



HAL
open science

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

I. Techer, L. Casteleyn, M. Rocher, Y. Missenard, P. Robion, J. Reynes

► **To cite this version:**

I. Techer, L. Casteleyn, M. Rocher, Y. Missenard, P. Robion, et al.. Identifying eroded Messinian deposits on the Maltese Islands by gypsum Sr isotopes. 14th International Symposium on Water-Rock Interaction, WRI 14, Jun 2013, Avignon, France. pp.830-833, 10.1016/j.proeps.2013.03.101 . hal-00817848

HAL Id: hal-00817848

<https://hal.science/hal-00817848v1>

Submitted on 12 Jul 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

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

I. Techer ^{a*}, L. Casteleyn ^b, M. Rocher ^c, Y. Missenard ^d, P. Robion ^b, J. Reynes ^a

^a *Université de Nîmes, Labo GIS, CNRS UMR 7330-CEREGE, 30 000 Nîmes, France*

^b *GEC-Géosciences et Environnement Cergy, University of Cergy-Pontoise, 5 mail Gay-Lussac, 95031*

Cergy cedex, France ^c *IRSN – Institut de Radioprotection et de Sécurité Nucléaire, BP 17, 92262*

Fontenay-aux-Roses, France ^d *Université Paris-Sud-11- Orsay, UMR IDES 8148, Département des Sciences de la Terre, 91405 Orsay cedex, France*

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.

© 2012 The Authors. Publis© 2013 The Authors. Published by Elsevier B.V. hed by Elsevier B.V.

Selection and/or peer-review under responsibility of Selection and/or peer-review under responsibility of the Organizing and Scientific Committee of WRI 14 – 2013 Organizing and Scientific Committee of WRI 14 – 2013.

Keywords : Malta; Messinian; gypsum; Sr isotopes.

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

* Corresponding author. Tel.: +33 (4) 66 70 99 73. E-mail
address: isabelle.techer@unimes.fr.

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.

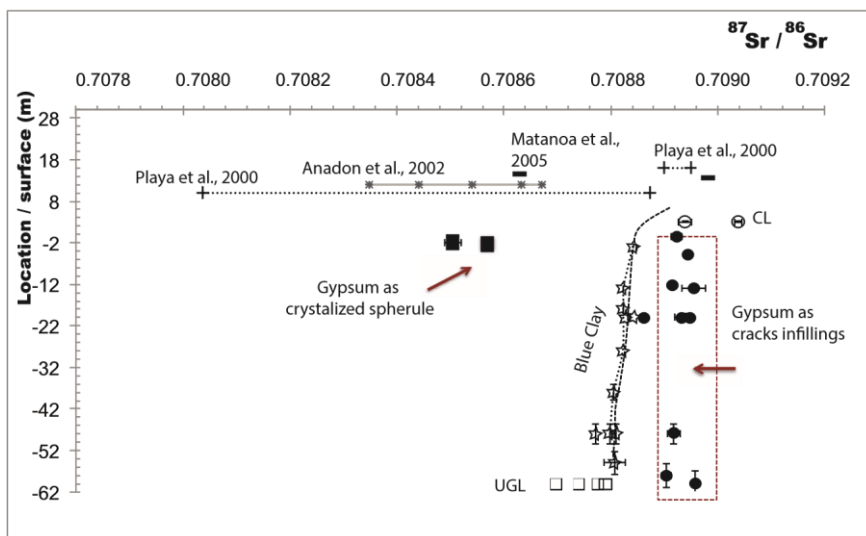


Fig. 1. $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the leached phase of the successive Upper Globigerina Limestone (UGL; empty squares), Blue Clay (empty stars) and Coralline Limestone (CL; empty circles) formations as a function of the stratigraphic level, and of the secondary gypsum found either as infilling 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.

References

- [1] Selli R. Il Messiniano Mayer-Eymar. Proposta di un neostratotipo. *G Geol* 1960; **28**: 1–33.
- [2] Hsu K, Montadert L, Bernoulli D, Cita MB, Erickson A, Garrison RE, et al. History of the Mediterranean salinity crisis. *Nature* 1977; **267**: 399 – 403.
- [3] Playa E, Orti F, Rosell L. Marine to non-marine sedimentation in the upper Miocene evaporites of the Eastern Betics, SE Spain: sedimentological and geochemical evidences. *Sediment Geol* 2000; **133**: 135–166.

- [4] Anadon, P, Ghattib P, Gliozzi E. Sr/Ca, Mg/Ca ratios and Sr and stable isotopes of biogenic carbonates from the Late Miocene Velona Basin (central Apennines, Italy) provide evidence of unusual non-marine Messinian conditions. *Chemical Geology* 2002; **187** : 213–230.
- [5] Matanoa F, Barbierib M, Di Noceraa S, Torrea M. Stratigraphy and strontium geochemistry of Messinian evaporite-bearing successions of the southern Apennines foredeep, Italy: implications for the Mediterranean salinity crisis and regional palaeogeography. *Palaeogeography, Palaeoclimatology, Palaeoecology* 2005; **217**: 87–114.
- [6] Missenard Y, Rocher M, Casteleyn L, Grare A, Bertrand A, Vergely P, et al. Sealing capacity of clays in multilayer systems: a field study of fracture-fluid flow relationships (Blue Clay formation, Maltese Islands). EGU General Assembly 2011, Vienna, Geophysical Research Abstracts, Vol. 13, 8406.
- [7] Casteleyn L. Transfert de fluides dans les milieux poreux, le cas des carbonates et des interfaces argiles/calcaire. Etudes intégrées de pétrophysique, de sédimentologie et des microstructures. Le cas de deux carbonates : l'Oolithe Blanche du Bassin de Paris et la formation du Globigerina Limestone des îles maltaises. *Thèse de doctorat Université de Cergy Pontoise* 2011.
- [8] Hardie LA, Lowenstein TK, Spencer RJ. The problem of distinguishing between primary and secondary features in evaporites. In: Schreiber B, Harner C, editors, *Sixth Symposium on Salt I*. The Salt Institute, Alexandria, VA, 1985; pp. 11–39.
- [9] Kushnir J. The composition and origin of brines during the Messinian desiccation event in the Mediterranean Basin as deduced from concentrations of ions coprecipitated with gypsum and anhydrite. *Chem Geol* 1982 ; **35** : 333–350.
- [10] Lu FH, Meyers WJ, Schoonen MA. ³⁴S and ¹⁸O(SO₄) isotopes of sulfate, simultaneous modeling, and geological significance. *Geochim Cosmochim Acta* 2001; **65**: 3081–3092.
- [11] Pedley HM, House MR, Waugh B. The Geology of Malta and Gozo. *Proc Geol Ass* 1976 ; **87** (3) : 325-341.
- [12] Bonson CG, Childs C, Walsh JJ, Schöpfer MPJ, Carboni V. Geometric and kinematic controls on the internal structure of a large normal fault in massive limestones: The Maghlaq Fault, Malta. *J Struct Geol* 2007; **29**: 336-354.
- [13] Giannelli I, Salvatorini G. I foraminiferi planctonici dei sediment terziari dell' archipelago Maltese. I. Biostratigrafia del Globigerina Limestone (in Italian). *Atti Soc Tosc Sci Men Ser* 1972; **A 79**: 49-74.
- [14] Felix R. Oligo-Miocene stratigraphy of Malta and Gozo. Meded. Landbouwhogeschool Wageningen 1973; **73** (20) : 1-103.
- [15] Mazzei R. The Miocene sequence of the Maltese islands: biostratigraphic and chronostratigraphic references based on nanofossils. *Atti Soc Tosc Sci Men Ser* 1985; **92**: 165-197.
- [16] Koepnick RB, Burke WH, Denison RE, Hetherington EA, Nelson HF, Otto JB, Waite LE. Construction of the seawater 87Sr/86Sr curve for the cenozoic and cretaceous: supporting data. *Chem Geol* 1985; **58**: 55-81.
- [17] Fortuin AR, Kelling JMD, Roep TB. The enigmatic Messinian- Pliocene section of Cuevas del Almanzora (Vera Basin, SE Spain) revisited-erosional features and strontium isotope ages. *Sedimentary Geol* 1995; **97**: 177-201.