Do megaspores of Otynisporites have a stratigraphic value for the correlation of Permian-Triassic deposits?

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Introduction

Dispersed megaspores of the genus *Otynisporites* (Fuglewicz) Karasev et Turnau, 2015 have been known to scientists since 1977, when Richard Fuglewicz (1977) published a study of megaspore assemblages from Upper Permian and Lower Triassic sediments of the Baltic Formation in the Polish part of the Central European Basin system (CEBs).

Fuglewicz (1980) defined the zone of *O. eotriassicus* in the Polish part of the CEBs. The zone was introduced after analysing the distribution of dispersed megaspore assemblages from five boreholes in the Fore-Sudetic Monocline and is best represented in Otyn IG 1 borehole in the depth interval 793.0–956.0 m. The base of the zone is defined by the first occurrence of *O. eotriassicus*. Ostracods, phyllopods, and hystrichospheres were also found in this interval (Mojski et al., 1986). The age of the zone ranges from the latest Changhsingian to the earliest Olenekian (Foster and Afonin, 2005; Kozur, 1998; Looy, 2000; Twitchett et al., 2001; Marcinkiewicz et al., 2014). The genus *Otynisporites* enumerates three more species, which have been reported from several basins all over the world (Fig. 1). Their possible stratigraphic value is still to be assessed.

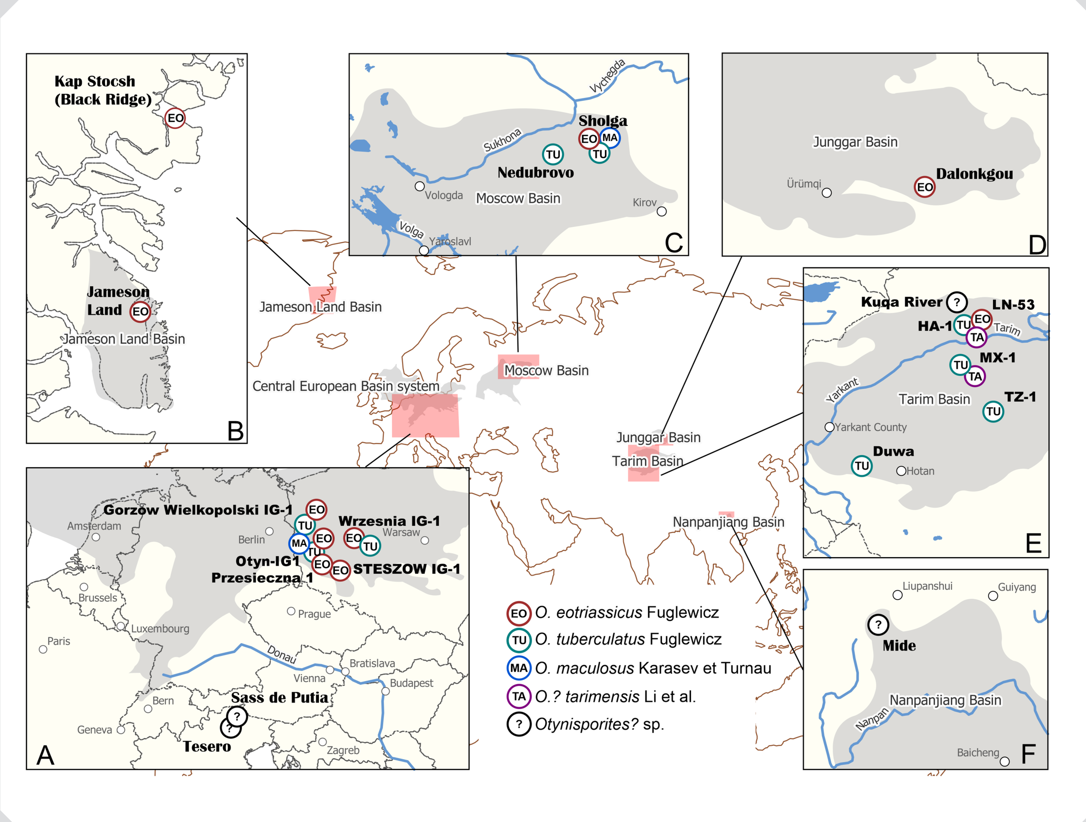

Fig. 1. Geographical range of *Otynisporites*. A. Central European Basin system (CEBs) including Polish and German parts and the Bellerophon Basin (BB) in the Italian part. B. East Greenland basins (EG) including the Jameson Land basin and sections at Kap Stosch subbasin. C. Moscow Basin (MB). D. Junggar Basin (JB). E. Tarim Basin (TB). F. Nanpanjiang Basin (NB).

Notes on megaspore morphology

The spores are round trilete with an outer thick spongy layer and inner thin lamellated layer. They are unexpectedly variable in details of the sculpture and ultrastructure (Fig. 3). Megaspores of *Otynisporites?* sp. and *O.? tarimensis* differ from the other studied megaspores. They are larger (Fig. 4, 5), their surface pattern is formed by elevations of the background sporoderm surface rather than by agglomerations of solid sculptural elements on a sporoderm surface that has a different morphology compared to the agglomerations, and sporoderm is densely packed with elements without any gradient in size or direction depending on the distance from the sporoderm surface. *O. tuberculatus*, *O. maculosus* and *O. eotriassicus* possess compound sculptural elements which are morphologically distinct from the sporoderm surface (Fig. 3); the elements of the outer sporoderm layer become smaller inwardly and their orientation gradually changes from random to predominantly horizontal. The three last species vary significantly by the surface patterns and several features of their sporoderm ultrastructure; moreover, three morphological groups can be distinguished within *O. eotriassicus* (Fig. 3, 5). Among the differentiating features are the cavate/non-cavate state of the sporoderm, the composition of the inner layer (either only one or several lamellae), and the occurrence of multilamellated zones in the proximal portion of the inner sporoderm layer. The fact that multilamellated zones are present only in *O. tuberculatus* and (much less distinct) in *O. maculosus* leads to the necessity to re-evaluate the phylogenetic value of this character.

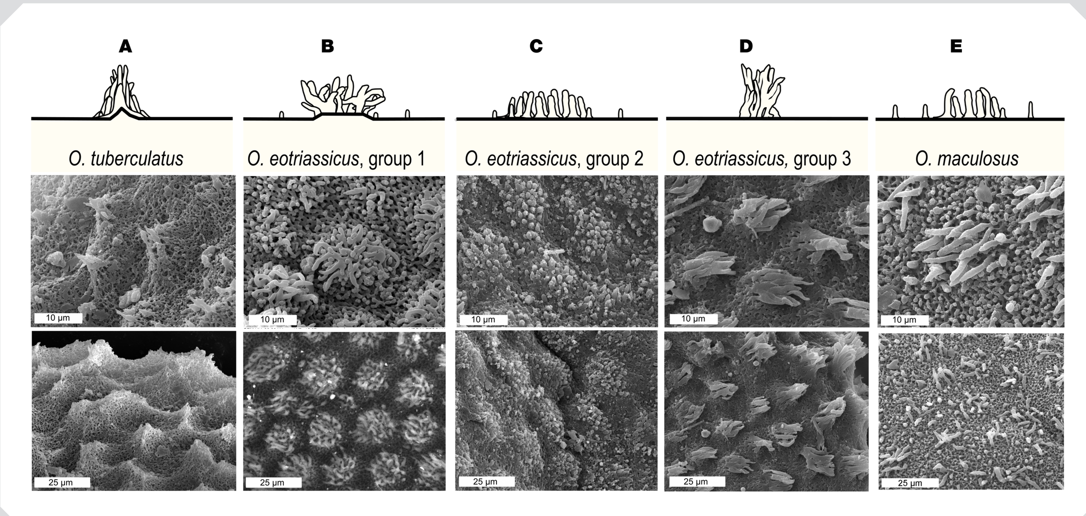

Fig 3. Surface patterns of species of *Otynisporites*. A. *O. tuberculatus*; B–D. *O. eotriassicus*; E. *O. maculosus*.

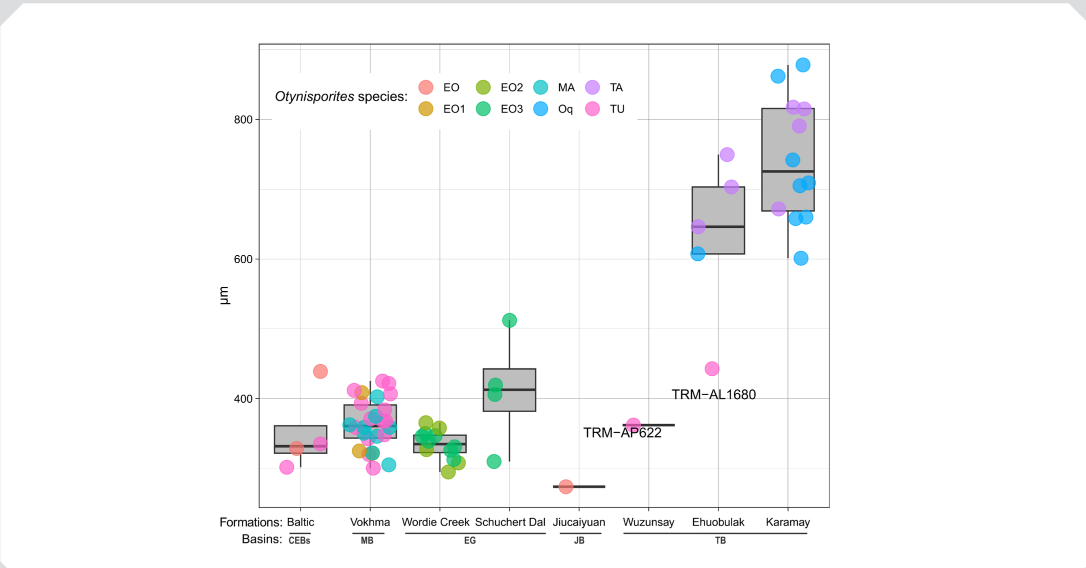

Fig. 4. Two size categories of megaspores species of *Otynisporites*: EO - *O. eotriassicus*, EO1 - *O. eotriassicus* group 1, EO2 - *O. eotriassicus* group 2, EO3 - *O. eotriassicus* group 3, MA - *O. maculosus*, TU - *O. tuberculatus*, TA - *O.? tarimensis*, Oq - *O.*? sp.

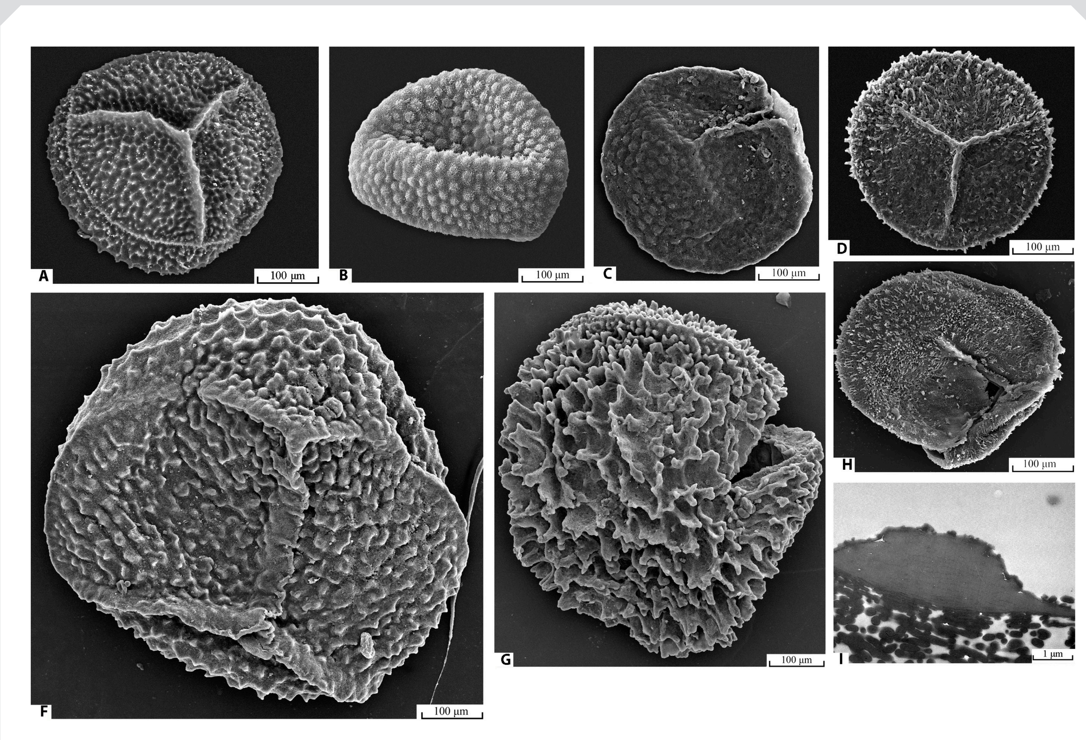

Fig. 5. Megaspores under SEM (A—H) and TEM (I). A. *O. tuberculatus*. B. *O. eotriassicus*, group 1. C. *O. eotriassicus*, group 2. D. *O. eotriassicus*, group 3. E. *O. maculosus*. F. *Otynisporites*? sp. H. *Otynisporites? tarimensis*. I. *O. tuberculatus*, multilamellated zone.

Results

Dispersed megaspores of *O. eotriassicus*, *O. tuberculatus*, and *O. maculosus* from the latest Changhsingian–early Induan of the Moscow Basin of Russia, *O. eotriassicus* from the Induan of the Kap Stosch subbasin of East Greenland, and *O.*? *tarimensis*, and *Otynisporites*? sp. from the Middle Triassic of the Tarim Basin of China (Fig. 2A) were studied using light, scanning and transmission electron microscopy. Megaspores of *Otynisporites*? sp. and *O.*? *tarimensis* differ from the other studied megaspores and were produced by a different heterosporous lycopsid than megaspores of the other species and should be excluded from the genus.

The geographic distribution shows that *Otynisporites*-producing plants grew under a moderately warm climate, in the middle latitudes (Fig. 2B).

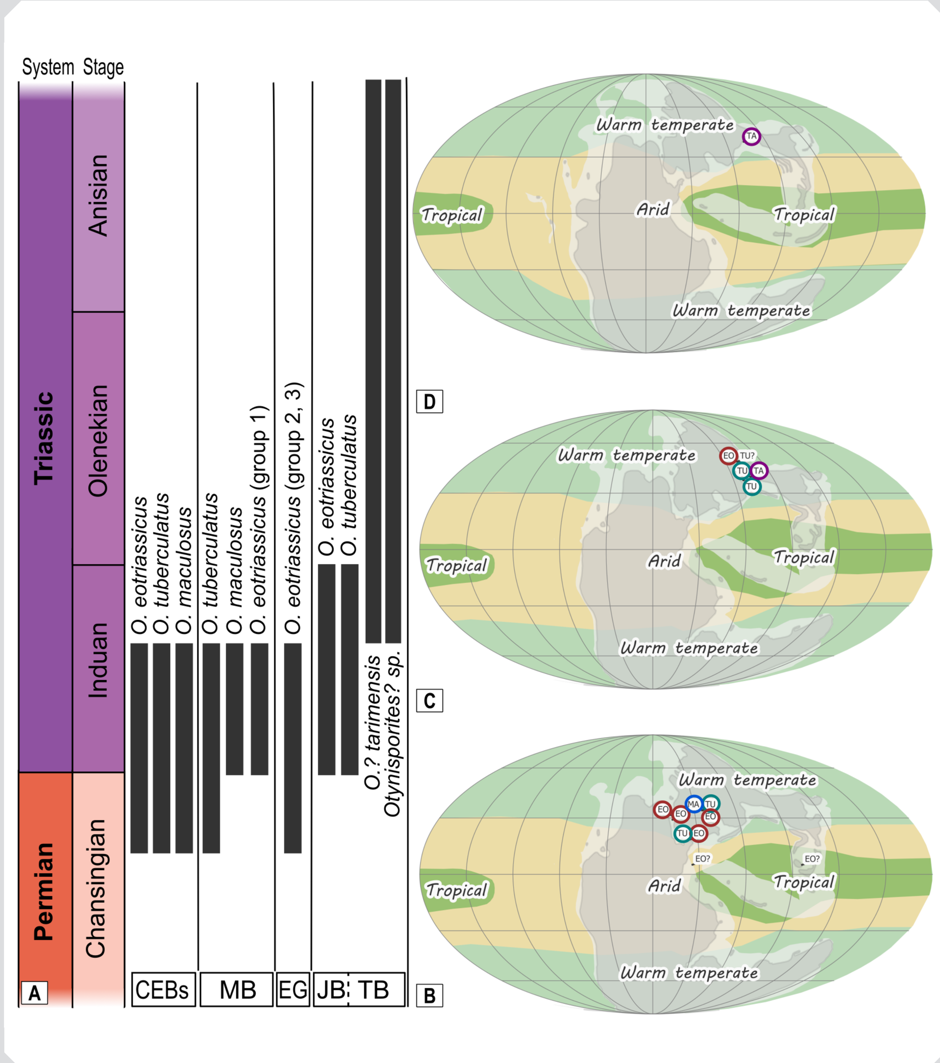

Fig 2. A. Stratigraphic range of the *Otynisporites* species in the sedimentary basins: the Central European Basin system (CEBs), East Greenland basins (EG), Moscow Basin (MB), Junggar Basin (JB), and Tarim Basin (TB). B–D. Paleogeographic map with distribution of *Otynisporites* species for latest Changhsingian (B), late Induan–Olenekian (C) and Anisian (D) stages. Mapping paleocoastlines according to Kocsis and Scotese (2021); paleo-Köppen climate zones according to Boucot et al. (2013).

Conclusion

Our analysis of morphology, stratigraphic and geographic ranges of earlier reports of *Otynisporites* show that confirmed findings are confined to the latest Changhsingian–Induan, with *O. tuberculatus* and *O. maculosus* sharing the same stratigraphic range as *O. eotriassicus*. Megaspores reported from younger deposits most probably do not belong to *Otynisporites* (Li et al., 2021), as our morphological analysis shows, and, therefore, the stratigraphic range of *O. eotriassicus* remain narrow. In addition, as *O. tuberculatus* and *O. maculosus* occur in deposits of the same age as *O. eotriassicus*, they are potentially useful as stratigraphic markers.

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