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Spongy-like porosity in peritidal carbonates: An interaction of cyclic sea-level oscillations, fresh water supply and sediment texture

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ABSTRACT

This paper focuses upon the analysis of a complex paleokarstic system recorded within uppermost Triassic peritidal cycles in northwestern Sicily. Besides documenting spectacular karstification at the Triassic/Jurassic boundary, it provides an example of stratabound 'spongy' or 'swiss-cheese' dissolution. On the base of field observations, microfacies analysis, transmitted-light and cathodoluminescence petrography and stable-isotope analyses we put forward an original model for the formation of this peculiar stratabound dissolution. It implies a complex interaction of several controlling factors at the interface between the marine and meteoric diagenetic realms during the relative cyclic oscillations of sea-level.

The presence of a fresh water supply from an adjacent emerged area is the key for the periodic formation of a mixing water lens during the relative sea level lowstand that brought about the subaerial exposure of the platform. The resulting dissolution pattern in the subtidal unit of a specific cycle is strongly controlled by the textural features of the sediments. In the case of bioturbated wackestones the 'spongy' or 'swiss-cheese' pattern develops, while in mollusk-rich beds biomoldic porosity occurs. In well-sorted subtidal members, such as algal grainstones, the dissolution originates as randomly distributed vuggy porosity. During periodic flooding of the platform, a new subtidal unit is formed and the dissolution stops as fully marine phreatic conditions are re-established.

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1. Introduction

Dissolution processes in modern and ancient carbonate platforms are very variable in shape and size as a result of different forcing factors (James and Choquette, 1988). Climate, sea-level fluctuations, texture, diagenetic features and tectonism, are among the most important controlling factors in the generation of different scales of dissolution from microkarstic cavities to giant blue-holes (Esteban and Klappa, 1983; Mylroie and Carew, 1995; Whitaker and Smart, 1998; Moore, 2001; Smart et al., 2006).

The literature contains numerous examples of dissolution features in modern (Smart et al., 1988; Beach, 1995) and ancient carbonate platforms (Choquette and Pray, 1970; James and Choquette, 1988; Christ et al., 2012 and references therein). However, one of the features that are less discussed is a particular type of porosity named "swiss-cheese" solution, which results in stratabound, centimeter-sized, rounded cavities forming a complex pore network (Back et al., 1986). Baceta et al. (2001, 2007) described a similar type of porosity from upper Danian platform limestones in the western Pyrenees, Spain, as a "spongy-like" dissolution pattern. The morphological comparison between swiss-cheese and spongy-like cavities seems appropriate. The latter authors favor dissolution from the formation of a marine-meteoric mixing zone. Moreover, the presence of CO_2 from bacterial sulfate reduction and/or root action can increase the water's potential for dissolution (Back et al., 1986; Smart et al., 1988; Walter and Burton, 1990).

Bioturbation may also facilitate dissolution; several authors have described traces of bioturbation expressed by tunnels, vugs and channels in modern (e.g. Beach, 1995) and Mesozoic carbonate limestones (Droser and O'connell, 1992; Lehmann, 1974; Scheweigert et al., 1997; Tonkin et al., 2010, among others). Bioturbators create their burrows, which can have widely varying dimensions, in sub-lithified muddy horizons. Burrows also have a distinct shape and are generally filled by sediments and microcrystalline calcite. These networks appear to form a template for subsequent diagenetic modification and can therefore have an important impact on hydrocarbon charge and productivity in oil and gas fields (e.g. Hollis, 2011).

The aim of this paper is to analyze an intense, stratabound dissolution that affects the uppermost Triassic peritidal cycles cropping out in northwestern Sicily (Italy), with the purpose of contributing to the discussion on the processes that leads to the particular dissolution morphology hereafter named "spongy-like". Based on field observations, microfacies analysis, transmitted-light and cathodoluminescence

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petrography and stable-isotope analyses, this study highlights the interplay between bioturbation, mixing-water dissolution and relative sea-level fluctuations as the principal controlling factors in the formation of the spongy-like pattern

2. Geological Setting

The study area is located in the San Vito lo Capo Peninsula, the northwesternmost part of Sicily, where a segment of the Maghrebian fold and thrust belt is well exposed (Fig. 1A, B). The San Vito Peninsula consists of an imbricate fan of thrust sheets that were stacked during late Miocene and Pliocene (Abate et al., 1991). The thrust system is in turn displaced by NW–SE and NE–SW trending normal and strike-slip faults of Pliocene and Pleistocene ages that are related to the evolution of the southern Tyrrhenian margin (Giunta et al., 2000). The stratigraphy of the structural units in the San Vito Lo Capo Peninsula consists of thick successions, up to 1000 m, of peritidal carbonates, Late Triassic–earliest Jurassic in age, that are overlain by Middle Jurassic to Eocene slope and

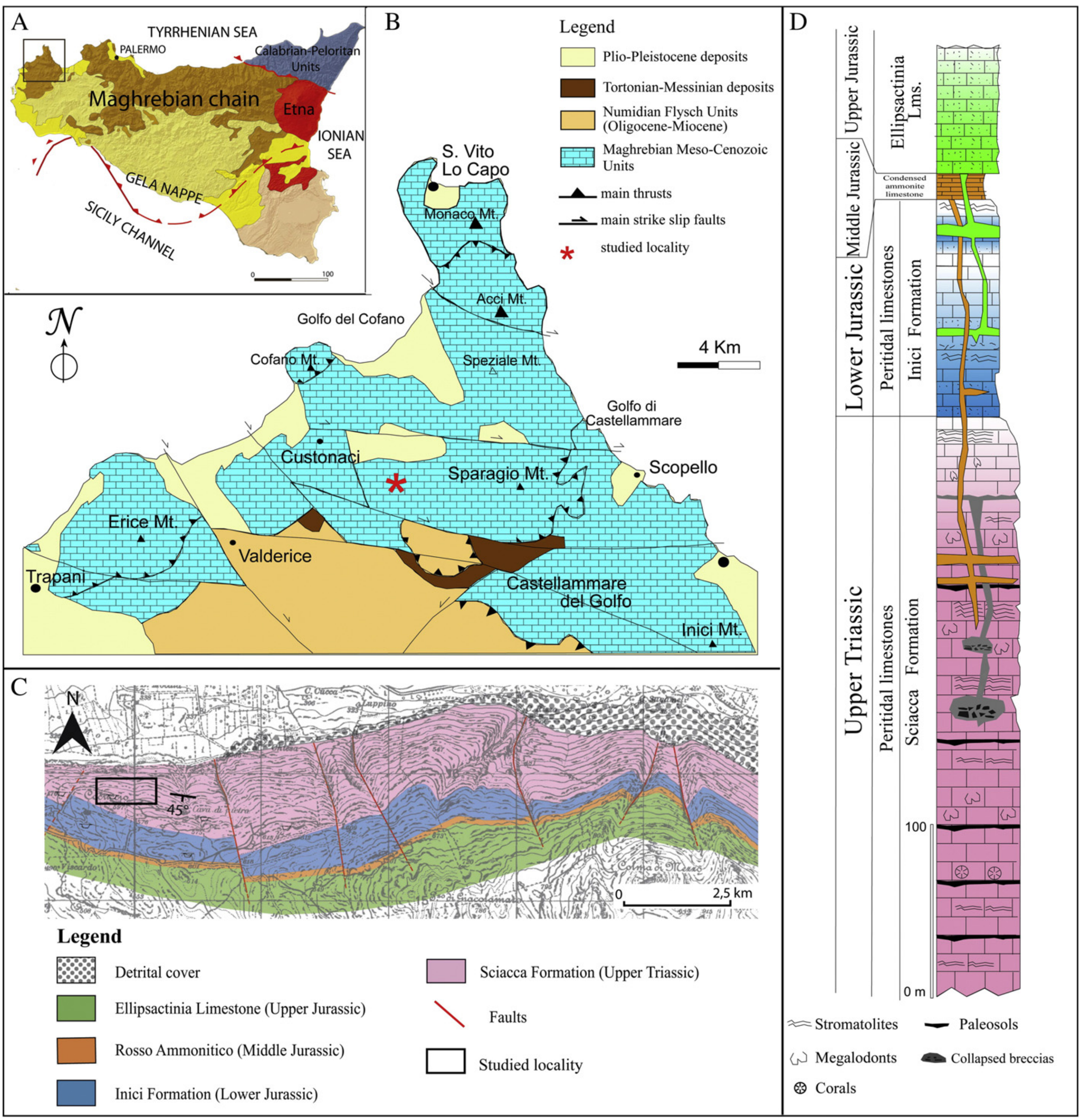

Fig. 1. Geological setting of the studied area. A) The San Vito Lo Capo Peninsula (black rectangle) in a schematic structural map of Sicily. B) Structural setting of the San Vito Lo Capo Peninsula showing the location of the Monte Sparagio structural unit: asterisk indicates the studied locality. C) Geological map of the northern slope of Monte Sparagio. D) Columnar section of the succession of Monte Sparagio.

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