RESEARCH PAPER



The study of geotourism and ecotourism attractions of Qeshm Island in the Persian Gulf, Iran

Mohsen Ranjbaran 🐌, Seyed Mohammad Zamanzadeh 🝺

School of Geology, College of Science, University of Tehran, Tehran, Iran

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Abstract

Qeshm Island is the largest island in the Persian Gulf, similar to a dolphin in shape. The island is located at the mouth of the Strait of Hormuz in Hormuzgan Province, Iran. The Island is dolphin-shaped, and most of the outcrops include sedimentary rocks. Qeshm is one of the most beautiful Islands of the Persian Gulf and due to its special geographic location has many beautiful natural and geological phenomena. Qeshm Island has a variety of cultural, handiworks, and local architecture as well as geological diversity. The geological formations of this belt may range from the late Precambrian to Cambrian in age and include diapirs called the Hormuz Series. Most of the mature salt diapirs formed in the Qeshm and the longest salt cave was created on the west of the island in a series of Hormuz Formation. The main geotourism attractions of the island include different forms resulting from erosion, as well as very attractive geomorphologic structures such as Star Valley, Khorbas Cave, Mangrove forest, Roof of Qeshm, and Chah-Kuh Gorge, Salt Cave, coral reefs, etc. Most of the landscapes are the product of wind and water erosion. Qeshm Island is one of the numerous places in Iran rich in many geologic, ecologic, cultural, and historic attractions and unique for geotourism and ecotourism. In addition to the geological and natural attractions. This study introduces geotourism attractions on Qeshm Island.

Keywords: Geotourism, Qeshm Island, Persian Gulf, Geosite Salt Dome, Cultural Tourism.

Introduction

Iran has a beautiful nature, varied climates, and regions representing unique geological phenomena, the study of which seems essential for more knowledge of them and geo-tourism development (Yazdi, 2013; Ranjbaran et al., 2020). Qeshm Geopark, as the only geopark in the West of Asia (Middle-East), has been registered by the Global Network of Geoparks (GGN) in Paris since March 2006. It is stretched tightly alongside the southern coastline (Hormozgan) of the Iran mainland (Kamyabi, 2014; Safarabadi, 2016; Qeshm Geopark website, 2019). Presently many development projects including commercial centers, office buildings and industrial installations, housing constructions, and educational and recreational facilities, are building or are under construction. Also, Qeshm Island is a free industrial and commercial zone in the Persian Gulf (Safarabadi, 2016; Shahhoseini et al., 2017).

Geotourism attempts to organize and make geological attractions of the earth being targeted and prevented from destruction by human beings through creating and defining Geopark. Maintenance of the environment and its perspectives, keeping it intact and abstaining from interfering with changing the earth's face are the main objectives of geotourism. People usually visit morphological features in the center and border of the island for a diversity of reasons, the

^{*} Corresponding author e-mail: m.ranjbaran@ut.ac.ir

major one is probably the relaxation in nature and use of the wonders of creation (Dóniz-Páez et al., 2011). With our nature-centered tourism, we have many experiences, interactions with people and nature, as well as lifestyles (Fanni & Rezazadeh, 2018). Ecotourism and geoparks are the main economic activities all over the world. Qeshm had natural attractions and due to special economic and political condition, its sustainable development depends on knowing ecologic aspects and special ecosystems of coral islands. Hara jungles, rare aquatic creations along with oil sources, huge oil ships and developmental plans of the mutually-interested countries and supervision on international standards, efficiency of the sources and environmental plans(Kamyabi, 2014). A part of geological diversity is considered the geological heritage and is called Geosite(Herrera-franco et al., 2022). Geosites are single points that may be visited by geotourists. Geotourism is one of the branches of nature tourism that introduce geological phenomena along with preservation (Pourahmad et al., 2018). Geosites are places with outstanding examples of geological history, and prominent geological processes contributing to the development of landforms, shapes, and globally valuable geological forms. "Geoheritage focuses on the diversity of minerals, rocks, and fossils, and petrogenetic features that indicate the origin and/or alteration of minerals, rocks, and fossils" (Brocx and Semeniuk, 2007; Mortazavi et al., 2017). There are many valuable attractive places such as beautiful landscapes around the Qeshm island, salt caves, coral reefs, rocky shores, various shapes and materials of coastal areas, native vegetation, resident wildlife on the island, and some cultural and historical features (Table 1). Since Oeshm Island is the biggest and first geopark in Iran and western Asia, we are going to represent the geotourism and ecotourism attraction of this island in this paper.

Iran is one of a few countries in the world that due to its geographically superior status enjoys a wide variety of beautiful natural and geological attractions ,and therein Qeshm Island can be considered the gate to Iran's geotourism .This big island due to having various and ,sometimes ,matchless geological and biological phenomena is blessed with the potential to be the great pole of ecotourism and geotourism in the Persian Gulf.

Code	Name	Purpose	Significance	Comments
G01	Stars Valley	Tourism	Geology: erosion	The most popular geosite with easy access from Qeshm City. Bearing capacity should be defined.
G02	Korkora kooh	Education	Geology: erosion	Not yet
G03	Roof of Qeshm	Ancient Qeshm	Environment	Need to study
G04	Tandis-ha (Statues) Valley	Art and events	Geology: erosion	Visitor center is under construction.
G05	Shour Valley	Education	Geology: erosion	To explain Selakh anticline
G06	Chahkooh Gorge	Tourism	Geology: erosion	Attractive; bearing capacity should be defined
G07	Namakdan Salt complex	Tourism/ Education	Geology: diapirism	Visitor center is under construction
G08	Dulab (Karion)	Unknown	Geology: diapirism and erosion	Not yet promoted
G09	Museum in Qeshm City	Tourism	Public space	Under development
G10	Mudflat	Protection	Environment	Not promoted yet
G11	Kargah Beach	Protected landscape	Environment	Not promoted yet
G12	Ghazi Terrace	Protected landscape	Geology: erosion	Not promoted yet
G13	Awli Gorge	Adventure	Geology: erosion	Not promoted yet
G14	Basira	Special tours	Geology	Not promoted yet
G15	Naz Islands	Tourism	Environment	Currently
G16	Chahkavir Gorge	Education	Geology	Not promoted yet
G17	Geolink	Protected landscape	Geology	Not promoted yet
G18	Basaeidu	Protected landscape	Geology	Not promoted yet
G19	Dolphin Bay	Protected area	Environment	Currently in use
G20	Mangrove forests	Tourism	Environment	Currently in use for visitors from three jetties
G21	Turtles Beach	Protected area	Environment	Limitedly used for tourism
G22	Crabs Rock	Protected area	Environment	Not promoted yet
G23	Laft Village	Historical fabric	Heritage	Currently in use
G24	Dokuhak	Protected area	Environment	Not promoted yet

Table 1. Type of Geosite in Qeshm Island (Qeshm Free Zone Organization, 2019)

Qeshm Island is known as a geopark for its diverse and unique geological and biological phenomena and its high potential for becoming a great geotourism site in the Persian Gulf. The island is located on a strip of tropical or subtropical vegetation in the northern hemisphere and is presented with unique geobotanical and phytogeographical characteristics (Ghahreman et al., 2000).

In addition, besides the geological and natural attractions of the area, the ancient and cultural characteristics of the island have a great potential in attracting ecotourism, as well (Amrikazemi, 2002, 2004, 2013; Amrikazemi & Mehrpooya, 2005, 2006).

The concept of the geopark reflects a list of endless activities to meet the demand for creative attractions for tourists (Dowling & Newsom, 2006). People enjoy visiting new places and learning about new visited natural attractions. Qeshm Island itself could be an education model center for the establishment of other geoparks. As a reminder to tourists, it should be noted that southern Iran is hot and humid in summer and even in spring. The visitors should plan their trip for the winter or fall. In this paper, we have attempted to analyze and discuss the geological structures, introduce details of the custom and culture of native people in Qeshm Island and their specific features in attracting domestic and international geotourists.

Materials and Methods

In this study, descriptive, analytical and environmental methods are utilized. For examining the importance and position of geotourism attractions on Qeshm Island, we referred to documents, reports, geological maps, photographs and library material and we also used other techniques such as field measuremets of the outcrops and identification of minerals and rocks via field methods in our field trip which took place in September 2019. The investigation is based on primary data collected during the field visits to Qeshm Island. There are very interesting geotourism attractions, including geomorphosites, cultural, historical, and social phenomena on Qeshm Island and these are described in this paper. The zonation of the island into four different zones (numbered from 1 to 4 clockwise) was based on Qeshm Free Zone Organization, 2019.

Geographical location and geomorphology of Qeshm Island

Qeshm Island is located at the entrance of the Strait of Hormuz to the Persian Gulf. The Coordinates of Qeshm Island are N 26°41′43″ and E 55° 37′06″, 18 km southeast of Bandar Abbas city in Hormozgan province, Iran. On this island, there are about 60 towns and villages which are mostly distributed along the coastal areas. The average area of Qeshm Island is 1565 km². The island is about 130 kilometers long and 30 kilometers wide, with an average width of 10 kilometers. The highest point of Qeshm Island is 397 meters above sea level at Namkdan Mountain in the southwest of the island. The smaller islands, such as Hormuz, Larak, and Hengam are located on the periphery of Qeshm (Fig.1). The present geomorphology of Qeshm Island is mainly shaped by erosion, which is mostly caused by wind, waves and seasonal rainstorms and should be considered as a certain factor that influenced its current form.

Geology of Qeshm Island

The characteristics of the geology and tectonic history of the region in the northern Persian Gulf formed a portion of the southeastern part of the Zagros Structural Zone. This has been folded and deformed by the latest Alpine *orogeny* phase in the Plio- Pleistocene. According to the tectonic and sedimentological evidence, Qeshm Island is a part of the southern Zagros Mountains (Figs. 2A). Based on associations between Qeshm Island's anticlines and Zagros

anticlines, it is estimated that Qeshm Island could be a part of southern Zagros(2C). In addition, another determining factor would be the salt dome, which has been pierced out on the western part of the island, creating morphologic and tectonic changes. The geological formations of this belt may range from the late Precambrian to Cambrian in age and include diapirs called the Hormuz Series. The Stratigraphy of outcropped formations in Qeshm Island includes the Hormuz series, at the Namkdan Cave. The lithology of this formation contains a series of evaporite rocks such as halite, anhydrite, black algal limestone, marl, and volcanic rocks. Other formations on the island are Mishan Formation (Miocene). Aghajari Formation(Miocene) is another formation in the Qeshm region that is alternated with calcareous and marly sandstones (Ahmadzadeh-Heravi et al., 1990). The Mishan Formation is mainly composed of gray marl and clayey limestone, and Aghajari Formation is mostly composed of limestone and red marl (Fig. 2B).



Figure 1. Location of the Qeshm Island and surrounding islands in the Persian Gulf at the Strait of Hormuz, red spots show exposed salt diapir (Bruthans et al., 2006)



Figure 2. (A) The satellite image of Qeshm Island. (B) Simplified geological map of Qeshm Island in the Persian Gulf and (C) Digital elevation model(30m) DEM of the state of the Qeshm Island

Geotourism attractions in some geo-sites of Qeshm Island

Qeshm Island is one of the numerous places in Iran rich in many geologic, ecologic, cultural, and historic attractions and unique for geotourism and ecotourism. The Stars Valley, Namakdan Cave, salt plug, Roof of Qeshm, Khorbas cave, Tala water wells, historic castles, coral reefs and Hara (mangrove) forests are among many beautiful attractions of Qeshm Island (Haghipoor, 1995; Zakeri & Habib, 2013a). Moreover, the land boundary of the island with seawater has created several types of beaches in geomorphologic terms (Amrikazemi, 2002, 2004, 2009, 2013; Amrikazemi & Mehrpooya, 2006).

Types of shores

Considering the lithology, sedimentology, and slope topography composition of rock units, there are three distinguishable types of shorelines in different parts of the island, including sandy beaches, mudflats, and rocky shores.

Based on the study of Naderloo et al. (2013) four main shore types are distributed alongside coastal environments in Qeshm Island (i.e. rocky/cobble, sandy, muddy, and mangrove). Most of the sandy beaches with rocky patches of Qeshm Island are located along the southern coast and beaches with pure sand show less species diversity. The Qeshm island coastline is about 292 Km (Fig. 3A).

Tidal mud flat

More than half of the northern beach is covered with muddy or sandy-mud sediments. Due to the low slope of the coast, as well as being protected from sea turbulence and waves, the sedimentary areas are usually rich in organic matter (Mirzabagheri et al., 2018; Noori-Koupaei et al., 2014, 2015). Mudflats of Qeshm Island are located in the northern parts of the island (Bruthans et al., 2006) (Fig. 3B). The majority of the study sites alongside the coastal zone were a combination of these four substrates. These geological features comprised interesting biodiversity and habitat diversity.

Sandy Beaches

This type of beach often extends in the form of narrow strips of about 20 to 30 meters in width in different parts of the island. In Sandy beaches, different species of sea birds are usually observed in all seasons. Areas with sandy beaches are more popular than other beaches (Fig. 3C).

Rocky Shores

These shores are seen as cliffs with or without a small sandy berm. Rocky shores benefit from coastal biodiversity, particularly bivalve and crustacean species such as oysters and crabs (Zakeri & Habib, 2013a) (Figs. 3D and E).

Salt deposits and geology of Namakdan Salt Cave

Many areas of the southern islands of Hormozgan province in the Persian Gulf are composed of salt domes (Ala, 1974; Razaghian & Arian, 2015). Most of the southern section of the island in the Persian Gulf is a salt dome. With salt dissolution at altitudes, the streams flowing from the domes of the salt dome downstream have brought them down and developed the salt cave and plains.



Figure 3. (A) Beaches with different morphology and sedimentological composition around Qeshm Island (Naderloo et al., 2013); (B) Mud flats in the northern part of Qeshm Island; (C) Sandy beach in the eastern part of the island; (D) View of the rocky shore formed a cliff and (E) debris of dead corals on the top rocky shore

This cave has been developed by the dissolution and fall of the salt layers, and its ceiling and floor are covered with white salt crystals in the cauliflower form. There are many salt deposits and salt caves on Qeshm and Hormuz Islands (Fig. 4A).

The Salt Dome of Qeshm is located on the southwestern part of the island and hosts the longest salt cave in the world (Namakdan Cave), the mouth of the cave faces southward through which the sunlight penetrates up to about 20 inside. This cave is 6500 meters in length. Namakdan Salt dome has an outcrop of 7 kilometers in diameter. Some of the wonderful structures found inside the salt cave such as stalactites and stalagmites were created by the deposition of salt. In addition, in some areas where water has penetrated the ground, some beautiful ponds have been created with salt crystals at the bottom (Figs.4B, C, D and E).

Salt domes emerged in areas that have weak surface structures and openings and appear as Salt domes on the earth's surface. Similar to other calcareous caves of the world, the formation of the Salt Cave has been following a Karst-like mechanism, by which water penetrating through a joint may gradually dissolve the surrounding areas, forming open and large cave-like structures. The salt dome (diapir) of Namakdan is a unique structure on the island, including several outstanding structural, mineralogical, erosional, and sedimentary sceneries. Namakdan Salt Dome has been formed in Hormuz Series deposits (Precambrian-Cambrian). "The plug is composed mostly of chemogenic sediments with abundant varicolored halite with folded laminae to bands (about 65 %), and less common gypsum and anhydrite" (Bosak et al., 1998).

The spatial distribution of these different types of salt diapirs is shown in Figure 4A (Jahani et al., 2007; Talaei Hassanlouei & Rajabzadeh, 2019). The majority of salt diapirs close to the Persian Gulf belong to type D" (figure 4). On Qeshm Island, we encountered two types of salt domes at the time of formation. Salt domes beneath the ground and rising, like salt domes in the Gorzine anticline in central Qeshm and the Salt dome of Namakdan mountain west of the island that is in late stages of maturity and disappearing.



Figure 4. (A) Distribution of different types of salt diapirs in the eastern Fars province. The legend shows schematic profiles of salt diapir types A, B, C, D, E, and F. Salt diapirs with red and orange colors are showing activity at present (type B, C, and D with the lowest activity), whereas yellow color type E is not active. The majority of salt diapirs close to the Persian Gulf are of type D (Jahani et al., 2007; Talaei Hassanlouei & Rajabzadeh, 2019). (B) The entrance of Cave in the west of Qeshm Island, (C) The colorful salt wall adorned by regular vertical threads in the upper part, the more resistant layers of the facial protective layer have prevented more erosion, (D) Salt ponds around the Namakdan Cave are formed from temporary, seasonal rivers and seasonal springs and (E) stalactites form a deposit

Chah- Kuh Gorge Geosite

Chah- Kuh Gorge Geosite is located about 85 km south of Qeshm town in the southwest of Chahoo village. This gorge is formed in a sandstone layer in which there are marl, silt and lime layers. This gorge resulted due to dissolution erosion and the production of cavities in the aforementioned marl, silt and lime layers. There are so many beautiful cuts that stun the eyes of every viewer. This gorge is composed of two perpendicular gorges, and because the bottom of the gorge is the source of water after any rainfall, local people have dug wells to use the water in the canyon. Since Qeshm Island is an extremely dry area, water is worthy and important in this region. For this reason, they chose the name of the "well" (which is called Chah in Persian) for this gorge (Figs. 5A and B). This geosite is a product of weathering and erosion by running water that forms a valley. The erosion was the second parameter to create this valley; it happened along deep jointed and cracked beds, resulting from the Selakh Anticline movement. This geosite is a perfect example of valley erosion. Aghajari - Mishan in Chah-Kuh is resistant; it causes rainwater to run over the surface. Chah-Kuh Gorge is shaped inside the alternation of sandstone and marl formations of Aghajari - Mishan (Miocene-Pliocene).

Star Valley

The Star Valley has located 5 km from the southern coast of the island and north of Boka Khalaf Village. This valley is the most visited of all geosites on Qeshm Island. The star Valley is a unique example among all Geosites in which erosional processes should be studied. This region surrounds one of the most beautiful geomorphological forms and effects caused by severe erosion initiated by surface water and seasonal storms in old alluvial gullies creating significant volumes of striped walls, sharp cones, columns, and blades. The Star Valley geosites consist of soft and erodible marl layers with calcareous sandstone in composition that contains a large portion of mollusk fossil remnants. The beauty of the valley has added to the beauty of the shape, perfectly vertical walls, numerous bridges, and holes in the valley. The Mishan formation is the main formation of the Star Valley. In Qeshm Island, this formation is composed of the alternation of marl and silty marl layers in olive green to a grey color. From the structural geology point of view, the layers in the Star Valley have a low dip, or they are horizontal. Due to tectonic activity, systematic joints have been created in Mishan formation in this area. The gravity force, weathering and erosional phenomena are the main reasons for joints opening (Figs. 5C and D).

Naz Islands

Two islands are located near the village of Suza on Qeshm Island. These two islands are connected to the mainland during low tide. These islands are about three hectares and present beautiful small islands in the Qeshm Geopark. The cliff walls of the islands are three to five meters high and connect to the beach with a muddy surface. During the tidal ebb, these islands are connected to the shores of Qeshm Island. During, high tide, they can only be seen off the coast, but at low tide, a relatively narrow path opens up to the two islands that can be reached. Because the two islands are continually connected and separated, they are known as Naz. As a reminder to tourists, southern Iran is hot and humid in summer and even in spring. The visitors should plan their trip for the winter or fall. These islands are entirely flat and during low tide, attach a piece of cute narrow land to the Qeshm Island. There are no inhabitants on these islands, and only native fishermen visit the islands for landing their fish catch. The facing coast of these islands is an excellent place for camel riding (Fig. 6A and B).



Figure 5. (D) A view of the entrance of the grooved walls of the Chah-Kuh Gorge (C) a dug well in Chah-Kuh Gorge. (A) A general top view of the stars Valley (Darreh- Setareha) and (B) a part of the valley of stars therein pinnacles, single walls, and other shapes resulting from erosion are visible



Figure 6. (A) A general top view of the Naz Islands in high tide. (B) A general view of the Roof of Qeshm

The Roof of Qeshm

"The Roof of Qeshm is one of the main attractions among all Geosites. It is a semi-high plateau that is located in the central parts of the island, stretching towards the western parts of the island overlooking the northern coastline. It is named the Roof of Qeshm because it is the largest and highest plateau on the island and offers a unique opportunity for visitors to observe the beautiful landscapes from above (Güney, 2020). The Roof of Qeshm overlooks the Tandi's Valley from the north, where its beautiful geomorphology is visible. The top layers at the Roof of Qeshm are formed from limestone containing numerous fossils, while in its outer sections, the presence of silt and marl, as well as sand, resulted in massive erosion" (Fig. 6B). There are also some ruins in the Roof of Qesh area representing development of ancient civilization. In addition, in the ruins there are also some pieces of pottery and baked mud bricks, which probably date back to the Islamic period. The view of Harra Forest from above the Qeshm Roof including the north coasts of the Persian Gulf and the fascinating erosional scenes in the south of the plateau is among the landscapes which can attract visitors for long hours. These attractive scenes arouse enthusiasm in the visitors to put up a tent to stay overnight watching the stars while breathing in the fresh air in such mild weather (Amrikazemi & Mehrpooya, 2005).

The areas with biological attractions and environmental zoning

"Qeshm Island is divided into four zones based on the major ecosystem and marine environment, as shown in Figure 7. Characteristics of each zone, as well as the viewpoint regarding conservation and development potential, are summarized in Table 2".

The island has a variety of ecotourism attractions, including arid and semiarid, tidal flats, and onshore and marine ecosystems. Qeshm Island's biological attractions include reefs, mangrove forests, and mudskipper habitats.

Coral Reefs

On the southeast beaches of the island, coral reefs colonies of shallow water thrive on the bedrock of the seafloor.

		Zone I	Zone II	Zone III	Zone
	Mangrove	Х	(x)	(x)	Х
	Seagrass	Х	Х		X
Major	Seaweed	Х	Х	Х	Х
ecosystem	Coral	Х	Х		
ccosystem	Turtle				
	nestig		Х	Х	
	beach				
Characteristics of nature		 Transplanted mangrove area Mudflat 	 Urban area Coral Turtle Beach Dolphin Nog Islands 	Sandy beachTurtle Beach	 Natural mangrove area Transplanted mangrove area Seagrass bed Dolphin
Designated protected area		• Bird sanctuary	Turtle BeachDolphin Bay		Hara Mangrove Area
Viewpoint on conservation		Bird sanctuaryMudflat	• Coral, turtle and dolphin	 Scenery of sandy beach Turtle Beach 	• Mangrove and seagrass bed
Viewpoint on development potential		 Moderate development Nature conservation 	TourismCoral snorkeling	Tradition al lifeContact with nature	Moderate development

Table 2. Characteristics of Each Environmental Zoning Area (Qeshm Free Zone Organization, 2019)



Figure 7. Expediential Zoning of the Ecosystem (Qeshm Free Zone Organization, 2019)

These ecosystems mainly consist of the hard bed, in particular with limestones, in which corals and scattered sands and gravel dominate. Bearing a wide variety of aquatic animals, the coral reefs of the region provide a suitable place for turtles to feed and dwelling. In the southwest, i.e. Shibderaz area, coral colonies are found with a variety of beautiful colorful species. We can also see wider colonies in the vicinity of Hengam Island and the biggest and broadest of all the coral colonies lies on the margins of Larak Island ,which is considered as one of Qeshm's satellite slands (Amrikazemi & Mehrpooya, 2005). By affecting the water status of the surrounding area, these corals have created a small ecosystem and involved many of the region's wildlife (Fig. 8A).

Hara or Mangrove Forests

In general ,Qeshm plants are categorized as tropical and need much humidity in summer and are mostly observed in the form of desert short shrubs. Tidal flats, along with intertidal salt marshes and mangrove forests, are important ecosystems in the Qeshm. Mangroves are trees and shrubs that grow in saline coastal habitats in the tropics and subtropics - mainly between latitudes 25° N and 25° S (Salehipour Milani & Jafar Beglu, 2012). The first and most crucial plant community in Qeshm Island is the Harra (Mangrove) sea forest which covers 200 km², the intertidal zone of the total island area. Usually, with this extreme variation of temperature and salinity, these specific trees adapt themselves to this extreme salinity and the hottest part of the sea in the world. Mangrove or Hara Forest, a unique wetland ecosystem in Qeshm Island, is located on the northeast beach. There are over 60 mangrove sites in the world (Samper-Villarreal et al., 2012). Two species of mangrove spread on Hormuz Island. Common types of mangrove on Qeshm Island include Rhizophora macrunata and Avicennia marina (Zahed et al., 2010; Ghahreman et al., 2000; Salehipour Milani & Jafar Beglu, 2012). The trees of these forests are evergreen. Hara forest is the vegetation set, including trees and shrubs observed in coastal saline waters in the form of a strip. These plants are classified in the group of halophyte plants (Figs. 8B and C). For the last thirty years, there is a program of mangrove planting on Qeshm Island (Ghahreman et al., 2000). The leaves of this tree absorb the fresh water from seawater and excrete salts. The water depth of the mangrove forests is about one and a half meters, so the roots and basal part of the trees appear for six to seven hours during the low tide. There is a specific, special mangrove, and they have a unique aerial root that allows them to absorb the oxygen through the atmosphere and sent it to the branches. Due to their suitable conditions, Hara forests are a safe habitat for fish, mollusks, crustaceans, and migratory birds from tropical areas (Ghasemi et al., 2010). Hara Forest of Qeshm Island covers a muddy intertidal wetland zone. Crabs, gastropods, and mudskippers are among the primary inhabitants of these areas. The largest mangal ecosystem of the Persian Gulf is located in Harra of Tabl north of Qeshm and Covers more than 6,800 acres (Naderloo et al., 2013).

Mudskipper of Bandar-e Darghan

In the northern part of Qeshm Island, between the mangrove forests and the port of Darghan, there are vast, low coastlines suitable for living mudskipper. These fish live only on muddy beaches and adjacent mangrove forests. Mudskipper is air dwelling fish that live in mangrove forests. In addition, because of the low slope of the coast as well as being protected from sea turbulence and waves, the sedimentary areas are usually rich in organic matter (Mirzabagheri et al., 2018; Noori-Koupaei et al., 2014, 2015). Dargahan port is one of the perfect areas for biologists in the tidal flat area for studying mudskipper. During the high tide, a large area is underwater, and the fish are present in the water. They have undergone some evolutionary changes to perform this unique lifestyle. For example, the prominent eyes have been well

changed for a clear aerial view (Figs. 8D and E). Feet-like pectoral fins enable these to walk while living out of the water, climb on stems or muddy domes, and even jump from point to point. The mudskippers are mainly observed in the intertidal zone around the Qeshm island Coast. The mudskipper has biological activities such as crawling, burrowing, mowing, and mud pellets making (Hashemi et al., 2015; Ranjbaran & Sotohian, 2015). The mangroves made a suitable home for other species like mudskippers. The private place for each mudskipper helps them to escape from the animals such as birds that prey on them. They slide themselves through the mud at low tide and they jump into little pools to pour water on their body. They have large eyes on the top of their heads, which helps them to have an all-around view and control their territory.



Figure 8. (A) A colony of coral reef (*zoanthus* sp.); (B) A general view of Hara (Mangroves) Forst and (C) a close-up of mangrove trees and their aerial roots seen at the low tide; (D) A general view of the intertidal zone burrowing by mudskipper and, (E) a Close up view a mudskipper around private water pit

Historical and cultural attractions of Qeshm Island

Historical and cultural attractions of Qeshm Island are home to numerous examples of monuments, including the Khoarbas Cave, Tata Wells, Portuguese Castle, Historical Cemeteries and more. About 191 archaeological sites of different ages were identified on Qeshm Island (Mohammadi Ghasrian, 2017; Yazdi et al., 2014). Based on a preliminary study of the letters from the ancient sites of Qeshm, the most stagnant sites date back to the third millennium BC. Most of the identified sites belong to the Islamic period.

Portuguese Castle

Part of the island, the ruins of the "Portuguese Castle" and its protruding nose are the most important historical monument of the Hormuz and Qeshm islands. The Portuguese Castle of Qeshm and Hormuz islands incorporate the geotic, biotic and anthropic aspects of the monument (Martínez-Torres, 2018; Ranjbaran et al., 2020). Portuguese castles are observed in many southern islands of Iran. The castles built by the Portuguese during their colonial rule in the Persian Gulf in the 16th and 17th centuries are scattered across its littoral areas and islands, including Qeshm Island, Kong Port, Oman, Ras al-Khaimah (UAE), and Chabahar. They date back to the governance of the Portuguese in the southern regions of Iran. The materials used in the construction of the castle have been all from the mineral resources of the island. The main components of materials include volcanic rocks and residuals of beach rocks and dead coral skeletons(Moradi, 2016). The Portuguese castle was constructed in June 1507 under the command of Alfonso de Albuquerque, an offensive Portuguese sailor on the northern side of islands in the Persian Gulf. The Portuguese occupation of this vital naval waterway lasted for 110 years. Over this time, they constructed fortifications and fortresses, such as the fortresses of Qeshm and Larak. The Imam-Quli Khan's soldiers, with the help of the British navy, captured the Portuguese castle at Hormuz Island in April 1622. The Portuguese Castle in Qeshm and Hormuz islands include weapon warehouses, large water cisterns, barracks rooms, prisons, churches, command base, and halls (Figs. 9A and B).

Khorbas Cave

In the southeast region, of the island there are some big caves in a big clayey marl hill which resulted from the erosional activity of the sea. These caves are dug by humans inside the hills up to a few meters and some of them are linked together to form a network of caves. The Khoarbas Cave is located 15 kilometers from Qeshm town on the right side of Qeshm road to the village of Khoarbas and the village of Ramchah. These caves are located inside a marl-clay hill overlooking the sea and the plain between the bowls. Due to the composition of cave walls, which consist mainly of loose rocks (marl and silt) and the presence of large fossils, these holes and caves appear to have been initially eroded and later expanded and enlarged by the native people. In the southeastern region, within a large marl-clay hill that was eroded from the sea, many large holes extended several meters into the wall, sometimes interconnected and forming a network. These caves were probably used by the island's ancient inhabitants in the past as a shelter against enemy attacks (Figs. 9C and D). The Khorbas cave is a Lower Palaeolithic site on Qeshm Island in the Persian Gulf. An assemblage of Palaeolithic artifacts were discovered at the Khorbas Cave and rock shelters on the present-day coastline of the island (Mohammadi Ghasrian, 2017) (Figs. 9E and F).

Significant Programs and Projects

It is planning to develop geotourism in four locations. Four locations are proposed for tourism

information centers on the island (Fig. 10). Qeshm City should have one general tourist information center, since almost all visitors come to Qeshm City, as this is where most hotels are found.



Figure 9. (A) and (B) are two views of the remnants of the Portuguese Castle on Qeshm Island. (C) a general view of Khorbas cave and (D) a close-up of an inside of cave Qeshm Island. (E) Middle Paleolithic hunter-gatherers at Qeshm (Qeshm Museum) and (F) Photograph of Lower Palaeolithic artifacts from Khorbas: a-b) hand axe; c) chopper; d) core; e) hammer stone (Mohammadi-Ghasrian, 2017)



Figure 10. Proposed Locations of Tourist Information Centers (Qeshm Free Zone Organization, 2019)

Since many tourists whose purpose is shopping visit Dargahan, it is better to allocate one information center. Sohil is located within the Ecotourism Reinforcement Zone and already has the Mangrove Information Center. By utilizing this existing facility, Sohil can be a hub for distributing information on ecotourism and aqua tourism products (Qeshm Free Zone Organization, 2019).

The candidate projects are grouped into four divisions, namely, economic development, infrastructure development, environmental management, and regional and community development. Table 3 shows the number of priority projects and the title of the priority projects in each category.

Category	Subcategory	Number of candidate projects	Number of priority projects	Title of priority project
	Agriculture and animal husbandry	11	0	
Economic development	Fishery	7	4	Market-based aquaculture development plan Dissemination of aquaculture to local communities Habitat rehabilitation Community- based fishery resource management
	Industrial	5	1	LNG industry development
	Tourism	4	2	Capacity development in marketing and promotion of ecotourism One Village One Product (OVOP) promotion
	Transportation	6	0	
	Water supply	2	1	capacity of leakage detection and non-revenue water (NRW) in Qeshm City and rural areas
Infrastructure development	Sewage treatment	3	1	Development of an urban sewerage system for Dargahan City
development	Solid waste management	7	1	Sanitary landfilling at Towla
	and renewable energy	2	1	Promotion project for PV generation
	Marine ecosystem management	3	1	Rehabilitation of the coral community
Environmenta l management	Inland ecosystem management	4	3	Integrated management of the Hara Protected Area Rehabilitation of native species for better ecosystem services Phasing out harmful economic incentives and strengthening positive incentives for better ecosystem services
	Geopark management	1	1	Promotion of QIGG as a regional hub for Middle Eastern and North African countries
	Institutional system	1	0	
Regional and community	Regional development	2	2	Integrated regional development in Southern Iran Capacity building of the QFZO in sustainable administrative systems
development	Community development	1	1	Establishment of a participatory approach for public participation
Total	-	59	19	

Discussion

The question is why we chose Qeshm Island as a case study. Qeshm is the largest island in the Persian Gulf with a large population. The Qeshm is the first geopark of the Middle East

registered by UNESCO and the best place to hold scientific tours and see some specialties and geologic structures. This island offers to provide a wide range of health, travel agencies, tour operators and accommodation facilities. There are also many cultural and handicraft facilities on the island. Geoparks and geosites play an important role in protecting the natural and geological heritage. Qeshm Island has contributed to the cultural sustainability of its rural areas and has also attracted an increasing number of visitors, contributing to the socio-economic development of the island (Torabi Farsani et al., 2012). This island has been considered the first Halal (religious permits) tourist attraction center in Iran and was launched in September 2018. Halal tourism is said to be tourism following Islamic law and in the past few years, many non-Muslim countries have also begun to use the Halal brand in food products. The largest Mangrove forests are spread along the northern coasts of Qeshm Island. The unique cultural heritage of the island is also the result of an old cultural place and a variety of traditional crafts. Due to the geodiversity, geography, as well as archaeology and wildlife, this island can be introduced to tourists as a paradise geopark in the Persian Gulf.

Geocities and Geoparks are the gates to Creating plenty of job Opportunities with Mass Production on Qeshm Island (Shekhar et al., 2019; Ranjbaran et al., 2020). Geosites and geoparks are really good places for economic growth and development of these areas, with travel and travel services, and advertising programs in various fields (Errami et al., 2015; Shekhar et al., 2019). The geopark of Qeshm along with geotourism reduces the rate of migration and unemployment in The rural area. There are more locations, in Qeshm geopark such as karstic features in a Namakdan cave which attract most people to the area.

Conclusion

Erosion is the most effective factor in creating and forming the geological phenomena on Qeshm Island .After erosion ,we should consider the effect of the Namakdan Salt dome , which has pierced the surficial rocks and caused genesis of various iron minerals which illustrate colorful outcrops and varied color layers. The major factor which caused the formation of the Qeshm Island includes both tectonic and eustatic factors. The former caused the folding of sedimentary layers resulting in the formation of the Gavarzin anticline which forms the backbone of Qeshm Island. The latter has caused marine erosion of the anticline flanks resulting in the development of both escarpments and marine terraces in rocky shore of the southern part of the island. Erosion in Qeshm is primarily due to the work of wind ,sea waves , seasonal rainstorms, temperature change ,humidity ,mineral crystallization and secondarily factors such as tectonics and gravity. Erosion mainly happens in the Neogene's softer sediments mostly in the silt ,marl and sandstone layers. In many regions because of the rapid erosion of the lower softer layers ,the space beneath the hard layers gets emptied and the upper layers collapse due to the effect of gravity. This kind of erosion causes the diversity of geomorphosites and landforms.

Today, geoparks have a special place in the tourism industry in the world. Qeshm Island is the first and the only geopark of Iran located in the Persian Gulf in the Middle East. Qeshm Island is the largest island in the Persian Gulf, seen as a dolphin shape and is located at the mouth of the Strait of Hormuz. This island has abundant potential for expanding the tourism industry, in particular, geotourism. Due to the unique area, variety of geosites, and suitable natural and cultural conditions, geomorphologic examples of Stars valley, as well as colored Salt caves, are exceptional examples of Qeshm Island. The Qeshm region is one of the islands with high tourist potential (especially geotourism including unique geomorpho tourism attractions) and a free trade area similar to Kish Island and Chabahar city in the south and southeast of Iran. One of the special effects that Qeshm Geotourism's development in the geopark can bring is to provide a more fundamental understanding of foreigners' capabilities. Ultimately, the possibility of attracting and increasing foreign investment, especially as Qeshm is a free trade zone, followed by a system of employment and income growth was conceived. One of the most important results of the development of Qeshm geotourism is its introduction into a more general system. So that it can be proposed that Qeshm Island in the Persian Gulf is a suitable model for other regions of the country, which have the potential to become geopark. Qeshm Island has a variety of cultural, handiworks and local architecture as well as geological diversity.

The majority of Qeshm residents have a positive attitude toward geotourism. The residents' positive attitude is the outcome of the job opportunities provided by the tourism industry. This indicates that the greatest achievement of the tourism industry is providing a broad range of career opportunities.

The advantages of the first stage are new job opportunities and income rise. At this stage, only a minority of local people are irritated by the tourists' presence. One of the most important positive impacts of the tourists' presence in the Qeshm region is the development of ethnic and cultural pride.

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