contribute to wider social benefits such as contributing to the United Nations National Sustainable Development Goals, as well as promoting tourism in the region.

Non-destructive methods such as laser scanning and unmanned aerial vehicle (UAV) is very useful in cultural heritage studies [53,54]. In the future, it is planned to model the terrain using UAV. With the UAV technology, the terrain can be modeled in three dimensions with high precision [55,56].

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