"IMPROVING WELL PRODUCTION OF CBM WELLS: INCREASING OF FRACTURE CONDUCTIVITY BY RESTIMULATING FRACTURES, USE OF LWC PROPPANT & TSO DESIGN"

Apoorv Agarwal, +91-9808969345 apoorv0511@gmail.com , SPE
Harsh Kapoor,+91- 9456174597, harshkapoor1990@gmail.com, SPE
Akash Sharma, +91-9568023600 akashsharma750@gmail.com , AAPG, SPE
Tarang Jain, +91-9927415404 jain_tarang@yahoo.com , SPE

Department of Petroleum Engineering and Earth Sciences,
University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India

I: Abstract

Coal bed Methane reservoirs are dual porosity reservoirs where most of the gas is stored in low permeability coal matrix by sorption. The paper suggests various techniques to optimize production of gas from Indian CBM fields where the low permeability reservoirs pose serious problem in recovery. It brings about a contrast between the CBM extraction techniques used in San-Juan basin and the various CBM fields in India and also demonstrates the relationship between fracture conductivity, well productivity and economic viability.

In modest rate coal bed methane wells, it is generally accepted that very high fracture conductivity is needed to ensure dewatering, which has made 12/20 a common choice. The two successfully completed CBM wells in San-Juan basin were restimulated with 20/40 ceramic proppant which eventually lead to increase in production. The results from San-Juan basin wells bear ample testimony in support of this technique.

The field results are in analogy to the Damodar rift channel where the bituminous coal is found in abundance .Coal fields in India like Jharia, Bokaro ,North Karanpur and Raniganj lies in Damodar valley. In the wells closure stresses are modest and the strength of ceramic proppant is generally not required. However, the improved non-darcy characteristics of uniform spherical ceramic proppant have numerous benefits .The use of spherical synthetic proppant with minimal beta factors even in extremely shallow CBM formations have resulted in expansion of gas volume and high velocity in propped fractures, leading to large non-darcy effects and corresponding benefit to higher conductivity fractures.

The paper suggests various remedies to ensure optimization of gas recovery from low permeable CBM wells by using methods like Restimulating fractures, use of LWC proppants &TSO Design.

II. Introduction :

In Indian scenario, total coal resources have been estimated to be around 248 billion tons. Gondwana Basin contributing about 99%of it. Damodar Valley coalfields contribute 50% of this resource and is the primary target for CBM Exploration. The estimated CBM resource is around 1.5 TCM in 26 allotted blocks covering an area of 17700 sq km.
The preliminary assessment indicate 4 Damodar valley coal fields viz.Jharia ,Bokaro,North Karanpura and Raniganj to be most prospective. These coal fields falls under category 1, where Coal ranking high volatile bituminous A and above are found.Most of the blocks allotted are in the Exploration Phase 1 & 2 whereas the rest are in the development phase.The commercial production of CBM was started in 2008-09 since then production has drastically increased from 0.15 MMSCMD to 3.16 MMSCMD in 2011-12.
The biggest technical challenge emerging for the E &P companies in CBM exploitation from Damodar valley is the low permeability of the reservoir .The production of CBM gas can be enhanced by optimizing hydraulic fracturing techniques,use of LWC proppants ,and restimulating the fractures in such formations.In this paper we have analysed various field data obtained from CBM fields of San-Juan Basin where the use of LWC proppants, restimulating fracture techniques have lead to the drastic rise in the production of gas from the wells.
In India where the CBM potential is high but there is a strong need to increase the production to meet our growing energy demands ,currently sand proppant is used to increase fracture conductivity by various operators. .However the use of LWC proppants of mesh sizes - 16/20,12/20and 20/40 will definitely lead to the increase in the production rate as compared to the use of sand proppants.

III. Field Analysis:

San Juan field

San Juan field has two important formations Fruitland and Menefee having huge potential for CBM recovery. Coal bed methane is generally from upper cretaceous formations. Coal is accumulated over sandstone platform. Menefee is older and more dispersed than fruitland formation. Individual coal beds are as thick as 40 ft. Greatest of all is 100 ft bed in northwest trending belt. Rank of fruitland coal increases towards northeast from sub bituminous coal to medium volatile bituminous coal. It has average porosity of 10% and average permeability less than 2 md. Average reservoir pressure is about 1700 psi. Estimated gas content of san juan is 600 scf/ton. Coal bed methane of fruitland formation is composed of 23% methane, 13% Carbon dioxide, 11% Nitrogen. Fruitland formation has huge number of aquifers, due to which individual well produces 2000 barrel/day of water.

Indian field from Damodar Basin (Jharria Field)

Basis exposes lower gondwana formations of Permian age. Two important formations of Jharria field with huge CBM potential are Barakar formation and Raniganj formation. It has fault line which runs from west northwest-east southeast represented by number of parallel fractures. It has throw of 1800 m towards north because of which coal seams are preserved. Rank of coal ranges from medium volatile bituminous B to high volatile bituminous A. Permeability of upper seams ranges from 0.34 md to 3 md while for lower seams 0.05 md to 0.5 md. Ash content of upper seams is 10% to 20% and of lower seams is 25% to 30%. Volatile matter content of upper seams is 30% to 34% and of lower seams is 18% to 24%. Estimated gas in the field is about 15 billion cubic m. During testing phase a 10 m of seam was perforated and subjected to hydraulic fracturing. At its initial stage it produced 970 m3 /day of water, after six days methane production reached 2550 m3/ day, afterwards water production reduced to a constant of 2 m3/day and gas to a constant of 1200 m3/day.

IV. Discussions :

In the API test, the fluid velocity is extremely low. Pressure losses are dominated by friction, and can be described by Darcy's Law :

$$\Delta P/L = \mu v / k$$

$\Delta P/L$ - Pressure drop per length of proppant pack

$\mu v / k$ - viscous force

In actual fractures, the fluid velocity is high. Pressure losses are dominated by acceleration (inertial effects), and are described by Forchheimer's Equation. This departure from Darcy's Law can be considered a loss of effective conductivity.

$$\Delta P/L = \mu v / k + \beta \rho v^2$$

β- coefficient of internal resistance

ρ- fluid density

Forchheimer's Equation recognizes the additional energy losses by repeated accelerating and decelerating of fluid as it flows through tortuous flow path within the porus media.Both Darcy and Forchheimer equations are based on superficial velocity of fluid which assumes 100% porosity in fractures.The same fluid velocity is assumed in damaged fractures.The pressure losses in fractures is related to the fluid velocity,which is the function of proppant characteristics. The improved non-darcy characteristics of uniform spherical ceramic proppant have numerous benefits .The use of spherical synthetic proppants with minimal beta factors

even in extremely shallow CBM formations have resulted in expansion of gas volume and high velocity in propped fractures,leading to large non-darcy effects and corresponding benefit to higher conductivity fractures. (Table 2)
Carbo-ceramics have done a comparative study on the use of Sand and Ceramic proppants in the Vastar CBM field of San Juan Basin where the use of 16/20 or 12/18 was recommended but due to economical constraints 20/40 was selected.This registered a 33% improvement in the beta factor as compared with the sand of 20/40,Percentage retained conductivity,post cleanup conductivity were also improved therby lead to the increase in production of gas. (Figure 7, Figure 8).

In this paper we have done a comparative study between the formations of the San-Juan basin with the Damodar valley fields ,the resemblance of the coal characteristics, reservoir conditions and permeability are taken into account. This field study as discussed before shows great similarity between two for the basis of completion technique.

Comparative Study of Both Fields :

• **Permeability < 2md**	• **Permeability < 3md**
• **Coal rank - Sub-bituminous to medium volatile bituminous**	• **Coal rank - Medium volatile bituminous to High Volatile bituminous**
• **Average Cleat spacing = 2 cm**	• **Average Cleat spacing = 2.5cm**
• **Thickness of Bed – 20-40 ft**	• **Thickness of Bed – 3- 69 ft**
• **Reserve - 355 Scf/ton**	• **Reserve- 353.1 Scf/ton**
• **Porosity (avg)– 10 %**	• **Porosity (avg)– 10 %**
• **Pressure gradient – 0.43 psi/ft**	• **Pressure gradient – 0.42 psi/ft**
• **Temperature gradient- 8.19×10^-3 ° C/ft**	• **Temperature gradient - 8.62× 10^-3 ° C/ft**
• **Critical gas desorption pressure - 450 psi**	• **Critical gas desorption pressure - 450 psi**

Now, before we even consider CBM issues such as embedment, coal fines plugging, and multiphase flow, there is reason to suspect that our propped fractures have inadequate conductivity.
There are three options to increase fracture conductivity which includes increase fracture width and reduce gel damage but these methods are often compromised since many use 12/20 sand to increase proppant permeability.

There are numerous benefits of propped fractures such as-

- Very high fracture conductivity is needed to ensure rapid dewatering .
- Ultimate gas recovery from CBM depends on maintaining fracture conductivity .
- They are superior to under-reaming in cost and performance.
- CBM wells are more sensitive to fracture conductivity than traditional reservoirs. In CBM, desorption is driven by Fickian diffusion, which is highly pressure-dependent.
- High conductivity fractures distribute pressure drop over larger area, which can reduce the mobilization of coal fines .

Advantages of Restimulating fractures with LWC proppants have lead to the increase in production of gas by Anadarko in Utah where the production registered a 15-fold increase. (Graph)

For tip screenout designs, the fracture may be packed full, to retain the entire hydraulic width generated, regardless of the proppant chosen. However, for typical fractures that are allowed to close on the proppant, the density of the proppant will significantly impact the achieved fracture width. For a given proppant concentration in the fracture there will be a proportionate decrease in propped fracture width for a more dense proppant.

V. CONCLUSIONS :

• The conductivity needs of low pressure CBM wells are often underestimated.

• For rapid dewatering and ability to handle multiphase flow, superior fracture conductivity is needed.

• Many frac gels are extremely damaging to coals. It is desirable to use low damage fluids but maintain conductivity.

• Small reductions in wellhead pressure can dramatically increase production. Reducing pressure losses within the fracture can be equally or more leveraging! (cleanup, effective length)

• Light weight ceramic proppants provide superior conductivity, but are expensive.

• Restimulating fractures with LWC proppants can leads to increase production rate .

• Techniques used to restimulate the fractures in San juan fields can be applied in Indian CBM fields particularly in Damodar valley fields where the geology,coal characteristics finds ample resemblance .This is justified through the data obtained from the fields and correlating it with the fields .

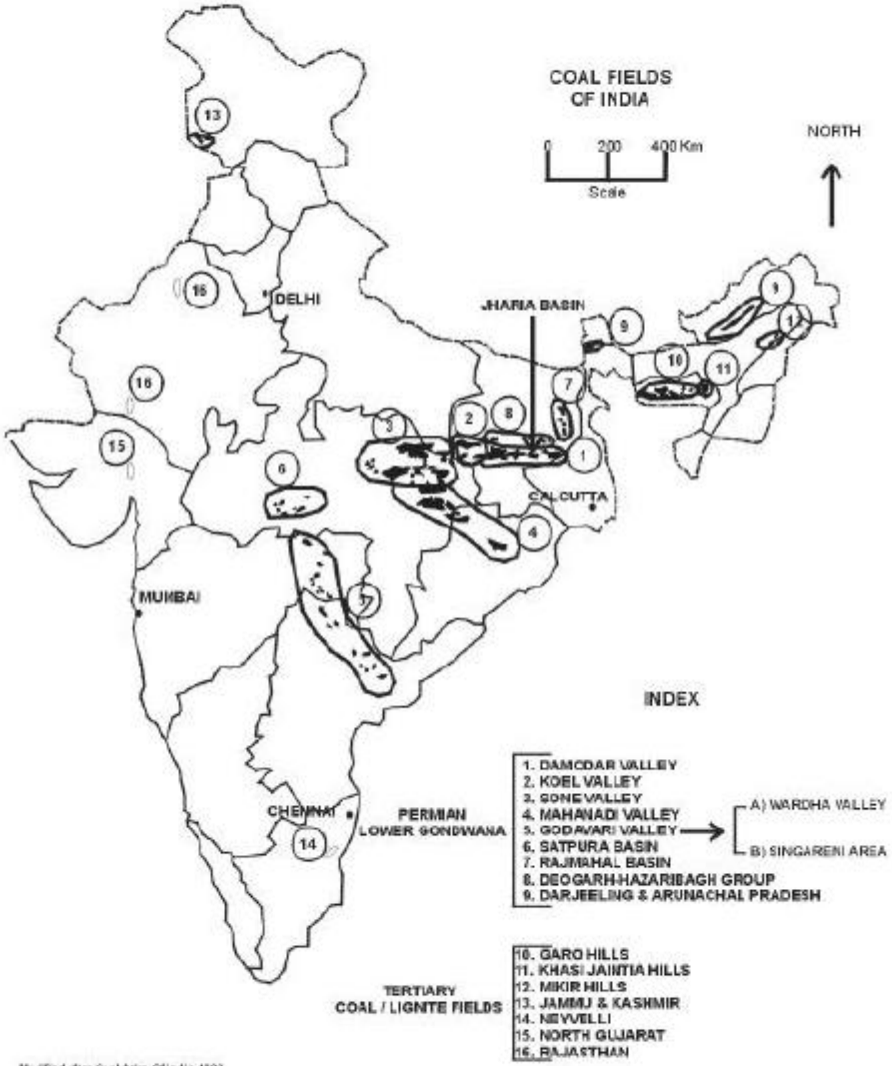
VI. Acknowledgement:

We are thankful to Dr Pradeep Joshi who was a source of inspiration for us. Our special thanks to Dr. Srinivasan and Dr. K.S. Mishra for their valuable support and suggestions. At last we express a special thanks to all of them who were the source of motivation for us.

VII. References:

- James Peters, Evaluation Of Coalbed Methane Potential Of Jharia Basin, India, SPE 64457, 2000.
- Proceedings of National Seminar on Recent Advances in Geology of Coal and Lignite Basins in India, Calcutta, 1997, Geological Survey of India, Pub. No. 54, 2001, pp 127-134, pp 287-294, pp 321-328, pp 329-338.
- Sunil Ramaswamy, Selection Of Best Drilling, Completion And Stimulation Methods For Coalbed Methane Reservoirs, A Theisis Report, Texas A & M University, 2007.
- Mike Vincent, Optimization of hydraulic fractures in CBM wells, Carbo Ceramics.
- Ajay Kumar, DC Roy, N. Yadav, Y.R.L. Rao, A K Sah, ONGC, India, Productivity Enhancement: Pretreatment Of Coal Seams For Removal Of Coal Fines From CBM Wells During Hydro Fracturing, The 2nd South Asain Geoscience Conference and Exhibition,GEOIndia2011, 12-14th Jan,2011,Gearter Noida,New Delhi,India.
- Lyle. V Lehman, Halliburton Energy Services, Inc, SPE 51063.
- Refracturing in Low Permeability Reservoirs, JPT Online, March 2006.

MAP 1: INDIAN CBM FIELDS



Modified after Coal Atlas Of India, 1983

MAP 2

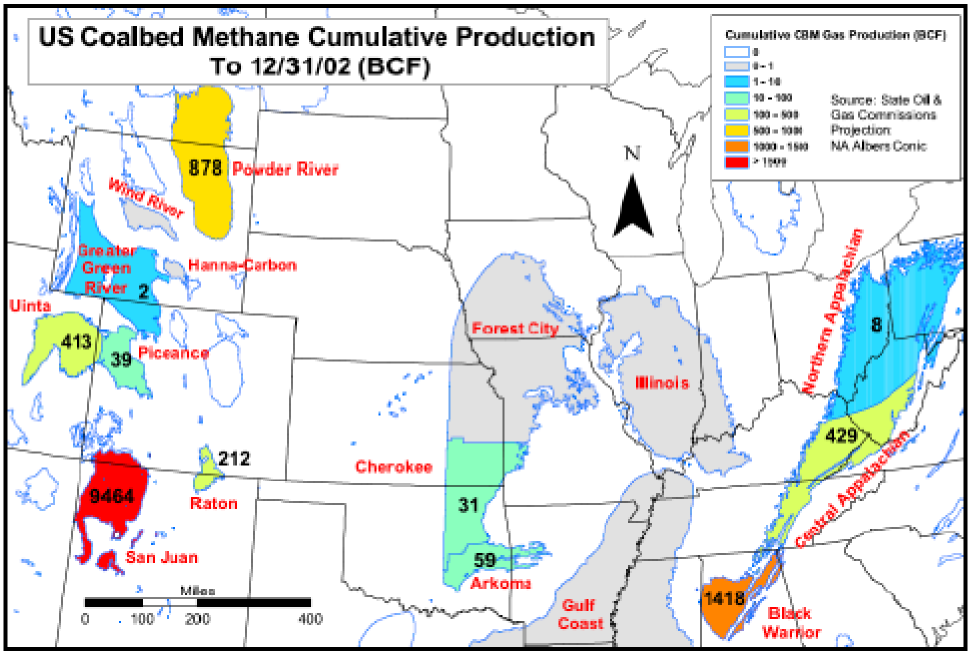


TABLE 1: RESERVOIR PARAMETERS OF WELL TESTING , JHARRIA FIELD

WELLS	A	A	B	C
PARAMETERS				
COAL SEAM	UPPER	UPPER	LOWER	LOWER
TESTING	OPEN HOLE	OPEN HOLE	OPEN HOLE	OPEN HOLE
PRESSURE	UNDER PRESSURED	UNDER PRESSURED	UNDER PRESSURED	UNDER PRESSURED
PRESSURE GRADIENT	0.37 PSI/FT	0.42 PSI/FT	0.42 PSI/FT	0.41 PSI/FT
PERMEABILITY	0.5-2.0+ md	0.34-3.0 md	0.05-0.5 md	0.5 md
SKIN	- 4.1	-2.5 to –4.8	-	-
BHT	111^{0} F	110^{0} F	157^{0} F	147^{0} F
RESERVOIR TYPE	LAYERED	LAYERED	LAYERED	LAYERED
FRACTURE EXTENSION	0.87 PSI/FT	0.72 PSI/FT	0.74 PSI/FT	0.7 PSI/FT
FRACTURE ENCLOSURE	0.85 PSI/FT	0.72 PSI/FT	0.68 PSI/FT	-
AVERAGE GAS PRODUCTION	1200 M^{3}/DAY	-	-	-
AVERAGE WATER PRODUCTION	3 M^{3}/DAY	-	-	-

TABLE 2: Density Effects on Flow Properties (Relative to Sand)

Proppant Type	Width or Conductivity Multiplier	Darcy/Viscous Pressure Drop Multiplier	Inertial Pressure Drop Multiplier
Sand	1.00	1.00	1.00
Light Weight Ceramic	1.08	0.92	0.86
Intermediate Strength Ceramic	0.88	1.14	1.30
Bauxite	0.83	1.20	1.44

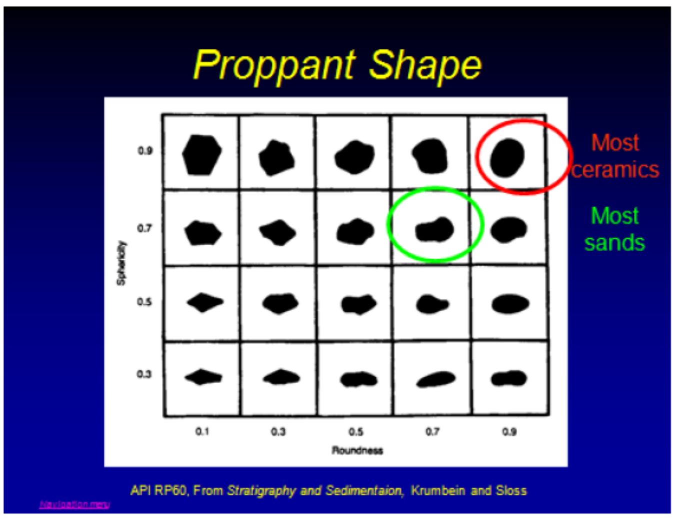


FIGURE 1

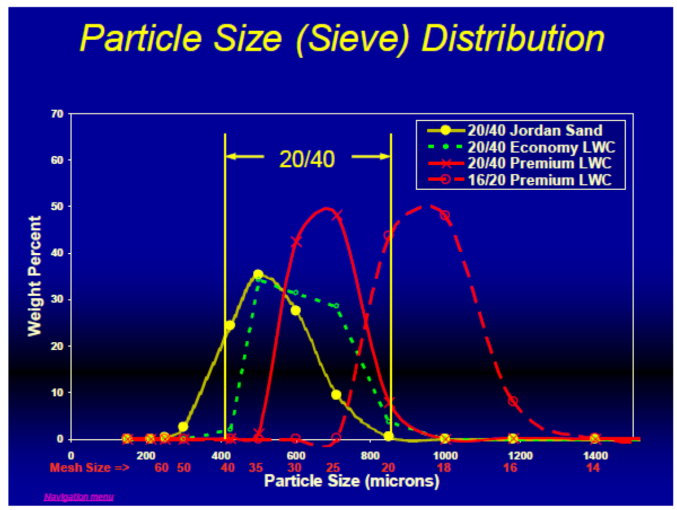


FIGURE 2

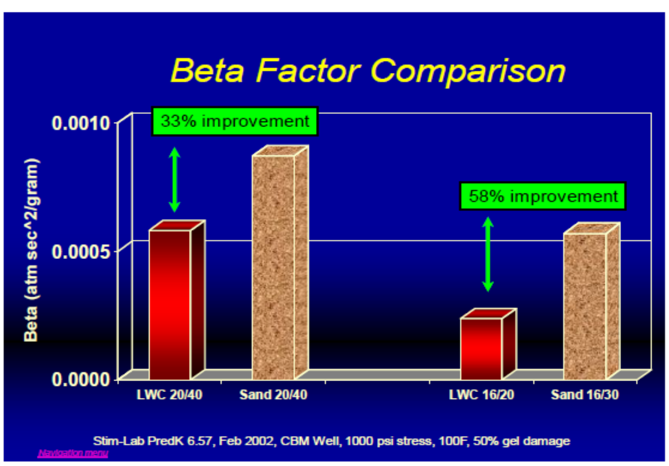


FIGURE 3

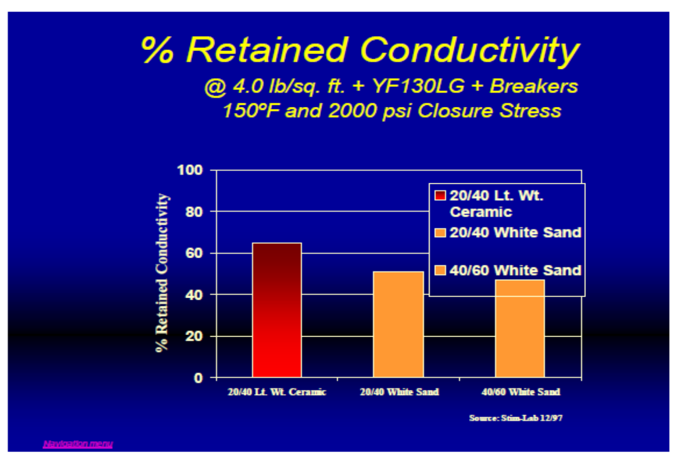


FIGURE 4

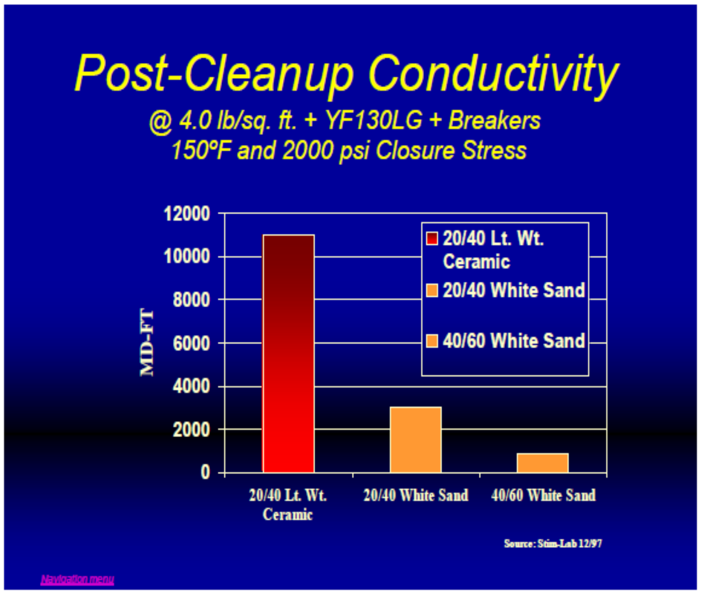


FIGURE 5

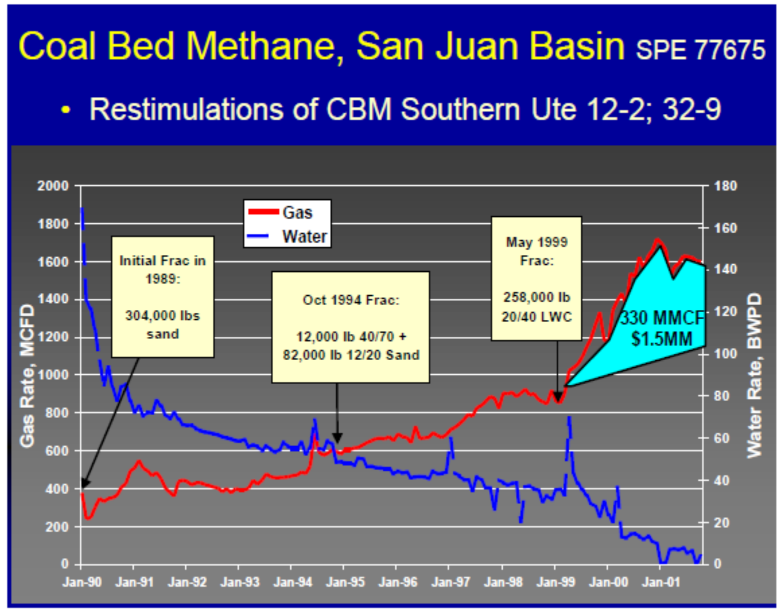


FIGURE 7

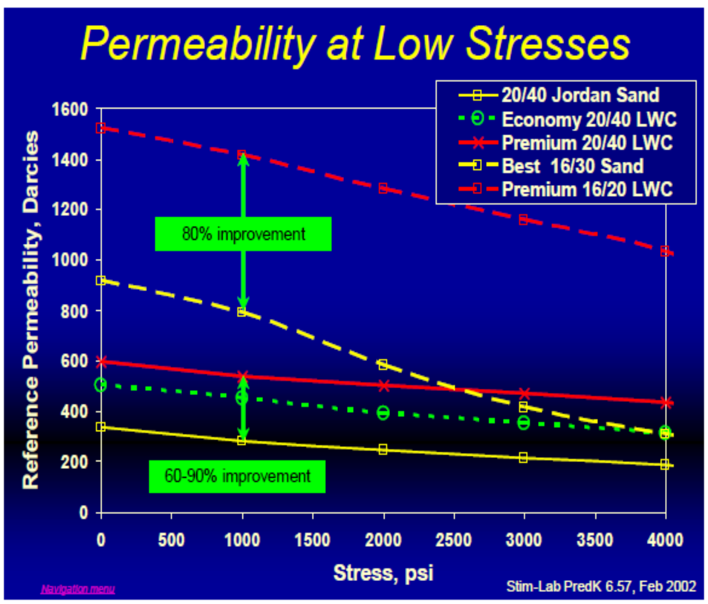


FIGURE 6

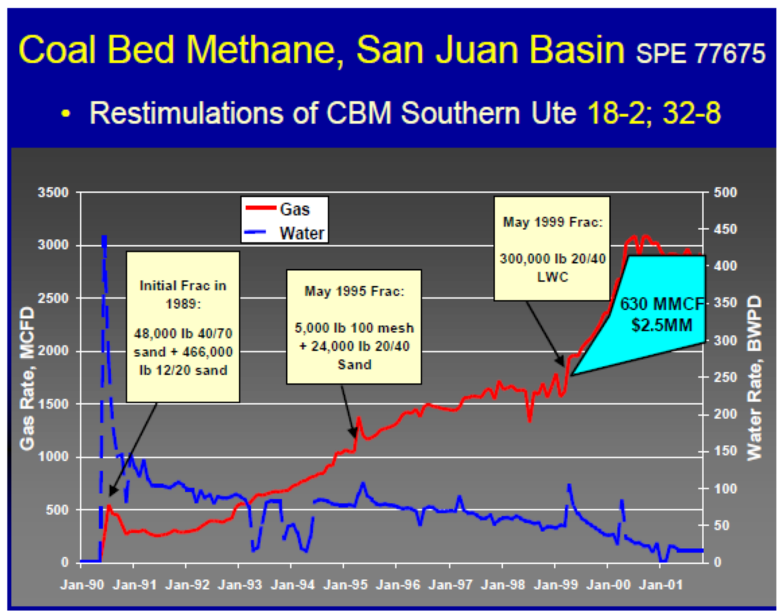


FIGURE 8