Coal, Permeability

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The capability or specifically the capacity of a coal bed to transmit gas or fluid through it is generally expressed as permeability (Chandra 1997). This is one of the most significant characteristics of coal-bed reservoir in relation to the CBM exploitation.

Availability of the passage or drainage path in the coal bed is essential for movement of gas and fluid through it. If drainage path is available, the desorbed gas accumulated at distant points flows toward the exit/outlet point and accumulates there to come up to the surface level following the exit/outlet passage. In such a case, the coal bed is said to be permeable. On the other hand, if the coal bed is not permeable (without any drainage path), the desorbed gas fails to move and reach to the borehole point which results in nonrecovery of methane gas.

So permeability of a coal bed is the most vital parameter for coal-bed methane (CBM) recovery and its production. At the same time, it is most significant for prediction of reservoir performance during production of CBM. Flow/movement of gas and fluid along the available drainage path within the coal bed is guided by Darcy’s law, and permeability is measured in terms of darcy (D)/millidarcy (mD). The principle that governs how fluid moves in the subsurface is called Darcy’s Law. It defines the ability of a fluid to flow through a porous media such as rock. It is based on the fact that the amount of flow between two points is directly related to the difference in pressure between the two points, the distance between the points, and the interconnectivity of flow pathways in the rock between the points.

The permeability of a coal bed is dependent upon the mega- and macroporosity of the coal, i.e., cleats and fracture system which plays a significant role for production of methane gas (Bustin 1997; Laubach et al. 1998; Pashin et al. 1999). Cleat/fracture system varies markedly depending upon composition and rank of coal. Compositionally vitrite-rich (bright) coals are more permeable than dull coal which is due to greater abundance of cleating in the vitrite-rich coals (Smyth and Buckley 1993). Clarkson and Bustin (1997) recorded the following order of decreasing permeability, in average, with coal lithotype – bright (4.1 mD), banded (0.79 mD), fibrous (0.50 mD), banded dull (0.14 mD), and dull (0.016 mD). It is well understood that rank-wise, high-rank coal (up to Ro 1.35 %) having a higher degree of cleat development, i.e., cleat frequency, should be more permeable than the low-rank counterpart. Above this rank (Ro 1.35 %), cleat frequency decreases with further increase in rank indicating decrease in permeability (Su et. al. 2001). This behavior pattern of cleat development is a very significant one and
should be carefully taken into consideration at the time of evaluation of reservoir characteristics in relation to permeability. Thus semianthracitic to anthracitic coal having very high Ro% may not be potential from the production point of view as its permeability decreases.

The orientation, continuity, interconnectivity, and frequency of these structures (cleats), in addition to coal rank and composition, are important parameters in assessing permeability during the production of coal-bed gas. When all fractures/cleats occur in isolation without interconnection among them, flow rate would be limited by matrix permeability and there will be no enhancement of permeability due to the fracture/cleat. Network geometry and connectivity of fractures/cleats in a system are very significant for the permeability enhancement. Coal-bed permeability may be three to ten times greater along the face cleat direction in comparison to any other directions indicating the strong preferred orientation and greater length of interconnected fractures in that direction (McCulloch et al. 1974). On a local scale, cleat connectivity results from their cross-cutting and abutting relations. Vertical connectivity of cleat network is commonly restricted due to confinement of small cleats at interfaces between coal types and large cleats at coal-non-coal-bed interfaces.

Microcleat study renders good scope of studying many more aspects like aperture width, height, spacing, cleat type, frequency, degree of interconnectivity, and mineralization along cleat opening (Solano-Acosta et al. 2007; Datta 2005; Datta et al. 2007). Each of these properties has significant control for permeability of a coal bed. Of these, aperture width, height, and frequency (inverse of spacing) are directly proportional to permeability. Population % of primary, master cleat, and interconnected cleat system enhances permeability because of higher degree of interconnectivity. If the open space of cleat is filled in by secondary minerals, the drainage path is blocked/sealed and hence it reduces permeability. This way population % of non-mineralized cleat is directly proportional to permeability. Based on the above said relation, permeability of coals may be qualitatively assessed.

It is to be mentioned that aperture width of a coal changes when a core sample is brought to the surface from its subsurface occurrence (in situ condition) as a coal matrix shows plasticity at high pressure and temperature when it occurs in the coal bed at depth. Little information is available on in situ cleat aperture (Laubach et al., op. cit), which may differ a bit when the sample is studied in our crop or in laboratory.

Harpalani and Chen (1995) suggested the following formula to determine permeability of coal.

$$K = \frac{a^3}{12s}$$

[K = permeability, a = aperture, s = spacing]

In the formula two parameters, i.e., aperture width and spacing, are taken into account.

Study on fractured carbonates established an equation of permeability in terms of aperture width and spacing of fractures (Lucia 1983).

$$K = \left[84.4 \times 10^5\right] \frac{w^3}{z}$$

[K = permeability in darcy, w = fracture aperture in cm, and z = fracture spacing in cm]. Scott (1999) used the above formula for permeability in coal, though it does not take into account the geometric distribution of microcleats and their possible contribution for permeability.

**Importance of Permeability in Coal-Bed Methane Investigation**

Coal beds which are heterogeneous with respect to composition and fabric are responsible for significant vertical and lateral variation in permeability and thus may be important in making production decision in the extraction of hydrocarbons from coal. Permeability is the most important parameter in the prediction of reservoir performance. Average permeability influences the production rate, whereas permeability heterogeneity has a bearing on efficiency. Thus the successful production of coal-bed methane is, in major part, dependent upon the knowledge and understanding of the cleat system.
References