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Identifying eroded Messinian deposits on the Maltese Islands by gypsum Sr isotopes.

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Abstract

Evaporite sediments are known to have formed during the Messinian high salinity crisis that has been recognized in many Mediterranean areas. This event was however never identified on the Maltese Islands. In this study, a Sr isotopic characterization of gypsum, found as secondary minerals in the Oligocene-Miocene formations of Malta and Gozo is performed. The $^{87}\text{Sr}/^{86}\text{Sr}$ values are discussed on the basis of comparison with the surrounding rock Sr isotopic signature. The data outline two distinguishable $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for gypsum according to their facies. Most of crack-infilling mineral data suggest a downward fluid circulation in the Miocene sediment associated with interaction in the currently outcropping limestones. Some gypsum crystals found as crystallized spherules show significantly lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, close to those defined in the literature for Messinian evaporate sediments. Taken together, this may suggest that an evaporate formation of Messinian age had in the past covered the present-day sedimentary sequence in Malta and Gozo.

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1. Introduction

The Mediterranean region is known to have suffered a high salinity crisis during the Messinian (the Mediterranean Messinian Salinity Crisis, MSC), which resulted in the deposition of a huge volume of evaporate sediments [1,2]. Such formations are recognized for instance in Italy, Spain or Sicily [3-5]. They are however completely missing on the Maltese Islands, composed of Oligocene-Miocene clayey and limestone formations, the younger being of Tortonian age. Nevertheless, the occurrence of a

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Messinian evaporate layer capping these formations and nowadays disappeared has been proposed to explain the presence of large amounts of gypsum secondary minerals found as infilling minerals in fractures, as well as in the rock mass of the Miocene clayey formation, the 'Blue Clay' Formation [6, 7].

In this study, a new geochemical framework dealing with Sr isotopes of the Malta and Gozo primary and secondary formations gives clues to discuss the occurrence of Messinian evaporate-bearing successions on the Maltese Islands. Commonly, the origin of gypsum can be determined either by the mineral assemblage and facies [8] or by isotopes that allow discrimination between marine and continental origins (e.g. [9, 10]). In this way, Sr isotopes ($^{87}\text{Sr}/^{86}\text{Sr}$) can be used to specify the origin of secondary mineralization resulting from water/rock interactions.

2. Geological context and sampling

The Maltese Islands (mainly Malta and Gozo) are located on the northern flank of the Pantelleria Rift, between Tunisia and Sicily to the south of the Sicilian platform. Stratigraphic and tectonic settings of these islands are well documented by previous authors [11, 12, 6]. The stratigraphic succession outcropping on these islands consists of five main litho-stratigraphic units of Oligocene-Miocene ages defined from the basement to the top by: the Aquitanian-Burdigalian Lower Coralline Limestone (140 m thick; [11]), the Chattian to Langhian Globigerina Limestone (20 - 200 m thick; [12, 13, 14, 15]), the Langhian Blue Clay Formation (75 m thick; [11]), the Greensand Formation (few meters thick) and the Tortonian Upper Coralline Limestone (100 m thick). The Globigerina Limestone is composed of three members called Lower, Middle and Upper Globigerina Limestone.

The structural study of Malta and Gozo Islands carried out by Missenard et al. [6] has highlighted a fracture network related to the opening of the Pantelleria Rift, associated in some cases with fluids paleocirculation and secondary minerals precipitation, sometimes affected by more recent tectonics. For instance, large and intermediate faults (i.e. with 100s and 10s meter throw) were identified and characterized respectively by smearing structures and by gypsums infilling. In order to discuss the origin of the fluids responsible for this gypsum mineralisation and to precise the fluids/rocks interaction (upward or downward migration), a detailed Sr isotopic study ($^{87}\text{Sr}/^{86}\text{Sr}$ isotopic ratio) of the Miocene Globigerina Limestone and Blue Clay formations and of sealing cracks minerals is proposed herein.

Three sites of the Malta and Gozo Islands showing a thick stratigraphic sequence composed of the Upper Globigerina Limestone, the Blue Clay Formation and the Coralline Limestone were investigated. Several samples were collected in each sedimentary layer as a function of the distance to the top of the sequence. In the same time, gypsum minerals found either as infilling crystal in centimeter cracks or as 'crystallized spherule' in the mass of the Blue Clay were sampled and referred as a function of their position in the stratigraphic sequences. All the samples were chemically treated for separation of their soluble carbonated fraction (acid acetic dissolution) in case of the clayey and limestone formation, and for total dissolution for gypsum pure crystals. Sr isotope measurements were performed by thermal ionization solid source mass spectrometry (Finnigan Triton TI, GIS Nîmes) with an analytical error (2) of about 5×10^{-6} . The external reproducibility of the isotopic measurements was checked by repetitive analysis of the NBS987 standard, yielding a mean value of $0.710258 \pm 2 \times 10^{-6}$ (2)

3. Results and discussion

values obtained on the gypsum crystals are identical to this Tortonian high radiogenic composition, whatever the location into the sedimentary sequence (Fig. 1). This might be explained by fluids circulation downwards from the Coralline Limestone, more recent than Tortonian.

¹ $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the leached carbonated phase of the Globigerina Limestone and of the Blue Clay Formation corresponds to that of the seawater at the time of the sediment deposition [16, 17], ranging from 0,708609 ($\pm 6.10^{-6}$) and 0,708841 ($\pm 8.10^{-6}$). The Coralline Limestone is characterized by a high $^{87}\text{Sr}/^{86}\text{Sr}$ ratio, nearly 0,708999 ($\pm 9.10^{-6}$) higher than that of Tortonian seawater [16]. Most of Sr isotopic

Two gypsum samples are however identified by low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0,708505 and 0,708569 ($\pm 7.10^6$) (Fig. 1). These gypsum samples correspond to those sampled in ‘crystallized spherule’ generally found at the top of the Blue Clay Formation. The Sr isotope values of these minerals are close to those reported for Messinian evaporate formations of Spain and Italy [3, 4, 5]. Taken together, this suggests that an evaporate formation has covered the present sedimentary sequence in the past. This formation, as for that discussed by Playa et al. [3], Anadon et al. [4] and Matanoa et al., [5], would have deposited in non-marine conditions during the Messinian, in open sedimentary basins. The alteration of this Sr low-radiogenic Messinian formation might be responsible for the secondary spherule-type gypsum found at the top of the Blue Clay Formation.

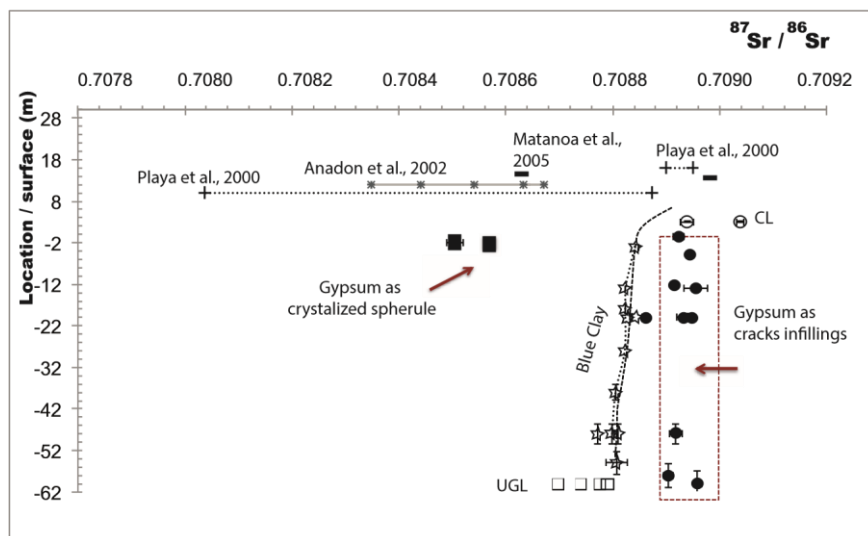


Fig. 1. $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the leached phase of the successive Upper Globigerina Limestone (UGL; empty squares), Blue Clay (empty stars) and Coralline Limestone (CL; empty circles) formations as a function of the stratigraphic level, and of the secondary gypsum found either as infilling minerals (black circles) or as crystallized spherules (black squares). Comparison with values measured for Messinian evaporate sediments in Spain and Italy (Playa et al. [3]: black single crosses; Anadon et al. [4]: gray double crosses; Matanoa et al., [5]: black dashes).

4. Conclusion

The Maltese Islands gypsum crystals found in the Oligocene-Miocene formations were studied from an isotopic point of view in order to discuss their nature, their origin and the occurrence of a now-eroded Messinian deposit overlying these sediments as suggested by preliminary studies. This approach helps to identify at least two water/rocks interaction events. The first one is related to the Coralline limestone samples and involves a fluid in equilibrium with the Tortonian calcareous formation. The second one, identified in ‘crystallized spherules’, involves a fluid in equilibrium with less radiogenic formation that could be Messinian in age. Further isotopic measurements will be performed in the environment of the Maltese Islands to refine these hypotheses.

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