GEOLOGY PAPER 9

SOURCE OF COAL BED METHANE

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Commercial viability of a coal bed methane project exclusively depends on the available source of methane. By default it is expected that the source of methane is bacterial / thermal actions on organic biomass during coalification process. Carbon isotope signatures and chemical composition of the produced gases are not always favourable supports to the coal origin of the available methane. Moreover, all the major successful coal bed methane projects are geographically located over one or the other petroliferous basins. Does it mean that the coal bed methane has some intricate source relation with occurrence of petroleum?

Critical review suggests as such methane generation from coal is difficult because average molar H/C for coal is around 0.8 (Hunt, 1995) whereas molar H/C for methane is 4.0. Therefore, even if it generates some methane it may not be commercial because of non-availability of sufficient hydrogen in coal. However, it is possible for coal / organic biomass to generate methane if deficient hydrogen is compensated by water. Conversion of organic matter to methane is represented by the following reaction:

$$C_6H_{12}O_6 = 3CH_4 + 3CO_2$$

The chemical potentials at STP for the simple carbohydrate $C_6H_{12}O_6$, methane, and carbon dioxide are −218.720, −12.130, and −94.260 kcal/mol, respectively. The thermodynamic affinity for the reaction accordingly is 100.42 kcal/mol and therefore permitted by the second law. Although, thermodynamically it is possible but this reaction cannot represent methane generation from coal because coal is dominantly aromatic with lots of free carbons and always have low hydrogen concentration. Kenney (2002) experimentally showed that free carbon and hydrogen from water catalytically can be combined to form CH_4. Fischer-Tropsch synthesis also shows similar combination to form petroleum but these reactions do not take place spontaneously in natural conditions.

Methane is generated in the process of coalification using either biogenic or thermogenic process. Biogenic methane is initially generated by some aerobic bacteria while the sample is in peat / swamp condition. Trapping of this early biogenic methane in coal is not possible because this is generated before proper gellification / coalification process starts. Next, methane generative stage commences with anaerobic methanogens during lignite stage and possibly continues till high volatile bituminous stage of coal. Although it is said that bacterial methane is generated by methanogens using coal of any maturity but it is

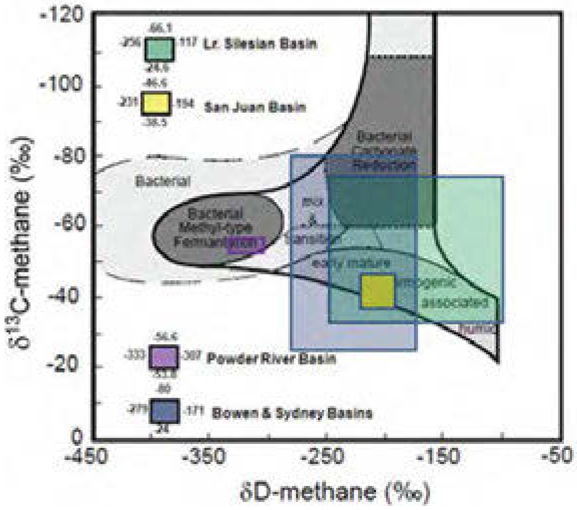

Figure 1: Modified after Whiticar, 1996

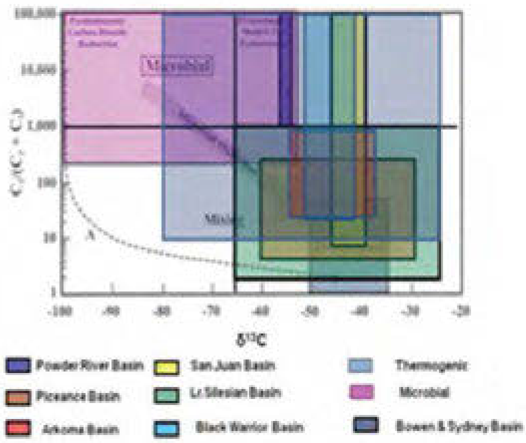

Figure 2: Bernard Plot, modified after Whiticar, 1996.

difficult to accept because methanogens can reduce only low molecular weight carbon compounds.

Methanogens spontaneously generate methane using CO2 or methyl type fermentation of some methyl compound.

$CO_2 + 8H+ + 8\ e^- \longrightarrow CH_4 + 2H_2O$ ----------------- (1)

$CH_3COOH \longrightarrow CH_4 + CO_2$ ------------------- (2)

The formation of methane by microbes using CO2 of reaction type-(1) gets all the hydrogen from water and it generally takes place in marine conditions (Whiticar et al., 1996) whereas, the hydrogen availability in reaction type – (2) is disputable. Initially it was suggested that only one hydrogen is introduced from water (Whiticar et al., 1986) now it has been suggested that all the hydrogen in methane is made available from water (Waldron et al., 1999). All these changes confuse the interpretation using hydrogen isotopes. However, interpretation using combined carbon and hydrogen isotopes is more satisfactory.

Thermogenic methane starts generation during late lignite stage and continues to high volatile bituminous stage whereby methoxy groups from lignins are separated. Finally, during bituminous to anthracite coalification jump (Vro exceed more than 2.0) aromatic condensation reactions dominate to generate some amount of methane.

From all of the above, it is apparent that anoxic bacterial methane may be the main source of coal bed methane because thermogenic methane cannot be commercial as coal is deficient in hydrogen.

Table-1 shows coal bed methane data from available eight basins of the world and Figures-1 and 2 show modified (Whiticar et al., 1996) plots for characterization of coal bed methane. Isotope values for carbon and hydrogen (Figure 1) suggest methane in Powder River Basin of USA generated as biogenic whereas San Juan Basin of USA show thermal genesis and Lr. Silesian Basin of Poland show mixing influence of biogenic and thermal genesis.

This is further verified with Bernard plot (Figure 2) using wettability versus carbon isotope composition. Here also samples from the Powder River Basin matches with biogenic origin of the gas. Gases of San Juan Basin USA and Lower Silesian Basin of Poland suggest thermogenic origin and Piceance Basin of USA suggest mixing of thermogenic and biogenic source.

Data as available from the Australian basins (Faiz, 2009) are also reviewed and it appears that the gases from Surat Basin, Bowen Basin and Sydney Basins of Australia all suggest mixing of biogenic and thermogenic source.

Results of the above four basins confirms methane generation only from the Powder River Basin to be of biogenic and others are all mixed thermogenic or pure thermogenic. If bacterial methane is the only source of coal bed methane then in the other three basins commercial methane generation from coal is difficult to explain.

Table-1

Approximate range in Carbon & Hydrogen isotope for different types of petroleum gas

Gas Type	$\delta^{13}C$	δD
Dry Bacterial	-110 to -60	-250 to -150
Wet Thermogenic	-60 to -30	-300 to -120
Dry Thermogenic	-40 to -15	-150 to -70

Ref. Petroleum Geochemistry & Geology By J. M. Hunt, Part 2 Chapter-7, Table 7-1, Page 189

Measured ranges of Carbon & Hydrogen isotopes from Coal Bed Methane projects in Different Basins

Sample	$\delta^{13}C$	δD
Powder River Basin	-56.6 to -53.8	-333 to -307
San Juan Basin	-46.6 to -38.5	-231 to -194
Piceance Basin	-60.3 to -29.1	Not Available
Arkoma Basin	-56.0 to -38.0	Not Available
Black Warrior Basin	-51.0 to -41.9	Not Available
Lr. Silesian Coal Basin	-66.1 to -24.6	-256 to -117
Bowen & Sydney Basins	-80.0 to -24.0	-279 to -171

Ref. Composition & Origin of Coal Bed Gas by Dudley D. Rice

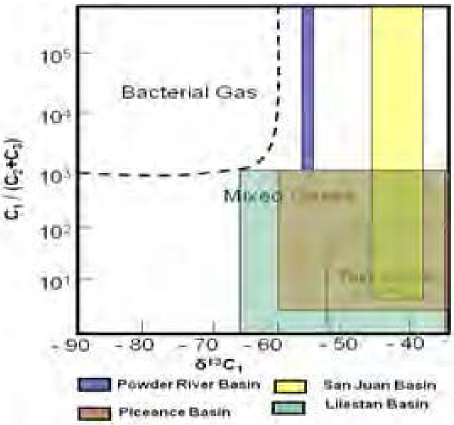

Figure 3: Revised Bernard Plot comparing gas wetness and δ13C of methane to characterize origin of gas. (Modified after Hunt, 1995). Areas of bacterial, mixed and thermogenic sub-divisions have been taken Claypool & Kvenvolden (1983).

Critical review of successful CBM projects reveal most of them are geographically lying over producing petroliferous basins. The available data of coal bed methane is now plotted in the same way as to characterize the petroleum natural gas (Figures 3 and 4). Both Bernard and Schoell plots suggests the coal bed methane can also be originated in the same way as petroleum natural gas.

Thus, methane from coal bed and petroliferous reservoirs is indistinguishable. Further, since successful projects are associated with petroliferous basins, it is most possible that the source of methane in coal bed is the same source rock in individual petroliferous basins.

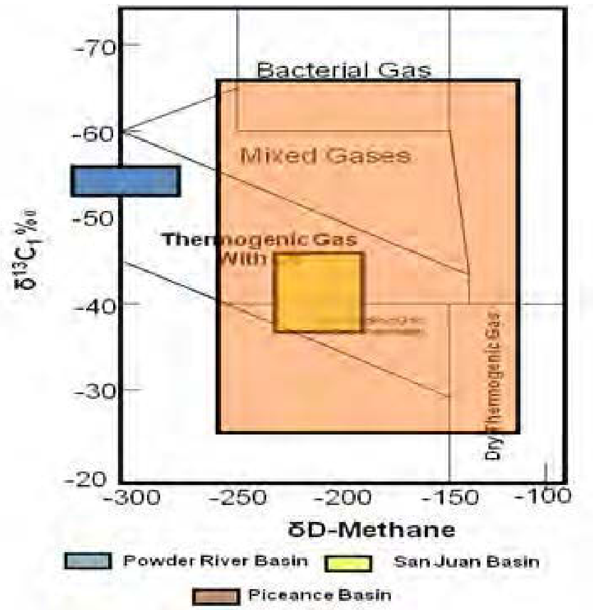

Figure 4: Scholl's plot of δD-methane versus δ13C1 for characterizing the origin of natural gases (Modified after Hunt, 1995). Values of Coal Bed Methane from San Juan Basin, Powder River Basin and Lr.Silesian Basin are superposed.

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