

A specialized feeding habit of Early Permian oribatid mites



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ABSTRACT

Oribatid mites (Acari: Oribatida) are very diverse and important detritivorous and fungivorous micro-arthropods in modern forest ecosystems. Although the fossil record of oribatid mites can be traced to the Early Devonian, the paleoecology of oribatid mites during the deep geological past remains poorly understood. Remarkably good preservation of tunnel networks in a permineralized conifer wood specimen is described from the Early Permian of Germany. This fossil provides evidence for four aspects of oribatid mite feeding habits. First, there is preferred consumption of the more indurated tissues from growth-ring cycles. Second, tracheids were targeted for consumption. Third, feeding on tissues resulted in fecal pellet accumulations at the bottoms of tunnels. And fourth, the absence of feeding on ambient decomposing fungi such as necroses and rots, but rather the processing of pristine plant tissues, indicate the presence of a self-contained, microorganismic gut biota. These rather specialized feeding habits allowed oribatid mites a prominent role in the decomposition of digestively refractory plant tissues in Early Permian ecosystems.

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1. Introduction

Oribatid mites (Acari: Oribatida) are a very diverse group of small, detritivorous and fungivorous arthropods (Schatz and Behan-Pelletier, 2008; Walter and Proctor, 2013). They are a dominant component of the microarthropod fauna in most forest ecosystems (Behan-Pelletier et al., 2008), and are speciose and numerically dominant in temperate forest canopies (Behan-Pelletier and Walter, 2000). Body-fossil records indicate that oribatid mites were present during the expansion of Early Devonian terrestrial ecosystems some 410 million years ago (Norton et al., 1988), but little is known of their paleoecological history (Labandeira, 1998, 2007). Oribatid mite borings and their typically co-occurring coprolites are observed worldwide in Late Paleozoic silica permineralized or petrified woods, as well as in plant tissues preserved in chert or carbonate permineralized coal balls (Labandeira et al., 1997; Rößler, 2000), and consequently provide a basis for understanding their relationships to their abiotic and biotic environments. Although coprolite dimensions within tunneled tissues have been used to determine fossil oribatid mite morphotypes (Feng et al., 2010, 2012), their feeding habits, including detritivory, are poorly understood.

Here, we describe distinctive oribatid mite borings contained in a specimen of exceptionally well-preserved conifer wood from the Early Permian Manebach Formation near Crock village, in Thuringia State, Germany. The borings are rectangular or sub-rectangular in transverse section, with smooth interior walls filled with small, ovoidal to sub-spheroidal coprolites. The borings occur amid tracheid elements and are bordered by rays, indicating that the mites preferred to feed on lignified cells and avoided fleshier parenchymatous cells.

2. Material and methods

A permineralized wood specimen containing three-dimensional networks of borings with infilled coprolites was obtained from the Early Permian Manebach Formation of Crock, a small village located ca. 10 km southeast of Schleusingen, in the south of the Thuringia State, Germany.

Historically, there were several coal mines in Early Permian strata producing anthracite coal near Crock. Crock is the only known locality within the Thuringian Forest Basin providing lower ranked coals that would allow for maceration (Kerp and Barthel, 1993). Although there is a long history of fossil collection and paleobotanical research in the Thuringian Forest Basin (Barthel, 2009), formally mentioned fossil woods have been only occasionally reported. Recently, Witter et al. (2011) described in detail several new finds of fossil woods from Crock.

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The wood described from Crock is found in coarse-grained alluvial fan deposits that crop out on the surfaces of slopes of Irmelsberg Hill. These sediments from the southwestern part of the so-called Schleusingen marginal zone belong to the southernmost occurrence of the Rotliegend Group, consisting of Early to Middle Permian strata within the Thuringian Forest Basin. These wood-containing basal, alluvial-fan strata were overlain by coal-bearing, fine-grained clastic sequences that were assigned to the Manebach Formation. The stratigraphic level for the fossil wood locality is comparable with basal Rotliegend strata of Asselian age, and is located within the Manebach Formation sequence of the Thuringian Forest Basin (Lützner et al., 2012).

The Late Paleozoic continental succession of the Thuringian Forest Basin is 5–6 km thick and consists of eleven formations from the lowermost Stephanian C representing the Late Pennsylvanian, to the Upper Rotliegend of the Middle Permian (Lützner et al., 2012). Chert and fossil wood fragments commonly are encountered in the Early Permian Manebach Formation, which consists of gray conglomerates,

sandstones, mudstones and locally intercalated coal seams (Barthel et al., 2010).

Permineralized woods containing borings and coprolites collected from Crock were sectioned for detailed examination. Thin sections from transverse, tangential and radial planes of wood were prepared as follows. First, a specimen was sectioned to an appropriately thin wafer with a diamond saw, of which the upper surface was ground using a grinding wheel with carborundum grit in a decreasing series of #240, #400 and #800 grade sizes. The smooth upper surface was attached to a glass slide with Buehler EpoThin™ Epoxy Resin (20-8140-032) and EpoThin™ Epoxy Hardener (20-8142-016), and the exposed surface was subsequently ground to a thickness of 30–50 µm.

Photographs were taken with a Nikon Eclipse ME 600 transmitted light microscope and a Nikon SMZ 1500 stereoscopic light microscope. Images were taken on both microscopes, which were equipped with a Nikon DS-5M-L1 digital camera. Composite images were stitched

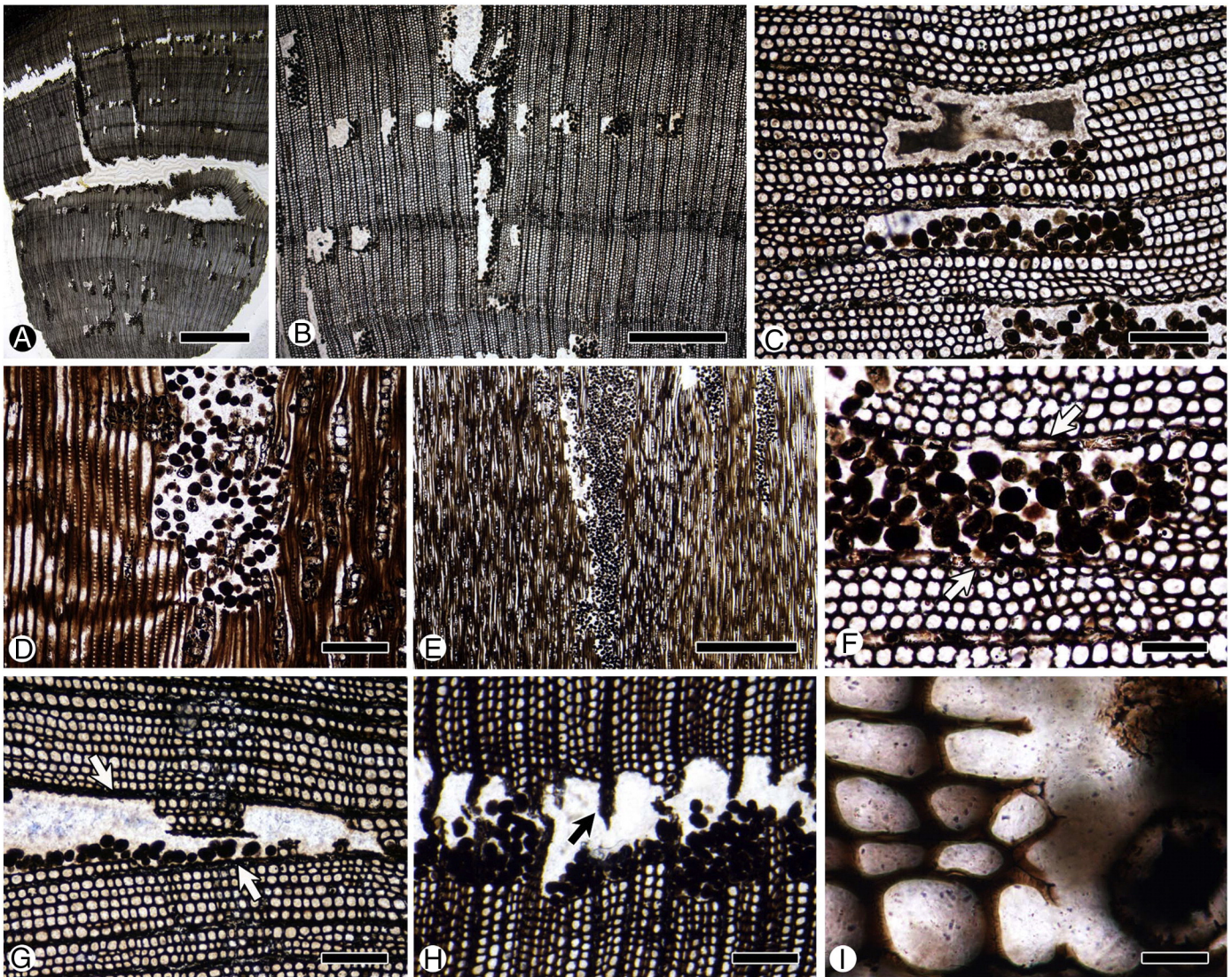


Fig. 1. Oribatid mite borings and coprolites preserved in gymnospermous wood from the Early Permian Manebach Formation, Germany. (A) – Transverse section (TS) showing the concentric arranged bands of borings in secondary xylem, scale bar = 3 mm. (B) – TS, borings restricted to growth rings, occasionally intersecting several growth rings, scale bar = 200 µm. (C) – TS, rectangular or sub-rectangular outlines of borings with effaced margins and right-angle wall junctures, scale bar = 200 µm. (D) – Longitudinal radial section, effaced inner-wall surfaces and truncated bottoms of the borings, scale bar = 200 µm. (E) – Longitudinal tangential section, borings vertically extend along the wood axis, scale bar = 1 mm. (F) – TS, borings bordered by ray cells; arrows indicate ray cells, scale bar = 100 µm. (G) – TS, long borings bordered by single rows of ray cells (arrows), scale bar = 200 µm. (H) – TS, discontinuous rays (arrow) locally projecting into an excavated area, scale bar = 200 µm. (I) – TS, displaying incompletely attacked tracheid elements at the tunnel edge and the succeeding undamaged tracheid elements with intact cell walls, scale bar = 25 µm.

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