Coal Bed Methane Exploration and Production

Sunjay ,M.Banerjee Geophysics,BHU , Varanasi-221005,India

Sunjay_sunjay@yahoo.com, manasgp@yahoo.co.in

Aarif Jamal,Rakesh Kumar Mining Engg. ITBHU, Varanasi-221005,India

ajamal.min@itbhu.ac.in,rakesh.kumar.min08@itbhu.ac.in

Key Words: High resolution Reflection Seismic Surveys,Thinbed resolution ,Anisotropy ,Tuning effect,Wavelet analysis

Background

Non conventional energy resources, Black Diamond bounty, Coal Bed Methane (CBM) exploration and production is quite important with a view to energy security of the world. High resolution Shallow Reflection Seismic Surveys are carried out for CBM exploration seismology. Coal has low seismic velocity and low density with respect to its bounding strata , thus,although coal seams are extremely thin with respect to seismic wavelenth, their exceptionally large acoustic impedance contrast with surrounding rock result in distinct reflections. The tuning thickness is the bed thickness at which two events become indistinguishable in time, and knowing this thickness is important to seismic interpreters who wish to study thin reservoirs. The recording of amplitude and frequency tuning in the seismic wavelet is not only an indication of a thinning bed, but may also suggest the detection of a sequence of thin beds. The thicknesses of thin beds, their acoustic properties, and their location relative to other thin beds in space can cause the seismic wavelet to tune to a specific frequency with a resultant increase in amplitude that can double in magnitude. Investigation of azimuthal anisotropy to delineate structural sweet spots (zones that appear to have higher fracture density) has been proven effective in unconventional gas plays. Limit of resolution for coal beds are approximately wavelength/8 , and their limit of detection is less than that for other strata , often approximately wavelength/40.CBM production and CO_2 sequestration is challenging task to understand gas flow behaviour.

Aims

Very high frequency and high bandwidth data is desirable for precise imaging of thin coal seams. Faults are of great importance in mine design, and may also interfere with coal bed methane production if the throw is greater than the seam thickness. When interpreting high-resolution seismic data, it is essential to differentiate two important concepts: namely, delection and resolution. Detection deals with the recording of a composite reflection from a certain horizon with good S/N ratio, regardless of whether the composite reflection can be resolved into the separate wavelets that compose it. Thus, an event that is detectable may or may not be resolvable. Resolution deals with the ability to resolve the top and base of a thin bed which differs from the problem of detecting the presence of a bed. Resolution is primarily associated with frequency bandwidth of the recorded wavefield data, whereas detection is principally associated with acquisition technique.

Methods

Tuning effect-a phenomenon of constructive or destructive interference of waves from closely spaced events or reflections. At a spacing of less than one-quarter of the wavelength, reflections undergo constructive interference and produce a single event of high amplitude. At spacing greater than that, the event begins to be resolvable as two separate events. The tuning thickness is the bed thickness at which two events become indistinguishable in time, and knowing this thickness is important to seismic interpreters who wish to study thin reservoirs. The recording of amplitude and frequency tuning in the seismic wavelet is not only an indication of a thinning bed, but may also suggest the detection of a sequence of thin beds. Reflections from the thin beds can result in constructive or destructive interference depending on the traveltime delay of the wavelet. The thicknesses of thin beds, their acoustic properties, and their location relative to other thin beds in space can cause the seismic wavelet to tune to a specific frequency with a resultant increase in amplitude that can double in magnitude. Analysis of seismic reflections from thinly bedded coal seams typically involves a study of thin-bed interference and reflection Amplitude Variation with Offset (AVO). Infact the existence of cleat systems in coal beds is one of the key factors controlling gas production from coal bed gas systems, the AVO method is applied to include azimuthal AVO analysis. Investigation of azimuthal anisotropy to delineate structural sweet spots (zones that appear to have higher fracture density) has been proven effective in unconventional gas plays.

CBM Reservoir Characteristics: Coal bed methane reservoirs contain an orthogonal fracture set called as cleats that are oriented perpendicular to the bedding and provide the primary conduit for the fluid flow gas diffuses from the matrix into the cleats and flow to the wellbore. In virtually all coal bed reservoirs, cleats are the primary permeability mechanism. Like conventional reservoirs, coals can also be naturally fractured. In deeper coal seams, higher overburden stresses can crush the coal structure and close the cleats. In such locations, subsequent natural fracturing tends to be the main permeability driver. Coal is generally characterized as a dual porosity system. It consists of matrix (primary porosity) and a network of fracture (secondary porosity). As in conventional reservoir the matrix contains the bulk of the gas but it has very little permeability. On the other hand the network of fracture provides the conductive capacity for the gas production due to its high permeability but it has very little storage capacity. This is where the similarity between the conventional gas reservoir and the coal bed methane reservoir ends. Taking porosity into consideration, in conventional reservoir the gas is stores in the matrix, similar to it in the coal bed methane reservoir the gas is also in the matrix but it is not stored in the pore volume but it is stored on the surface of the micro porosity of the matrix. In a coal bed methane reservoir the primary storage mechanism is adsorbs ion. The permeability of the reservoir is so small that gas diffusion exists in the reservoir.**Cleats-**The fracture or network of fracture in a coal terminology is called as a cleat. There are two kinds of cleats.. **Face cleats**-They are assumed to be continuous throughout the reservoir, and are the main pathway for the gas to be produced. They are in contact with large areas of the reservoir. **Butt cleats**- They are assumed to be discontinuous and they serve as a feeder network for the face cleats. They are considered to be perpendicular to the reservoir this classification is completely idealised.

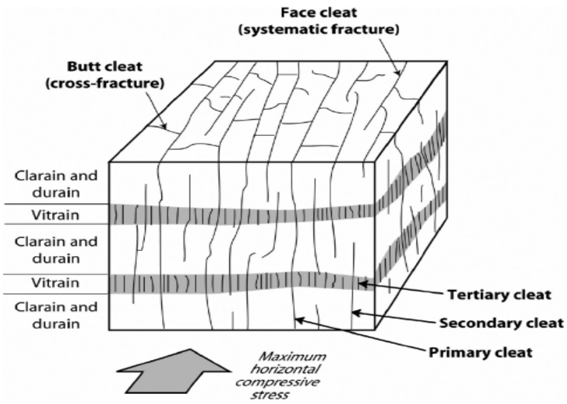

Fig.1: Generalized block diagram showing basic properties of cleat systems in coal.

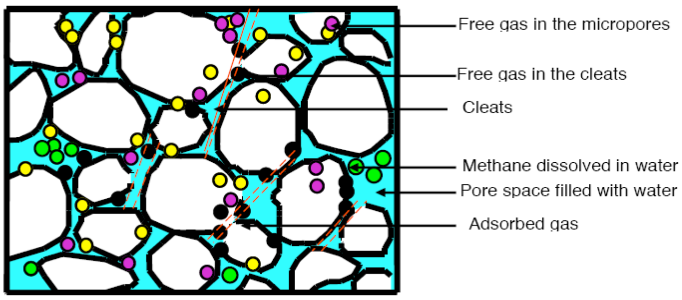

Fig.2 : Principal Mechanism for primary storage of methane within the coal's cleat and micropores

Gas Flow Rate : The methane gas initially diffuses through coal matrix and micro-pores towards the cleat and fracture system following the FICK'S LAW of diffusion and subsequently, two-phase flow is governed by *Darcy's Law*. Gas content is critical of a coal, which determines the prospectively of a coal. The fluid flow in the cleat porosity is a laminar flow due to larger pore sizes and governed by the Darcy's law while the flow in the coal matrix is a diffusional flow due to smaller pores and governed by Fick's Law.The reservoir pressure of the coal seam holds methane adsorbed in the coal in it, which is generally hydrostatic. Production of methane from coal seams involves reducing seam gas pressure to below saturation, enabling desorption of methane. The production of gas from coal is a three-step process (i) desorption from the matrix, (ii) diffusion to cleat system, and (iii) flow through the fractures.

Porosity is the portion of the total coal volume that can be occupied by water, helium, or a similar molecule. Coal pores are classified by size in macropores (>500Å), mesopores (20 to 500 Å) and micropores (8 to 20 Å). Macro-porosity includes cracks, cleats, fissures, voids in fusinite, etc. Pore volume and pore size both decrease with rank through low-volatile bituminous coals. The macropore spaces (fractures) in the coal are occupied mostly by water and some "free gas". Also, some gas can be dissolved in the water moving within the pores of the coal. The micropore structure usually has a very low flow capacity with less permeability (in microdarcy range), whereas coal cleats have a much greater flow capacity with higher permeability (millidarcy range). Therefore, coals are considered as materials with dual porosity system.

Permeability which is the ability of a material (generally an earth material) to transmit fluids through a porous medium when subjected to pressure, represents one of the most important and crucial properties to produce gas at an economical rate. In the United States, absolute permeabilities can range from 0.1 to 250md. In coalbed methane, there are two major fluids flowing in the interconnected cleat network which result in a two phase flow regime. In this case, effective and absolute permeability take place in order to differentiate two fluid flows in the porous media. The effective permeability is referred to each individual fluid. The effective permeability of individual flowing phase is always less than the absolute permeability of the porous media, and the sum of the effective permeabilities of all flowing phases is less than or equal to the absolute permeability. Relative permeability is defined as the ratio of effective to absolute permeability. After gas production starts, (long-time production of CBM) a two-phase condition is initiated. At that point relative permeability controls the behavior of the reservoir.

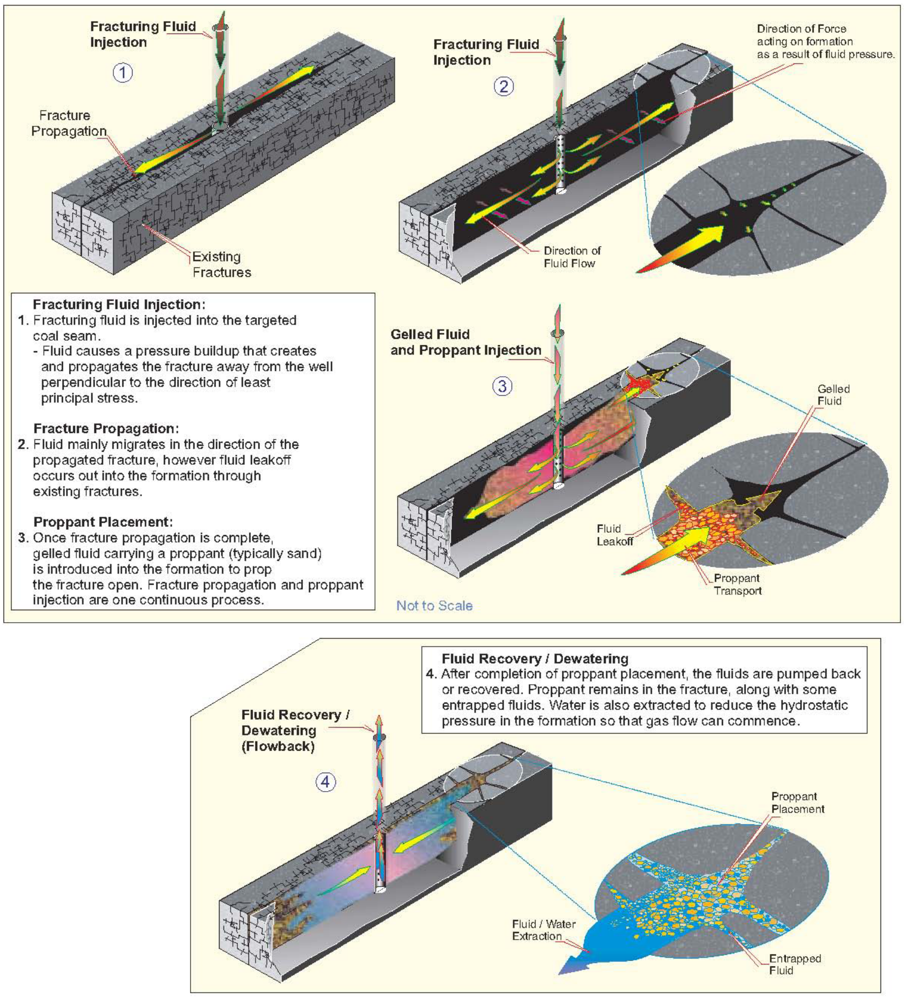

Fig.3 : A Graphical Representation of the Hydraulic Fracturing Process in Coalbed Methane Wells

Coal seam sequestration of CO_2 is particularly attractive in those cases where the coal contains large amounts of methane (CH_4) .In these cases, not only the CO_2 is stored in the coal seam in an adsorbed state but the coalbed methane (CBM) can also be produced to generate revenue that offsets the expense of sequestration

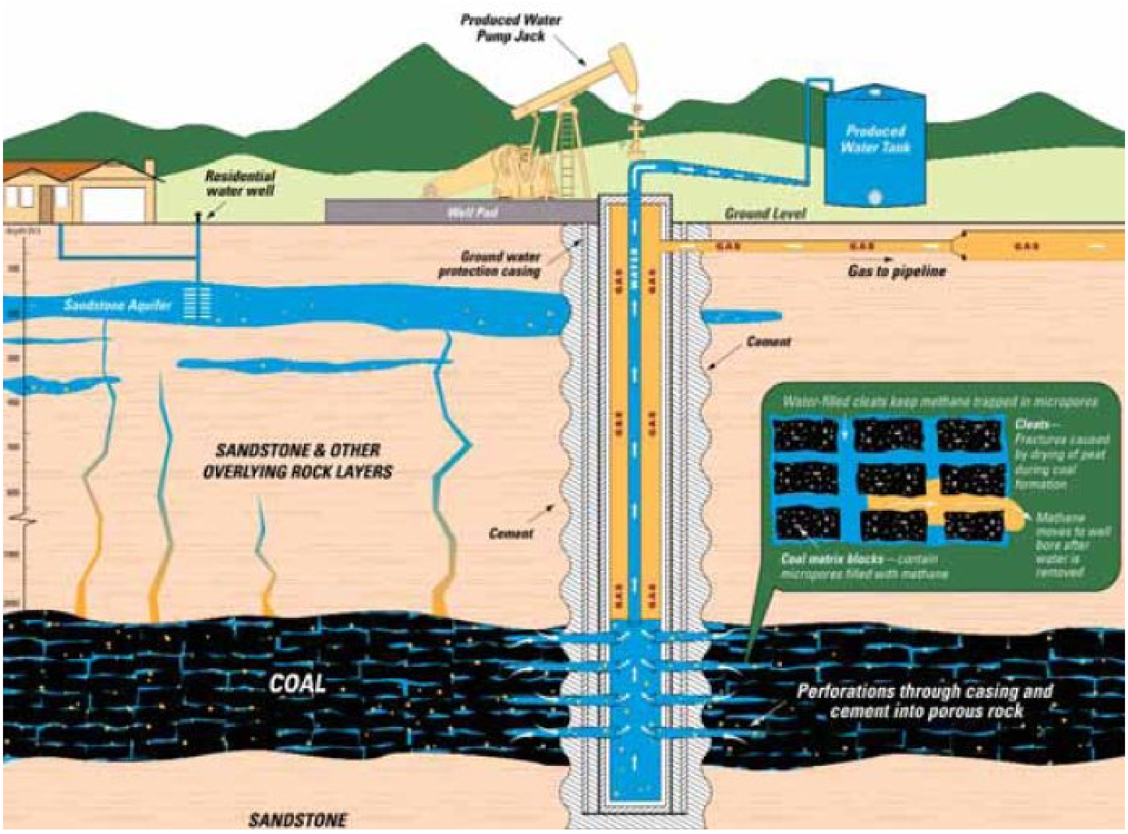

Fig.4 : Typical Coalbed Methane Well. (Source: Ecos Consulting)

Coalbed methane production

Coalbed methane production passes through three phases during the life-time of the reservoir. This behavior differs significantly from the normal decline curve of conventional gas wells. The production profile of coalbed methane well is shown in figure

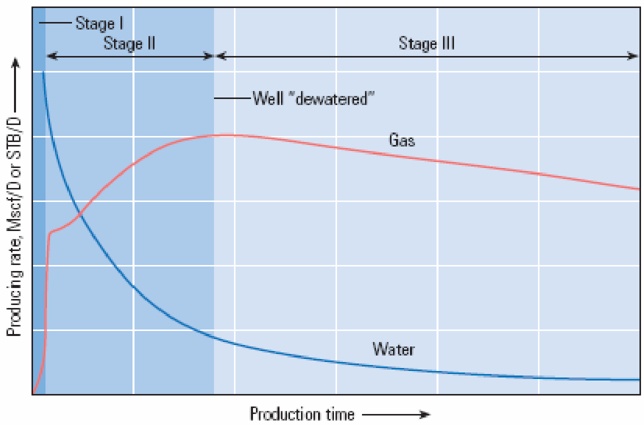

Fig.5: Typical Coalbed Methane Production Profiles for Gas and Water Rates:Three Phases of Producing Life

During phase I, CBM wells experiment a constant water production with a very low or negligible incline in gas production and decline in flowing bottomhole pressure. Initially, most CBM wells are naturally water saturated because water liberation occurs during the coalification process. The water is occupying the principal cleat network. There is the need of removing the water from the major fractures system in order to produce gas. Ideally, water production will relieve the hydraulic pressure on the coal in order to start the production by desorption of the gas from the coal. This process is known as dewatering.
The major physical properties that affect the efficiency of the dewatering process are: (a) permeability, (b) adsorbed gas content, (c) relative permeability and capillary pressure curves, (d) diffusion coefficient and, (e) desorption isotherm. Phase II is described by a dramatically decrease in the water production and increase of the gas production rate. The water relative permeability decrease and the gas relative permeability increase. Outer boundary effects become significant and gas desorption rates change dynamically. The limit between phase II and III is determined when the peak gas rate is reached. The gas production has stabilized and starts to experience a typical decline trend. During phase III, the well is considered to be dewatered, so the water production is in the low level or negligible. The water and gas relative permeabilities do not change extensively. The pseudo-steady state exists for the rest of producing life.

Result

Seismic Anisotropy for Detection of Coal Bed Methane Methods of measuring seismic azimuthal anisotropy are being used increasingly to detect fractures in reservoirs. Coal reservoirs are usually more abundant in fractures than any other ore bodies. However, not all the fracture nets have the same feature, neither can they lead to the same permeability and the same anisotropy. In coal exploitation, research on fractures is of vital importance in guiding the layout of working faces, mining and driving, the exploration and development of coal bed methane. Therefore, to be able to forecast the direction and density of fractures in coal seams is of great importance for safe production and high efficiency of coal mining. This assigns that estimates of seismic anisotropy can be used for detecting cleats in the coal bed methane (CBM) reservoirs. Azimuthal anisotropy is observed in seismic data when a seismic wave passes through a single set of vertical or near vertical fractures with a density below the seismic wavelength. Coal cleats meet these criteria and so swarms of seismic cleats may be observable through seismic anisotropy .Cleats tend to occur in pairs with a dominant set of “face cleats” providing directional permeability and a secondary set of “butt cleats” that truncates against them. Dominant and secondary cleats exchange permeability roles. There is a strong possibility that seismic azimuthal anisotropy will be observable since this dominant cleating direction anisotropy sees fluid filled and gas filled fractures. Seismic anisotropy has been observed in all mode of seismic waves. The Amplitude versus angle and azimuth (AVAZ) method is used to detect HTI (Horizontal Traverse Isotropy) anisotropy.

Conclusions

Coal Bed Methane(CBM) is naturally occurring methane adsorbed on coal seams with small amounts of other hydrocarbon and non-hydrocarbon gases contained. It is often produced at shallow depths through a borehole that allows gas and large volumes of water with variable quality to be produced. Shallow aquifers, if present, need to be protected. CBM resources represent valuable volumes of natural gas within and outside of areas of conventional oil & gas production. CBM is intimately associated with coal seams that represent both the source and reservoir.With depleting oil and gas reserves, increased focus on unconventional resources and large proven reserves, CBM is being looked upon as a potential hydrocarbon source. CBM is almost pure methane adsorbed on coal seams. It is recovered by dewatering which reduces the downhole pressure resulting in desorption and subsequent rise of methane to surface. The production is however a slow process and is accompanied by large amounts of water.Significant differences in reservoir fundamentals and mechanism demands changes in conventional procedures. So it is today's need to improvise tools and methods of estimation and maximize production with minimal cost. Logging tools are run to estimate the presence and thickness and also the porosity and permeability of coal beds. Coal bed methane reservoirs contain an orthogonal fracture set called as cleats that are oriented perpendicular to the bedding and provide the primary conduit for the fluid flow gas diffuses from the matrix into the cleats and flow to the wellbore. It is the cleat density which affects the permeability of coal beds. Increase in cleat density increases permeability and thus production potential and vice-versa. Thus to increase the output it is necessary to intersect maximum number of cleats possible. However, significant differences in the coalbed reservoir properties, gas storage mechanisms, the gas-transport phenomenon, resource decline, and water disposal have required innovations and changes to the conventional procedures. Emerging is a process unique to CBM production. Research behind these innovations has added knowledge often applicable to conventional oil and gas operations, as illustrated by two examples. First, for the first time, mine throughs provide visual study of fractures from hydraulic fracturing. Second, the effects of in-situ stresses and extreme rock properties on the coal reservoir performance are so important that their study has added significantly to the pool of oilfield knowledge.

References

www.journalseek.net,www.worldcoal.org, www.cslforum.org, www.iccop.org, www.globalmethane.org, www.coalinfo.net.cn,www.cbmdata.com, www.ECBM.org, www.co2captureandstorage.info, www.ieaghg.org , www.coal-seq.com/,coalbedmethane.org,www.natgas.info/html/coalbedmethane.html http://www.adv-res.com/coalbed-methane-unconventional-resources.asp, www.cmpdi.nic.in/cbm.htm, http://www.cbmindia.org/,www.australiancoal.com.au,www.americancoalcouncil.org, www.nationalcoalcouncil.org, www.clean-coal.info, www.miningcoal.com.au,www.weatherford.com, www.fekete.com, www.spe.org, www.halliburton.com

Krishna Chandak "New Recovery Technique for Coal Bed Methane atSPE OGIC'2010,Mumbai.

Kumar Rakesh ,2012,Estimation of Methane in Coal ,Project,B.Tech.Mining Engg.ITBHU,Varanasi,India

Lawrence M. GochiocoTuning effect and interference reflections from thin beds and coal seams, Geophysics, Vol. 56, No. 8 (August 1991): P. 1288.1295,

Ilya Tsvankin, James Gaiser, Vladimir Grechka, Mirko van der Baan, and Leon Thomsen Seismic anisotropy in exploration and reservoir characterization: An overview, Geophysics,Vol. 75, No. 5 September-October 2010; P. 75a15–75a29,

Ekrem Ozdemir , Modeling of coal bed methane (CBM) production and CO2 sequestration in coal seams, International Journal of Coal Geology 77 (2009) 145–152, doi:10.1016/j.coal.2008.09.003

Halliburton “Coal bed Methane: Principles and Practices”
Jerrald L. Saulsberry, Paul S. Schafer, Richard A. Schraufnagel,1996, A Guide To Coalbed Methane Reservoir Engineering , *Gas Research Institute,* Chicago, Illinois 60631,USA