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Interpretation of "fungal spikes" in Permian-Triassic Boundary sections

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Key words: Permian/Triassic extinction event; "fungal event"; "fungal spike"; *Reduviasporonites*; recent contamination

Abstract

Abundant occurrences of the palynomorph *Reduviasporonites* have been described as "fungal spike" from several Permian/Triassic boundary sections and related to the supposed destruction of woody vegetation by fungal pathogens during the Permian/Triassic extinction event. The biological affinity of this taxa considered by some authors of fungal origin is still controversially discussed since there is geochemical evidence that it is most probably related to algae. The abundance peak of this species is used by some authors as a stratigraphic marker, notably in terrestrial Permian/Triassic boundary sections from South China. Illustrations of the reported fungal remains however show potentially erroneous taxonomic identification of *Reduviasporonites*, and, based on differences in thermal maturation, they may represent recent contamination. Here Reduviasporonites *chalastus* of Early Triassic age is illustrated together with recent fungal remains originating from a strongly weathered and otherwise barren sample from a Middle Triassic section.

1. Introduction

Based on the abundance of the palynomorph *Reduviasporonites* Eshet et al. (1995) and Visscher et al. (1996) defined a so-called "fungal event" or "fungal spike", which they related to the Permian/Triassic extinction event (PTEE) and to a "collapse of terrestrial ecosystems". Visscher et al. (1996, p. 2155) associated *Reduviasporonites* to a saprophytic metabolizer of dead vegetation and postulated that in the latest Permian there is an *"unparalleled abundances of fungal remains, irrespective of depositional environment (marine, lacustrine, fluviatile), floral provinciality, and climatic zonation"*. However, the biological affinity and the ecological implications of the occurrence of *Reduviasporonites* are far from being elucidated. Whereas some authors attributed it to fungi, saprophytic fungi or even plant pathogenic fungi (Visscher et al. 1996; Visscher et al., 2011), others , based on its morphological features and isotopic composition, assigned it to algae (Afonin et al. 2001; Foster et al. 2002; Spina et al. 2015). Based on extensive geochemical studies Sephton et al. (2009, p. 877) concluded **"***consequently, use of Reduviasporonites as a fungal marker of terrestrial ecosystem collapse should not be merely discounted. In the absence of sufficient chemical criteria, however, fuller understanding of the biological and ecological identity of the organic microfossils, particularly in light of the end-Permian environmental crisis, awaits more intensified morphological comparisons with potential counterparts among modern categories of filamentous fungi and algae."* Based on the same evidence presented by Sephton et al. (2009) Cui et al. (2016) stated that *"geochemical and isotopic signatures indicate that Reduviasporonites are indeed fungi instead of green algae"*. Searching for additional evidence for the fungal affinity of *Reduviasporonites* Visscher et al. (2011) suggested an affinity to recent *Rhizoctonia,* a saprophytic or facultative pathogenic group of fungi, which shows a superficial resemblance to *Reduviasporonites* (see also Figure 1C). In their recent review of structurally preserved fungi from Antarctica and their interaction in Late Palaeozoic and Mesozoic forests Harper et al. (2016) mentioned previous records of *Reduviasporonites* on Antarctica and stressed the fact that the asserters of the "fungal event" dismissed the geochemical evidence published by Foster et al. (2002), who attributed *Reduviasporonites* to green algae.

However, high abundance of *Reduviasporonites* are comparative rare, widely dispersed and occur at various stratigraphic levels. Beside the controversy of the biological affinity the occurrence of "fungal remains" in terrestrial Permian/Triassic sections has been used as a stratigraphic marker (e.g., Peng et al. 2005; Steiner et al. 2003). Most recently Bercovici et al. (2015) and Cui et al. (2016) described the "fungal event" from four Permian–Triassic boundary sections from South China representing a terrestrial to marine transitional setting. Bercovici and Vajda (this issue) elaborate on the palynoflora from P-T sections in China arguing for their in situ nature. It is argued here that specimens illustrated in these papers as misidentified as *Reduviasporonites* and instead may represent evidence for contamination with recent fungal remains taken for the Permian/Triassic "fugal event".

2. *Reduviasporonites* – morphology and stratigraphic range

Morphologically reviewed by Foster et al. (2002), *Reduviasporonites* is commonly found as straight or branched chains of cells or as single dispersed cells of sub-circular or sub-rectangular shape. Most cells contain an inner body of similar shape. The joints of cells in the chain and the ends of the dispersed cells are broad and thickened. Thickness of the cell-wall varies between 1 and 2μm. The size of the species normally found in the PTB intervals (*Reduviasporonites chalastus* (Foster) Elsik 1999)) is over 50μm. Based on the shape of the individual cells Foster et al. (2002) differentiated two different species - *Reduviasporonites* *chalastus* (Foster) Elsik 1999 and *R. catenulatus* Wilson 1962. *R. chalastus* regularly occurs in Late Permian and earliest Triassic sections. The genus *Reduviasporonites* ranges from Late Permian up to the Induan. *R. chalastus* occurs regularly from the Changhsingian up to the top of the Induan (Spina et al., 2015 and Hochuli, personal observations). Occasional occurrences in the higher part of the Early Triassic of the Barents Sea area have been considered reworked (Vigran et al. 2014). This species has been reported as abundant or predominant in several worldwide distributed areas (e.g., Israel (Yamin Fm.; Eshet et al. 1995) Southern Alps (Bellerophon Fm. and base of the Werfen Fm.; Spina et al. 2015), South Africa (Karoo Supergroup; Steiner et al. 2003), and Antarctica (Vajda & McLoughlin, 2007). However, the stratigraphic position of some of these abundance spikes such as the one in the Karoo Supergroup (Steiner et al. 2003) is most probably unrelated to Permian/Triassic boundary event (Ward et al. 2005). In more expanded records *Reduviasporonites* occurs regularly without showing an abundance peak across the Permian/Triassic boundary such as in the Norwegian Barents Sea and on Svalbard (Hochuli et al. 2010; Mangerud, 1994; Vigran et al. 2014) as well as in East Greenland (Looy et al., 2001) or Australian sections (Foster, 1979). Mangerud (1994, plate 7-F) and Foster et al. (2002) documented excellently preserved specimens showing the relatively massive two-layered wall. A wide range of morphologies has been illustrated under http://www.bgs.ac.uk/taxonomy/reduviasporonites.

The samples supposedly representing the “fungal event” in South China as documented by Bercovici et al. (2015) contain diverse assemblages of fungal remains. The palynomorphs illustrated by Bercovici et al. (2015, fig.9) show distinct differences in preservation between the fungal remains and the sporomorphs. In fresh (recent) material chitinous fungal remains are generally characterised by brownish colouration contrasting clearly with the pale yellowish colour of pollen. Fungal spores showing the same thermal maturation as the pollen grains figured by Bercovici et al. (2015, fig. 9. 30-32) should be almost or completely black. The diverse fungal remains include spores, hyphae, and reproductive structures. Moreover, in one spore remains of the cell content are recognisable (fig.9, 48). Similarly diverse associations of fungal remains have never been reported from Permian/Triassic boundary section and have nothing in common with the "fungal event" described by Eshet et al. (1995) or Visscher et al. (1996).

3. Comments on the assumed "fungal spike" in Permian/Triassic boundary sections in South China

Publishing isotope records from the same sections Cui et al. (2016) stated that *"The successions at the top of the Xuanwei Formation host fungal spores, including Reduviasporonites (Bercovici et al., 2015)."* In their figure 2 these authors reproduce pictures from the paper of Bercovici et al. (2015) showing three fundamentally different fungal remains, which they attribute to *Reduviasporonites.* Two forms from the Jiucaichon section represent a series of coupled, small, rounded cells, which are connected to hyphae. Hyphae have never been mentioned in connection with *Reduviasporonites*; shape and size are also entirely different. The illustrated forms probably represent reproductive structures of fungi. The cell illustrated from the Mide section (Cui et al. 2016, figure 2) superficially resembles *Reduviasporonites*; however, it differs in its spindle-like shape, in its thin, highly translucent wall, and it lacks the inner body.

Assemblages of fungal remains identical to those published by Bercovici et al. (2016) are commonly found in strongly weathered surface samples – representing fungal growth in degraded sediments. Figure 1 A, B, C and E illustrate extant fungal remains from weathered, otherwise barren surface samples from the Middle Triassic Mels Formation of the Alps. The forms shown in Figure 1 A and B are similar to the specimen determined as *Reduviasporonites* spp. by Bercovici et al. (2015) and Cui et al. (2016), whereas the specimens shown in Figure 1 C and E resemble at first glance *Reduviasporonites,* and are superficially similar to the specimens compared to *Rhizoctonia* aff. *solani* shown by Visscher et al. (2011, fig. 1A and B). However, the illustrated specimens as well as the forms shown by Visscher et al. (2011) differ by the thickness and structure of their walls and lack inner bodies. For comparison *Reduviasporonites chalastus* (Foster) Elsik 1999 - originating from the Early Triassic Wordie Creek Formation of East Greenland - is shown in Figure 1 D and F.

4. Conclusion

Evidence for the “fungal event” related to the PTEE has to be challenged due to the questionable fungal affinity of *Reduviasporonites,* the key witness of this event, and due to the fact that similar abundance peaks seem to occur at various stratigraphic levels. Assessment of assemblages of fungal remains from South China, recently attributed to the Permian/Triassic “fungal event” by Bercovici et al. (2015) and Cui et al. (2016), leads to the conclusion that they represent recent contamination.

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Figure 1

***Reduviasporonites* und recent fungal remains**

A Fungal remain – reproductive structure connected to hyphae – representing recent contamination in strongly weathered, otherwise barren sample from the Middle Triassic, Mels Formation, Swiss Alps, Canton of Glarus; Locality: Obersand, sample, PL 5 (coordinates: 46° 49' 28" N; 8° 54' 12" E). This specimen is similar to the forms illustrated as *Reduviasporonites* spp. by Cui et al. (fig. 2).

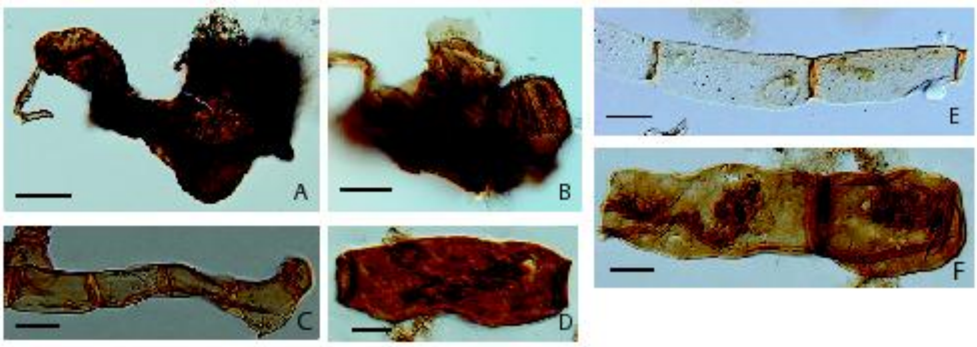
B as above; sample Planura, PL 5.

C Fugal remain, resembling *Reduviasporonites* sp. but with different wall structure representing recent contamination in a strongly weathered, otherwise barren sample; Locality: Obersand, sample, PL3.

D *Reduviasporonites chalastus* (Foster) Elsik 1999 (syn. *Tympanicysta chalasta* Balme 1979, described from Kap Stosch) from the Early Triassic Wordie Creek Formation, Kap Stosch, NE-Greenland; sample BRW 42 (coordinates: 73° 59' 58.5" N; 21° 24' 58" W).

E as C; sample Planura, PL 5

F *Reduviasporonites chalastus*, Wordie Creek Formation, Kap Stosch; sample BRW 28.



Highlights

- „Fungal spikes“, associated with the PTB event, are controversially discussed
- *Reduviasporonites* - key witness of this event - is probably of algal origin
- Erroneously determined *Reduviasporonites* probably represent recent contamination