First evidence of borings in calamitean stems and other plant-arthropod interactions from the late Pennsylvanian of the Saale Basin

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Abstract:

Hitherto, plant-arthropod interactions have been rarely reported from the late Pennsylvanian (Gzhelian, Stephanian C) of the Saale Basin (Saxony Anhalt, Germany). A re-examination of material from the collections of the Martin-Luther-University Halle-Wittenberg and private collections revealed the presence of different damage types on plants. Among them are at least three types of endo- and exophytic oviposition, the first evidence of borings in calamitean stems, margin feeding, and leaf mining.

Keywords: plant-arthropod interactions, Gzhelian, oviposition, boring, leaf feeding

Introduction

Since Germar (1844-1853) published his monographs about the fossils of the Wettin coal mines, the rich flora and fauna of the late Pennsylvanian of the Saale Basin has been subject of intensive research. Nevertheless, only a few plant-insect interactions have been described yet. Among them are approximately semicircular excisions of the leaf margins of *Odontopteris subcrenulata*, which were interpreted by Müller (1982) as leaf mines and described as *Cuniculonomous (Acrophionomus) undulatus*. Recently, this damage type is regarded as margin feeding and assigned to the ichnospecies *Phagophytichnus ekowskii* Van Amerom 1966 (see also damage type DT12 according to Labandeira et al. 2007).

Furthermore, Laass & Hoff (2014) reported the earliest record of damselfly-like endophytic oviposition in the fossil record from the Wettin Subformation of the Siebigerode Formation (see Fig. 1g).

As described in the following section, new observations on fossils from the Wettin Subformation revealed that the number of plant-arthropod interactions was higher than previously thought.

New plant-arthropod interactions from the Wettin Subformation

The palaeontological collections of the Martin Luther Universität Halle-Wittenberg are an important archive of fossils, particularly from Central Germany (Hauschke 2018). One of these collections houses palaeontological objects from the coal mine district of Plötz-Wettin-Löbejün (Saxony-Anhalt). E.F. Germar (1786-1853) was the first, who collected systematically fossil plants, invertebrates and vertebrates from the Wettin Subformation. A re-examination of this material brought to light new evidence of leaf feeding on Neurodontopteris auriculata (Brongniart) Potonié (Fig. 1a), which strongly resembles the ichnotaxon *Cuniculonomous (Acrophionomus) undulates* Müller (1982) on *Odontopteris subcrenulata*. In some cases, undulating leaf mines can be observed. This supports Müller´s interpretation of this ichnotaxon as leaf mines. In other cases, it cannot be excluded that some traces represent margin feeding (*Phagophytichnus ekowskii* Van Amerom, 1966). Typically, damaged leaf margins are thickened, which resulted from the growth reaction of tissue. On some leaves of the same species mines can be observed, which run parallel to the venation (Fig. 1c).

Borings in wood from the Carboniferous are well-known from gymnosperms and tree ferns (e.g. Cichan & Taylor 1982, Rössler & Fiedler 1996, Barthel, Krings & Rössler 2010). Hitherto unknown are borings in Calamite stems. In this paper two new types of this kind of plant-arthropod interaction are described (Fig. 1b, e). The first type is characterized by three-dimensionally preserved boring casts, which run almost parallel to the impressions of the vascular bundles (Fig. 1b). This suggests that these borings were situated in soft tissue of the pith cavity and/or in the region of the metaxylem of a young calamitean stem. Similar borings were described by Rössler & Fiedler (1996, Fig. 4: Type 2) in wood of the gymnosperm genus *Dadoxylon* from the Lower Permian of Chemnitz. Another type of borings in a calamitean stem is depicted in Fig. 1e. These borings form a three-dimensional meshwork consisting of straight to meandering canals, which often run nearly perpendicular (Fig. 1e:1), but sometimes also parallel to the vascular bundles (Fig. 1e:2). In some cases, the borings enter the pith cavity of the stem (Fig. 1e:3).

Fig. 1d shows the earliest evidence of possible insect egg masses attached on the surface of plant foliage (exophytic oviposition) (Laass & Hauschke 2019).

In contrast, Figs. 1f, g show examples of endophytic oviposition, i.e. the eggs were inserted by the insects with their ovipositors into plant tissue. This damage caused the growth of elliptical scars. In Fig. 1f the ovipositor slits of the scars are still visible. As shown in Fig. 1g the scars are often arranged in rows. A similar arrangement of the eggs can also be observed in some extant damselflies (Hellmund & Hellmund 1996).

These new results suggest complex relationships between plants and arthropods in late Pennsylvanian ecosystems.

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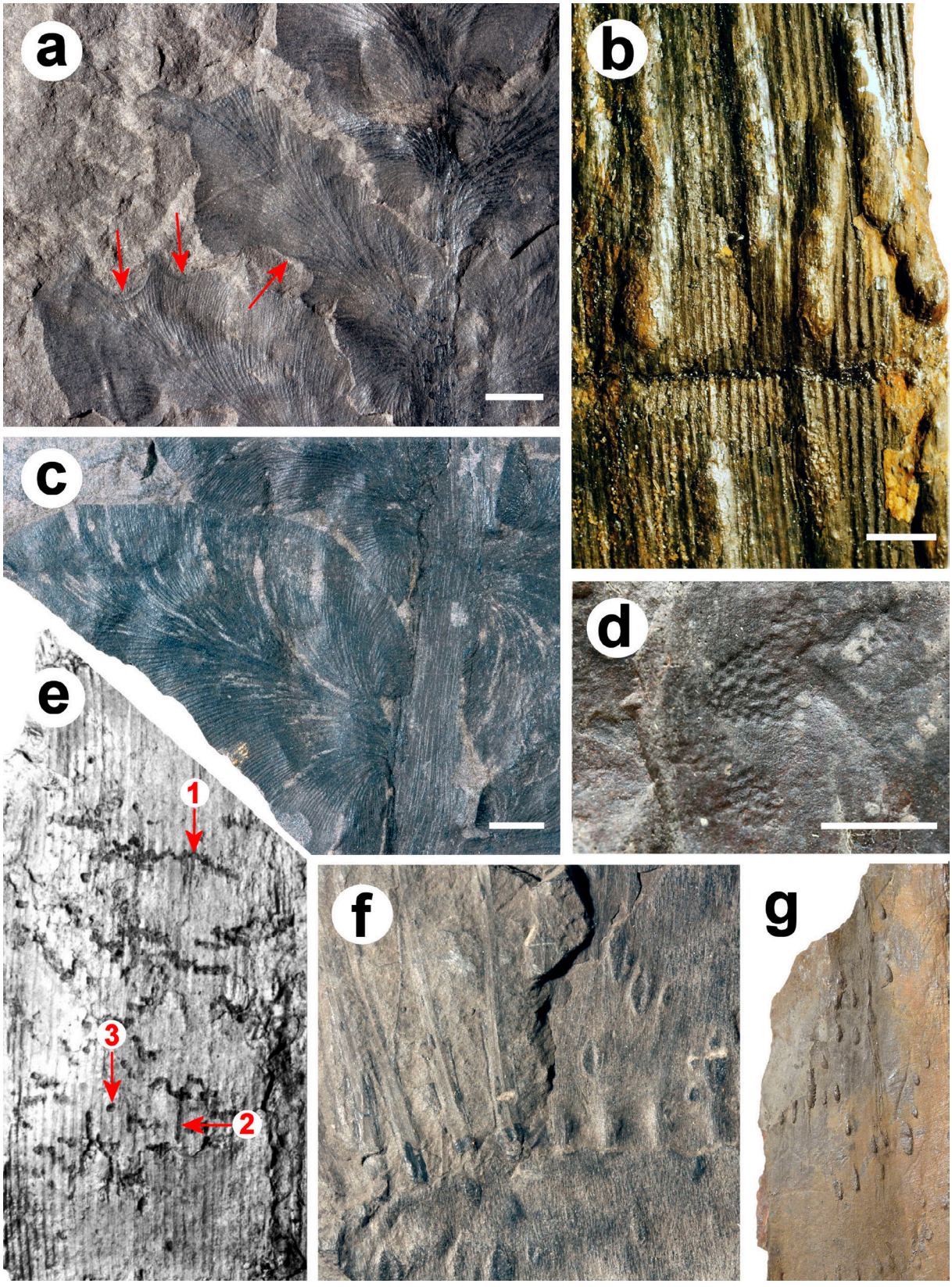

Fig. 1: Plant-arthropod interactions from the late Carboniferous of the Saale Basin. a: Leaf feeding on *Neurodontopteris auriculata* (arrows), b: Borings (Typ 1) in a calamitean stem, c: Mines on a leaf of *Neurodontopteris auriculata*, d: Possible exophytic insect eggs on plant foliage (from Laass & Hauschke 2019), e: Borings (Typ 2) in a calamitean stem (arrows 1-3), f: Endophytic oviposition on the outer cortex of a calamitean stem, g. Endophytic oviposition on plant foliage (from Laass & Hoff 2014). Scale bar = 5 mm.