Research programme on the carbonate platform record of global perturbations of the carbon cycle from the latest Triassic to the middle Jurassic.

The geological archive of marine and continental organic matter and of marine carbonates, is characterised by some large and geologically short (10s to 10^2 kyr) negative carbon isotope excursions (CIE) that have been interpreted as episodes of short-term massive injection of CO_2 in the atmosphere–ocean system (see Jenkyns, 2010, for a review). A wealth of geochemical and palaeontological data indicates that these global perturbations of the carbon cycle are invariably associated with abrupt climatic changes and severe palaeonvironmental crises (e.g. Jenkyns, 2003). These past episodes, which were caused by natural increases of atmospheric pCO_2, are of great interest inasmuch as they could serve to test models and predictions of anthropogenic CO_2-induced global change. About one third of the CO_2 released into the atmosphere from anthropogenic sources is transferred into the oceans where it reacts to form carbonic acid (Sabine et al., 2004). As a result, the pH and the carbonate saturation of the ocean decrease in a process called ocean acidification (Doney et al., 2009; Raven et al., 2005). Detrimental effects on extant calcifying organisms, which use carbonate minerals to build their protective shells and skeletons, have been documented in the laboratory (Fabry et al., 2008) and in the oceans (Hall-Spencer et al., 2008). However, due to the spatio-temporal limits of laboratory manipulations and of field observations of living marine communities, the long-term impact on marine ecosystems and the adaptative potential of marine fauna and flora are best investigated by looking at the geological record of past episodes of ocean acidification (IPCC, 2011; Hönisch et al., 2012; Zeebe, 2012). Among these episodes, in the time interval considered for this project, the best studied ones are the end-Triassic event and the early Toarcian Oceanic Anoxic event (T-OAE).

The end of Triassic, around 201.7 +/- 0.3 Ma, was characterized by three global events: 1) the emplacement of the Central Atlantic Magmatic province (CAMP); 2) the end-Triassic mass extinction; 3) a severe perturbation of the carbon cycle (Marzoli et al., 2004; Schoene et al., 2010; Blackburn et al., 2013; Bond & Wignall, 2014; Wotzlaw et al., 2014). This latter is evidenced by three sharp negative carbon isotope excursions (CIEs) in organic matter and marine carbonate, suggesting a massive input into the oceans and atmosphere of large quantities of ^{13}C-depleted CO_2 (Hesselbo et al., 2002; Ruhl et al., 2011; Dal Corso et al., 2014). Given the age overlap, the emplacement of the CAMP seems to be the most likely cause of the negative CIEs (Marzoli et al., 2004; Cirilli et al., 2009; Davies et al., 2017). In the marine realm, ocean acidification greatly influenced carbonate-secreting organisms (Hautmann, 2004; van de Schootbrugge et al., 2007; Kiessling et al., 2009). A significant drop in carbonate production has been recorded in the pelagic realm and in some carbonate platforms (Greene et al., 2012). The pattern of extinction in the

subtropical carbonate platforms, affecting selectively the massive hypercalcifiers, has been taken as a strong evidence of ocean acidification (Kiessling and Simpson 2011; Hönisch et al., 2012).

After the major perturbation across the Triassic-Jurassic boundary interval, the carbon cycle seems to become stabilized up to the Hettangian-Sinemurian boundary. Stabilization of the carbon cycle appears to have coincided with a recovery of skeletal carbonate producing biota. During the Early Jurassic time, the subtropical carbonate platforms of the peri-Tethys Ocean experienced significant changes in their architectures, as well as in their biota compositions. Starting from the Pliensbachian, a prolific biotic carbonate factory developed, dominated by large bivalves (the so-called lithiotid bivalves) and dasycladalean algae. According to Franceschi et al. (2014, 2019), the rise of this metazoan-dominated carbonate factory at the expense of the earliest Jurassic microbial carbonate factory, occurred across the Sinemurian-Pliensbachian boundary, coinciding with a global perturbation of the carbon cycle.

A further dramatic change in the carbonate platform biota occurred across the early Toarcian Oceanic Anoxic Event (T-OAE; ~183 My). This is considered as one of the most severe of the Mesozoic era. It is associated with a major negative carbon isotope excursion, global warming, biocalcification crisis, increased primary productivity, triggered by higher fluxes of nutrient from continents, and intensified upwelling under greenhouse conditions (Jenkyns, 2010; Erba, 2004). The documentation of the T-OAE in shallow-water is sparse (Merino-Tomé et al., 2012; Trecalli et al., 2012; Sabatino et al., 2013; Han et al., 2018), but the selectivity of extinction (see also Kiessling and Simpson, 2011) and the abrupt shift from biotic to mainly abiotic carbonate production, support the hypothesis that the demise of carbonate platform hypercalcifiers in the early Toarcian was caused by ocean acidification (Trecalli et al., 2012; Posenato et al., 2018).

After the T-OAE, further perturbations of the global carbon cycle, associated with negative and positive excursion of the $\delta^{13}C$ of marine carbonates and organic matter, have been recorded around the Aalenian-Bajocian boundary (Hesselbo et al., 2003) and in the early Bajocian (Bodin et al., 2017; Erba et al., 2019).

The main aim of the present research project is to investigate the response of tropical carbonate platforms to global perturbations of the carbon cycle during the latest Triassic to middle Jurassic time interval. In particular, we will look at changes in the composition of the carbonate factory and at the changes in the abundance, diversity and pattern of mineralization in the main biocalcifiers. We aim also at investigating a suite of geochemical proxies that could potentially illuminate important paleoenvironmental parameters like the carbonate saturation and the redox state of the ocean, the timing and intensity of global volcanic activity, and the intensity of continental weathering.

Proposal for a PhD position

The PhD student will contribute, together with one post-doc and the senior researchers involved in a wider project funded by the Italian Ministry of Research (PRIN 2017, principal investigator Elisabetta Erba, University of Milan), to the study of carbonate platform sections of the southern and central Apennines across the key stratigraphic intervals delineated above. For each studied section, the first phase of the PhD project will involve a detailed sedimentological and stratigraphical study, based on the integration of the following datasets: facies and microfacies analysis; cyclostratigraphy and sequence stratigraphy; biostratigraphy; carbon isotope stratigraphy; strontium isotope stratigraphy. The stable isotopes of carbon (of carbonate and total organic matter) and oxygen will be analysed at external labs (University of Bochum and University of Lausanne) in the framework of a scientific cooperation established during previous research projects. Strontium isotopes and trace element concentrations will be analysed in the geochemistry labs at the Department of Earth Sciences of the University of Naples.

The second phase of the PhD project will involve the quantitative analysis of the diversity and abundance of the biotic assemblages, with special emphasis on the main biocalcifiers. The third phase will involve the study of geochemical proxies of paleoenvironmental and paleoceanographic parameters, including: U isotopes as tracers of global ocean anoxia (Romaniello et al., 2013), Hg concentration as tracer of global volcanic activity (Percival et al., 2018); P content as tracer continental weathering intensity (Mort et al., 2007). The Uranium isotopes of carbonates will be analysed at the Arizona State University, in the laboratory directed by Prof. Thomas Algeo, in the framework of a scientific cooperation established for a wider project on related topics, which has been submitted for funding to the National Science Foundation of the United States. Hg and P concentration will be analysed at the University of Lausanne. The PhD student will be responsible for the preparation of the samples and will participate to the laboratory analyses at the University of Naples and at the external labs cited above.

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Funded Projects

"Biota resilience to global change: biomineralization of planktic and benthic calcifiers in the past, present and future". Research Project of National Interest (PRIN) funded by the Italian Ministry of University and Scientific Research. National coordinator: Elisabetta Erba, University of Milan. Scientific responsible of the research unit at the University of Naples: Mariano Parente. Duration of the project: 36 months. Funding: ca. 80000 €.