A Coastal Enclave Worth Conserving: Xatt L-Aħmar (the 'Red Coast', Gozo)

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Abstract

Tucked away in the south-east coastal corner of the island of Gozo, a stone's throw from the busy Mġarr Harbour, is Xatt l-Aħmar. It owes its name to the reddish hues of the surrounding soils and of the sand it contains. The site is a treasure trove both for geologists and geomorphologists, because of the variety of its landforms (e.g. the widest shore platform on Gozo), and for naturalists, in view of numerous, highly restricted floral and faunal species, which still thrive despite the extremely restricted dimensions of the two sandy beaches and dune remnants that are found in this locality. Its lack of accessibility by car has largely shielded the enclave from mass tourism and its impacts. A snapshot of the geological assets and biodiversity of Xatt l-Aħmar, which may be termed 'Gozo's best-kept secret', is presented in this short chapter.

Keywords

Landforms • Limestone • Biodiversity • Shore platform • Headland • Sandy beaches

17.1 Introduction

It is hard to conceive how, in a small and densely populated archipelago such as the Maltese Islands (Schembri 2019, Chap. 2), there are still coastal localities whose whereabouts are unfamiliar to many residents. This is the case for Xatt l-Aħmar, which owes its name to the reddish hue of its soils, the Blue Clay slopes overlooking it and the two sandy enclaves which it contains. 'Xatt' in Maltese in fact denotes 'coastline' whilst 'aħmar' is the Maltese word for 'red'. Like a vigilant sentinel, the imposing Fort Chambray overlooks Xatt l-Aħmar. It was completed in 1758 in an attempt to instil some security for those navigating the Malta–Gozo Channel at a time when incursions by Ottoman pirates were still common. This massive fortification was named in honour of a Norman knight, Francois Chambray, who offered to pay single-handedly for its construction, to the tune of 40,000 'skudi' (roughly equivalent to 10,000 euros at current currency rates). During the nineteenth and early twentieth centuries and following the end of the tenure of the Knights of St John (also known as the Knights Hospitaller) in Malta, the fort fell into disrepair, only to be given a new lease of life during the First World War, when the British stationed a number of soldiers, built a hospital in the fort and consecrated a number of cemeteries within its structure. The fortification currently houses a high-value real estate project.

A carpet of chequered fields, a hallmark of intensive agriculture, characterises the slopes leading down to the Xatt l-Aħmar coastal area. The cultivation of broad beans (*Vicia faba*), and sulla (*Hedysarum coronarium*) as animal fodder, prevails within the fields and a sizeable freshwater pond, known as Għajn il-Papri (in Maltese meaning the duck pond, or duck spring), is to be found at the top of the cultivated area. It attracts regular freshwater visitors such as numerous species of dragonflies.

The coastline at Xatt l-Aħmar is a microcosm of different geomorphological formations, ranging from eroding clay

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slopes and limestone cliffs to shore platforms, pocket beaches and boulder screes, with such formations juxtaposed within a secluded corner of the island of Gozo.

17.2 Geographical, Geological and Geomorphic Setting

Xatt l-Aħmar is not exactly a backwater location, because it is located merely one kilometre away from the ferry harbour at Mġarr, in a south-east corner of Gozo. Xatt l-Aħmar stretches its coastal margin all the way to Mġarr Harbour area and has an approximate coastal length of 1747 m (Ciantar 2011). Negotiating access down the steep and craggy hill leading to Xatt l-Aħmar is a challenge for the motorist, and hence, this part of the coastline is best accessed on foot from the harbour. The bay is accessible only by a small concrete road from the village of Għajnsielem. The area can be also reached by a number of footpaths or tracks and stairs built into the Blue Clay slopes. These stairs are situated on the right-hand side of the bay, but unfortunately are in a state of disrepair. Some of the footpaths either go through the fields along the valley, others criss-cross the clay slopes overlooking the bay and some skirt along the coastline from Mġarr Harbour leading to Xatt l-Aħmar through the boulder screes found in the area and ends at Mġarr x-Xini. This latter track is very well known by ramblers, locals, tourists and countryside lovers.

The geological formations and structure present at Xatt l-Aħmar Bay consist of Upper Coralline Limestone (both Tal-Pitkal Member and Mtarfa Member), Blue Clay, Upper Globigerina Limestone, Middle Globigerina Limestone and Lower Globigerina Limestone (Fig. 17.1; Scerri 2019, Chap. 4). All of the mentioned rock units are affected by coastal erosion differently, according to the rock resistance (Gauci and Scerri 2019, Chap. 5). The most noticeable effect is on the Upper Globigerina Limestone and Blue Clay, since both formations are easily eroded. Blue Clay is easily broken down and washed away by rain or marine erosion. The Upper Coralline Limestone (Tal-Pitkal Member) is very

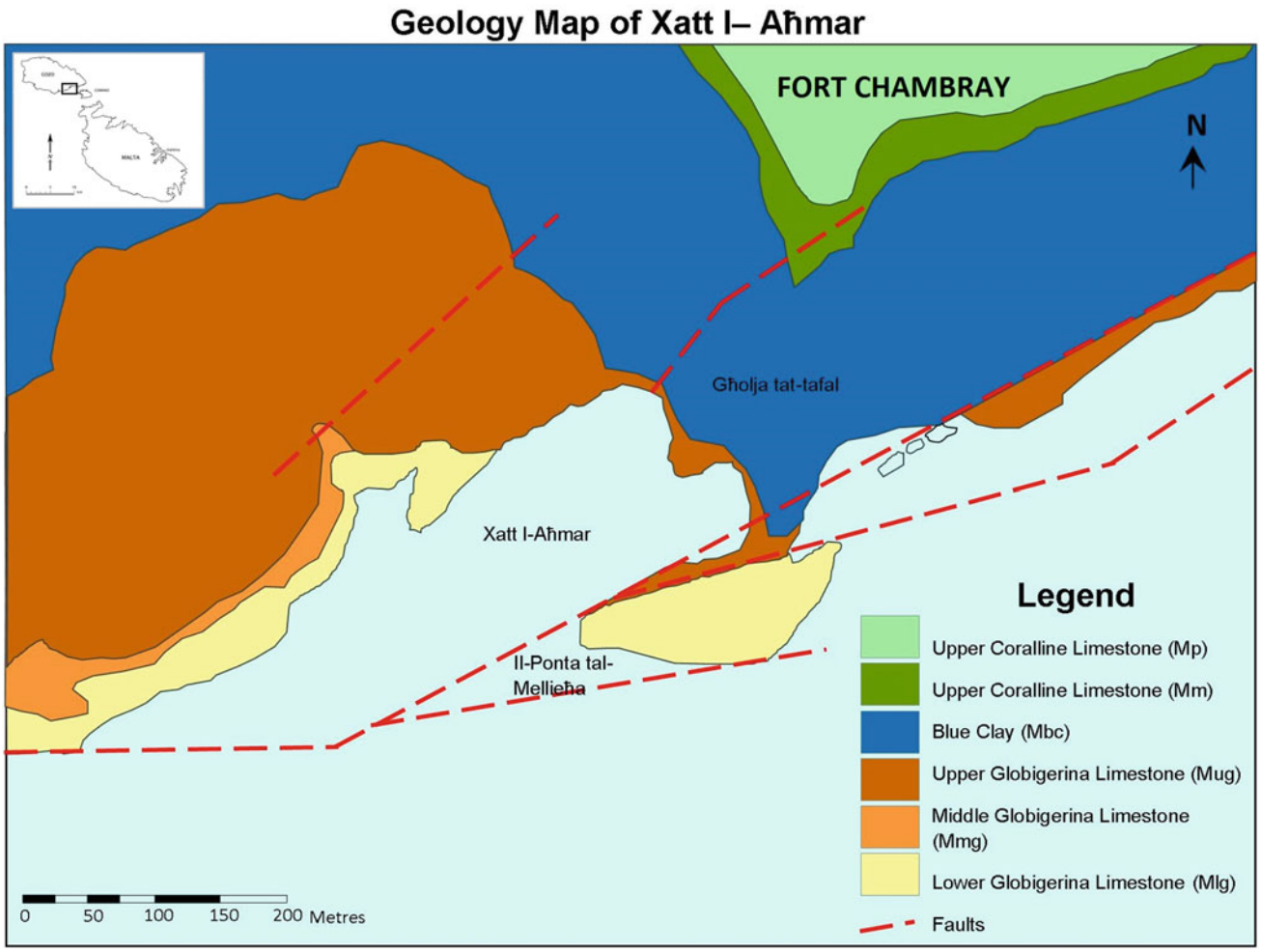

Fig. 17.1 Geological map of the Xatt l-Aħmar coastal stretch. *Source* Redrawn from Oil Exploration Directorate (1993) and Ciantar (2011)

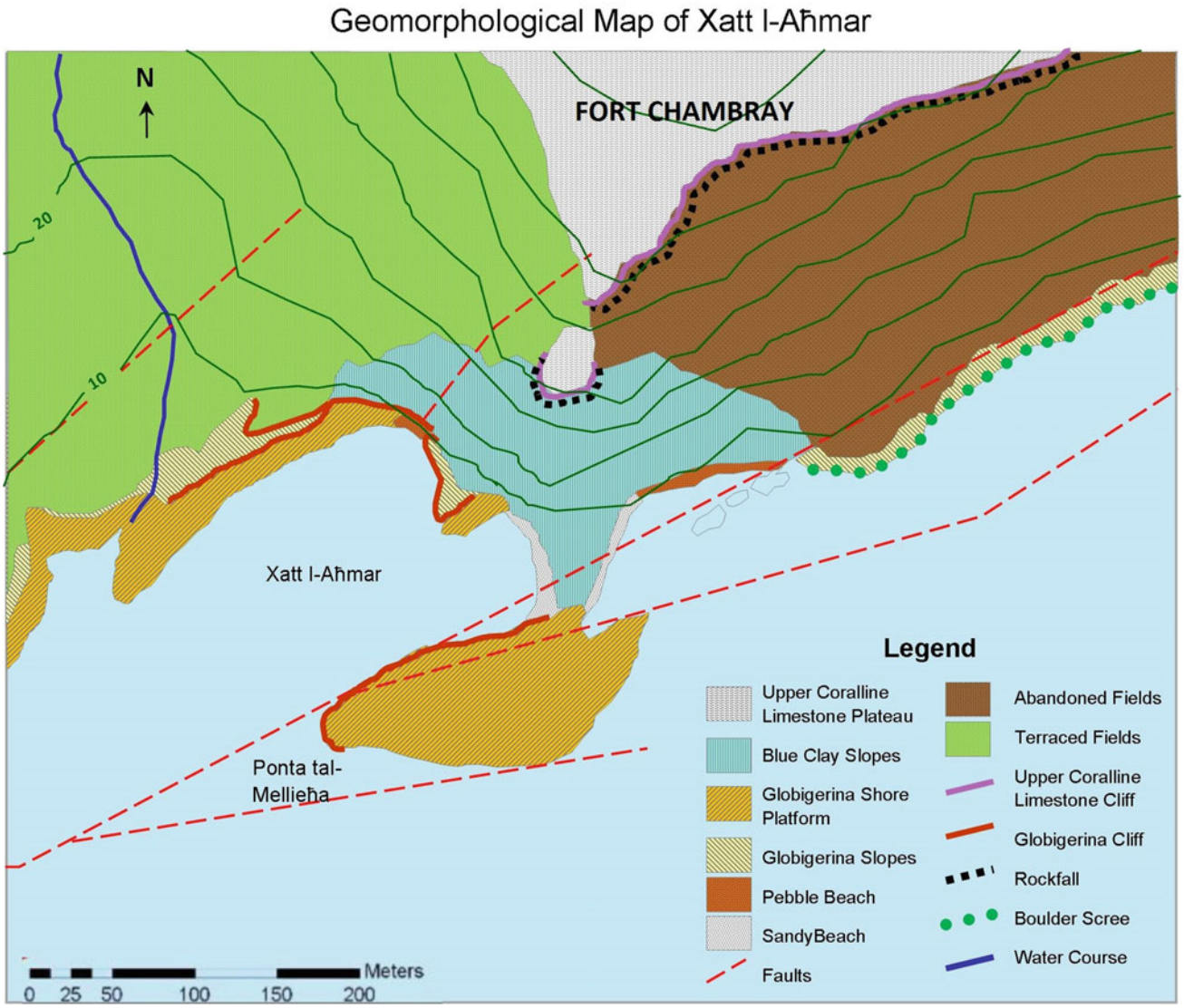

Fig. 17.2 Distribution of the various geomorphological features to be encountered at Xatt l-Aħmar. *Source* Redrawn from Oil Exploration Directorate (1993) and Ciantar (2011)

resistant to surface erosion, but it is weakened by undermining, that in turn generates mass movements in the form of rock slope failures.

A set of faults runs through Xatt l-Aħmar, with a major fault running through the area in SW-NE direction, from the headland at Mellieħa Point towards Mġarr Harbour (Pedley et al. 2002; Figs. 17.1 and 17.2). The fault line scarp is made up of the Upper Globigerina Limestone, but this is overlain by the Blue Clay. A second fault is located at Mellieħa Point headland where the Lower Globigerina Limestone seems to be elevated south as the upthrow side of the fault (Fig. 17.3). The downthrow side of the fault, which is the other side of the Malta-Gozo Channel, overlooks Xatt l-Aħmar bay and is composed of the Upper Globigerina Limestone (Figs. 17.1 and 17.2). The fault line scarp is between 2 and 3 m high. The fault runs through the northern embayment of Xatt l-Aħmar, forming a Lower Globigerina Limestone shore platform, and runs upslope to Fort Chambray which lies on Upper Coralline Limestone. This fault can only be seen from the shore platform where Upper Globigerina Limestone folds are exposed within the cliff face, such that the different topography can be observed on both sides. The prolongation of this fault is not seen on the surface, because it is covered with the Blue Clay (Ciantar 2011).

The Lower Globigerina Limestone has a nearly horizontal attitude. Strata dip at 4° to the south-east both at the Tal-Futma headland and along the shore platforms of Xatt l-Aħmar (Fig. 17.2)

Fig. 17.3 Interplay between the most prominent geomorphological features endowing Xatt l-Aħmar. Legend: **a** Tal-Futma headland. **b** One of the two small sandy beaches. **c** Blue Clay slopes. **d** Terraced fields. **e** Lower Globigerina Limestone shore platform. *Photo* A. Deidun

17.3 Principal Landforms and Landscapes

A kaleidoscope of different geological and geomorphological formations is encountered at Xatt L-Aħmar, all being the result of an interplay between erosional processes (mainly wave-mediated and gravity-induced) and limestone geological resistance, which has yielded a number of stunning landforms. Figures 17.2 and 17.3 illustrate the interplay between some of the most prominent geomorphological features endowing Xatt l-Ahmar. The underlying stratigraphy of the foreshore at Xatt l-Aħmar consists of the Lower Globigerina Limestone and the overlying Lower Conglomerate Bed (C1) (Scerri 2019, Chap. 4).

17.3.1 Shore Platform

The most prominent landform at Xatt l-Aħmar is the shore platform. The low-lying shore platform known as 'Il-Ponta tal-Mellieħa', or 'is-Salina', juts out into the sea and separates the northerly and easterly facing beaches (Figs. 17.2 and 17.3). This shore platform is the largest on the island of Gozo, having a shore-parallel length of almost 200 m and a maximum width of 80 m, forming a horizontal limestone bench in the form of a ramp at the foot of the cliffs (Ciantar 2011). Within the same shore platform, a number of salt pans have been etched, with the salt trapped within and still being harvested annually by a Gozitan septuagenarian who accesses the site by boat. Shore platforms are subject to a

combination of processes, including mechanical wave action, sub-aerial processes such as mass movement (e.g. rockfall) and biological weathering (Trenhaile 2000), whilst they are themselves the product of a combination of erosional forces (i.e. mechanical wave action, abrasion and attrition) (Gauci and Inkpen 2019, Chap. 27).

17.3.2 Pocket Beaches

Despite sandy beaches generally dominating the open coasts of tropical and temperate regions (Davies 1974), they are rare in the Maltese Islands (Paskoff and Sanlaville 1978; Anderson and Schembri 1989) and constitute just 2.4% of the 271 km long coastline of the Maltese Islands (Gauci et al. 2005; Zammit Pace et al. 2019, Chap. 18). The coastline of the islands is in fact almost entirely rocky, broken at intervals by sandy stretches which are no more than a few hundred metres long and which are still fondly known as 'beaches' (Gauci and Scerri 2019, Chap. 5).

Xatt l-Aħmar comprises two sandy pocket beaches: an exposed one facing to the east and a more sheltered one facing to the west (Figs. 17.1 and 17.3). Whilst Lambie (2005) and Micallef (2003) define pocket beaches as 'sediment-tight' and headland-flanked, along which no significant lateral longshore drift occurs, for Defeo and McLachlan (2005) they are merely beaches of restricted length. Xatt l-Aħmar beaches accord closely to such a definition of pocket beaches, being very small, with the larger of the two covering an area of only 500 m^2, and they are flanked by headlands. The eastern-facing pocket beach is slightly more exposed to wave action. A cobble beach is contiguous with a sandy one along this side of the shore platform (Ciantar 2011). The western-facing inlet is much more sheltered with respect to wave action and contains a sandy beach, because of the protection afforded by the Tal-Futma headland. As a result, seagrass debris is deposited exclusively on this beach. Such debris supports the establishment of pockets of dunal vegetation in the backbeach area of the western-facing sandy beach, at the foot of the Blue Clay slopes.

According to Deidun and Schembri (2008), the median grain size of sand contained within these two miniscule beaches is ca. 0.4 mm, which places the sediment within the medium sand category. This scale categorises sediment types depending on the median particle size of the same sediment and is the main reference scale used within granulometry protocols.

17.3.3 Headlands, Cliffs and Scree Slopes

On the eastern side of the bay, the slopes above the weak rock strata are usually steep, producing accelerated erosion of the Blue Clay, underlying the Upper Globigerina Limestone plateau (Fig. 17.3). Erosion of the Blue Clay is by shallow clay slips while erosion of the plateau is the result of undermining and limestone block detachment (toppling) from the plateau characterised by weak and strong rock strata, lying at sea level. The resistant rock strata form headlands, while embayments form in exposed weak strata. As the Upper Globigerina Limestone cliff face is eroded, toppling occurs along certain stretches of the vertical cliff and this translates into rock fall, with boulders falling onto the shore platform below. These toppled boulders are progressively polished and smoothed by wave action, with some boulders having an angular shape which implies that boulder fall has occurred in several stages (Said 2001). The boulders are progressively broken down into pebbles and cobbles by wave action, with these acting as abrasion tools, so extending the impact of erosion further inland (Ciantar 2011).

The tal-Futma headland is made up of the Lower Globigerina Limestone and a part of its surface is formed by hard-grounds and conglomerate beds (C1), around 30 cm thick which makes it very resistant to marine erosion (Scerri 2019). This headland has a gentle dip of 4° to the south-east which can also classify it as a raised shore platform. A number of marine potholes are found along the seaward margin. These are vertical, circular and cylindrical depressions that are created by the grinding action of sand, gravel, pebbles and boulders which are moved or rotated by the energy of waves (Sunamura 1992). These potholes have been easily transformed into salt pans that are still in use today for the production of salt (Gauci and Inkpen 2019, Chap. 27).

The prevalence of erosional processes at Xatt l-Aħmar is evident through the shifting shoreline over the last century, as indicated in Fig. 17.4. Ciantar (2011) compared current aerial photographs of Xatt l-Aħmar with those dating from the 1950s, and this comparative analysis revealed elevated levels of wave-mediated erosion of the Blue Clay cliffs along the eastern section of Xatt l-Aħmar. Coastal landslides, especially in winter, are responsible for gradual sediment supply and resultant extension of the eastern inlet beach. Partially submerged boulders also act as a natural breakwater along the northern side of Xatt l-Aħmar, dissipating the incoming wave energy.

17.4 The Ecological Assets at Xatt L-Aħmar

Xatt l-Aħmar may be considered a naturalist's paradise. With respect to its small size, the site has a disproportionately rich biodiversity that extends both to the floral and faunal domains. By virtue of the site supporting one of the few sand dune pockets on the islands, and by virtue of its

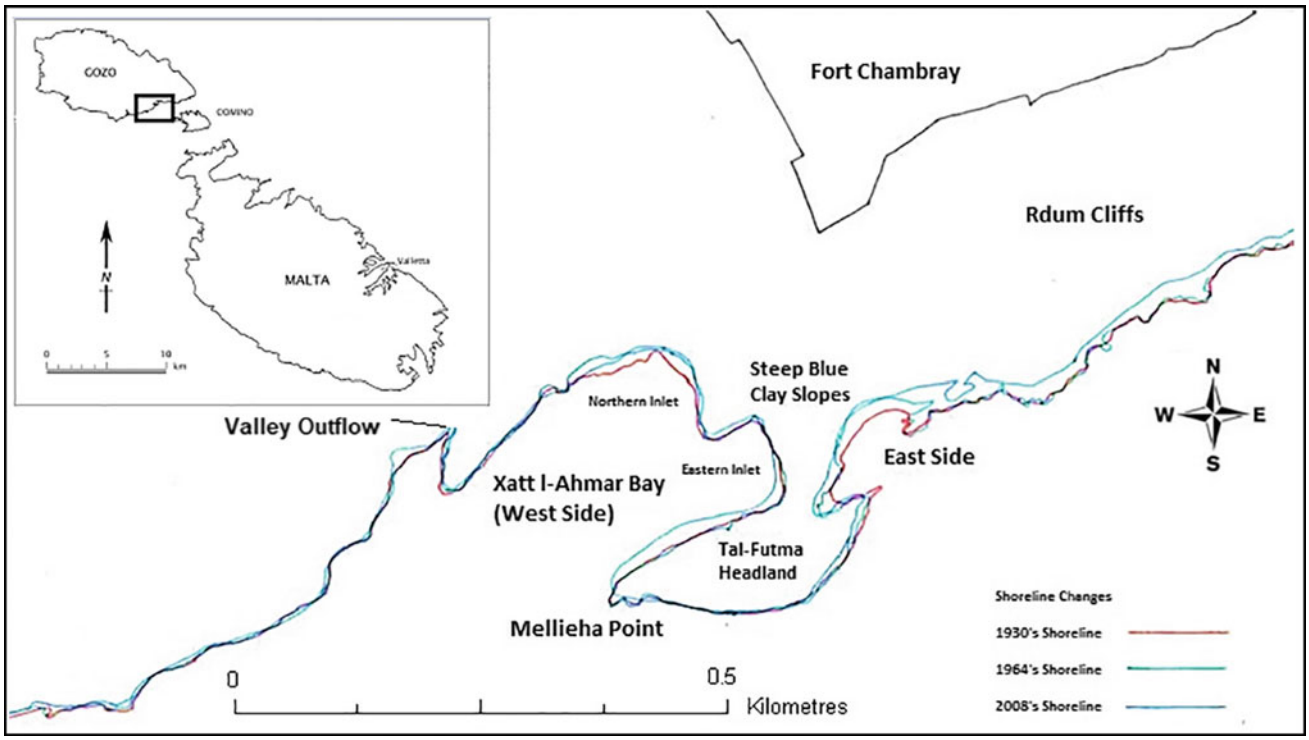

Fig. 17.4 Shifting shoreline baseline at Xatt l-Aħmar, since the 1930s. *Source* Redrawn from Ciantar (2011)

relative isolation, which has spared the site from anthropogenic degradation suffered by other sand dune remnants, Xatt l-Aħmar now constitutes a refuge for a number of sand dune plants which have been under threat in other parts of the Maltese Islands. These include the Purple Spurge (*Euphorbia peplis*), the Sea Holly (*Eryngium maritimum*) and the Sea Knotgrass (*Polygonum maritimum*) that were formerly much more widely distributed in the Maltese Islands but which are currently restricted to Xatt l-Aħmar and, at most, to two or three other beaches. Some dune plants are hanging on by an even finer thread. For instance, cottonweed (*Otanthus maritimus*), which was formerly known from a number of beaches in the Maltese Islands, has virtually disappeared and was only re-discovered at Xatt l-Aħmar as recently as 2008 (Tabone 2008). These rare dune species are interspersed at Xatt l-Aħmar with more frequently occurring halophytic plants such as the prickly saltwort (*Salsola soda*) and sea-rocket (*Cakile maritimum*) (Fig. 17.5). As its scientific name implies, the tissue of the former is impregnated with soda/alkali and has been being burnt in the past for its ash which was used for soap and glass-making.

The vegetational mosaic at Xatt l-Aħmar is further enriched by floral species that have colonised areas located landward of the remnant dunes. For instance, where boulders and rocks form scree, large bushes gain a foothold, such as the caper (*Capparis communis*), whose flower buds are placed in vinegar and eaten, and the olive-leaved germander (*Teucrium fructicans*). Further inland Blue Clay slopes support single stands of tamarisk trees (*Tamarisk africana*), which resist high salt loads through their salt exudation mechanism (a desalination of sorts, whereby excess salt is eliminated within brine released from glands located on the leaves of the trees), prickly pears (*Opuntia ficus-indica*), imported from the Americas 500 years ago and now fully naturalised, the endemic Maltese salt tree (*Darniella melitensis*), the Golden Samphire (*Limbardia crithmoides*), now used to indicate the extent of the coastal zone, and grass species, which include the Clay Restharrow (*Ononis mitissima*) and the Argolian Cotton Thistle (*Onopordum algoricum*). Higher up the Blue Clay slopes, a shallow watercourse occurs that forms a slight depression in the slope, and here, a tuft of Giant Reed (*Arundo donax*) is found. Also associated with water infiltration are the hemispherical Tree Spurge (*Euphorbia dendroides*) and the Spiny Asparagus (*Asparagus aphyllus*).

Isolation and the lack of human disturbance are not the sole agents behind the floral diversity at Xatt l-Aħmar. The prodigious accumulation of banquettes of a seagrass; i.e., Neptune Grass (*Posidonia oceanica*) is also significant (Fig. 17.6). The coastal accumulation of such subsidies is common along low-lying Mediterranean coastlines, but is even more pronounced along sheltered coastlines and along those where grooming—that is the clearing of debris—is not

Fig. 17.5 Blue Clay slopes, dominated by halophytic species such as the golden samphire (*Limbardia crithmoides*), giving way to levelled *Posedonia oceanica* banquettes which have been colonised by dunal species, including the prickly saltwort (*Salsola soda*). *Photo* A. Deidun

regularly carried out. Once again this may be seen on the northern beach at Xatt l-Aħmar which is colonised by 2 m high deposits of *P. oceanica* debris for most of the year. These deposits, known in the Mediterranean as 'banquettes', if left undisturbed for long enough, are well known for promoting the establishment of pockets of sand dune vegetation through the stabilization of the sandy substrate (Deidun et al. 2009).

The importance of Xatt l-Aħmar for conservation is not, however, restricted to the flora alone. The fauna equally merits attention and consists mainly of insects. Deidun and Schembri (2008) report that, of all the sandy beaches sampled in the Maltese Islands, Xatt l-Aħmar registered the highest fraction of psammophilic species which have a very specific habitat preference and are in fact restricted to sandy environments.

17.5 Conservation Considerations

The living assemblages of high conservation value at Xatt l-Aħmar are supported by a highly dynamic geomorphology borne in turn out of a unique geographical setting largely devoid of human structures and interventions and a congenial set of rock types which lends itself to different weathering processes. The low degree of elevation of the sub-cliff coastal area at Xatt l-Aħmar and its exposure to the elements (wave action, especially under south-westerly wind conditions) bestow upon it the status of the ideal geological crucible, where the time span over which evident geomorphological evolution occurs is somewhat reduced The geomorphological dynamics of the site, coupled with its relative inaccessibility such that it has largely escaped the

Fig. 17.6 Accumulations of *Posidonia oceanica* debris known as 'banquettes'. Recently detached Globigerina Limestone slabs are seen in the forefront, whilst older Upper Coralline Limestone boulders, partially submerged in seawater, are to be seen at the back. The plunging Blue Clay slopes are also visible in the background. *Photo* A. Deidun

bane of human intervention which has blighted so many other sites in the Maltese Islands, strengthens the case for a comprehensive conservation of the site as a living laboratory for geomorphologists and ecologists alike.

Species having narrow habitat preferences are normally ascribed higher value by naturalists in view of their vulnerability to human impacts. The species with specific habitats preferences have a refuge in Xatt l-Aħmar which is buffered from mainstream tourism. If mass tourism were introduced at Xatt l-Aħmar, then the psammophiles will give way to the less-demanding more cosmopolitan species, unravelling the biodiversity fabric of the site. Darkling beetles (tenebrionids) burrow into the sand, emerging out at night to scavenge on whatever the sea deposits. Deidun and Schembri (2008) report at least three such endemic species—*Allophylax picipes melitensis, Stenosis schembrii* and *Erodius siculus melitensis*—and one species which is restricted to the Maltese Islands and Tunisia—*Clithobius ovatus*. Another beetle species recorded from Ix-Xatt l-Aħmar and having a restricted local distribution is the Psammophilic Anthicid *Cyclodinus minutus minutus*, which, along with other dune and marsh associated anthicids, is considered to be locally threatened (Nardi and Mifsud 2003). Recently, Freudenschuss et al. (2013) reported a new species of jumping spider —*Menemerus fagei*—specifically from Xatt l-Aħmar. There seems little doubt that the same site will continue to be a focus for the search for new species that have been eliminated from other coastal sites in the Maltese Islands.

It is not just the bare sand and the living vegetation which act as refuges for interesting fauna at Xatt l-Aħmar, but also the seagrass debris. For instance, Deidun et al. (2009) reported the faunal community within the seagrass banquettes at Xatt l-Aħmar to be distinct from that sampled within banquettes at other beaches in the Maltese Islands.

Such distinctiveness is attributed by the authors to high densities of the gastropod snail *Truncatella subcylindrica*, the isopod *Spelaeoniscus vallettai*, the amphipod *Orchestia stephenseni* and arachnids such as opilionids (harvestmen) and pseudoscorpions (false scorpions).

Xatt l-Aħmar is also a popular diving site in Gozo where experienced divers may explore three shipwrecks sunk for a purpose such that, after so long in oblivion, the direction to Xatt l-Ahmar is signposted along the main Mgarr port-Victoria road. These shipwrecks are the Gozo Channel's former MV Xlendi, MV Comino Land, and MV Karwela. After serving for many years ferrying around the Maltese Islands, they ended up at the bottom of the seabed for divers to explore. Apart from the economic value of these wrecks, these ships serve as shelter for many types of fish and different marine life inhabiting them, effectively serving as oases of life in a largely depauperate marine environment, especially since most of the said wrecks are laid to rest on sandy bottoms. A large number of iconic marine species seek refuge in the wreck environment, some (e.g. cephalopods, including squid and cuttlefish) even choosing to lay their eggs within these structures.

17.6 Conclusion

It is refreshing to note that the Maltese Islands, despite their hustle and bustle, still harbour coastal localities which have an intrinsic appeal to geologists and naturalists alike. No wonder that 30 years ago Schembri et al. (1987) listed the Chambray-Mġarr ix-Xini coastal stretch—that includes Xatt l-Aħmar—as a site of conservation importance. Policy GZ-RLCN-1 of the 2006 Gozo and Comino Local Plan proposes the Xatt l-Aħmar area as a Level 2 SSI/AEI (Site of Scientific Importance/Area of Ecological Importance) and as an Area of High Landscape Sensitivity (AHLS), the second highest rank in terms of landscape value afforded to sites around the Maltese Islands within the Landscape Assessment Study conducted in 2000 (Spiteri and Stevens 2019). According to the same study, within an AHLS as Xatt l-Aħmar 'development on coastal areas should be limited to essential facilities related to navigation, maritime operation safety or very limited coastal access facilities'.

Despite this legislative framework, Xatt l-Aħmar is still subject to occasional human impacts, most notably exposure of bare sand and clearance of accumulated seagrass debris ('grooming') for bathing purposes, which Tabone (2007) lists as the major threat to dune floral species at this site. Xatt l-Aħmar sheds some light on what the coastal biota of the Maltese Islands could have been prior to the tourist boom, whilst at the same time acting as a living geological laboratory through the variety of dynamic processes that are etched in its landforms.

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References

Anderson EW, Schembri PJ (1989) Coastal zone survey of the Maltese Islands report. Planning Services Division, Works Department, Beltissebħ, Malta

Ciantar A (2011) Characterization of the coastal landscape and investigating the coastal erosional processes along the shoreline—case study: Xatt L-Aħmar Bay. Unpublished MA thesis, Department of Geography, University of Malta, 124p

Davies JL (1974) The coastal sediment compartment. Aust Geogr Stud 12(2):139–151

Defeo O, McLachlan A (2005) Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. Mar Ecol Prog Ser 295: 1–20.

Deidun A, Schembri PJ (2008) Assessing inter-beach differences in semi-terrestrial arthropod assemblages on Maltese pocket sandy beaches (Central Mediterranean). Mar Ecol 29(1):108–117

Deidun A, Saliba S, Schembri PJ (2009) Considerations on the ecological role of wrack accumulations on sandy beaches in the Maltese Islands and recommendations for their conservation management. J Coast Res SI 56 [Proceedings of the 10th International Coastal Symposium, Portugal]: 410–414

Freudenschuss M, Bauer T, Sciberras A (2013) Menemerus fagei new to Malta and Europe (Araneae: Salticidae). Arachnologische Mit 46:6–8

Gauci R, Inkpen R (2019) The physical characteristics of limestone shore platforms on the Maltese Islands and their neglected contribution to coastal land use development. In: Gauci R, Schembri JA (eds) Landscapes and Landforms of the Maltese Islands. Springer, Switzerland, pp 343–356

Gauci R, Scerri S (2019) A synthesis of different geomorphological landscapes on the Maltese Islands. In: Gauci R, Schembri JA (eds) Landscapes and Landforms of the Maltese Islands. Springer, Switzerland, pp 49–65

Gauci MJ, Deidun A, Schembri PJ (2005) Faunistic diversity of Maltese pocket sandy and shingle beaches: are these of conservation value? Oceanologia 47(2):219–241

Lambie J (adm.) (2005) District of Metchosin. http://www.district.metchosin.bc.ca/ocp2environmental.htm (visited October2005)

Micallef A (2003) Monitoring beach stability on the Mediterranean island of Malta. In: E. Ozhan (ed) Proceedings of the sixth international conference on the mediterranean coastal environment, MEDCOAST 03, 7–11 October 2003, Ravenna Italy, MEDCOAST, Middle East Technical University, Ankara, Turkey, pp 1357–1368

Nardi G, Mifsud D (2003) A review of the Anthicidae of the Maltese Islands (Central Mediterranean). Fragmenta Entomol 35(2):77–127

Oil Exploration Directorate, Office of the Prime Minister (1993) Geological Map of the Maltese Islands, Sheet 1 and 2 –Malta, Gozo and Comino, scale: 1:25,000, resurveyed by Pedley HM, revised by Debono G, Scerri S, cartographer Simpson C. British Geological Survey, Keyworth

Paskoff R, Sanlaville P (1978) Observations géomorphologiques sur les côtes de l'archipel maltais. Zeitschrift für Geomorphologie 22 (3):310–328

Pedley HM, Hughes-Clarke M, Galea P (2002) Limestone isles in a crystal sea: the geology of the Maltese Islands. Publishers Enterprises Group (PEG Ltd), San Ġwann, Malta, 109p

Said G (2001) A geomorphological classification for the Gozitan coast. Unpublished M.A Thesis, University of Malta

Scerri S (2019) Sedimentary evolution and resultant geological landscapes. In: Gauci R, Schembri JA (eds) Landscapes and landforms of the Maltese Islands. Springer, Switzerland, pp 31–47

Schembri JA (2019) The geographical context of the Maltese Islands. In: Gauci R, Schembri JA (eds) Landscapes and landforms of th Maltese Islands. Springer, Switzerland, pp 9–17

Schembri PJ, Lanfranco E, Farrugia P, Schembri S, Sultana J (1987) Localities with conservation value in the Maltese Islands. Environment Division, Ministry of Education, Valletta, 27p

Spiteri L, Stevens DT (2019) Landscape Diversity and Protection in Malta. In: Gauci R, Schembri JA (eds) Landscapes and Landforms of the Maltese Islands. Springer, Switzerland, pp 359–372

Sunamura T (1992) Geomorphology of rocky coasts (vol 302). Wiley, Chichester

Tabone TJ (2007) A list of records of some rare vascular plants occurring in the Maltese Islands (Central Mediterranean). Cent Mediterr Nat 4(3):178–186

Tabone JT (2008) A list of records of some rare vascular plant species occurring in the Maltese Islands (Central Mediterranean). Cent Mediterr Nat 4(4):311–337

Trenhaile AS (2000) Modelling the development of wave-cut platforms. Mar Geol 166:163–178

Zammit Pace ML, Bray M, Potts J, Baily B (2019) The beaches of the Maltese Islands: a valuable but threatened resource? In: Gauci R, Schembri JA (eds) Landscapes and Landforms of the Maltese Islands. Springer, Switzerland, pp 213–227