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Bridging natural and cultural values of sites with outstanding scenery: evidence from Gozo, Maltese Islands / Coratza, P., Gauci, R., Schembri, J., Soldati, M., Tonelli, C.. - In: GEOHERITAGE. - ISSN 1867-2477. - 8:1(2016), pp. 91-103. [10.1007/s12371-015-0167-7]

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07/11/2026 20:44

(Article begins on next page)

Geoheritage

Bridging natural and cultural values of sites with outstanding scenery: evidence from Gozo, Maltese Islands

--Manuscript Draft--

Manuscript Number:	GEOH-D-14-00047R1
Full Title:	Bridging natural and cultural values of sites with outstanding scenery: evidence from Gozo, Maltese Islands
Article Type:	SI: Geomorphosites
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Funding Information:	
Abstract:	The paper focuses on a site of outstanding scenery located along the NW coast of the Island of Gozo (Malta, Central Mediterranean Sea), which was included in the Malta's UNESCO World Heritage Tentative List in 1998 on the basis of the four criteria related to natural properties. The aim of the study is to bridge scientific and cultural values of the Dwejra area by examining in particular its geological and geomorphological features, which have been fundamental in shaping such a spectacular scenery and determining its historical and cultural importance. The coast of the Maltese Islands, with a series of occupiers over the last ten millennia, has led to the development of a high density of coastal uses. Such uses superimpose on both a diverse range of aesthetic natural qualities and also different cultural properties that have changed over time. Sinkholes were a source of shelter on rectilinear coasts and are now areas that attract visitors due to their outstanding natural beauty. Low sloping limestone coast provided an ideal geological setting for salt panning production, whereas today these are main areas for recreational activities. Along the years, the investigated area has however suffered the pressure of diverse human activities, often leading to conflicting interests and resultant landscape damage. As a result, geo-conservation aspects of this site have often been at the centre of national debates. In the light of these issues, this work aims at providing a better understanding of the geological and geomorphological value of the Dwejra area, in order to strengthen the basis for the setting up of sustainable geo-conservation plan, which includes geotourism issues.
Response to Reviewers:	We revised the manuscript following the suggestions of the reviewers. In particular, according to reviewers' comments and observations we have: 1) Re-worked section 1 (Introduction) 2) Reorganized section 2 (Geographic and cultural setting)

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	3) Deleted section 3 (Dwejra in the context of Word heritage) including its contents in other sections (mainly in Introduction) 4) Re-worked section 4 (Geological setting) 5) Re-worked section 5 (Outstanding geomorphological features) 6) Re-worked section 6 (Cultural heritage as an added value) trying to emphasize those natural/geomorphological features that might have enhanced the cultural importance of this area. In order to emphasize the cultural aspects we have included a new illustration consisting of a historical lithograph of Fungus Rock. 7) Re-worked section 7 (Geotourism) by: - adding the description of some existing or planned examples of geotourism in the area; - highlighting the bridge between cultural and natural heritage. - including the geotourism perspectives in the conclusive remarks Please note that the title has been slightly changed to be make it more appropriate and effective.

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Bridging natural and cultural values of sites with outstanding scenery: evidence from Gozo, Maltese Islands

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ABSTRACT: The paper focuses on a site of outstanding scenery located along the NW coast of the Island of Gozo (Malta, Central Mediterranean Sea), which was included in the Malta's UNESCO World Heritage Tentative List in 1998 on the basis of the four criteria related to natural properties.

The aim of the study is to bridge scientific and cultural values of the Dwejra area by examining in particular its geological and geomorphological features, which have been fundamental in shaping such a spectacular scenery and determining its historical and cultural importance.

The coast of the Maltese Islands, with a series of occupiers over the last ten millennia, has led to the development of a high density of coastal uses. Such uses superimpose on both a diverse range of aesthetic natural qualities and also different cultural properties that have changed over time. Sinkholes were a source of shelter on rectilinear coasts and are now areas that attract visitors due to their outstanding natural beauty. Low sloping limestone coast provided an ideal geological setting for salt panning production, whereas today these are main areas for recreational activities. Along the years, the investigated area has however suffered the pressure of diverse human activities, often leading to conflicting interests and resultant landscape damage. As a result, geo-conservation aspects of this site have often been at the centre of national debates. In the light of these issues, this work aims at providing a better understanding of the geological and geomorphological value of the Dwejra area, in order to strengthen the basis for the setting up of sustainable geo-conservation plan, which includes geotourism issues.

KEYWORDS: Geoheritage, Cultural landscape, Geomorphology, Dwejra, Gozo, Maltese Islands, Mediterranean Sea

1. Introduction

Cultural landscape, its relationship with environmental components and its enhancement are topical issues nowadays in many countries since they represent a new way to construct the relationship between Man and Nature and can favour new insights for the tourism development of a territory. The Maltese archipelago can be considered as a natural laboratory for the study of the relationship between cultural components of the rich heritage of the islands and the geological and geomorphological context in which they are located. *Culture* is a complex concept and therefore no single definition of it has achieved consensus in the literature. Hofstede (1980) defines culture as "*the collective programming of the mind which distinguishes the members of one group from another*", which is passed from generation to generation but which is also changing all the time because each generation adds something of its own before passing it on. Mulholland (1991) describes culture as "*a set of shared and enduring meaning, values, and beliefs that characterize national, ethnic, or other groups and orient their behaviour"*. Hall (1976) argues that, though culture is not genetically inherited and cannot exist on its own, it is always shared by members of a society and it affects every fabric of society because of ideas, values, attitudes, and normative or expected patterns of behaviour shared by its people. These definitions highlight how culture bonds members of society together in the spirit of collective manifestation of human behaviour and concurrently serves to distinguish one society from another.

Heritage would represent one aspect which members of a society would collectively consider as valuable since its existence survives the passage of time and generations. Heritage is frequently, but generally artificially, divided into natural and cultural components, even if this kind of distinction is often meaningless and almost always blurred. In this context landscape represents a clear example of the artificiality of such division. Landscape owes its origin and expresses the long and complex relationships between physical and anthropogenic factors that interacted, are conditioned and still condition the landscape, in space and in time (Reynard and Coratza 2015). Only the mix of natural and cultural values gives each landscape its heritage importance leading to community support for its conservation and enhancement (Aplin 2002). In these terms a landscape can be considered as the most complex cultural asset which offers potential for sustainable tourism.

This is particularly true for the islands of Malta and Gozo, where tourism is considered one of the three pillars of the national economy. Gozo, small in size but strong in identity, is characterised by a highly scenic landscape and a very rich and distinctive natural and cultural heritage. Tourism in Gozo, which started about 50 years ago, contributes to the socio-economic wellness of the island. The Gozo's tourism market is mainly related to foreigners who spend entire or part of holiday there, Maltese who spend brief periods and foreign and Maltese day-visitors.

Many recent studies in several regions of the world are engaged with the research theme that investigates the strong relationship between the environment and the cultural heritage (e.g. Franchi et al. 2009; Lollino and Audisio 2006; Gigli et al. 2012) and the relationship between geoheritage and tourism (e.g. Newsome and Dowling 2010; Joyce 2010; Gordon 2012; Zglobicki and Bran-Zglobicka 2013; Del Monte et al. 2013). The importance of developing studies linking geology, geomorphology and cultural heritage can be traced to Panizza and Piacente (2003) who brought together the three themes under one coherent title as cultural geomorphology. The awareness of the relationship between geomorphological aspects and cultural and natural heritage has increased over the past years

(Panizza and Piacente 1991; May 1993, 2007; Soldati et al. 2008a). With respect to the Maltese archipelago, this issue was previously explored during the International Workshop on the "Integration of the geomorphological environment and cultural heritage for tourism promotion and hazard prevention" held in Malta in April 2007 (Cyffka 2008; Soldati et al. 2008a). The papers presented (Soldati et al. 2008b) dealt with different aspects of the integration of the physical environment and cultural heritage through case studies from different parts of the world including Malta. As regards the Island of Gozo, this issue was marginally explored only later on (Coratza et al. 2012) and is here analysed more in depth.

This paper is focused on the Dwejra area (Fig. 1), on the western coast of the Island of Gozo, which was included in 1998 in the Malta's Tentative List, an inventory of those properties which each country intends to nominate to the UNESCO Word Heritage List. The site was investigated, due to its scientific and cultural importance, as previously highlighted by Anderson and Schembri (1989), Anderson and Schembri (1990), Fava et al. (1996), Hathaway (2000) and Geoscience Consulting (2013). Apart from becoming a Natura 2000 site, Dwejra received EU funding under the LIFE-Third Country strand in 2003 to become Malta's first coastal heritage park. The inscription of Dwejra on the UNESCO Tentative list has been made on the basis of the four criteria relevant to natural properties (Criteria vii, viii, ix, x). As stated in the Tentative List, the "*site combines interesting geology, both on land and under the sea, rich diverse wildlife and habitats, dramatic seascapes dominated by a rocky shoreline, cultural elements spanning from the 3rd century BC to the 19th century AD and a general wilderness feel*", showing the complex connections existing between the rich geo-, bio- and human heritage of this area. Against this background, this paper aims at highlighting why the exceptional natural beauty of this area mainly resides in its geomorphological heritage (cf. Goudie 2002; Migon 2009). In particular, we would like to point out how the integration of environmental and cultural heritage aspects makes the Dwejra area a site of remarkable value to be promoted for a more holistic and varied tourism.

According to the Qawra/Dwejra Heritage Park Action Plan (MRRA 2005), about 750,000 tourists visit the Dwejra area every year, of which 40,000 visit the site for diving purpose. Dwejra is considered as a prime diving site with over eight possible dives of national and international merit. The 'Blue Hole', in particular, is considered one of the top dive sites in the Mediterranean. In addition, approximately 100,000 of locals visit the site annually for recreational and diving purposes, making Dwejra the third most popular site in the Mediterranean. The latest addition to the list of marine touristic attractions in Dwejra includes the setting up of the first environmental education centre at Dwejra in March 2013, exclusively dedicated to the edutainment of marine biodiversity on the Maltese Islands.

On the other hand, the impact and pressure of diverse human activities, last but not least tourism, on this area have been growing significantly, often leading to conflicting interests and resultant landscape damage. As a result, geo-conservation aspects of this site have often been at the centre of national debates.

2. Physical setting of Dwejra area

The Maltese archipelago is located in the central Mediterranean Sea and consists of three inhabited islands: Malta

(246 km^2), Gozo (67 km^2) and Comino (3.5 km^2) (Fig. 1). Gozo is roughly circular in shape and its main dimensions are 14 km in length and 7.25 km wide, with a resident population of circa 31,400 people (National Statistics Office, 2014), and a transient population of domestic and international visitors numbering over 700,000 per year (Conrad et al. 2011). Gozo is hilly and the highest point is in the north-western part near Ta' Dbiegi at 191 m on the outskirts of the village of San Lawrence.

Large stretches of the coastline are relatively rectilinear with plunging cliffs outlining most of the Gozitan coast and mostly found along the southern and north-western coastal areas of Malta. Coastal slopes with stepped profiles, characterised by structural benches on outcrops of thin hard pebble beds, are prominent near Marsalforn along the north-eastern part of Gozo (Said and Schembri 2010). Climate is typically subtropical Mediterranean and characterised by warm and dry summers and, relatively wet autumns and short and mild winters. The average annual temperature is 18°C and the monthly averages range from 13 (January) to 27°C (August).

The Dwejra area is located a few kilometres south of the north-westernmost point of the Island of Gozo and falls within the jurisdiction of the town of San Lawrence.

Dwejra boasts one of the most impressive scenery of the Maltese Islands, displaying a great variety of geological and geomorphological features as well as unusual and unique ecological systems, concentrated in a relatively small and remote area (Fig. 2). The landscape is made of a large set of landforms shaped through time by several processes (Fig. 3): (i) karst dissolution, forming at least four large solution subsidence structures in the area (Dwejra North, Dwejra Bay, Qara, Ghajn Abdul); (ii) fluvial processes, marked by the presence of perennial freshwater pools, seepage from cliffs, waterfall and several dry valley systems (*widien*); (iii) marine erosion processes, as evidenced by the great variety of features including with sea-caves, tunnel, arches, stacks and reefs. The most famous features of geomorphological importance are the bays of Dwejra North and Dwejra with a massive rock known as Fungus Rock (Fig. 2) and the arch formed as a result of erosion known the Azure Window which is arguably the site of greatest tourist attraction on the Maltese Islands.

The area is also of considerable palaeontological interest, due to the presence of fossils deposits both in the Oligo-Miocene marine succession, as well as in the Quaternary lacustrine and terrestrial one. At present, it contains the most important and significant habitats, the presence of unique communities of higher plants (some endemic to Gozo) and the presence of endemic, rare and endangered species. Its ecological importance in general is based on the superimposition of many of the typical habitat types of the Maltese Islands as well as significant number of unusual ones (Cassar et al. 2004; Lanfranco and Cassar 2007).

Moreover the presence of cultural features spanning from rubble walls and rural structures, to cart-ruts of unknown age and structures of the 19th Century enrich the interest in the area and allow it to become a landmark of cultural importance to the history of the island as a whole. In this context, it is particularly worth noting the integration of nature and human culture, represented by the rocky islet of Fungus Rock (Fig. 2), with its long history of discovery, conservation and exploitation of the so called “Malta Fungus” (Lanfranco 1979).

The study area has been subject to significant anthropogenic modification and its land use has changed over the years. This change can be identified with the changes to the locals’ life-style and socio-economic modifications, especially the emergence of tourism and the marketing of leisure facilities, mainly pleasure boating tours and

underwater guided dives.

3. Geological features

Dwejra area exhibits the entire Oligocene-Miocene succession of marine sedimentary rocks which compose the islands (Fig. 3). A number of researchers have outlined the geological aspects of the Maltese archipelago (e.g. Spratt 1843; Trechmann 1938; Hyde 1955; Pedley 1976, 1978; Zammit Maempel 1977; Reuther 1984; Pedley and Bennet 1985; Oil Exploration Directorate 1993; Gatt 2014).

Due to a regional tilting to the north-east of the Island of Gozo (Pedley et al. 1976), along the coastal cliffs of Dwejra it is possible to observe all the four members of the oldest lithostratigraphic unit, the *Lower Coralline Limestone Formation*, which are, conversely, partly submerged in the northern coast. Over this hard limestone with abundant fossil corals and marine calcareous algae, in the area extensively outcrops a softer fine-grained limestone, named *Globigerina Limestone Formation* due to the presence of abundant fossils of *Globigerina*, a planktonic foraminifera. The overlying *Blue Clay Formation*, composed of marls and clays, outcrops in the eastern part of the area and within large paleosinkholes located westwards. The topmost unit, a hard limestone similar to the Lower Coralline Limestone, is the *Upper Coralline Limestone Formation* and is now limited to erosive outliers located to the east.The tectonic setting of the area is characterised by annular dip-slip faults bounding collapse paleosinkholes (Pedley 1974; Soldati et al. 2013; Galve et al. 2015) which are associated with E-W-trending normal faults (Pedley et al. 1976; Illies 1981). The latter are probably related to the collapse mechanism and do not reflect the regional tectonics which is defined by two intersecting fault trends, the NW-SE-trending Pantelleria Rift and the ENE-WSW graben system (Dart et al. 1993).

From a paleontological viewpoint, different fossils, such as pectinid bivalves and *Schizaster* echinoids, are well observable in the Dwejra area shoreline, where a platform formed in the Globigerina Limestone outcrops. In the Globigerina Limestone there are also traces of burrowing animals that may form complex systems of tunnels whose aspect is enhanced where weathering is more active. In the area also outcrops a layer containing abundant *Scutella* sea-urchins (sand dollars) that marks the top of the Lower Coralline Limestone.

Valley fill deposits located in Qawra allow indicate that the area was subject to different phases of erosion and deposition and thus provide giving significant information about the Quaternary climatic conditions and associated sea-level changes. These levels of different depositional strata can be identified through fossilised fauna and flora that inhabited the littoral zones in the Quaternary.

4. Outstanding geomorphological features

The geomorphology of the Maltese Islands has been discussed in classical literature by House et al. (1961), Paskoff and Sanlaville (1978), Paskoff (1985) and Alexander (1988). Recent investigations have been carried out by Hunt (1997), Hunt and Schembri (1999), Dykes (2002), Farrugia (2008), Magri et al. (2008), Said and Schembri (2010), Coratza et al. (2011; 2012), Soldati et al. (2011; 2013), Devoto et al. (2012), Mantovani et al. (2012), Micallef et al. (2013), Biolchi et al. (2014) and Galve et al. (2015).

A number of geomorphological elements, most of which have a name of Semitic origin, and today exhibit socio-

cultural and touristic importance are evident. The geomorphological features of the Dwejra area are mainly controlled by the different resistance to erosion of the outcropping rock units. In particular, the coastal landforms have been shaped by tectonic activity, lithology of outcropping rocks and changes in sea-level (Said and Schembri 2010). The coastline of Dwejra is also greatly influenced by an E-W trending fault that cuts through the western side of the Bay. Nevertheless, other important features can be found inland and, to an extent, are the result of other faults affecting parts of the hinterland. These include the Wied Għorf network that drains into Qawra and the Wied Ta' Kerrex network that drains into Dwejra Bay.

Dwejra displays outstanding geomorphological features relevant both for their contribution to the understanding of the geological processes acting through time on landscapes and for their aesthetic importance (Fig. 3). The geomorphological landscape of the area, and more in general of the island, shows a strong rock control: sheer coastal cliffs, sea caves and arches are typical of the resistant Lower Coralline Limestone Formation, whereas shore platforms have been shaped on the relatively soft Globigerina Limestone Formation. The latter tends to form erosional landforms, such as potholes, whereas inland forms irregular slopes with terrace-like steps due to the presence of several hardgrounds alternating with softer beds. The clays tend to form gentle slopes and develop badlands when exposed at the surface. They are usually capped by a thin layer of Upper Coralline Limestone, that only outcrops in erosive outliers. The erosion processes are locally enhanced by faults which juxtapose rocks with different resistance. The resulting landscape is a succession of mesas, gorges and depressions.

Dissolution processes contribute in shaping outstanding landforms such as large and scenic paleosinkoles, karst pavement, solution pans, solution holes sea caves and arches, mainly scattered along the coastline where the coralline limestone formations outcrop (Soldati et al. 2013). Evidence of climate change can also be observed in the area: ancient fluvial modelling is witnessed by a series of erosion features, such as dry valleys shaped in previous much wetter climatic conditions. Moreover caves at different heights are observable along the north wall of Qawra which may be indicative of sea level changes.

Coastal features. The coastline of Dwejra is mainly influenced by an E-W trending fault which cuts the western cliff of Dwejra Bay. This fault lowered the northern coast bringing the Globigerina Limestone at sea-level whereas the southern coast is formed by the more resistant Lower Coralline Limestone. It follows that steep cliffs were formed in Dwejra Bay and further south whilst a flat solution platform, shaped by solution and wetting and drying processes, is located northwards (Said and Schembri 2010). Coastal features include the Azure Window arch, the Fungus Rock stack, the Dwejra Bay, cliffs and sloping rocky shores and a sea water lagoon (Inland Sea – Qawra) (Fig. 4). Other minor features of geomorphological importance are a shingle beach within the Qawra Inland Sea, intermittent watercourses on valley beds, and solution pools on the shore platforms. Coralline plateaux exhibiting typical karst features, cliff faces, minor clay outcrops, saline marshland and a freshwater wetland are also encountered. Agricultural areas typical of a rural environment with abandoned land especially on the steeper slopes are evident.

Landforms along the Dwejra coastline are also strongly influenced by the presence of paleosinkholes which shaped the peculiar semicircular bays, unique in the Maltese Islands (Fig. 2 and 4a). A smaller rounded dissolution feature, the partially submerged Blue Hole, occurs between the Azure Window and Dwejra North bay (Fig. 4d). These

features are strictly related to morphoselection processes described below and contribute to the geomorphological diversity of the Dwejra coastline.

Paleosinkholes. The most significant paleosinkholes of the Maltese archipelago are concentrated in the Dwejra area. Sinkholes and dissolution pans are a frequent features of the landscapes of Mediterranean coasts: well-known examples include those of Apulia (Basso et al. 2013; Margiotta et al. 2012), Tremiti Islands (Miccadei et al. 2012), Sardinia (De Waele et al. 2009) in Italy and others examples in Greece (Karymbalis et al. 2012) and Morocco (Enniouar et al. 2015; Theilen-Willige et al. 2014). Anyhow the large sinkholes in Dwejra display features of notable size, comparable to the largest sinkholes of the world (Galve et al. 2015) and present high aesthetic interest, attracting tourists because of their spectacular shape (Coratza et al. 2012). They are circular to elliptical in plan view, with diameters up to 600 m, and are bounded by annular dip-slip faults (Galve et al. 2015). According to the existing theories, these paleosinkholes were formed by submarine cave roof collapse (Pedley 1974) or dissolution of evaporites and subsequent subsidence of the overlying sediments in Miocene period (Illies 1980).

Different morphostructures associated with paleosinkholes are displayed in the Dwejra area. These morphostructures depend on the relative resistance to erosion of the rock units that outcrop inside and outside the subsidence structure (Soldati et al. 2013; Galve et al. 2015). The Ghajn Abdul mesa, the subcircular Qawra depression (Fig. 4b) and the rounded Dwejra and Dwejra North bays (Fig. 2 and 4a) are different evolutionary phases of the paleosinkholes since the end of the Miocene. Qawra shows many peculiar geomorphological features. It is partially flooded by seawater, an inland sea (Fig. 4b) connected to the open sea through the narrow karstic channel, L-Għar tad-Dwejra, that cuts the western margin of the depression (Lanfranco and Cassar 2007). A beach was shaped by the sea within the depression. Blue Clay outcropping in Qawra forms two hills with gentle slopes capped by a Quaternary deposit rich in fossils of terrestrial gastropods. Other Quaternary deposits are the fluvial terraces located at the base of the hills. A small permanent freshwater pool, known as Il-Qattara, is located along the eastern wall of Qawra and is linked to the inland sea by an intermittent watercourse (Lanfranco and Cassar 2007).

The western high coastal cliffs of the area are interrupted by two rounded bays, Dwejra and Dwejra North, set within pre-existent collapse sinkholes (Figs. 2 and 4a). The bays were formed when the sea entered the external wall of the sinkhole and started eroding the infill sediments. Dwejra Bay still shows steep circular walls whose western margin is now represented by the isolated massive block of Fungus Rock. Dwejra North also displays a smaller partially submerged isolated block known as Crocodile Rock. Tal Harrax, inland Dwejra Bay, is the less spectacular paleosinkhole in the area, but still of interest from a scientific viewpoint. It has a NW-SE trending elongated geometry around 600 m long and its NW sector is significantly narrower than the opposite one. These features suggest that the structure may have resulted from the coalescence of two adjoining collapses (Galve et al. 2015).

Morphoselection features: Azure Window and Fungus Rock. The influence of erosive processes on the landforms of Dwejra area has already been emphasised in this section, but two morphoselection features, the Azure Window and the Fungus Rock, deserve an in-depth examination due to their high geomorphological representativeness and their significant aesthetic value. Both features are shaped by sea erosion which took advantage of areas of weakness in the rocks, such as fractures and faults.

The *Azure Window* is arguably the site of greatest tourist attraction in the Maltese Islands. It is a large arch

protruding westwards from the cliff and formed by selective sea erosion. The window is progressively opening due to strong storms which cause heavy erosion at the base of the arch. The last large collapse took place in April 2012 and significantly enlarged the window (see Fig. 5). Further collapses would generate risk for people who usually dive beneath the arch and walk on the roof, as well as cause a loss in landscape value (Geoscience Consulting 2013). As a matter of fact, the rapidly eroding features of the Azure Window attracts regularly the attention of local media (such as the Times of Malta 28/10/2003, 10/08/2006, 17/04/2012, Orizzont 12/04/2012), fueling a much debated controversy on whether the government should allow nature (and more specifically coastal geomorphic processes) to take its toll and allow the Azure Window to collapse or whether protective engineering measures should be set up in order to protect this coastal feature from environmental change. Dwejra, including the Azure Window, has benefited from the European Union's Life Third Countries scheme project, involving a relevant investment.

The *Fungus Rock* is a large isolated massive block, 60 metres high, bounding westwards Dwejra Bay (Fig. 2 and 4a). It was originally the external wall of the paleosinkhole in which the bay originated. Sea erosion then removed part of the wall, taking advantage of the weakness of faulted and fractured areas, and the present impressive feature was originated. The rock owes its name to the presence at its top of a plant which was considered to have medical properties during the time of the Knights of St. John. Further historical remarks will be discussed in next section.

Dry valleys. The main natural drainage pattern on the Maltese Islands is through a system of valleys (*widien*) that, due to the strongly-featured topography of the islands, are divided into a number of catchments and drainage areas. These dry canyon-shaped valleys are mainly developed along geological structures by stream erosion during previous much wetter climatic conditions (Schembri 1993). Their origin can also be related to tectonics, although their present shape has resulted from the large discharge regimes occurring during the Pleistocene. The system of dry valleys in the Dwejra area reflects these systems with an overall elaborate dentritic pattern with four separate valley systems spreading the main pattern over about a 4 km^2 catchment area starting at about 2 km from the coast. These valleys are listed as Category A by the Malta Environment and Planning Authority, meaning that no development can take place within them. The main valley system is formed by Wied il-Mans, Wied Ilma, Wied il-Kbir (Fig. 4e) and their tributaries. It discharges into the depression of Qawra and is mainly cut in the Lower Coralline Limestone. The minor valley systems of Wied Sufar and Wied Għorf with Wied Merell, both cut in the Lower Coralline and located northwards the main system, also discharge in Qawra. The second largest system, mainly cut in the Globigerina Limestone, is formed by Wied Ta' Birrix and Wied Ta' Kerrex and discharges into Dwejra Bay via a waterfall.

The valley systems follow the faults' pattern meaning that their formation is highly influenced by tectonics. The dry valleys are deeply carved in the rock, suggesting that they probably started to form in different environmental conditions, when sea-level was lower than the present. A long-term evolution must then be taken into account. It follows that dry valleys can provide important information on past sea-level changes and on the tectonic evolution of the area.

5. Cultural heritage as an added value

The Dwejra unique geological and geomorphological features – which span millennia due to the effects of physical and human processes, including present-day ones – are associated with artistic and literary works of national significance enhancing their value.

The Coastal Strategy Topic Paper by the Maltese Planning Authority (Borg 2002) emphasizes that the cultural resources of the Maltese Islands are enriched with historical and archaeological remains of different periods which are located especially along the coast. This is particularly true for the Island of Gozo whose history and tradition are strictly linked to its natural configuration (topography and landforms). The coast of the Maltese Islands, with a series of occupiers over the last ten millennia, has led to the development of a high density of coastal uses that superimpose on both a diverse range of aesthetic natural qualities and different cultural properties that have changed over time. Low sloping limestone coast provided an ideal geological setting for salt panning production, whereas today these are main areas for swimming off-the-rocks. *Rdum* (scree slopes) are areas where fertile agricultural practices were possible and today they are zones for which their aesthetic and ecological qualities are highly prized. Sinkholes were a source of shelter on rectilinear coasts and are now areas of outstanding natural beauty, shelter for sailors and highly appreciated dive sites at international level. Cultural heritage of the Gozitan coast is mostly associated with industry and defence as it is also witnessed in the study area by the coastal tower built by the Knights of St. John.

Emphasis on the cultural heritage in Malta was traditionally focused on the architectural forms and the activities made by the local population and foreign governments. The area surrounding Dwejra has received a high degree of attention since prehistoric times and has witnessed human activity in one form or another for more than 7000 years, as testified by various cultural, historical and archaeological landmarks (Farrugia 2008). Pottery shreds recovered from the Għajn Abdul site have indicated the presence the first known Neolithic culture on the Maltese Islands, together with evidence of activity in the Bronze Age. Other archaeological artefacts includes rock-cut rectangular chambers, a cistern and a reservoir at Ras il-Wardija site, dating back to 300 BC - 200 AD. Cart ruts, though less common in Gozo than in Malta, are present as system of seven separate stretches in the Dwejra/Qawra area. Originally interlinked, these rut lines have become separated through erosion of the bedrock. Nonetheless, some stretches are very well preserved and show unusual characteristics such as differences in level between one rut and another. Other features include salt pans and surface quarries which may also represent early forms of mineral resource extraction in the area (MRRA 2005).

Fungus Rock, which is colloquially known in Maltese as 'il-Gebla tal-General' (the General's Rock), is situated at the entrance of the almost circular Dwejra Bay. The inaccessibility of this isolated massive block, remnant of the large paleosinkhole of Dwejra Bay, is partly the results of geological and geomorphological conditions and partly due to man's hands. The Fungus Rock is called in remembrance of the Italian General who centuries ago fell to his death while supervising quarrying activities in the area. In fact, in Gozo there are several quarries and all of these are located in the Dwejra area, where good Globigerina limestone used in the building industry is found.

History tells us that a special plant with medicinal and healing properties used to grow on Fungus Rock and because of this, the Rock used to be heavily guarded during the era of the Knights of Malta. Anyone caught stealing the crop was sentenced to death or to life on the galleys.

The Knights Hospitaller apparently discovered what is popularly known as the Malta Fungus, growing on the stack's flat top. This parasitic plant, *Cyno-morium coccineum*. is actually a rare tuber not a fungus; yet Medieval Europeans referred to it *Fungus melitensis* –'Maltese mushroom' or 'Malta fungus', names by which it is still known today. The Maltese inhabitants named it 'Gherq is-Sinjur'. Doctors at the time of the Knights of St. John believed that it had medicinal properties and the Knights used it as a styptic dressing for wounds and a cure for dysentery. The Knights prized it so much that they often gave gifts of Malta Fungus to distinguished noblemen and visitors to the Maltese Islands.

Dwejra Tower, built during the reign of Grand Master Anton de Paule in 1651 as a coast guard from pirate raids, started to serve another function in 1744, to guard the Fungus Rock after a decree from Grand Master Pinto declaring the Rock as a protected area. Grand Master Pinto went to great lengths to protect the plant: he posted a permanent guard and built a precarious cable-car basket from the rock to the mainland to control harvesting (Fig. 6). The sides of the rock were also smoothed in order to discourage handclimbing and access from sea and potential trespassers risked also a three-year spell as oarsmen in the Knights' galleys.

In his account of Maltese botany, Cleghorn (1870) narrates of finding images of the plant painted on drawers in shops in Palermo as a testimony of the plant's historical fame as an excellent remedy in dysentery, haemoptysis and menorrhagia. However, Cleghorn is quick to point out that the plant 'has fallen in disuse and is no longer employed by the Maltese physicians, though still used by a few illiterate inhabitants in Gozo'. In 1992, this rock was declared a nature reserve and bird sanctuary.

Additional features on the shore platforms and gently sloping rocky shores in the area include the presence of fossilized shells embedded in the rock strata, and solution hollows that served as collection of sea water and its subsequent evaporation in the salt-harvesting process.

Traditional agricultural activity with the system of dry-stone walls marking different levels of terraced fields and winding foot-paths bear witness to the areas contribution to the food-producing processes. Unfortunately most of these fields are today abandoned. A group of valleys also feature in the area with a total length of approximately 10 km draining fresh waters into the sea or into Il-Qattara freshwater pool and a permanent wetland at Ta' Sarraflu.

In recent times, the scenic qualities of Dwejra, its breathtaking scenery strictly related to landforms, their assemblages and the processes that shaped them in the past and still active, have attracted the attention of the international film industry over the last thirty years and the site was featured in various film productions such as Clash of the Titans (1981), Actor III (1985), Christopher Columbus – The Discovery (1992), The Odyssey (1997), The Count of Monte Cristo (2002) and HBO's TV series Game of Thrones (2011).

Finally, the site of Dwejra is also described by the MEPA Local Plan for Gozo and Comino as a Dark-Sky Heritage Area. It is one of the very few remaining sites on the Maltese Islands to offer an unpolluted nightscape for astronomical observations. The said MEPA plan makes also provision for the preservation of the Maltese dark sky heritage at several areas on the islands, including Dwejra. Apart from the astronomical heritage, the nightscape of Dwejra serves an important ecological function given that the site hosts several hundred pairs of nesting Cory's Shearwater which are very sensitive to light pollution when they return to the cliffs at night. The Astronomical Society of Malta & the Light Pollution Awareness Group, Nature Trust (Malta), Friends of the Earth Malta, Din l-

Art Ħelwa and Birdlife Malta have recently urged MEPA to enforce its regulation in the interest of national landscape.

The area is an embodiment of local cultural heritage, aligned well with the definition of cultural heritage in the Cultural Heritage Act of the Maltese Islands (Chapter 455: Part 1, Para. 2): *'a movable or immovable objects of artistic, architectural, historical, archaeological, ethnographic, palaeontological and geological importance and includes information or data relative to cultural heritage pertaining to Malta*'. This definition would include archaeological, palaeontological or geological sites and deposits, as well as intangible cultural assets comprising arts, traditions, customs and skills employed in the performing arts, in applied arts and in crafts and other intangible assets which have a historical, artistic or ethnographic value. With reference to Dwejra, one may add to this definition the importance of geomorphological processes (which couple which geological processes) have been responsible for the formation of important landforms in the area such as the sink hole formations in the area, the stack (Fungus Rock) and the sea arch (Azure Window).

6. Concluding remarks and geotourism perspectives

The Maltese Islands, having a high population density and about 1.6 million tourist visitors annually, experience strong pressures on urban, rural and coastal areas with the result that environmental protection and conservation should be an important feature in the legislative, administrative and management scenarios of the country, to which the planning of adequate geotourism activities may highly contribute.

Concerning Dwejra, the unique integration of natural and cultural heritage within this area contributes in making it a site of extraordinary heritage value and of high tourism vocation, with high picturesque quality and pristine wilderness feel which are becoming increasingly hard to find on the Maltese Islands. The attraction of Dwejra, declared as a Heritage Park in 2007, is due both to the presence of terrestrial geomorphological features which merit some drawn-out exploring and also the presence of attractive coastal and marine geomorphological features rare and distinctive, which are all clustered within walking distance of each other. This area has always been on the tourist itinerary to the extent that it appears as one of the main sites that tourists are encouraged to visit. This can be gauged from the numerous glossy publications advertising Malta or Gozo. In particular stacks, arches, lagoon, submerged caves, tunnel, rocky shoals, make the site the most coveted ones by Maltese and foreign divers alike (Tab. 1).

Despite the unique combination of geological l.s., historical and biological heritage makes Dwejra area an ideal tourist destination for fostering a varied form of nature tourism, no specific comprenshive initiatives have been foreseen so far for enhancing a sustainable tourism development. Nevertheless information panels are located nearby the most spectacular features of the Qawra/Dwejra Heritage Park (Inland Sea – Qawra, Croccodile Rock and Fungus Rock, Dwejra Bay) which may be the starting point for clearer and more effective interpretative planning at different scales, from the whole Park to a single display.

In this sense, a new way to ensure a sustainable and responsible exploitation of this area, and prevent landscape damage, could be to encourage the development of a geotourism market, in which the geomorphological environment is the key to its attractiveness as a tourism location and its scenic characteristics are used to promote it as a product (Tab. 1). Favouring an easy understanding and comprehension of the landscape and of its hazards,

highlighting its "geo-aspects", could contribute to make visitors aware of the geo-history of the site and thus generate an awareness climate which could be knowledge-based and continuous in time. This can be achieved by outlining and promoting off-the-beaten track product, such as cycling and walking trails and geological-cultural itineraries which can be used and enjoyed by the public coming from all walks of life. Several examples of this kind of geoturism products – excursion and educational footpath with panel, geoturism maps etc. – have been elaborated in the last decades in several countries (cf. Reynard and Coratza 2013). The elaboration of this geoproducts may be performed according to the methodological approch proposed by Martin et al. (2010), which foresees the definition of the target public, the site, the content/theme and the medium, before the fulfilment of the product. The final geoproducts would be able to favour the understanding of the remarkable geological and geomorphological features which characterise the landscape and, at the same time, the close relationships between geoheritage and environmental and cultural elements. A recent local example of such geo-tourism initiative in this direction is the Xrobb l-Ghagin Nature Park and Sustainable Development Centre, situated on the scenic Delimara peninsula on the south-eastern shores of Malta. Set up in 2013, with the support of both local and foreign grants (such as the Norway grants and EEA grants), the purpose of the project is environmental education, demonstration and research in sustainable environment solutions with the overall objective of increasing the use of renewable energy, wastewater management and safeguarding biodiversity). However, apart from the typical activities daily organised by the park officials, the park is different from the mainstream: it is the first natural park in the Maltese Islands to incorporate a thirty bed hostel, conference facilities with a hundred seat capacity, classroom space, and catering facilities for full-board long stays, in order to fulfil more its role as a geo-touristic destination.

This kind of approach would ensure a robust tourist product, inducing the tourism industry to operate protection strategies and concurrently recognising that damage to this product will damage the value of the location for toursim with spill-over consequences on income and employment.

In order to favour the development of integrated tourism experiences and geoconservation measures, this work could provide the means for a better understanding of the value of Dwejra as a geoheritage, increase the awareness of the geomorphological value of the area and highlight which geo-products would best fit the promotion of the site. From the point of view of tourism activity, the geological-geomorphological resources of Dwejra area, up to now representing not fully exploited destinations, can be valorised by connecting them to more consolidated thematic routes related to diving or beach tourism. Only highlighting the peculiarities of the landscape seen as a dynamic expression of man-nature relationship, its role in environmental protection and defining a logical scheme for the connection and integrated use of the various heritage resources will guarantee a responsible and sustainable tourism of this outstanding and fragile area.

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Captions

Fig. 1 The location of Dwejra area within the Maltese archipelago

Fig 2 The bay of Dwejra North in the foreground and the stack of Fungus Rock located in front of Dwejra Bay

Fig 3 Geomorphological sketch of the study area

Fig 4 Relevant geomorphological features of the Dwejra area: a) sinkhole corresponding to Dwejra Bay and relict stack of Fungus Rock; b) Inland sea within Qawra sinkhole c) potholes along Dwejra North bay, in the background the Azure Window d) the rounded dissolution feature of Blue Hole at Dwejra North bay e) the dry valley (*wied*) of il-Kbir

Fig 5 The Azure Window before (a) and after (b) the collapse of April 2012. The arrow indicates the rock block which collapsed in April 2012

Fig 6 The Fungus Rock and the cable-car active during the Knights' period in a lithograph by L. Mazzara's (published in Paris in 1827)

Table 1 Dwejra coastal features: attributes and use

Figure 1
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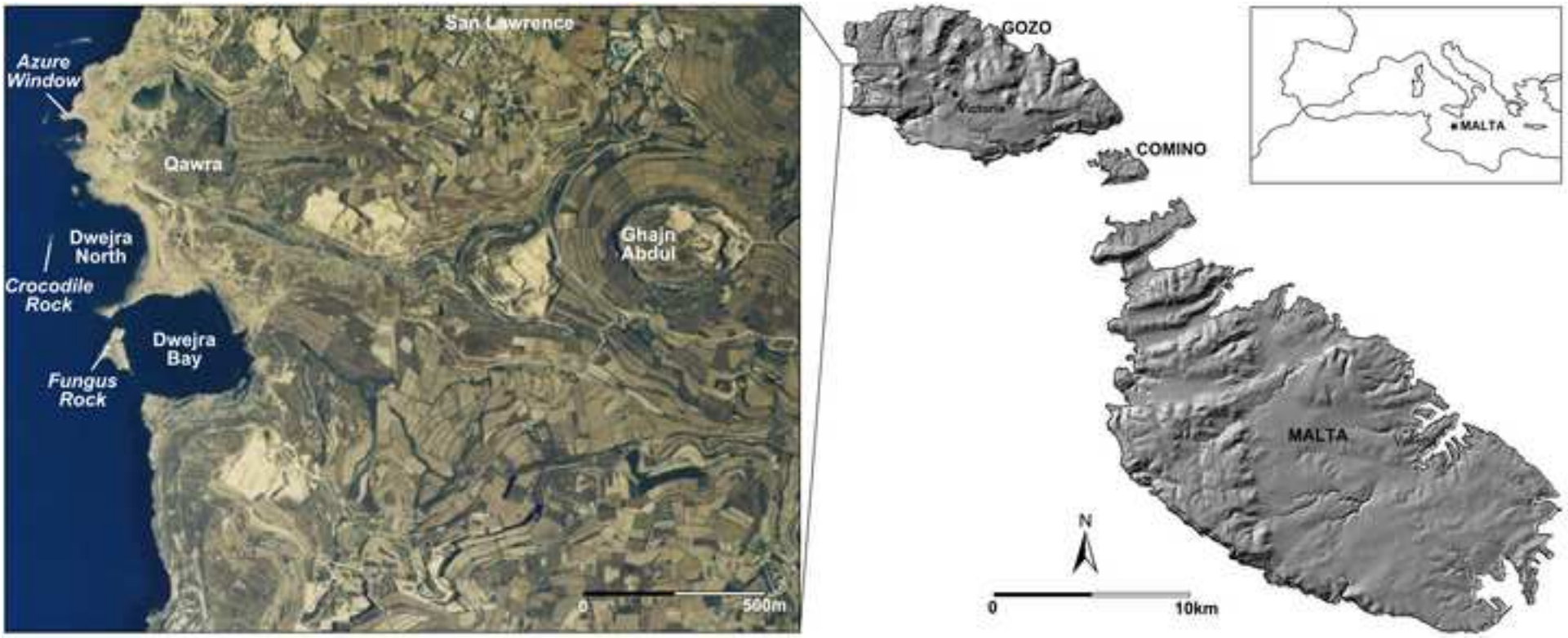

Figure 2
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Figure 3
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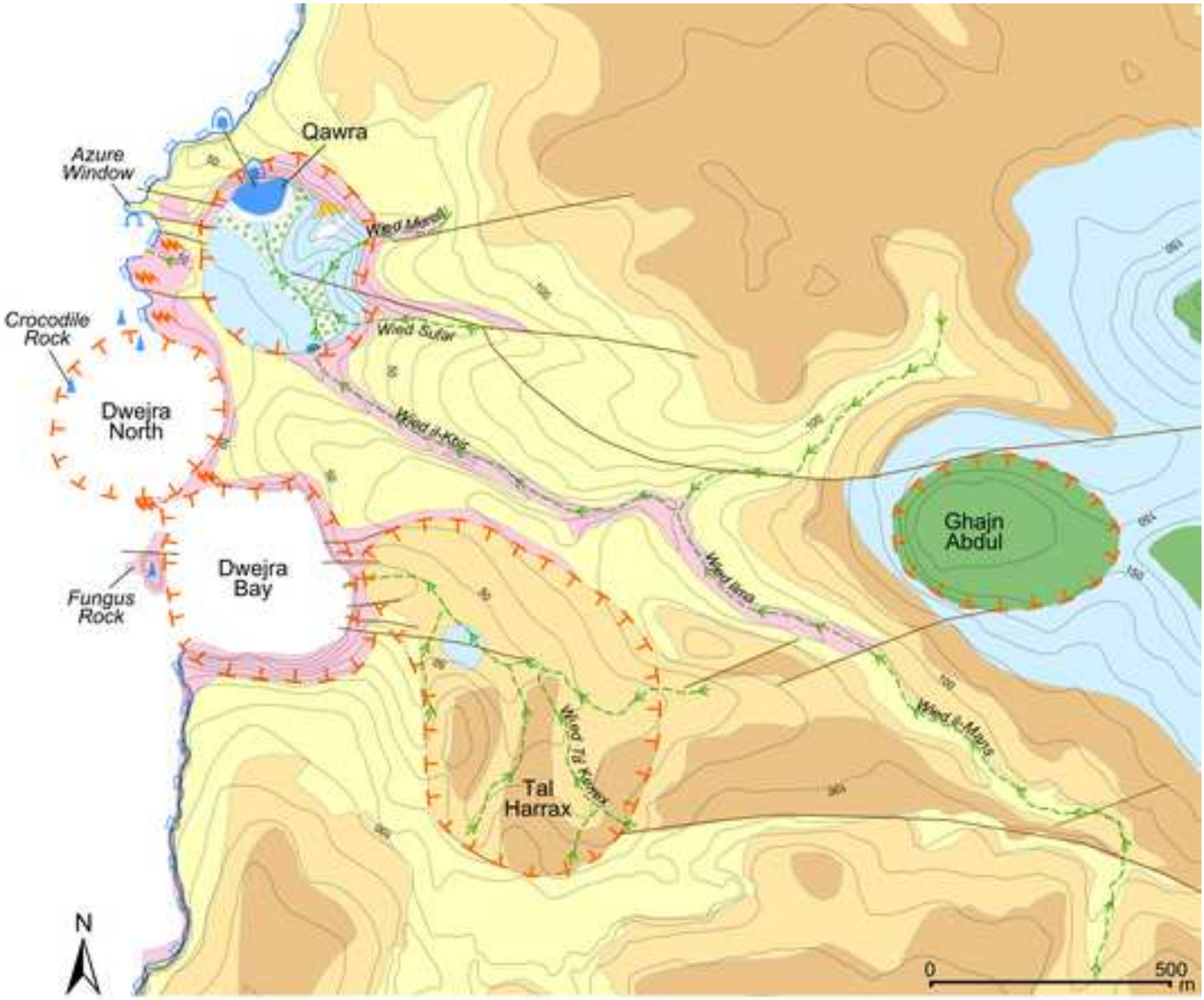

STRUCTURAL DATA

- Upper Coralline Limestone Fm.
- Blue Clay Fm.
- Globigerina Limestone Fm. a. Upper b. Middle c. Lower
- Lower Coralline Limestone Fm.
- Fault

MORPHOLOGICAL FEATURES

- Edge of marine cliff
- Sea cave
- Isolated rock
- Marine arc
- Inland sea
- Shingle beach
- Dry valley
- Quaternary deposit
- Karren
- Paleosinkhole edge

Figure 4
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Figure 5
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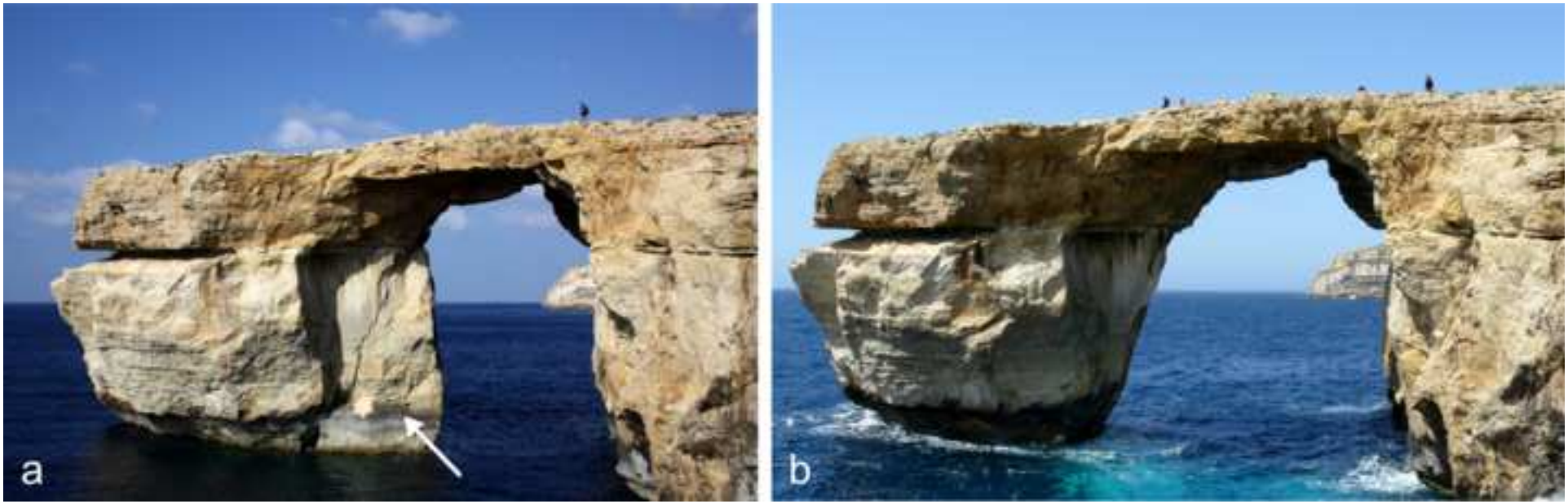

Figure 6
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Table 1

Popular name	Local name	Literal translation into English	Landform	Access	Visitors	General use	Potential educational use	Present promotion
Azure Window	It-Tieqa	The Window	Arch	Forbidden	Tourist attraction	Sight-seeing	Very high (geomorphological evolution)	Very high
Fungus Rock	Il-Gebla tal-General	The General's Rock	Stack	Inaccessible	Environmentalists (with permission)	Sight-seeing	High (geomorphological evolution and historical heritage)	High
Inland Sea	Qawra	A circle	Lagoon	Accessible	Fishing and diving communities	Boathouses	High (geological and geomorphological evolution)	Very high
Dwejra Bay	Il-Port	A harbour	Bay	Accessible from marine area	Boats and yachts	Berth, shelter	Very high (geological and geomorphological evolution)	Moderate
Rdum and il-blat	Rdum and il-blat	Scree slopes and rocky shores	Cliffs, scree slopes and rocky shores	Partly accessible	All visitors	Walking, sightseeing, film set	High (palaeontological and geomorphological interest)	Low