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# Petrology and palynology of the Middle Pennsylvanian Leatherwood coal bed, Eastern Kentucky: Indications for depositional environments

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ABSTRACT

The Eastern Kentucky Coal Field is located in the central portion of the Appalachian Basin. The Pennsylvanian Breathitt Formation in this region is characterized by numerous sequences of bituminous coal-bearing sedimentary rocks. These coals have distinct maceral compositions due to variations in depositional environments. Coal characterization is an important method for determining conditions that influenced peat accumulation and overall depositional settings of mires. This study focuses on the characterization of the maceral composition of the Middle Pennsylvanian-age Leatherwood coal bed. It utilizes petrographical, palynological, and geochemical analyses to describe specific depositional environments and associated peat accumulation conditions. Petrographic analyses indicate that these coals have relatively high liptinite and varying inertinite content, along with trace amounts of mineral matter. Vitrinite, mainly in the form of collotelinite, is the most dominant maceral group. Geochemical data reveals low ash and sulfur content. Ancillary palynological data shows the palynomorph assemblage to be dominated by tree fern and large *Lycopod* tree spores, with lesser amounts of small *Lycopod* tree, small fern, and *Cordaites* and *Calamites* spores. The petrographic, geochemical and palynological data indicate that both domed, ombrotrophic, and planar, rheotrophic mire conditions, with limited local detrital influx, contributed to the formation of the Leatherwood coal.

## 1. Introduction

The Eastern Kentucky Coal Field (EKCF), part of the Central Appalachian Basin covers all or parts of 31 counties (approximately 34,628 km$^2$) and spans about 33% of the state's area (Fig. 1). The lithology in this region is composed of numerous sequences of bituminous coals, many of which have distinct maceral (*i.e.*, microscopically recognizable organic constituents present in coal) compositions due to varying depositional environments (Chesnut, 1989). Coal characterization is an important method for determining conditions that influenced peat accumulation and overall depositional settings, especially in Kentucky where coal contains variable maceral assemblages.

The bituminous coal found in Kentucky's coal field region encompasses a broad range of coals with varying maceral composition. Many of these coal beds have undergone extensive palynological, petrographical, and geochemical analyses. Even though the Leatherwood coal bed, which occurs within the Hazard Coal Zone has been extensively mined, its petrology and palynology have yet to be examined in detail. This study focuses on the organic petrography of the Middle Pennsylvanian-age (Bolsovian) Leatherwood coal bed. The identification of maceral assemblages through organic petrography provides vital information necessary for the interpretation and assessment of the conditions under which the peat accumulated and the associated depositional environments (Helfrich and Hower, 1991; Greb et al., 1999; Hower et al., 2007; Hower and Wagner, 2012). Geochemical and palynological data will be incorporated to better define the complex processes behind the accumulation and coalification of the Leatherwood coal and coals in other areas (*e.g.*, Dai et al., 2002, 2006). Specifically, maceral analyses provide indicators of peat degradation and preservation. Miospore analyses provide an overview of the original mire flora, as well as temporal changes in vegetation during mire development; and geochemical analyses provide additional information about mire hydrology (Eble et al., 1994). These proxies have been effectively combined to reconstruct paleoecological and paleoenvironmental conditions during peat accumulation in numerous Pennsylvanian-age coal beds (Grady and Eble,

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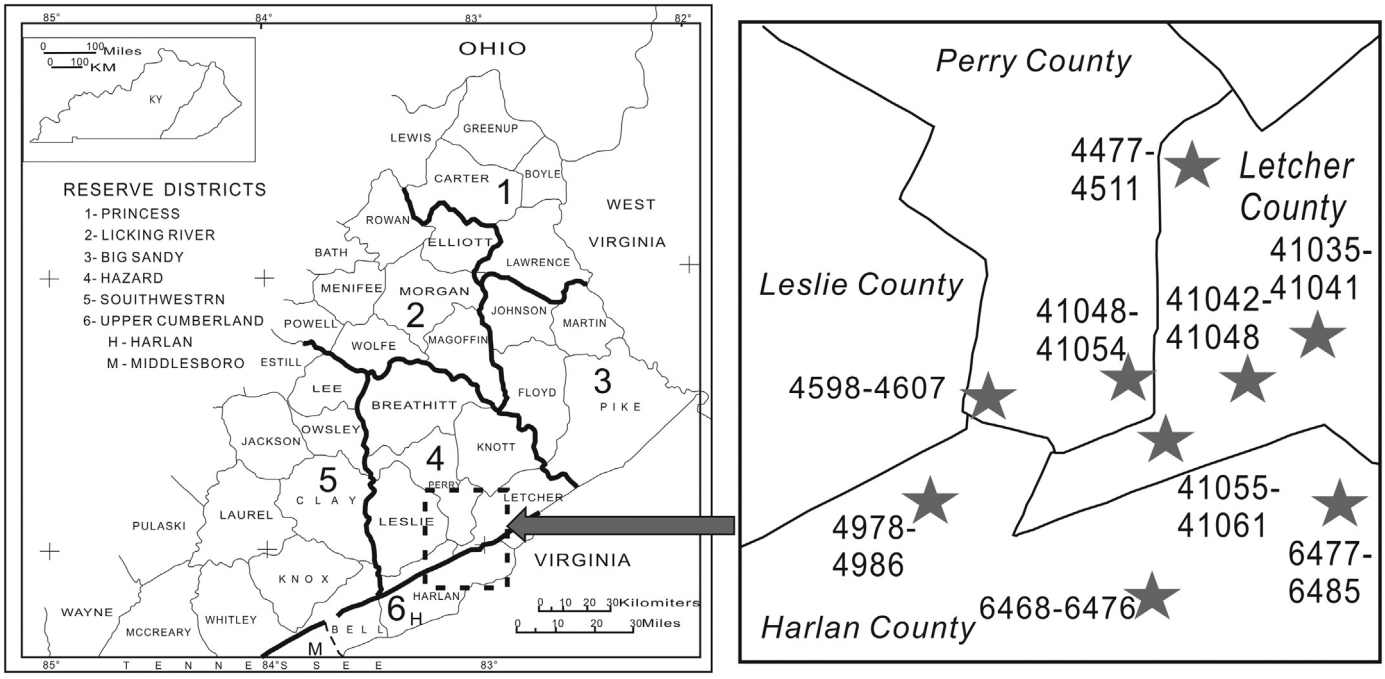


**Fig. 1.** Coal reserve districts in the Eastern Kentucky coalfield (left) and sample locations (right) within dashed area on reserve district map.

1989; Hower and Bland, 1989; Eble and Grady, 1990; Helfrich and Hower, 1991; Eble et al., 1994; Greb et al., 1999, 2001, 2002; Hower et al., 2007).

## 2. Geologic setting and ecologic background

The Leatherwood coal bed (Fig. 2) is located near the middle of the Middle Pennsylvanian Breathitt Group, which is characterized by subgraywacke sandstone, gray shale, and gray siltstone layers, as well as 26 major coal zones spanning a sequence up to 760 m thick (Rice and Smith, 1980). The high volatile A bituminous Leatherwood coal bed occurs within the Hazard (also referred to as Prater) coal zone, and consists predominately of alternating clarain, durain, and fusain lithotypes. The Hazard coal zone includes the Hazard No. 5A, Hazard No. 6, and the Leatherwood (also called Prater or Adele) coal beds (Rice and Smith, 1980). The zone is Middle Pennsylvanian in age, and is equivalent with Atokan age strata of U.S. mid-continent basins, and the early Bolsovian of Western Europe (Eble et al., 2009).

### 2.1. Paleoenvironment

The development of the Appalachian basin was an important component in creating a depositional setting necessary for coal formation. The Appalachian basin is a foreland basin that resulted from thrusting caused by collisional tectonics along eastern North America during the Paleozoic (Tankard, 1986). Although the formation of the Appalachian basin was impacted by the Middle Ordovician Taconic and the Late Devonian Acadian orogenies, the foreland thrust belt of the Appalachians evolved from the Pennsylvanian-Permian Alleghenian orogeny. This resulted in periodic basinal subsidence in response to successive thrust-belt loading (Tankard, 1986). The changing topographic depressions, as well as the fluctuating water levels induced from glacial waxing/waning cycles during the Carboniferous period (Greb et al., 2001), became a principle control on wetland environment accumulating peat. During periods of consistently high-water base levels, mires (*i.e.*, a wetland type environment that accumulates peat) developed along the margins of the paleo-continent, Pangaea (Tankard, 1986). The mires were characterized by relatively consistent water cover, anaerobic conditions, and limited local detrital influx (Greb et al., 1999). Regional subsidence provided accommodation space for sediment and peat accumulation. Greater subsidence rates in the Appalachian Basin resulted in a thicker sediment/coal package than equivalent sediments/coals in western Kentucky (Illinois Basin; Tankard, 1986).

### 2.2. Palynology

Palynological studies conducted on eastern Kentucky coals similar to the Leatherwood (*e.g.*, the Fire Clay coal bed) indicate that the Middle to Late Pennsylvanian coal-forming floras in eastern Kentucky consisted of a diverse assemblage of large and small lycopod trees, tree ferns, *cordaites*, and *calamites* (Greb et al., 1999; Hower and Eble, 2004; Hower et al., 2011a). These peat-forming plants developed both in planar, rheotrophic-ombrotrophic mires (*i.e.*, a mire in which peat formation is caused by a high groundwater level) that are rich in plant nutrients (Taylor et al., 1998; Greb et al., 1999) and topogenous-ombrogenous mires (*i.e.*, domed mires dependent exclusively on the precipitation for its sustainment) (bog forests) with perched water tables.

Arborescent lycopods dominated the vegetation during the Middle Pennsylvanian due to their ability to exploit low-nutrient mires more effectively than other contemporaneous plant types (DiMichele and Phillips, 1985, 1994; Eble and Grady, 1990). Major lycopod tree genera include *Lepidodendron*, *Diaphorodendron/Synchysidendron*, and *Lepidophloios*, which were predominately composed of bark (periderm) instead of the woody tissues (secondary xylem). They frequently reached heights over 30 m, and had broad-based root systems, assigned to the form genus *Stigmaria*, which spread laterally, rather than deeply, to provide support for the trees in wet environments (DiMichele and Phillips, 1985; Greb et al., 1999). Perhaps most importantly, they had developed a specialized megasporangium (*Lepidocarpon* and *Achlamydocarpon*) that allowed them to reproduce in consistently flooded areas.

Subarborescent lycopods, attributable to *Chaloneria* (*Endosporites*) and *Omphalophloios* ("densospores" – *Densosporites*, *Cristatisporites*, and *Radiizonates*) were also elements of Middle Pennsylvanian mire floras that apparently were able to inhabit "stressed" areas of mires, areas that were prohibitive to the establishment and expansion of other flora. Coal layers with abundant "densospores" are almost always associated with high liptinite and/or inertinite contents, indicating poor or, at least reduced levels of peat preservation.

Other plants that were major contributors to peat formation include *calamite* and *cordaite* trees and ferns (tree-like and small forms).