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Charcoalified logs as evidence of hypautochthonous/autochthonous wildfire events in a peat-forming environment from the Permian of southern Paraná Basin (Brazil)

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ABSTRACT

Evidences of paleowildfires from the upper coal seam S from the Faxinal Coalfield have been analyzed through petrographic, fluorescence, and scanning electron microscopy (SEM) specifically at the base (1) and top (2) boundaries of an interlayered tonstein bed and revealed recurrent charcoal deposition in the peat-forming environment. An unusual accumulation of adjacent, large-sized (21.8 × 13.4 cm and larger) charred logs occurs throughout the coal seam area (1.6 km^2) beneath the tonstein bed (boundary 1) reflecting an extensive wildfire event in hypautochthonous/autochthonous conditions. The logs display a semifusinite–vitrinite–semifusinite sandwich-like structure (*sensu* Jones et al., 1993) indicating burning in growth position, and reflectance measurements below 1%Ro suggest that this was a low-temperature fire. Dryness in the peatland during the fire event was clearly detected by altered fluorescence of spores and algae. Corroborating previous studies, the paleoecological setting can be characterized as a swamp forest based on the presence of pollen clusters and organs observed under fluorescent light and on the identification under SEM of the morphogenus *Agathoxylon* Hartig as a single wood type, reflecting the dominance of arborescent gymnosperms (glossopterids) in the peatland. Homogenized cell walls observed under SEM ratified the recognition of the material as charcoal. The reestablishment of regular conditions of peat deposition following the major fire episode is represented by alternate bands of vitrinite and semifusinite in both boundaries 1 and 2, suggesting an oscillation from dry to wet conditions in the climate pattern and the occurrence of wildfires as common and systemic events. Fire ignition, activity, and spread in the peat-forming environment resulted from a combination of lightning strikes, dryness, fuel abundance, and high atmospheric oxygen levels.

1. Introduction

Wildfire events play important roles in different terrestrial environments (Belcher, 2013; Scott, 1989 and references therein; Scott and Glasspool, 2006; Scott et al., 2014) and charcoal fragments are present in the fossil record since the Silurian in different settings, from terrestrial to marine (e.g. Glasspool et al., 2004; Scott, 2010).

In addition to reflectance measurements of coal macerals and scanning electron microscopy (SEM) in extant and fossil material, charring experiments lead to the confirmation of fusain (inertinite) as charcoal, a product of wildfire (Scott, 1989; Scott and Glasspool, 2007). However, according to Hower et al. (2013) and O'Keefe et al. (2013), biotic (bacterial, fungal, or invertebrate) or abiotic interactions (aerobic exposure or biochemical alteration) may have been relevant for the maceral formation in the inertinite group, in particular macrinite.

In Recent peat-forming swamps, fires have affected extensive areas, as observed by Hudspith et al. (2014); Page et al. (2002), Prat et al. (2015), Rein et al. (2008), and Turetsky et al. (2015). According to Scott et al. (2014), while charcoal corresponds to roughly 4% of the total volume in modern peat, in the Late Paleozoic it could reach 70%. Based on fossil evidence and experimental observations, several authors (Belcher et al., 2013; Bergman et al., 2004; Chaloner, 1989; Cope and Chaloner, 1985; Glasspool and Scott, 2010) concluded that the percentage of charcoal in coals through the geologic record can be considered as a proxy for atmospheric oxygen levels.

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In the Early Permian, atmospheric oxygen levels were estimated to have reached a peak of 35% (Scott and Glasspool, 2006). Therefore, if the percentage of charcoal in coal (inertinite) is indeed a proxy for atmospheric oxygen content, then Early Permian coals should have high inertinite contents. In coals from the southern Paraná Basin, inertinite contents can be larger than 50% (Kalkreuth et al., 2006). In addition, Jasper et al. (2011a) reported the occurrence of macroscopic charcoal (*sensu* Jones and Chaloner, 1991; Scott, 2010) in clastic sediments associated with hypautochthonous coal seams in Brazilian coalfields. The study therefore demonstrated that fires were relatively common events in and around peat-forming environments in the Early Permian Paraná Basin.

Along the five coal seams of the Faxinal Coalfield inertinite contents range from 6 to 15% (Henz and Corrêa-da-Silva, 1987). For the interlayered tonstein bed in the coal seam S, Jasper et al. (2011b) reported macroscopic charcoal fragments of gymnospermous affinities. Unabraded edges and dimensions up to 3.5 cm indicated low-energy transport, pointing to a hypautochthonous deposition. It was observed that the presence of fusain in the coal both overlying and underlying the tonstein bed could indicate that fire events were not restricted to the ash-fall interval.

For the present study, a reassessment of the upper coal seam S (Fig. 1A) from the Faxinal Coalfield (Fig. 2) is carried out, specifically at the base (1) and top (2) boundaries of the interbedded tonstein ply (Fig. 1B). Aiming to investigate wildfire events in the peat-forming environment, analyses were conducted through petrographic, fluorescence, and scanning electron microscopy in inertinite-rich levels associated with the tonstein ply. Logs, branch, and twig fragments occurring in the coal at the tonstein contacts had previously been considered as coalified in nature by Guerra-Sommer (1992). Here they are recognized as an impressive charcoalified wood assemblage of unusually large dimensions (Fig. 1C–G) occurring continuously over the entire exploitation area of the Faxinal open cast mine (ca. 1.6 km^2).

To support paleoenvironmental inferences, the present study investigates fire temperature, type, and ignition sources and identifies charcoalified and coalified biomass components, complementing previous studies on paleowildfires in various Permian ecosystems.

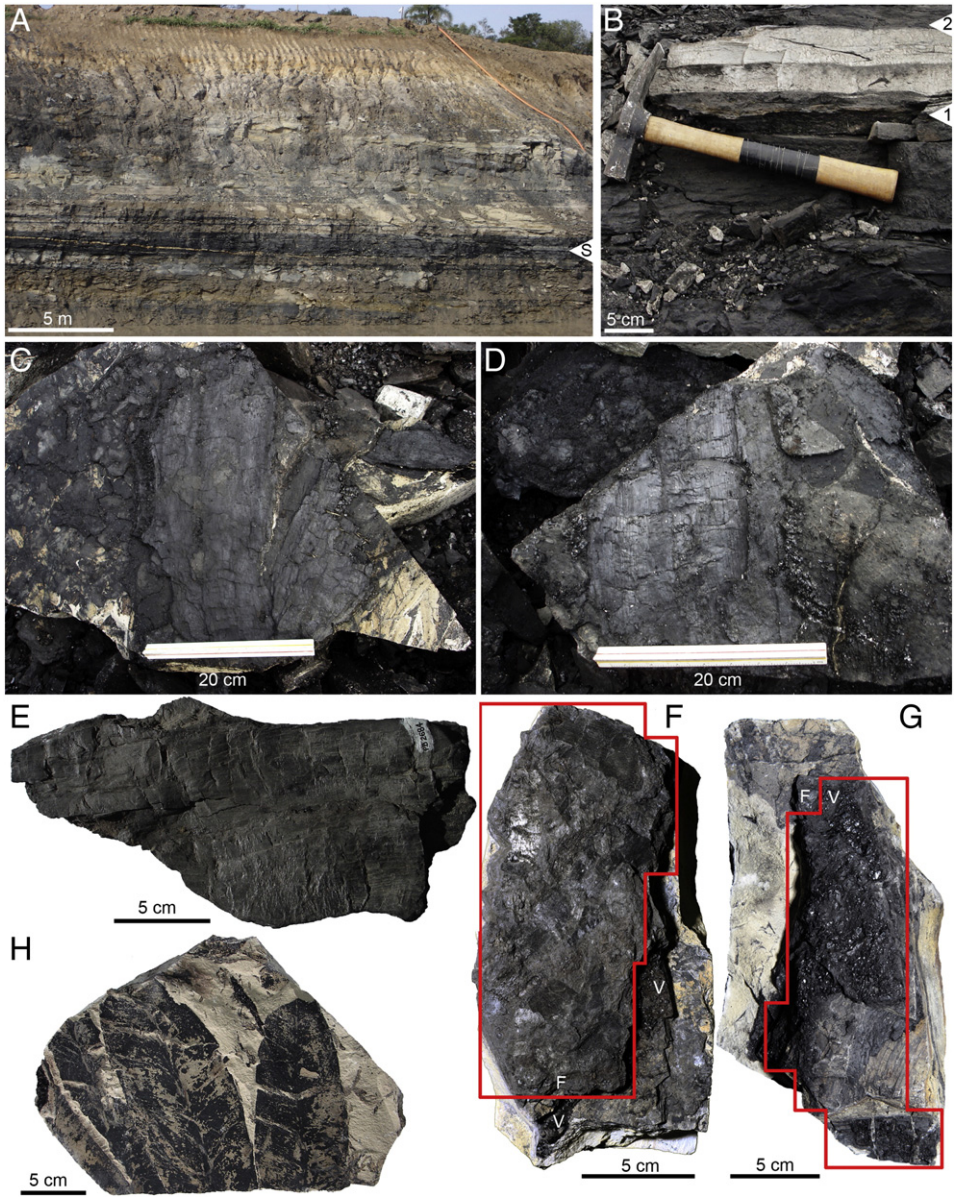

Fig. 1. Field and hand sample photographs. A) Pit bench exposure of coal seam S; B) close up of the interbedded tonstein ply in upper coal seam S; arrows indicate the coal-tonstein boundaries 1 and 2 here analyzed; C, D) large fragments of charred logs from boundary 1; E) charred stem fragment from the boundary 1 (PB2684); F) charcoal clasts from the boundary 2 (Pb4629); G) sample from boundary 2 showing high vitrain content (Pb4618); H) coalified leaves of the *Glossopteris* Flora preserved in the tonstein bed (Pb4762a).