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Early Pliensbachian (Early Jurassic) C-isotope perturbation and the diffusion of the *Lithiotis* Fauna: Insights from the western Tethys

Marco Franceschi [a,*], Jacopo Dal Corso [b], Renato Posenato [c], Guido Roghi [d], Daniele Masetti [c], Hugh C. Jenkyns [e]

[a] *MuSe — Museo Delle Scienze, Corso del Lavoro e della Scienza, 3, 38122 Trento, Italy*
[b] *Dipartimento di Geoscienze, Università degli Studi di Padova, via Gradenigo, 6, 35131 Padova, Italy*
[c] *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Polo Scientifico-Tecnologico, via Giuseppe Saragat 1, 44122 Ferrara, Italy*
[d] *Istituto di Geoscienze e Georisorse (IGG-CNR), via Gradenigo 6, 35131 Padova, Italy*
[e] *Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK*

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ABSTRACT

High-resolution carbonate carbon-isotope stratigraphy of Lower Jurassic marine shallow-water limestones are compared with the distribution of the *Lithiotis* Fauna on the Trento Platform (Southern Alps, Italy). The *Lithiotis* Fauna is the first example of globally distributed mound-building bivalves in the geological record and experienced global diffusion in the Early Jurassic. A set of carbonate carbon-isotope excursions of 2–3‰, illustrating three distinct negative shifts followed by positive rebounds, are recorded in the isotope stratigraphy and can be correlated with the global negative $\delta^{13}C$ shift of the Sinemurian–Pliensbachian boundary Event (S–P Event) and to the subsequent phase of C-isotope perturbation that characterized the lower Pliensbachian. In the studied stratigraphic sections, the S–P Event likely triggered eutrophic conditions illustrated by the presence of organic-rich facies and by fossil associations characteristic of poorly oxygenated waters. After the eutrophic phase, the amelioration of environmental conditions was marked by a positive ~3‰ rebound of the $\delta^{13}C_{carb}$ values, and by the occurrence of marine stenotypic faunas. On the Trento Platform, the stabilization of the $\delta^{13}C_{carb}$ values coincided with the appearance of the *Lithiotis* Fauna that subsequently became widely distributed in the entire range of platform environments and thrived in the late Pliensbachian when metric-scale bivalve mounds were generated. During the same time, the maximum proliferation of the *Lithiotis* Fauna is recorded both in the Tethyan and Panthalassa regions. Hence, the reported relationships between the $\delta^{13}C_{carb}$ data and the distribution and ecological characteristics of the genera contained in the *Lithiotis* Fauna suggest that the S–P Event and its aftermath, possibly coupled with the undergoing coeval continent reorganization that led to the opening of the Hispanic Corridor, could have set the stage for the rapid diffusion of these unusual bivalves across many parts of the globe.

1. Introduction

During the Early Jurassic, important palaeogeographic and faunal changes occurred following the rifting phase that ultimately led to the break-up of Pangaea. One such event was the radiation of the *Lithiotis* Fauna during the Pliensbachian (Early Jurassic): a global bio-sedimentary event which, together with the arrival of the Cretaceous rudists, represents one of the two Mesozoic evolutionary phases in which mound-building bivalves became globally widespread and played a central role in the dynamics of carbonate platforms throughout the tropical Tethys and Panthalassa (e.g. Bosellini, 1972; Broglio Loriga and Neri, 1976; Geyer, 1977; Nauss and Smith, 1988; Leinfelder et al., 2002; Fraser et al., 2004; Posenato and Masetti, 2012). With the *Lithiotis* Fauna, for the first time, mound-building bivalves underwent a global expansion in marine carbonate shallow-water environments, giving rise to large accumulations of shells also in the form of bivalve mounds (sensu Riding, 2002) that are a distinctive feature of many Pliensbachian sedimentary successions around the world (Fig. 1).

The factors that led to the appearance and adaptive radiation of these bivalves remain enigmatic. Fraser et al. (2004) suggested that Early Jurassic ecosystem instability following the end-Triassic mass extinction freed many niches, and global carbon-cycle perturbations linked to the formation of the Central Atlantic Large Igneous Province (CAMP; e.g. Marzoli et al., 2004; Ruhl et al., 2011; Dal Corso et al., 2014) coupled with sea-level rise, created large areas of suitable habitats by inducing a strong crisis in the corals that were the dominant reef-builders, and triggered conditions favourable for the origin of the *Lithiotis* Fauna. Similarly, Scott (1995) proposed that replacement of

* Corresponding author. Tel.: +39 0461 270354.
E-mail addresses: marco.franceschi@muse.it, marco.franceschi79@gmail.com (M. Franceschi), jacopo.dalcorso@unipd.it (J. Dal Corso), renato.posenato@unife.it (R. Posenato), guido.roghi@igg.cnr.it (G. Roghi), daniele.masetti@unife.it (D. Masetti), Hugh.Jenkyns@earth.ox.ac.uk (H.C. Jenkyns).

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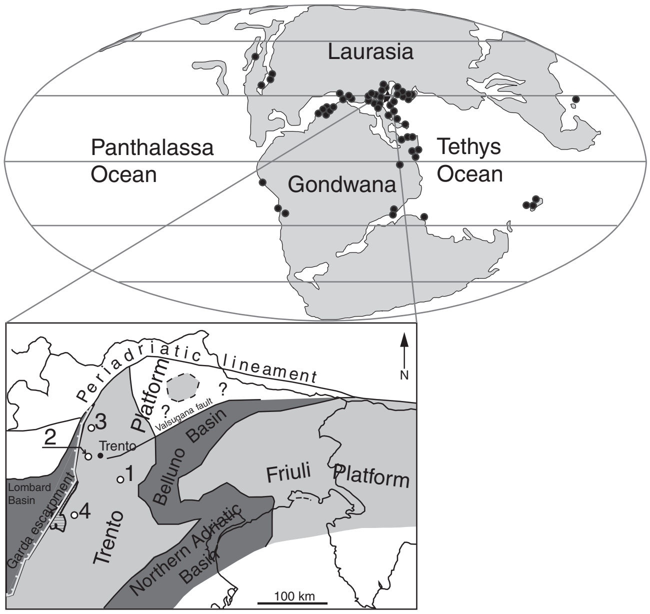

Fig. 1. Top: Palaeogeographic map of Early Jurassic time (base map from Schettino and Scotese, 2001, modified). Black dots show distribution of the *Lithiotis* Fauna (from Fraser et al., 2004). Bottom: Palaeogeographic reconstruction of the Southern Alps in the Early Jurassic. Location of stratigraphic sections: 1. Rotzo (45°51′29.59″N; 11°22′20.23″E); 2. Viote (46°01′40.11″N; 11°02′42.36″E); 3. Rocchetta (46°14′05.00″N; 11°03′39.36″E); 4. Madonna della Corona (modified from Masetti et al., 2012).

Cretaceous corals by the rudists followed multiple episodes of environmental stress deriving from the complex interplay of rapid rises in pCO_2 in the atmosphere and eustatic sea-level fluctuations. However, the appearance of the *Lithiotis* Fauna was delayed by ~10.5 Myr, according to the Gradstein et al. (2012) timescale, with respect to the end-Triassic mass extinction and associated carbon-cycle disruption and abrupt rise of pCO_2 (e.g. Ruhl et al., 2011; Steinthorsdottir and Vajda, in press) and so there can be no direct connection between these phenomena.

A global ~2‰ negative $\delta^{13}C$ shift recorded in bulk carbonate, marine benthic and nektobenthic molluscs and brachiopods and terrestrial wood marks the Sinemurian–Pliensbachian boundary and testifies to a sudden input of ^{13}C-depleted CO_2 in the ocean–atmosphere system (Jenkyns et al., 2002; Woodfine et al., 2008; Korte and Hesselbo, 2011). Given that the *Lithiotis* Fauna had their maximum diffusion in the Pliensbachian the question arises as to whether their stratigraphic distribution could be linked to the Sinemurian–Pliensbachian negative CIE.

This paper presents new high-resolution carbonate carbon-isotope analyses through the Lower Jurassic limestones that host the *Lithiotis* Fauna on the Trento Platform (Southern Alps of northern Italy), which contains historically important outcrops from which type collections of the large bivalves have been extracted in the past (e.g., Accorsi Benini and Broglio Loriga, 1977; Fraser et al., 2004; Posenato and Masetti, 2012, and references therein). The isotopic data are here considered in the context of the stratigraphic distribution and palaeoecology of the bivalves of the *Lithiotis* Fauna. Furthermore, the studied sections are correlated with the existing carbon-isotope curves from the marine shelf-sea sequences of north-east England that are well constrained by ammonite biostratigraphy and accompanied by oxygen-isotope data from calcitic skeleta of brachiopods, bivalves and belemnites (Korte and Hesselbo, 2011). These new high-resolution data allow fossil distribution and trophism to be interpreted in relation to global environmental changes, providing information on the timing and possible causes of the appearance of the *Lithiotis* Fauna on the Trento Platform. Even though palaeontological and sedimentological data are restricted to the Trento Platform the connection with global climate perturbations may help shed light on the mechanisms behind the spread of this characteristic fauna across the globe.

2. Geological setting

2.1. The Lithiotis Fauna

The *Lithiotis* Fauna comprises gregarious and aberrant bivalves with large, dorso-ventrally elongated, stick-like, or flattened shells, which are represented by the genera *Lithiotis*, *Cochlearites*, and *Lithioperna* (e.g. Debelijak and Buser, 1998; Posenato and Masetti, 2012) (Fig. 2). They are commonly indicated in literature as "lithiotids", although this term has no systematic value, these bivalves belonging to different taxonomical groups (e.g., Accorsi Benini and Broglio Loriga, 1977; Accorsi Benini, 1979). Systematic, functional morphology and palaeoecology of the *Lithiotis* Fauna have been investigated in several studies (e.g. Accorsi Benini and Broglio Loriga, 1977; Accorsi Benini, 1979; Chinzei, 1982;

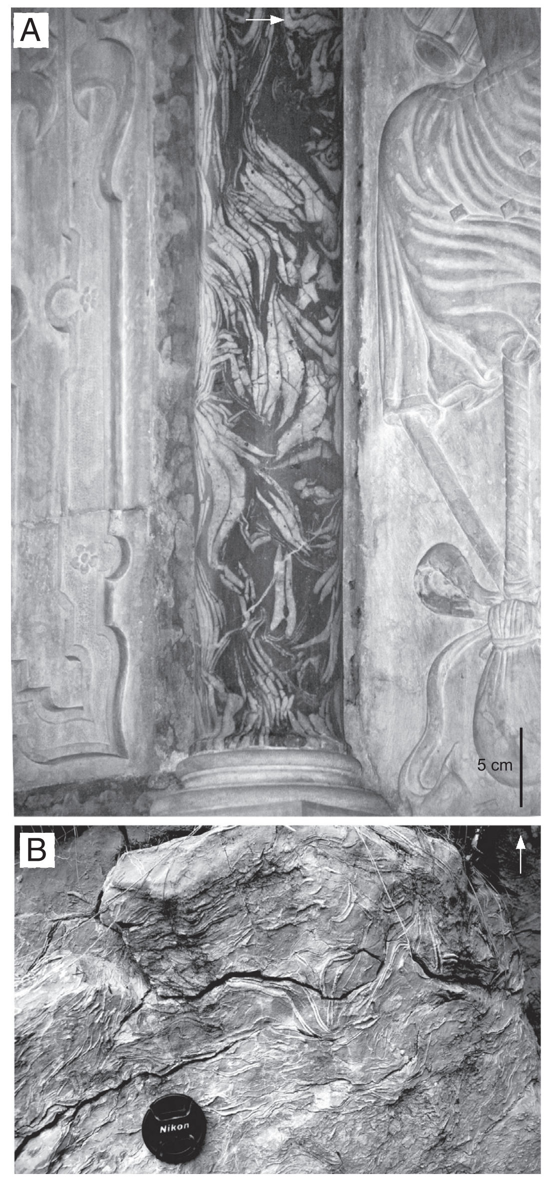

Fig. 2. Examples of bivalve (*Lithiotis* Fauna) accumulations from the Trento Platform. A) Accumulation of *Lithioperna* clearly visible on a column carved from the Rotzo Formation bioclastic limestone (church of San Pietro, Trento). Note the *bouquet* arrangement of the bivalves on the left of the column. B) *Bouquet* of thin-shelled *Lithioperna* in the upper part of the Rotzo Formation as seen at outcrop in the Viote section. White arrow marks stratigraphic high.