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Marine notches in the Maltese islands (central Mediterranean Sea)

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ABSTRACT

We present the first detailed survey of tidal notches in the central Mediterranean area, in particular along the coastline of Gozo and Comino (Malta). The Maltese Islands represent one of the few sites in the Sicily Channel which exhibits coastal carbonate rocks. Marine notches on the islands of Gozo and Comino were surveyed by means of a seven day continuous snorkeling survey around the entire perimeter of the two islands. We surveyed the occurrence, lack and typology of marine notches and we correlated them with late Holocene sea level changes. Sea temperature (T) and electrical conductivity (EC) were collected along the route in order to locate the submarine springs and to relate them to the surveyed notches.

A well-carved continuous roof notch was discovered along most of the plunging cliffs. It is well-carved out, in particular along the northern and western coast of Gozo. It develops from about 0.2 m above the mean sea level down and it can be up to 1.5–2 m deep. On the contrary, tidal notches are localised only in 8 sites. In 2 sites, Vermetid trottoirs develop at low tide level. In addition, at about −7 m to −10 m m.s.l., a 2–5 m wide marine terrace develops along extensive tracts of plunging cliffs, always in correspondence with the roof notches. This submerged terrace seem to be the result of the late Holocene slowdown of the sea level rise, which started to smooth the terrace and to carve out the submerged part of the roof notch, thanks to the exposed location of the islands and the favourable lithology.

Through the collection of hydrological data, the presence of 21 submarine springs were detected. They occur mainly in the south-western coast of Gozo and on eastern coast of Comino. Anyway, marine notches seem not to be related to the freshwater outflow, such as those in the Adriatic Sea, because the studied islands are very exposed. As a consequence, along the Maltese islands bioerosion seems to be the most effective process in notch development.

1. Introduction

The Mediterranean Sea is bordered by more than 60% of rocky coasts, but very short sectors were extensively surveyed in the field (Furlani et al., 2014a), mainly because of the challenging accessibility present on the typology of these coasts. Anyway, some carbonate coastal sectors are fundamental for the development of marine notches, such as the Maltese Islands (Fig. 1). They represent one of the few sectors of the Sicily Channel with carbonate coasts, so they represent one of the most favourable environments for the development of marine notches in the central Mediterranean. The elevation of marine notches with respect to actual sea level is fundamental to evaluate the relative sea level changes.

Notches develop as a result of the higher erosion rates in the tidal zone rather than in the supratidal or subtidal zone (Furlani et al., 2009, 2010; Furlani & Cucchi, 2013; Moses, 2012; Moses et al., 2014). These type of notches are called tidal notches, u-shaped, as suggested and described by Pirazzoli (1986). Antonioli et al. (2006) and Carobene and Pasini (1982) described the morphometric features of tidal notches in the central Mediterranean. Tidal notches are common features along Mediterranean sloping or vertical limestone cliffs and are widely used as sea level markers (e.g. Pirazzoli et al., 1996; Antonioli et al., 2006; Faivre et al., 2011; Evelpidou et al., 2014; Antonioli et al., 2015). Roof notches are

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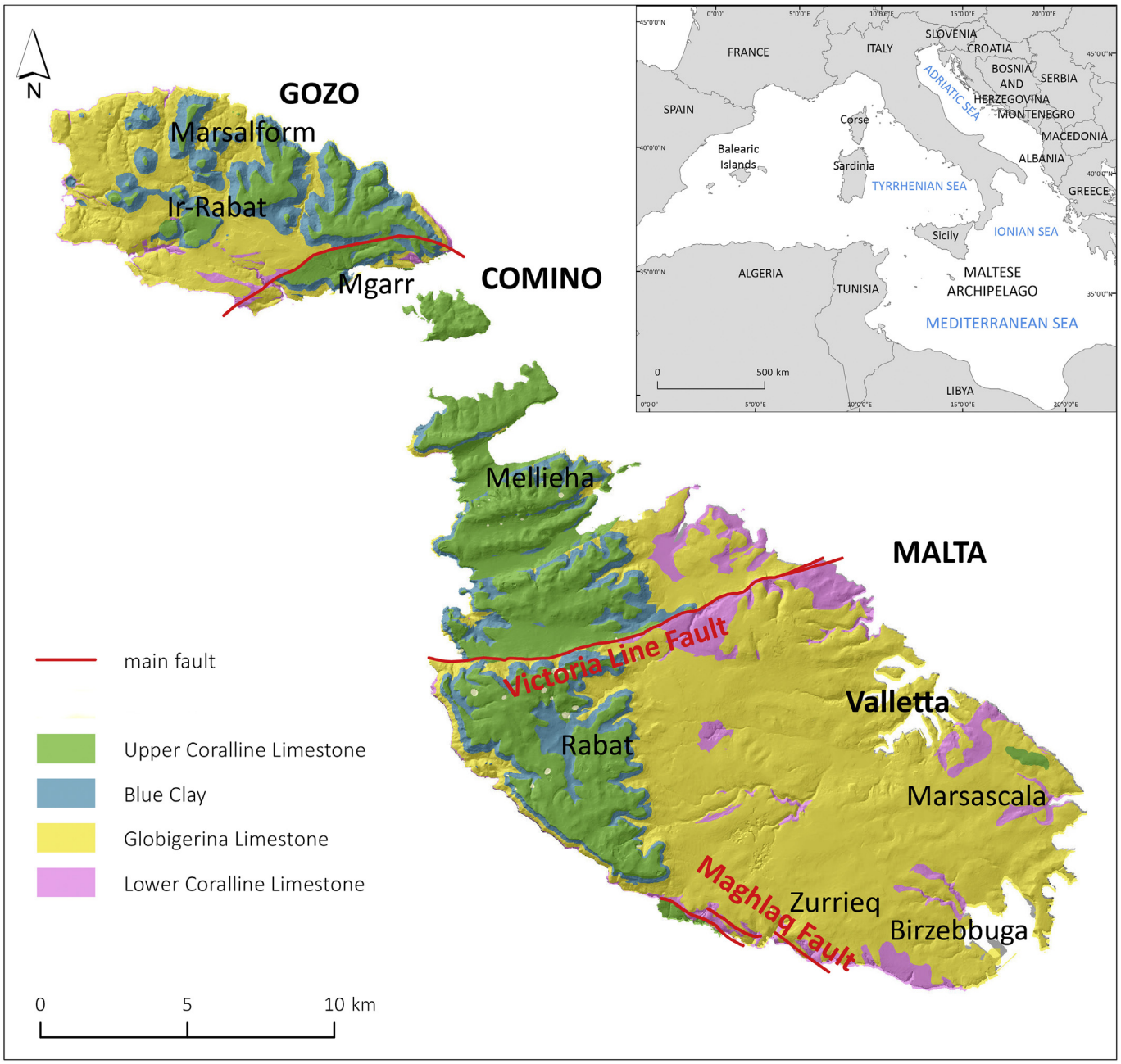

Fig. 1. The study area: the islands of Gozo and Comino (Maltese islands) are located in the Sicily Channel (Central Mediterranean). The studied coasts are one of the few carbonatic coastal sites in the Sicily Channel. The geological formations outcropping along the coast were obtained from the geological map of the island of Gozo and Comino (Pedley et al., 1978).

e-shaped (*sensu* Pirazzoli, 1986) and are characterized by an asymmetrical shape and well-developed roof top. They were identified and surveyed by many authors such as Benac et al. (2004, 2008) in the Gulf of Kvarner (Croatia), and Antonioli et al. (2007) and Furlani et al. (2011) in the Eastern Adriatic Sea. The morphometric features of roof notches were described by Benac et al. (2004, 2008) and Antonioli et al. (2015). Despite their importance in sea level change studies, their genesis and development are still not fully understood. Evelpidou et al. (2012) really suggested the global disappearance of present-day tidal notches. Most studies suggest that tidal notches are the result of bioerosional processes in sheltered or exposed sites (e.g. Focke, 1978; Pirazzoli, 1986), but some literature also supported the contribution of groundwater effects as the primary agent (Higgins, 1980) in view of the proximity of notches to submarine springs and suggested a one to one ratio between notches and submarine springs in Greece. Furlani et al. (2014a, 2014b) obtained the same results in the northeastern Adriatic Sea. Wave abrasion plays little or no contribution in notch cutting, both because of the usual lack of tools for abrasion close to the notch and because tidal and roof notches in the Mediterranean are absent in rocks other than limestones (Higgins, 1980), unlike other sites outside the Mediterranean (Trenhaile, 2015). Kaye (1957) suggested that agitation of surface water might act like an enhanced solution process.

Micallef et al. (2013) reconstructed the submerged morphology in the near off-shore of the Maltese Islands, whilst Furlani et al. (2013) reconstructed the evolution of the Holocene sea level rise and the paleo-connections with Sicily.

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