INTRODUCTION

The literature that describes natural fractures (cleats) in coal can be divided into two areas of activity, including an older mining industry viewpoint and a much newer petroleum industry viewpoint. Cleats in coal have been of interest to the coal mining community for more than 100 years. Knowledge of cleat geometry is important in designing coal mines for maximum extraction efficiency and for safety considerations. One of the earliest references on cleats in coal from the mining perspective is by Mammatt (1834, cited in Kendall and Briggs, 1933), who noted the uniform strike of cleats in coal fields of the United Kingdom. Since that time a large number of papers on cleats have been published.

Because of the relatively recent interest in commercial production of coal gas resources, many contemporary research efforts have been directed toward the development of a better understanding of factors that influence the production of gas from coal reservoirs. Among the more important of these factors is the cleat system. The importance of cleat development stems from the fact that the principal natural fracture permeability pathways for the flow of gas and water are through the cleat systems. Cleat permeability is often the reservoir characteristic that has the greatest influence on the economic success or failure of coal gas exploration and development programs (Dhir et al., 1991a, b). A better understanding of cleat genesis is therefore useful for reasons besides academic interest, which include the following: (1) One can better assess why certain coal gas plays are characterized by significant and highly variable cleat permeability; (2) development drilling and completion decisions can be made for areas where offset commercial production has been established; and (3) more efficient exploration for coal gas resources in frontier areas can be undertaken.

The estimation of reservoir quality prior to performing quantitative formation evaluation is a problem that will always be associated with the exploration and production of oil and gas resources. Coal gas reservoirs are in this sense no different, in that the reliable prediction of the presence of commercial cleat permeability before drilling is difficult at present. One of the many reasons for this problem is that a multitude of cleat genesis hypotheses have been postulated, which makes the formulation of predictive models more complex. Given the importance of cleat permeability development to the economic production of coal gas resources, the objectives of this paper are to: (1) discuss the relationships between cleats and cleat permeability; (2) characterize the geometry of cleats; (3) review previous hypotheses on cleat genesis; and (4) provide an opinion concerning which hypothesis or combination of hypotheses for the genesis of cleats satisfies the available data on cleat geometry.

The key conclusion of this chapter is that cleat genesis was commonly caused by the interdependent influences of desiccation, lithification, coalification, and paleotectonic stress. Several interlinked constraints on the selection of a tenable cleat genesis hypothesis have been elucidated by many workers that support this conclusion and are presented herein.

BACKGROUND

Cleats are natural fractures in coal that serve as permeability avenues for darcy flow of gas and water to a wellbore during depressurization (Gray, 1987a, b; Kolesar et al., 1990a, b). Darcy flow of gas and water in cleats has been verified by numerous researchers in the laboratory using whole cores, and in the field during drill-stem and production tests of wells drilled into coal gas reservoirs. Attempts to flow water through coal cores that did not contain cleats have been unsuccessful. Some drill-stem tests of Fruitland and Menefee (Upper Cretaceous) coal beds in the San Juan basin of Colorado and New Mexico were characterized by a virtual lack of fluid flow into the wellbore (Mavor and Close, 1989d; Mavor et al., 1991b; Close and Mavor, 1991; Pratt et al., 1992). Examination of coal cores from these zones showed that the cleats were not open and effectively interconnected at the scale of the core. Conversely, drill-stem and production tests of Fruitland and other coal gas reservoirs with substantial cleat development are often characterized by high rates of fluid influx and commercial rates of gas flow (Mavor and Close, 1989a, b, c; Close et al., 1992; Mavor et al., 1991a; Close and Mavor, 1991). Similar relationships between reservoir cleat development and fluid flow rates during well tests and production tests of research wells drilled into Pennsylvanian coals have been documented at the Gas Research Institute (GRI) Rock Creek site in the Black Warrior basin of western Alabama (Epstein et al., 1988). Many operators have also noted the common correlation between cores with well-developed cleat systems and high coal reservoir fluid productivity. These observations are concordant with previous work on the influence of cleat permeability on fluid productivity, such as that by Amosov and Eremin (1960) and McCulloch et al. (1974).