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Discussion

Reply to discussion on the article "Remarks on the Permian-Triassic transition in Central and Eastern Lombardy (Southern Alps, Italy)" by G. Cassinis, M. Durand and A. Ronchi

Contestación a la discusión sobre el artículo "Apuntes sobre el tránsito Pérmico-Triásico en Lombardía central y oriental (Alpes Meridionales, Italia)" de G. Cassinis, M. Durand y A. Ronchi

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1. Introduction

As the authors point out in the introduction of the paper (Cassinis *et al*., 2007), this research aims at investigating the Permian–Triassic transition in central and eastern Lombardy, since previous knowledge has been limited by the lack of, or the discontinuous presence of, palaeontological records. In fact, in the investigated areas, the Upper Permian is made up of continental fluvial red clastics, devoid of fossils (Verrucano Lombardo), whereas the Lower Triassic is represented, mainly in the mid-upper part, by shallow-marine to lagoonal, richly fossiliferous deposits (Servino Formation) known, in the Venetian region, as the Werfen Formation. In contrast with the Lombardy areas, the Permian–Triassic Boundary (PTB) in this eastern South-Alpine sector, where the Mid–Upper Permian to Lower Triassic fossiliferous succession consists, in ascending order, of the continental Val Gardena Sandstone (laterally correlated to the Verrucano Lombardo) and the marine Bellerophon and Werfen Formations, has until now been the subject of much stratigraphical, palaeontological, geochemical and geomagnetic research, which led recently to constraining the age of the lowermost beds of the last formation, *i.e.* part of the famous oolitic 'Tesero member', to latest Permian (upper Changhsingian *p.p.*; Posenato, 2001). Thus, the Dolomite Alps appear to be devoid of a PTB unconformity, and this boundary is marked by the first appearance datum (FAD) of *Hindeodus parvus*, marker of the basal Triassic (Yin, 2000), after the recent ratification by the International Union of Geological Sciences (IUGS) of the Global Stratigraphic Section and Point (GSSP) at the base of Meishan section, southern China (Orchard, 2001). In the Tesero section, the first occurrence of this conodont is 11 m above the Bellerophon/Werfen boundary (Nicora and Perri, 1999), whereas in the Bulla section, near Ortisei, *Hi. parvus* seems to occur at a lower level, about 1.3 m above the base of Werfen Formation (Farabegoli and Perri, 1998).

From some selected Permo–Triassic sections, between the Dolomites and western Trentino, the opening westwards of a PTB gap probably took place in the Adige Valley or in nearby areas. In Val Rendena and the lower Giudicarie, as far as the Camonica Valley in the Brescian Alps, the lower oolitic 'Praso dolostone' of Servino, locally (such as in the Passo Valdì, Upper Val Caffaro) underlain by 3–4 m of fine clastic layers, rests paraconformably on the Verrucano Lombardo, both lacking in fossils. Across the Orobic Alps, the basal Prato Solaro Member of the Lower Triassic Servino and the underlying Verrucano Lombardo also appear devoid of biotic data.

In this context, Cassinis *et al.* (2007) decided to calibrate the magnitude of the PTB gap in the cited Lombardy areas, on the basis of local literature, correlation with other Southalpine and extra-alpine successions, as well as new field investigations. Thus, from the above geological framework, our paper should only have been interpreted as a contribution towards some still unsolved or difficult problems on the Permian–Triassic transition of Lombardy, rather than a topic of harsh criticism for the authors promoting this discussion.

2. Orobic Alps (Central Lombardy)

In Valsassina, on the eastern side of Lake Como, Cassinis *et al.* (2007) reported for the first time from the Prato Solaro Member of the basal Servino the presence of 'ventifacts' (Evans, 1911), interpreted as wind-worn phenoclasts which testify to an arid climate in the depositional area just before the first Triassic transgression (Durand, 1972; Smith and Edwards, 1991; Durand, 2006). They are mainly quartz pebbles, having already acquired a certain roundness during fluvial transport, before being fashioned by aeolian sand-blasting (ridges and facets, pits). At Alpe d'Oro, where they assume a greater concentration, these phenoclasts were not greatly dispersed, indicating that their last reworking was of short duration. Such an interpretation is indicated everywhere by the good preservation of the secondary ridges and of the polarity expressed by smooth upper and rough lower faces. In the Orobic Alps, the discussed ventifacts were also found by Cassinis *et al.* in the Prato Solaro Member of other localities (such as in Val Muggiasca and Piani dell'Avaro), *i.e.* generally in the region between Lake Como and Brembana Valley. Therefore, it is surprising that these wind-worn lithoclasts passed unnoticed by some experts of sedimentary petrography, in several descriptions of the above-mentioned unit, also because the Prato Solaro Member includes near Parlasco, in Valsassina, its type section and other nearby reference sites (Sciunnach *et al*., 1996, 1999a, 1999b).

Undoubtedly, as already mentioned, the occurrence of ventifacts is in tune with arid conditions and, with no fossils in the continental successions, they can be interpreted not only as climatic indicators but are also potentially suitable, on account of their stratigraphic position and correlation with other known units, for indicating their presumed age. According to some recent literature (*e.g.* Durand, 2006; Bourquin *et al*., 2007), the 'ventifact event' of Prato Solaro has been considered coeval with the Volpriehausen Formation from the Middle Buntsandstein of the Germanic Basin, which was generally ascribed to the Smithian (Kozur and Bachmann, 2005) and/or slightly older times (*e.g.* Reitz, 1988; Fijałkowska-Mader, 1999). Magnetostratigraphic studies (Szurlies, 2004) concluded that the Volpriehausen Formation may be correlated to the late Dienerian–early Smithian interval. Consequently, according to this age assessment, in Spain (Castilian Branch and Minorca), SE France (Provence), Sardinia (Nurra) and Bulgaria (NW Prebalkan and Kraishte), where the presence of ventifacts and their potential value as indicators of an arid period has been emphasized by Durand (2006), this author maintains that, in our current state of knowledge, this dry climatic regime generally started from the late Induan to early Olenekian.

Therefore, from the above broad stratigraphic framework, the basal Prato Solaro Member of the Lower Triassic Servino in central Lombardy was related by Cassinis *et al.* (2007) to a late Dienerian–early Smithian interval, as clearly shown in figure 7 of their paper, but not excluding an older age (early Dienerian down to Griesbachian times) as indicated by the arrows set immediately below the small stratigraphic columms of the analysed sections. Such a graphical device, which is very common in geological schemes, points to a possible chronostratigraphical alternative for the investigated successions. In this context, Cassinis *et al.* cannot comprehend how the authors from Ferrara and Milano, who instigated the present reply, have misunderstood this simple and efficacious way for suggesting another plausible age-interpretation. However, there is a possibility that this misunderstanding is essentially based on the following reasons.

As is well known (*e.g.* Dallagiovanna *et al*., 1987; Gaetani *et al*., 1987; Sciunnach *et al*., 1996, 1999a; Sciunnach, 2007; Cassinis *et al*., 2007), the Prato Solaro Member of the basal Lower Triassic Servino in the Orobic Anticline rests unconformably on the Upper Permian Verrucano Lombardo. Towards the west, in Valsassina, it is capped (about 8 m above the base of the Servino) by many specimens of the bivalve *Claraia*, which led Posenato *et al*. (1996) to relate the first Triassic marine transgression in this area to an age presumably ranging, by correlation of these fossils with those found in the Dolomites (Siusi member) and other areas worldwide, from the latest Griesbachian to the early Dienerian. The majority of the specimens from these *Claraia* beds, which crop out 5 km SE of the Prato Solaro Member type section, in the lower part of the overlying Ca' San Marco member, have been referred to *C. intermedia* (Bittner). Other morpho-species, such as *C. radialis* (Leonardi), *C. tesidea* (Leonardi), *C.* cf. *bittneri* (Ichikawa), *C.* cf. *clarai* and *C.* cf. *aurita* (Hauer), could also be recognized. These bivalves, again according to Posenato *et al.* (1996, p. 208), 'do not yield any of the index species of the Dolomites, and thus only an indirect correlation is possible' with this region. Their age was also estimated on the basis of correlations with Iranian sequences (Posenato *et al*., 1996, p. 209). Moreover, as reported from Cassinis *et al*. (2007, p. 153), *Claraia* can display a very high genetic plasticity (Broglio Loriga *et al*., 1983, in Posenato *et al*., 1996, p. 206) and is also clearly facies-dependent, proliferating in stressful, mainly dysaerobic, settings (Wignall and Hallam, 1992; Twitchett and Wignall, 1996).

In this context we also point out that Yin, in the earliest paper (1985, p. 591) based on past literature, distinguished only two *Claraia* zones useful at the global scale within the Early Triassic, among which the second (*Claraia aurita - C. stachei - Eumorphotis multiformis* Zone), yielding *Claraia intermedia*, ranges from the latest Griesbachian up to early Smithian. Later, however, Yin (1990, p. 105) specifically assigned the Alpine 'Siusi beds', with *Claraia*, to Dienerian times. Finally, in a written communication sent in February 2008 to the senior author of this reply, Yin also shared the impression that the range of the *Claraia intermedia* group is 'not so index or so restricted in a certain age' and 'its regional range such as in western Mediterranean should be more accurately delineated by regional biostratigraphic correlation'. Moreover, from a review of the South-Alpine literature, Yin believes that the *Claraia* assemblage displayed by Posenato *et al*. in Valsassina and related to a latest Griesbachian–early Dienerian interval may be Dienerian in age.

To sum up, in the light of the above considerations, the discussed *Claraia* temporal range of the western Orobic Alps seems substantially similar to our former interpretation, *i.e*. mainly Dienerian in age. In spite of this, because of explaining the presence in the underlying Prato Solaro Member of ventifacts potentially spanning from Griesbachian to Smithian but generally related to the latter times, we felt constrained to invoke that this stratigraphic problem still deserves further study in central Lombardy (Cassinis *et al*., 2007, p. 153). Evidently, Posenato *et al*. (1996) have not taken into account these new perspectives and the geological complexity of the investigated area, which is a prelude on the western side of Lake Como to a rather radical change in the Permian and Triassic succession (Lehner, 1952; Bertotti, 1991; Sciunnach *et al*., 1996), due to marked syn-sedimentary tectonics.

In any case, if the first appearance of the *Claraia* assemblage in the Orobic Alps placed at the latest Griesbachian is correct, we share the attribution of Posenato *et al*. (1996) to their advanced chronostratigraphical range, *i.e.* to a latest Griesbachian–early Dienerian interval, but with due reservations derived from the discussion above. Thus, the letters sent by Posenato (19 September and 16 October 2007) about the intention of the current authors to demolish part of a well-affirmed bio-chronostratigraphical scale of the South-Alpine Lower Triassic, restated in a published wider reply, appear unreasonable after the explanations already and presently given.

From the above discussion, the Prato Solaro Member of the basal Servino should thus be indirectly related, for its position underlying the *Claraia* beds, to slightly older Griesbachian times. According to Sciunnach *et al.* (1996, p. 32), occurrence of the Triassic bivalves *Neoschizodus laevigatus* (Goldfuss) and *Unionites canalensis* (Catullo), found by Merla (1933) at the base of the formation, indicate an early to mid-Griesbachian age. This attribution seems risky and in any case premature. The still-debated age of these fossils (Cassinis *et al*., 2007, p. 153), the as-yet undefined gap between the Prato Solaro Member of the Servino Formation and the Verrucano Lombardo, as well as the stratigraphic position of the former unit which crops out below the *Claraia* Horizon, lead us to suggest that the Prato Solaro Member could be better related to a middle–late Griesbachian interval. In this regard, we also point out that towards the east, from the Lower Triassic succession of some Dolomitic areas to at least Cadore, part of the above interval, underlying the Siusi member, was favourable to the deposition of the supratidal evaporitic facies of the Andraz member, which ranges from 20–25 m in thickness (Broglio Loriga *et al*., 1983; Twitchett and Wignall, 1996). As suggested by Posenato *et al.* in their reply, the ventifacts found in the lowermost beds of the Prato Solaro Member could have originated from this dry climatic regime. In the same context, Posenato *et al.* also point out the occurrence of an arid episode in the Calvörde Formation of North Germany, which was correlated to the Andraz member of the Dolomites (Kozur,

1989) and is probably coeval with the middle part of the Induan Vokhmian sub-stage of Russia (Lozovsky, pers. comm.). However, in any of the various studied basins of Europe it has not been possible to distinguish the existence of two separate 'ventifact events' in the Lower Triassic. On the other hand, all the formations related to a frankly arid climate would seem to occupy the same position in the general sedimentological evolution of this series. Thus, a careful consideration of their synchronism should not be interpreted as a very hazardous hypothesis (Bourquin *et al*., 2007). Furthermore, it is appropriate to remark that the evaporites do not necessarily indicate a strictly arid climate. A semi-arid regime would be sufficient for their deposition in playas and coastal sabkha areas. An excellent Triassic example is provided by the evaporitic episode of the Germanic Röt (much more developed than that of the uppermost Calvörde Fm., considered equivalent of the Andraz member), which passes laterally, in the north-east of France, to continental siliciclastic deposits: "Couches intermédiaires" (Bourquin *et al*., 2006), where the presence of palaeosols with caliche is not uncommon, but where the rare wind-worn pebbles (broken, corroded and/or coated with chalcedony) clearly testify to older reworked deposits. From the above it is clear that the potential European correlations deserve further research. Also, the lack of the Andraz member, west of Val d'Adige, should be carefully verified for a more reliable interpretation of the Permian–Triassic transition.

3. Brescian Alps, South of the Adamello Alpine intrusion (Eastern Lombardy)

In this area, the investigated stratigraphic sections of the Lower Triassic Servino Formation have not been a subject of discussion by Posenato *et al*. (this volume). They show lithological successions which generally represent the topic of research carried out in recent decades by Cassinis (1968), Cassinis *et al.* (1990, 1993), Twitchett (1998), De Donatis and Falletti (1999), Sciunnach *et al*. (1999a), Sciunnach (2007), and Cassinis and Perotti (2007). In our discussed paper (Cassinis *et al*., 2007), some selected sections (such as in the Val Fontanelle, Upper Val Trompia and in the Passo di Croce Domini-Passo Valdì areas, located around the southern border of the Adamello massif) show, beneath the famous Gastropod member of the literature (Lepsius, 1878; and so on), the presence of grey micritic limestones, yielding a marly-siltstone matrix, probably correlatable with the Siusi member of the Werfen Formation, cropping out in the eastern Southern Alps. Along the road section SW of M. Rondenino, Twitchett (1998) confirmed the attribution of these strata to the Siusi member, pointing to the presence of *Diplocraterion*, *Palaeophycus triadica*, *Planolites*, *Skolithos* and of bivalve layers, containing pelecypods which are probably *Claraia*. Later, in Val Fontanelle, a grey to bluish well-bedded unit, with marls, siltstones, thin sandstones and dolomitic calcarenites, yielding *Claraia aurita* (Hauer) and foraminifers of the *Recto-cornuspira-Cyclogira* group, was reported from the left side of the river. As attested in our paper (Cassinis *et al*., 2007, p. 149), 'these strata may be interpreted, according to Neri (*in* Cassinis *et al*., 1990), as a lithostratigraphic equivalent of the Siusi member in the Werfen Formation of the Dolomites, and thus ascribed to a latest Griesbachian–early Dienerian age'. Thus, the authors of this reply clearly applied in the Brescian Alps, where possible, the bio-chronostratigraphic range of the *Claraia* assemblage followed by Posenato *et al*. (1996) in the central Southern Alps. The charges against us, doubting our capability as stratigraphers, were clearly unjustified and not at all proper.

Below the lower part of the Servino, perhaps through an erosional surface, locally there exists wave- and current-rippled fine clastics, 3–4 m thick, which are overlain by metre-thick layers of yellowish oolitic dolostones alternating with siltstones, practically continuous from the lower Camonica Valley to the western Trentino. This oolitic unit (improperly named, for its composition, the 'Praso limestone') could laterally correlate towards the east, in the western South-Alpine segment, with the famous oolitic Tesero member at the base of the Werfen Formation of the Dolomitic and Carnic Alps (Cassinis *et al*., 1993, 2007; Cassinis and Perotti, 2007). In the Brescia region, the 'Praso limestone', which is of as-yet-uncertain duration but could be ascribed for its pre-*Claraia* position to slightly older Griesbachian times, rests paraconformably on the Upper Permian Verrucano Lombardo. It seals a hiatus probably shorter than that seen in the western Orobic Anticlinale, possibly estimated at about 3–4 Ma.

Furthermore, in our opinion, the PTB gap of Central and Eastern Lombardy should be interpreted from the varying stratigraphic successions as discontinuous in time and space, generally spanning the latest Permian (top of Lopingian) and an as-yet undefined part of the Early Triassic.

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