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Cleats and their relation to geologic lineaments and coalbed methane potential in Pennsylvanian coals in Indiana

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Abstract

Cleats and fractures in Pennsylvanian coals in southwestern Indiana were described, statistically analyzed, and subsequently interpreted in terms of their origin, relation to geologic lineaments, and significance for coal permeability and coalbed gas generation and storage. These cleats can be interpreted as the result of superimposed endogenic and exogenic processes. Endogenic processes are associated with coalification (*i.e.*, matrix dehydration and shrinkage), while exogenic processes are mainly associated with larger-scale phenomena, such as tectonic stress.

At least two distinct generations of cleats were identified on the basis of field reconnaissance and microscopic study: a first generation of cleats that developed early on during coalification and a second generation that cuts through the previous one at an angle that mimics the orientation of the present-day stress field. The observed parallelism between early-formed cleats and mapped lineaments suggests a well-established tectonic control during early cleat formation. Authigenic minerals filling early cleats represent the vestiges of once open hydrologic regimes. The second generation of cleats is characterized by less prominent features (*i.e.*, smaller apertures) with a much less pronounced occurrence of authigenic mineralization. Our findings suggest a multistage development of cleats that resulted from tectonic stress regimes that changed orientation during coalification and basin evolution.

The coals studied are characterized by a macrocleat distribution similar to that of well-developed coalbed methane basins (*e.g.*, Black Warrior Basin, Alabama). Scatter plots and regression analyses of meso- and microcleats reveal a power-law distribution between spacing and cleat aperture. The same distribution was observed for fractures at microscopic scale. Our observations suggest that microcleats enhance permeability by providing additional paths for migration of gas out of the coal matrix, in addition to providing access for methanogenic bacteria.

The abundance, distribution, and orientation of cleats control coal fabric and are crucial features in all stages of coalbed gas operations (*i.e.*, exploration and production). Understanding coal fabric is important for coal gas exploration as it may be related to groundwater migration and the occurrence of methanogenic bacteria, prerequisite to biogenic gas accumulations. Likewise, the distribution of cleats in coal also determines pathways for migration and accumulation of thermogenic gas generated during coalification.

Keywords: Cleats; Lineaments; Coalbed methane; Permeability; Indiana; USA

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1. Introduction

Cleats can be broadly defined as linear discontinuities forming a structural fabric that develops in coals as a result of physical and chemical changes during coalification. Two main types of cleats (face and butt) are generally present in coal beds (Ammosov and Eremin, 1963; Ting, 1977; Close, 1993; Laubach et al., 1998). Face cleats represent the more prominent group and are developed perpendicular to bedding. Butt cleats are less conspicuous, perpendicular to bedding, and are oriented at nearly 90° to face cleats. In contrast, fractures are characterized by irregular discontinuities that do not follow a defined pattern. Their seemingly random distribution distinguishes fractures from face and butt cleats.

Cleats and fractures in coal are intimately related to stress conditions of the basin during and after coalification. Occurrence and development of cleats and fractures in coal have been interpreted as the result of endogenic stress in coal owing to devolatilization during thermal maturation, along with the concurrent exogenic (*i.e.*, not deriving from coal beds) tectonic stress that imposes preferred orientations to developing fractures (Close, 1993; Laubach et al., 1991, 1998; Pashin, 1998; Pashin et al., 1999; Condon, 2003; Pitman et al., 2003).

Characterization of cleats and fractures is important both for coalbed methane (CBM) exploratory strategies as well as for successful recovery of coalbed gases, and this has been emphasized in numerous studies (Bustin, 1997; Pashin et al., 1999; Scott, 1999; Su et al., 2001; Scott, 2002; Pitman et al., 2003). However, the link between cleat characteristics and CBM has remained elusive because of the lack of objective and quantitative measurements of cleats, and the presence of multiple populations of cleats. These populations are difficult to discriminate and it is even more difficult to obtain statistically important number of measurements in the subsurface. Also, we lack an understanding of the contribution of microcleats to coal permeability.

To our knowledge, the relationship between coalbed gas occurrence and cleat directions in relation to geologic lineaments has not been investigated in Indiana.

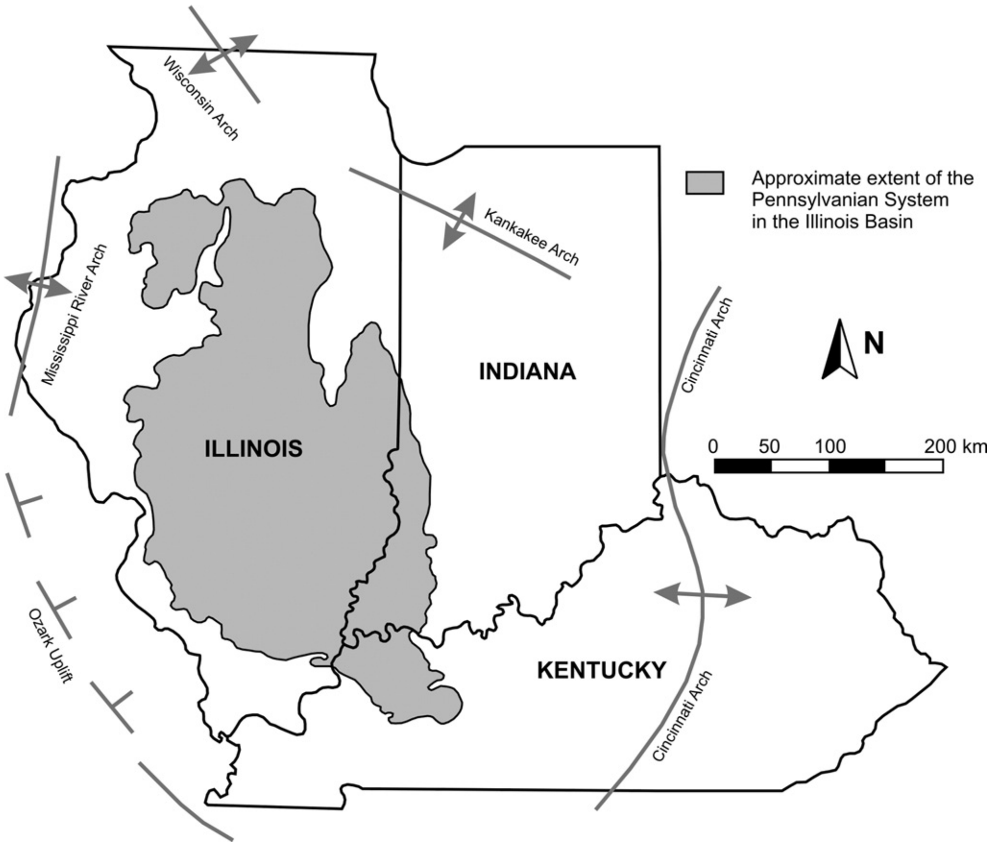

Fig. 1. Structural configuration of the Illinois basin and extent of the Pennsylvanian System.