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Is *Cyprideis agrigentina* Decima a good paleosalinometer for the Messinian Salinity Crisis? Morphometrical and geochemical analyses from the Eraclea Minoa section (Sicily)

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ABSTRACT

The living euryhaline species *Cyprideis torosa* (Jones) undergoes morphometric variations in size, noding and sieve-pore shape linked to the environmental salinity. In particular it is known that salinity values around 8–9 psu represent the osmoregulation threshold and also the turning point between smaller and greater valve dimensions and prevailingly noded against un-noded valves. The variation of the percentage of round-, elongate- and irregular-shaped sieve-pores on the valves has shown an empiric logarithmic correlation with the water salinity from 0 to 100 psu. Due to this ecologically cued polymorphism, *C. torosa* represents an invaluable paleosalinometer for the Quaternary brackish basins.

In this paper we attempt to verify whether the ecophenotypical behavior of the post-evaporitic Messinian species *Cyprideis agrigentina* Decima was comparable with that of *Cyprideis torosa*. To reach this goal, three morphometric characters have been analyzed: 1) size variability; 2) noding and ornamentation; and 3) variability of the percentage of the sieve-pore shapes. The paleoenvironmental interpretation was made using synecological and geochemical approaches [stable isotopes, trace elements, Sr-isotopes and natural radioactivity (NRD)]. For this study, the 250 m-thick Messinian Lago-Mare succession of Eraclea Minoa (Agrigento, Sicily) was chosen for the presence of monotypic assemblages made only by *C. agrigentina* for around 70 m of thickness. The results of the morphometric analyses showed that: 1) size variations are not related to the salinity changes recognized both from synecological and geochemical analyses; 2) no noded specimens have been recovered along the Section; 3) the salinities calculated on the basis of the percentage of the sieve-pore shape are not correlated with the salinities inferred from the synecological and geochemical analyses. Thus, in this paper we conclude that *Cyprideis agrigentina* cannot be considered a paleosalinometer for the Messinian Salinity Crisis. There is a correlation of the $\delta^{13}C$ with the percentages of sieve-pore shapes, linking them to the behavior of the dissolved inorganic carbon (DIC) and to the oxygen availability at the bottom of the basin.

1. Introduction

Since the pioneering studies by Schäfer (1953), Sandberg (1964), Vesper (1975) and Rosenfeld and Vesper (1977), it is known that the living anomalohaline species *Cyprideis torosa* (Jones) undergoes morphometrical variations in size, noding and sieve-pore shape linked to environmental physical and chemical parameters – especially salinity – showing a clear environmentally cued polymorphism. The species can withstand and thrive in a very wide range of salinity (0.4 to 150 psu according to Neale, 1988 and Griffiths and Holmes, 2000), thus it is commonly regarded as a valuable paleosalinometer for the Quaternary marginal marine and athalassic brackish deposits (Marco-Barba, 2010; Pint et al., 2012 with references therein). Its low-Mg calcite shell represents also a source of biogenic carbonate for the geochemical analyses (trace elements, stable isotopes and $^{87}Sr/^{86}Sr$ ratios) to infer the chemical composition of past waterbodies, because of its high rate of valve calcification. In many studies, morphometrical variations were coupled with the geochemical approach to make more detailed paleoenvironmental reconstructions of brackish environments (Barbieri et al., 1999; Anadón et al., 2002; Marco-Barba, 2010; Curry et al., 2013; Pint et al., 2013; Rossi et al., 2013).

Several studies (Carbonel, 1982; Aladin, 1993; van Harten, 1996, 2000; Keyser and Aladin, 2004; Keyser, 2005; Boomer and Frenzel, 2011; Frenzel et al., 2011, 2012 among others) showed that salinity values around 8–9 psu represent the osmoregulation threshold and also the turning point between smaller and greater valve dimensions

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and prevailingly noded against un-noded valves. Rosenfeld and Vesper (1977) showed an empiric logarithmic correlation between the variation of the percentage of round-, elongate- and irregular-shaped sieve-pores on the valves of *Cyprideis torosa* and the water salinity from 0 to 100 psu. This correlation has been confirmed by subsequent papers (Neale, 1988; Keating et al., 2007; Pint et al., 2012) and Frenzel et al. (2011) elaborated a transfer function based on the percentages of round sieve-pores.

In order to decipher the paleosalinity changes during the end of the Messinian Salinity Crisis (Hsü et al., 1973; CIESM, 2008; Roveri et al., 2014a), Rosenfeld (1977) and Bonaduce and Sgarrella (1999) applied the counting of different sieve-pore shapes to the fossil species *Cyprideis agrigentina* Decima, supposing that also this species could morphologically react as *C. torosa*. In both cases they obtained hyperhaline values for the waters hosting *C. agrigentina* specimens (respectively 35–50 psu and 50–70 psu) considering those values reliable for the evaporative paleoenvironment that yielded the deposition of the gypsum.

Cyprideis agrigentina (Fig. 1) is one of the most widespread ostracod that lived in the Paleomediterranean during the latest Messinian Lago-Mare event (5.53–5.33 Ma, CIESM, 2008; 5.55–5.33 Ma, Manzi et al., 2013; Roveri et al., 2014a). It seems to have been the first ostracod that colonized again the sterile bottoms of the Paleomediterranean after the deposition of the Primary Lower Gypsum and the partial desiccation of the basin. It has been recovered both in the Messinian sediments drilled on the Paleomediterranean bottoms and in those cropping out along the peri-Mediterranean chains, from the most western area (Malaga Basin) to the easternmost Adana Basin (Benson, 1978; Bonaduce and Sgarrella, 1999; Iaccarino and Bossio, 1999; Grossi and Gennari, 2008; Guerra-Merchán et al., 2010; Cosentino et al., 2012; Faranda et al., 2013). In their study on the Messinian Lago-Mare paleoenvironments inferred from the ostracod assemblages, Grossi et al. (2008) showed that *C. agrigentina* behaved as a very euryhaline species: it was associated a) with the benthic foraminifer *Ammonia tepida* ("*Cyprideis-Ammonia* assemblage") in very oligotypic assemblages supposed to be typical of high mesohaline environments; b) with *Loxoconcha muelleri* (Mehés) and *Loxoconcha eichwaldi* Livental ("*Cyprideis-Loxoconcha* assemblage") (low mesohaline environment); c) it was also a component, although not dominant, of the "pointed candonids-Leptocytheridae assemblage" and "pointed candonids assemblage", supposed to be characteristic of oligohaline to low mesohaline environments.

Anyway, despite its apparent capability to withstand different salinities, no noded specimens of *C. agrigentina* have been ever found (Ligios and Gliozzi, 2012) and this could arise some questions about the possible ecophenotypical reaction of *C. agrigentina* to the environment.

In this paper we attempt to verify whether the ecophenotypical behavior of *C. agrigentina* was comparable with that of *C. torosa*. To reach this goal, adult male and female valves of *C. agrigentina* from the long section of Eraclea Minoa (Agrigento, Sicily) were investigated and three morphometrical characters have been analyzed: 1) size variability; 2) noding and ornamentation; 3) variability of the percentage of the sieve-pore shapes. The paleoenvironmental framework to which the ecophenotypical characters displayed by *C. agrigentina* will be compared has been built based on synecological analysis (assemblages taxonomic composition and diversity) (-Chapter 3) and geochemical approaches [stable isotopes, trace elements, Sr-isotopes and natural radioactivity (NRD)] (Chapter 4).

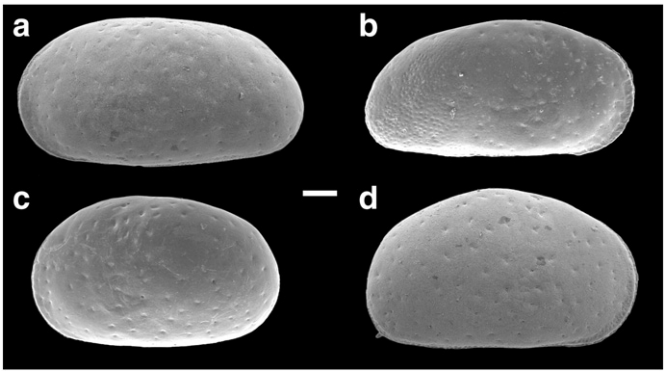

Fig. 1. SEM pictures of *Cyprideis agrigentina* Decima. a. male left valve, sample EM 8-3; b. male right valve, sample EM 7-2; c. female left valve, sample EM 7-2; d. female right valve, sample EM 8-3. White bar corresponds to 0.1 mm.

2. Material and methods

One hundred fifty-two samples have been soaked in a H_2O_2 5%$_{vol}$ solution for 24 h, sieved with 0.063 and 0.125 mm-mesh sieves and dried in oven at 40 °C. Total manual picking has been carried out on the 0.125 mm dried sieved samples. When possible, up to 300 valves where hand-picked from each sample. Ostracods have been identified and their frequency counted; the obtained values have been normalized to 10 g in order to get comparable figures all along the section to perform a reliable paleoenvironmental interpretation using the synecological approach proposed by Gliozzi and Grossi (2008) and Grossi et al. (2008). Shannon–Wiener index has been calculated on the basis of the normalized matrix.

When possible, supplementary adult specimens of *C. agrigentina* were picked to increase the amount of material on which the morphometrical and geochemical analyses were performed. The morphometrical and geochemical analyses have been carried out on more than 3000 adult valves of *C. agrigentina*, and several thousand juvenile valves were added for Sr-analyses.

2.1. Morphometrical analyses

All juvenile and adult valves of *Cyprideis agrigentina* were observed under the stereo-microscope to investigate the ornamentation and noding. Over one thousand adult female and male valves of *C. agrigentina* from fifty-three selected samples were measured under the stereo-microscope, using the Leica Application Suite 2.5.0. Mean values were calculated for each sample.

Around 20 adult female and male valves of *Cyprideis agrigentina* from fifty-three samples, chosen on the basis of its high frequency, were observed under the Scanning Electron Microscope (LIME Laboratory, Roma Tre University). Following the methodology proposed by Rosenfeld and Vesper (1977), the rounded, elongated and irregular sieve-pores were counted and each percentage was calculated. To obtain the inferred salinity value, the following transfer function elaborated by Frenzel et al. (2011), based on the percentage of rounded sieve-pores was used:

$$S = e^{-0.06RS+4.7}$$

where S = salinity (psu) and RS = percentage of rounded sieve-pores.

2.2. Geochemical analyses

2.2.1. Stable isotopes

Carbon and oxygen stable isotope analyses ($\delta^{13}C$ and $\delta^{18}O$) were performed on fifty-three ostracod samples each consisting of eight *Cyprideis agrigentina* clean adult valves. Two splits of each sample (4 valves each) were reacted with anhydrous phosphoric acid at 76 °C ± 2 °C in a Finnigan MAT Kiel preparation device directly coupled to the inlet of a Finnigan MAT 251 triple collector isotope ratio mass spectrometer (Stable Isotope Laboratory, University of Michigan, Ann Arbor, MI, USA). The isotopic results of the mean of the two splits are reported in permil (‰) notation relative to the Pee Dee Belemnite (PDB)