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Latest Permian carbonate carbon isotope variability traces heterogeneous organic carbon accumulation and authigenic carbonate formation

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This Supplementary Information file contains information pertaining to the lithology, fossil assemblages and biostratigraphy of the studied sites.

1 Geological background

The P–Tr rock successions situated in Iran display an extremely uniform lithology that can be traced over wide distances and across separate crustal blocks, notably the NW Iran and Sanandaj-Sirjan Terranes, which belonged to the Cimmerian Micro-continents and were located in the vast semi-enclosed Tethys ocean (Leda et al., 2014; Ghaderi et al., 2014). The base of localities in NW Iran consist of grey to red shale with nodular limestone and marlstone intercalations with abundant fossils remains of brachiopod, rugose and tabulate corals. These beds comprise the Julfa Formation containing conodont elements which have been assigned to the *Clarkina leveni*, *C. trancaucasica* and *C. orientalis* biozones of Wuchiapingian age. With the latter biozone ranging into the next unit, the Ali Bashi Formation, which can subsequently be divided into two distinct units; with at the base a predominant calcareous shale unit with nodular limestone intercalations, known as the Zal Member, and higher-up a transition to predominant red nodular limestone with shale intercalations, known as the *Paratirolites* Limestone Member. In consecutive stratigraphic-order the following conodont zones are defined in this lithological succession; *C. subcarinata*, *C. chanxingensis*, *C. bachmanni*, *C. nodosa*, *C. yini*, *C. abadehensis* and *C. hauschkei* of Changhsingian age. The Julfa and Ali Bashi Formations record an overall deepening towards a sedimentary system that has been interpreted as pelagic (Ghaderi et al., 2014; Leda et al., 2014). This unit is followed by the Elikah Formation, consisting of a clay-dominated unit at the base that conformably overlies the *Paratirolites* Limestone, containing a conodont assemblages that has been divided into the *Hindeodus praeparvus - H.changxingensis* and *Merrillina ultima - Stepanovites ?mostleri* zones of terminal Permian age (Ghaderi et al., 2014). The base of this unit marks the marine extinction horizon expressed as a pronounced depletion in fossil remains (Leda et al., 2014; Kozur, 2007). The return of limestone beds is in most localities accompanied with the first occurrence of *H. parvus*, the marker of the basal Triassic system (Yin et al., 2001). Facies of the Elikah Formation have been interpreted to reflect continuous marine sedimentation, based on fossil assemblages of sponge remains, ostracod valves, occasional gastropod and incidental massive occurrences of pectin shells (*Claraia*) (Leda et al., 2014). Conodont zones described in this lithology comprise the *H. parvus* , *H. lobata*, *Isarcicella staeschei* and *I. isarcica* zones (Kozur, 2007; Schobben et al., 2015).

The youngest Permian limestone successions occurring in central Iranian share commonalities with those previously described for NW Iran but have a more compact thickness, and consist primarily of nodular limestone, lacking significant thick shale intercalations (Leda et al., 2014). Rich conodont assemblages, however, enable a direct correlation with time-equivalent rock cropping out in NW Iran (Ghaderi et al., 2014; Korte et al., 2004; Farshid et al., 2016). The Elikah Formation is as well present at these sites with a similar type of earliest Triassic (Induan) platy limestone unit on top of clay-dominated latest Permian unit (Leda et al., 2014) that comprise in successive order the *H. parvus* , *I. staeschei*, *I. isarcica*, *H. postparvus* and *Neospathodus dieneri* (Korte et al., 2004; Farshid et al., 2016).

The homogeneity of P–Tr sedimentary environments encountered over vast areas in Iran contrasts with deposits of contemporaneous age as found in China, which have been linked to various bathymetrical settings, e.g., shelf edge to near shore environments, shallow carbonate platforms and intra-cratonic basins (Cao et al., 2010; Yin et al., 2014). In this light, the exclusive selection of the Meishan section, located in the Zhejiang Province of South China, abolishes this bias introduced by lithological heterogeneity, whilst providing a good reference point, as an comparatively extensive suite of $\delta^{13}C_{carb}$ data has been published for this site. More so, this site is internationally recognized as the P–Tr Global Stratigraphic Section and Point (GSSP) (Yin et al., 2001). The lithological succession of the Meishan site comprises carbonate rock and calcareous shale that formed in an outer shelf environment on the northern marginal basin of the Yangtze Platform (Yin et al., 2014). On top of the Wuchiapingian-aged Lungtan Formation, fine-grained limestones, containing macro- and micro-fossil assemblages of ammonites, foraminifera and conodonts, have been described. The conodont assemblages uncovered in this unit are the *C. wangi*, *C. subcarinata* and part of the *C. changxingensis* zone (Cao et al., 2009). Continuing up-section into the next lithological distinct unit, more coarse grained bioclastic limestones have been encountered, yielding brachiopods and bivalves (Gruszczyński et al., 2003). Both units combined comprise the Changhsing Formation, which is subsequently overlain by a clay-rich unit that bears similarities with the latest Permian clay-rich unit, occurring in Iran (Yin et al., 2001). These transitional beds mark the main phase of the extinction at these localities (Yin et al., 2014), although a recent studies places this horizon 4 cm lower (Yuan et al., 2014, and Shen, S-z pers. com. 2014). A marked difference between the clay-rich intervals of Iran and China comprises the upper half of the unit, which is of volcanic origin (Yin et al., 2001). Together with the following sequence of shale, marl, marlstone and fine-grained limestone these lithologies comprise the Yinkeng Formation (Cao et al., 2010; Gruszczyński et al., 2003; Yin et al., 2012). At 24 cm above the formation boundary, elements belonging to *C. parvus* have been identified (Yuan et al., 2014), the *C. parvus* biozone is subsequently followed by the *I. staeschei* and *I. isarcica* zones (Yin et al., 2012; Yuan et al., 2014, and Shen, S-z pers. com. 2014). Where after, the *C. tulongensis-C. planata* and *S. kummeli* conclude the investigated section, marking the remainder of the Induan (Cao et al., 2009). In agreement with finds in Iran and other sites around the world, the Meishan locality records a deepening, starting at the mid Changhsingian transition and culminating in the Early Triassic beds (Hallam and Wignall, 1999; Yin et al., 2001). However, several higher-order sea-level changes have been interpreted at Meishan that seem to punctuate the sequence of Changhsingian to Induan-age, but with no definite signs of complete exposure above sealevel (Yin et al., 2001, 2014).

2 Biostratigraphy

In the past it has often been suggested that sedimentation gaps might exist in the lithological sequences of Iran or the Meishan type-section (see Fig. 2 of Korte et al., 2004), or that regional-distinct conodont populations existed in the Late Permian south Chinese basin. The latter pointing to a possible provincialism of conodont species and, hence, with these discrepancies in mind, some compromises have to be made to enable a global correlation (Shen and Mei, 2010). The Wuchiapingian-Changhsingian boundary, which is defined by the FAD of *C. wangi* (Jin et al., 2006; Mei et al., 2004), has not been detected in the NW Iranian rock successions, but most likely correlates with a transitional fauna at the base of the *C. subcarinata* zone (Ghaderi et al., 2014). More correlative discrepancies exist between Late Permian conodont assemblages of Iran and China, as the species *C. nodosa*, *C. abadehensis* and *C. hauschkei* have never been found in deposits belonging to the south Chinese microcontinent (Shen and Mei, 2010). However the latter two species are likely geographic clines of *C. meishanensis* and the former species as well as *C. bachmanni* are regional representatives of *C. yini*, thus enabling a correlation for China and Iran latest Changhsingian deposits (Ghaderi et al., 2014; Shen and Mei, 2010). The successive boundary clay of Iran and China seems to contain comparable conodont assemblages with abundant *H. changxingensis* at both regions and with sporadic encounters of *C. zhejiangensis* in the upper parts, suggesting the clay units, as a whole, to be correlative (Ghaderi et al., 2014; Yuan et al., 2014). Furthermore, the detailed Triassic subdivisions, as presented in Schobben et al. (2015), needs to be simplified to facilitate a comparison with study areas as in central Iran and China, and, as such we lump *H. lobata* and *I. staeschei* with *H. parvus* and *I. isarcica*, respectively (Korte et al., 2004; Cao et al., 2009). The remainders of the Induan stage at Iran and China have been subsequently divided in the time-equivalent *H. postparvus* and *Ns. dieneri*, in the Iranian setting, and *C. tulongensis-C. planata* and *S. kummeli* in the Chinese basin (Korte et al., 2004; Cao et al., 2009). Although this approach might not be as rigorous as, e.g., the biochronological method, as adopted by Brosse et al. (2016), the facies uniformity among sites in Iran and Meishan should exclude a strong control of local ecological conditions and selective preservation in the here-encountered conodont fossil assemblages. Whereas the inter-basinal comparison of Chinese and Iranian P–Tr biochronological frameworks might harbour a larger uncertainty.

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