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Global correlations of mid Early Triassic events: The Induan/Olenekian boundary in the Dolomites (Italy)

Renato Posenato *

Dipartimento di Scienze della Terra, Università di Ferrara, Via Saragat 1, 44100 Ferrara, Italy

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ABSTRACT

The Dolomites (Southern Alps, Italy) are a reference-area for research on the end-Permian mass extinction and its Early Triassic aftermath. The effects on shallow marine benthic biota are recorded in the Werfen Formation, a thick mixed carbonate-siliciclastic sedimentary succession. Only in its lower (Griesbachian) and upper (Spathian) parts, this formation is bio-chronologically constrained by means of conodonts and ammonoids, whilst no significant bioevent occurs in its middle part. This represents an impediment to the biochronologic recognition of the Induan/Olenekian boundary (IOB).

The Bulla/Pufels (Val Gardena) succession is a key-section for the P/T boundary and Early Triassic for global correlation due to the abundance of studies on biostratigraphy (mostly on conodonts), magnetostratigraphy and chemostratigraphy carried out there by stratigraphers of various nationalities. Recent chemostratigraphic studies have permitted the recognition of some carbon isotope positive peaks, the strongest of which is considered to approximate the IOB. However, various authors have reached different conclusions on the position of the maximum peak and thus on the IOB location. This leads to important stratigraphic consequences for the calibration of conodont biostratigraphy. The critical revision of the traditional stratigraphic units (litho- and biostratigraphy), under-evaluated in most of the recent literature, and magneto-, chemo- and sequence stratigraphic units allowed herein an integrated stratigraphic scale for the Bulla/Pufels section to be proposed. This contribution highlights the mid Early Triassic Dolomites record for regional and global correlations.

The most significant results attained herein regard the different lithostratigraphic subdivisions of the middle Werfen Formation and its consequences on the position of the IOB with respect to the conodont and bivalve biostratigraphy and sequence stratigraphic units. The upper part of the section is attributed herein to the Gastropod Oolite Member, which is represented by the lithozone A, a predominant supratidal episode, and the lower part of the subtidal lithozone B. Between the lithozones A and B, a sequence boundary of 3th order (Sc2/Sc3) is located. The maximum carbon isotope excursion is near this boundary, which therefore approximates the IOB in the Dolomites. This proposal suggests a Dienerian age for the FO of the conodont *Pachycladina obliqua*, which occurs about 60 m below the stage boundary. No significant biotic event, either for molluscs or conodonts, occurred across this stage boundary.

Contents

* Tel.: +39 0532 974736; fax: +39 0532 974767.
E-mail address: psr@unife.it.

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1. Introduction

The Early Triassic represents a crucial epoch for the evolution of life on Earth. This time interval, about 5 m.y. long (e.g. Ovtcharova et al., 2006; Lehrmann et al., 2006; Galfetti et al., 2007a), records the survival, recovery and beginning of radiation phases for marine and terrestrial biota after the catastrophic P/T extinction (e.g. Erwin, 1993; Benton, 2003; Erwin, 2006). Despite other recovery periods following mass extinctions, the Triassic biotic recovery was strongly delayed because some ecosystems (e.g. metazoan reefs) re-appeared more than 5–7 m.y. after the end-Permian extinction (e.g. Flügel, 2002; Bottjer and Gall, 2005; Fraiser and Bottjer, 2005; Pruss et al., 2007). During the last decade these events have been extensively studied becoming one of the most debated themes of the scientific community (e.g. Bottjer and Gall, 2005; Algeo et al., 2007a; Yin et al., 2007), mostly with the aim of investigating the causes and effects of the extinction and for predicting models which could be applied to the fate of the Earth.

Extinction and recovery patterns are based on base data from the literature survey or on new or re-assessed information from key-areas. In both cases, the local bioevents must be chronostratigraphically located with great detail in order to trace global correlations and to propose new hypotheses. Unfortunately, Early Triassic biomarkers (some conodont or ammonoid species) are often restricted to deep water marine successions characterised by low sedimentation rates and hiatuses, whilst these biomarkers are rare or missing in many shallow marine successions, where the fossil record is more complete. It ensues, therefore, the difficulty in the biostratigraphic correlation between marine and continental environments. Since mass extinctions affected both terrestrial and marine biota, only an integrated stratigraphy provides the means to get over these constraints, to be reconstructed a plausible scenario. For this reason, new stratigraphic methods have been largely developed over the last few decades: magnetostratigraphy, chemostratigraphy, sequence stratigraphy and cyclostratigraphy. However, these methods are sometimes applied independently from each other, or the traditional stratigraphic units are disregarded or too schematised giving rise to a certain level of misinterpretation of stratigraphic record.

The base of the Triassic is well exposed in a section near the Bulla/Pufels village (Val Gardena, eastern Southern Alps, north Italy), a historical locality of western Dolomites well-known since the beginning of the 19th century (e.g. Emmrich, 1844; von Richthofen, 1860) and for the pioneering research on the Early Triassic conodonts (Huchkriede, 1958; Staesche, 1964) and their biozonation (e.g. Mostler and Kozur, in Mostler, 1982; Perri and Andraghetti, 1987; Perri, 1991; Perri and Farabegoli, 2003). Besides that, the Bulla/Pufels section has been recently examined for magneto- (Scholger et al., 2000) and chemostratigraphy (Korte and Kozur, 2005; Korte et al., 2005, Horacek et al., 2007a; Gorjan et al., 2007) as well as for bioevents connected with the Permian/Triassic boundary (PTB) (e.g. Chen et al., 2006; Groves et al., 2007; Farabegoli et al., 2007) and Induan/Olenekian boundary (IOB) (Korte et al., 2005; Horacek et al., 2007a); it has also been proposed as PTB parastratotype (Farabegoli et al., 2007). The abundant and highly valuable data recently carried out on the Bulla/Pufels stratigraphic succession have made this section a potential key-point within of the western Tethyan shallow marine domain for global correlations (e.g. Szurlies, 2004a,b; Kozur and Bachmann, 2005; Kozur, 2006; Szurlies, 2007; Algeo et al., 2007b; Baud, 2007; Chinese Triassic Working Group, 2007; Horacek et al., 2007b,c; Krystyn et al., 2007b; Korte et al., 2007; Orchard 2007; Sun et al., 2007).

This study aims to (a) discuss the various stratigraphic units and events of the middle Werfen Formation (Werfen Fm) of the Bulla/Pufels section and (b) integrate these data. The conodont stratigraphers (Mostler, 1982; Perri, 1991; Farabegoli and Perri, 1998), who worked in this section, adopted a lithostratigraphic subdivision of the Werfen Formation different from that used by other authors (e.g. Broglio Loriga et al., 1983, 1986a, 1990) who proposed the biochronostratigraphic framework of the formation based on macrofossils (bivalve and ammonoids). This different classification makes the comparison between the conodont and mollusc zonations difficult (Neri, 2007). Nonetheless, a non-critical approach has been recently applied to the chronostratigraphic framework proposed by the latter authors to the lithostratigraphic units of the former, giving origin to a misinterpretation of the stratigraphic record, in particular regarding the chemostratigraphic units. Here a critical revision of the stratigraphic units recognised in the Bulla/Pufels section is performed and the proposal of an integrated stratigraphic scale, which considers all the rock signals (litho-, bio-, magneto- and chemostratigraphic) is proposed in order to improving the global correlations for a better knowledge of the mid Early Triassic events.

2. The Werfen Formation

The Lower Triassic in the eastern Southern Alps (Fig. 1) is represented by the Werfen Fm, a thick mixed terrigenous-carbonate succession which records the survival and recovery phases connected with the P/T mass extinction. The importance of the Werfen Fm of the Dolomites derives from its great thickness (about 400–500 m), the well exposed and often little tectonized outcrops with abundant fossils, giving rise to abundant and prolonged research since the beginning of the 19th century (e.g. Wissmann, 1841; Emmrich, 1844; Catullo, 1847; von Hauer, 1850; von Schauroth, 1859; von Richthofen, 1860; Benecke, 1868; Lepsius, 1878; Tommasi, 1895). Palaeontologic and stratigraphic research continued in the 20th century (e.g. Bittner, 1900; von Wittenburg, 1908; Ogilvie Gordon, 1927; Leonardi, 1935, 1960; Bosellini, 1964; Leonardi, 1967; Bosellini, 1968; Assereto et al., 1973; Mostler, 1982; Farabegoli and Viel, 1982; Broglio Loriga et al., 1983, 1986a; Broglio Loriga and Posenato, 1986; Neri and Posenato, 1985; Broglio Loriga et al., 1990; Perri, 1991) and culminated with tens of papers about the end Permian mass extinction and its recovery, which sometimes disregarded this historical heritage (e.g. Wignall and Hallam, 1992; Twitchett and Wignall, 1996; Kozur, 1998; Cirilli et al., 1998; Farabegoli and Perri, 1998; Twitchett, 1999; Scholger et al., 2000; Rampino et al., 2002; Perri and Farabegoli, 2003; Newton et al., 2004; Koeberl et al., 2004; Korte and Kozur, 2005; Fraiser et al., 2005; Sephton et al., 2005; Chen et al., 2006; Groves et al., 2007; Farabegoli et al., 2007; Gorjan et al., 2007).

The Werfen Fm is divided into 9 members (see references in Neri, 2007), whose distinction may be very complicated in the field due to their repetitive lithologies. Thus, the lithostratigraphic classification of this formation may be subjective and controversial, making problematical on occasion the use of bio-chronological schemes. The formation is biochronologically constrained (Fig. 1) only in its lower (Tesero and Mazzin members by means of conodonts) and upper (Val Badia and Cencenighe members by means of ammonoids and conodonts) parts (Broglio Loriga et al., 1983; 1986a, 1990; Perri, 1991; Perri and Farabegoli, 2003). These parts can be respectively referred to the Griesbachian and Spathian substages. In the middle part of the formation (Siusi, Gastropod Oolite and Campil members), conodonts and/or ammonoids of the Lower Triassic standard zones are lacking, so that its chronostratigraphic