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Review article

Coal more than a resource: Critical data for understanding a variety of earth-science concepts

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ABSTRACT

Coal is one of the world's primary energy sources and it is critical for making coke, used in steel making; and is used for a multitude of chemical products. Aside from its significance as a fuel or product, however, coal and data derived from the exploration or mining of coal have also provided the foundation and testing ground for diverse geologic concepts. Because of coal's economic importance, and common variability in thickness, distribution, and quality, it has been critical to collect and correlate a wide variety of surface and subsurface data sets at relatively high-spatial frequency, which varies from the mine to basinal scale. Also, because many coal beds occur in most coal basins, the collection of coal data from multiple beds creates relatively high-temporal frequency data sets at scales from laminae to bed to larger unit scale. These data have been important for the development and expansion of many earth science concepts including aspects of basin analyses, paleogeography, paleoclimatology, paleontology, stratigraphy, sedimentology, structural geology, and tectonics.

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1. Introduction

Coal is one of the world's premier fuel resources. It remains an important component of coke to make steel, which spurred (and is still spurring) the industrial revolutions of many countries, and it is used to make a variety of chemicals and compounds. Coal has also been an important contributor to infrastructure with many towns, roads, rail lines, river ports, etc., developed as a result of mining and the need to get the coal to market. Coal mining, processing, and utilization also had negative environmental impacts, of which concerns about climate change are the most recent.

Another aspect of coal geology, which is sometimes overlooked, is the many ways in which data collected from coal basins including samples from mines and tailings, borehole data, in-mine data, mine highwalls, and roadcuts and railway exposures along coal transport routes has been fundamental in shaping and testing a variety of geological concepts. The following essay examines just some of the ways in which data and methodologies derived or enhanced as a result of coal exploration, mining, development, and research have been important in shaping our understanding of broader concepts in general geology and earth history. Special focus is placed on examples from eastern and central North America (Figs. 1, 2), which have been major coal research areas for more than one hundred years.

2. Stratigraphy and sedimentology

2.1. Coals as stratigraphic markers

In some coal basins, tens of thousands of exploration bore holes and coal measurements are made during exploration and development. Some coal beds have distinctive partings or roof strata, which allows relatively easy regional correlation. Other coals are primary economic targets, so significant research is spent on insuring their regional correlation. The large amount of data and economic incentive for correlating coal beds provides for relatively detailed stratigraphic frameworks for the coal-bearing parts of many coal basins (Eble et al., 2009; Heckel, 1995; Peppers, 1996; Rice and Hiett, 1994; see also Section 3.1). In the Appalachian and Illinois Basins (Fig. 1), coals can be used as marker or key beds at vertical distances of 10- to 30-m intervals, which is a relatively high degree of stratigraphic resolution. Lithostratigraphic correlations are combined with palynologic and other paleontological data (see Section 5) to corroborate basinal correlations and facilitate extra-basinal correlations. These data can be used for a wide array of additional stratigraphic, sedimentological, and tectonic analyses.

2.2. Depositional facies and sedimentology

The detailed correlation of coal beds in individual basins, and then between basins, allowed for a wide range of analyses of the strata between the mapped coal beds, which continues to this day. In the late 1950s and early 1960s, field work on modern sedimentation patterns in the Mississippi River delta led to increased use of depositional facies in stratigraphic analyses, which rapidly transferred into interpretations of coal-bearing strata (Donaldson, 1966; Ferm and Cavaroc, 1968; Moore, 1959). Widespread exploratory coring, exposure of surface mine highwalls (especially prior to surface mine reclamation laws), and road cuts along coal haul roads provided a wealth of data to the expanding field of clastic sedimentology. Ferm (1970) noted that data being gathered in studies of modern coastal-deltaic sediments should be applied to rock strata, and that in turn, "the generation of rock data that will be meaningful to the student of recent sedimentary processes (p. 346)." In many publications, classic examples of lower delta plain, transitional delta plain, and upper delta plain-fluvial facies, and details of subfacies (washovers, levees, floodplains, etc.) were described in outcrops along US Highway 23 and Kentucky Highway 80 in eastern Kentucky (Figs. 2, 3), and in other parts of the Appalachian Basin, and compared to modern analogs from the Gulf and Atlantic coasts (Baganz et al., 1975; Cobb et al., 1981; Donaldson, 1974; Ferm, 1970; Horne et al., 1978; Saxena and Ferm, 1976). Similar examples from coal basins around the world were gathered (Fielding, 1987; Flores, 1981; Galloway and Hobday, 1983; McCabe, 1984, 1987), and have become staples of sedimentary geology text books. Two additional examples are highlighted in the following section from the Illinois Basin.

2.2.1. Paleochannels

In many coal basins, mine maps and exploration borehole data have been used for mapping the positions of paleochannels because of their adverse effects on coal thickness and roof control in underground mines (e.g., McCabe and Pascoe, 1978; Nelson, 1983). In the Illinois Basin, channels may also be associated with low-sulfur coals (e.g., Gluskoter and Simon, 1968). Because mines sometimes encounter paleochannels (Fig. 4A), compilations of data from coal mine maps (Fig. 4B) allow correlation of paleochannel systems between mines; in some cases, for hundreds of kilometers (Fig. 4C, Beard and Williamson, 1979; Eggert, 1984; Krausse et al., 1979; Nelson, 1983). Recognition and mapping of paleochannels and extensive fluvial sandstones allowed for subsequent regional correlation of incised paleovalleys and the position of lowstand sequence boundaries (Aitken and Flint, 1995; Martino, 2004; Pashin, 2004), and has provided data for interpreting aspects of fluvial sedimentology, paleoslope, source areas, and paleoecology, as well as changes in those characteristics through time (e.g., Etheridge and Schumm, 1978; Gardner, 1983; Greb et al., 2003).

2.2.2. Tidal rhythmites

Tidal facies are also among the many facies associated with coal beds. Tidal rhythmites were initially discovered in non-coal-bearing facies, but have perhaps been most widely recognized and researched in Carboniferous Midcontinent and eastern U.S. coal basins. Kvale et al. (1989) published a report on vertically-accreted rhythmites in a siltstone with in-situ lycopod trees above a coal bed in the Mansfield Formation (Fig. 2) in Orange County, Indiana (Fig. 1). The Hindostan whetstone beds preserved daily, monthly, and yearly tidal cycle periodicities. Soon, similar rhythmites were found throughout the coal fields in other eastern and midcontinent Carboniferous basins preserving a host of long- and short-term paleo-tidal periodicities (Archer, 1998; Demko and Gastaldo, 1996; Feldman et al., 1993; Greb and Archer, 1998; Martino and Sanderson, 1993). Aside from their possible relationships to coal quality and mine roof heterogeneity, data from these rhythmites helps to constrain aspects of paleogeographic reconstructions; paleoceanography including interpretations of paleo-ocean resonance periods (e.g., Archer, 1996); and even the rate of the retreat of the moon from the earth (e.g., Sonett et al., 1996).