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Analysis and Diagnosis of CBM Fractured Wells' Productivity Damage in the Middle of Qinshui Basin, China

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Abstract
CBM differs from conventional reservoirs, which is easily damaged with complex factors. There were massive papers on CBM damage mechanism, but with fewer studies on pollution types and stimulating measures. This paper studies various factors on SHI Zhuang CBM field's production from the perspective of geology, engineering and drainage, establishes typical production model to determine reservoir pollution types, and builds up well and layer selection standard for recovering potential reservoirs. The result proves that impacts on CBM wells productivity cannot be ignored because their damages are huge, such as subsided column, fracturing fluid soaking time, fracturing problems, pumping efficiency, drainage time interval, production efficiency, and liquid loading rates etc. Major factors' determination and typical curves' establishment offer references on reservoir diagnosis, which is of great significance on layer selecting stimulation of inefficient wells.

Key words: CBM fractured wells; Productivity; Formation damage; Typical curves

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INTRODUCTION

As self-generating and self-preserving reservoir, CBM reservoir differs from conventional ones on reservoir characteristics and seepage mechanism. CBM exploration needs to take water drainage, pressure reduction, desorption, seepage and production. CBM wells' productivity is affected by many factors. Generally speaking, geological factors have dominant impacts on productivity as well as engineering and recovery factors. Past studies focus on reservoir damage mechanism but ignore exploitation techniques' influences on productivity such as fracturing, drainage and recovery. On the basis of massive wells' production statistics, this paper does research on various influencing factors of reservoir productivity. Four kinds of typical curves are established to describe reservoir pollution according to factors' changes such as casing pressure, gas rate and water rate. The result shows geological factors have great impacts on reservoir productivity such as CBM content, subsided column, and faults; wells' production can be affected by engineering factors which include well bore enlargement, pump efficiency, and fracturing problems. The study on fractured wells' productivity is of great significance to analyze low-yield wells' damage factors and offer reservoir stimulating measures.

1. FACTORS ON THE CBM WELLS' PRODUCTIVITY

During the hydraulic fracturing procedure proppant-blockage or sand bridge easily happen to CBM wells, whose fracture length is shorter than ones in sandstone or carbonate reservoir. Additionally, CBM reservoir differs from conventional reservoir which contains more adsorbed gas with fewer free gas; desorption rate of adsorbed gas is affected by drainage and pressure declining degree. From low-yield wells' statistics of Qinshui Basin, various CBM wells' distribution is shown in Figure 1.

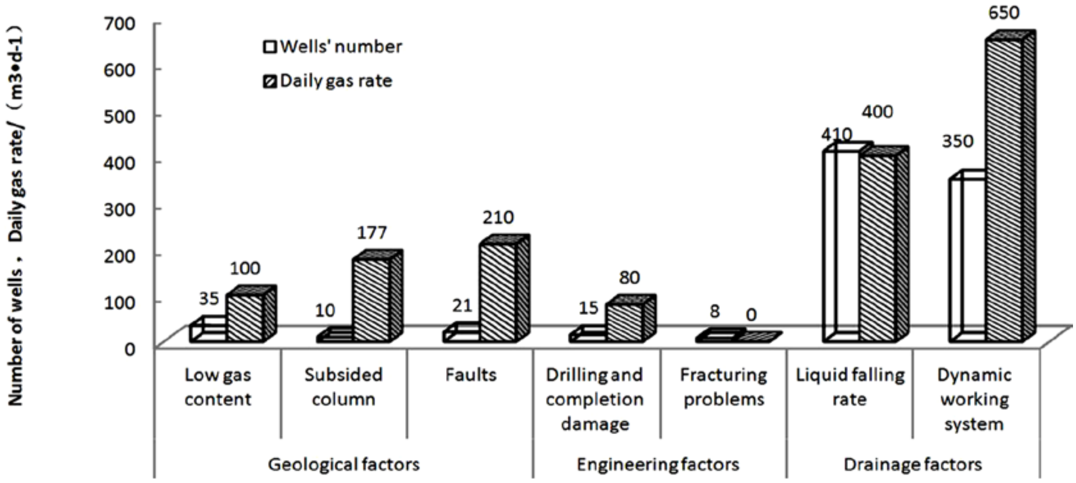

Figure 1
Distribution of CBM Low-Yield Wells' Main Factors

As can be seen from Figure 1, drainage factors on CBM wells take up 87%, and engineering factors cover less.

1.1 Geological Factors' Effect

1.1.1 Gas Content

Through 80 CBM wells' statistic from Qinshui basin, the linear relation between gas content and gas rate is shown in Figure 2. As when coalbed gas content is higher, wells' productivity will be better.

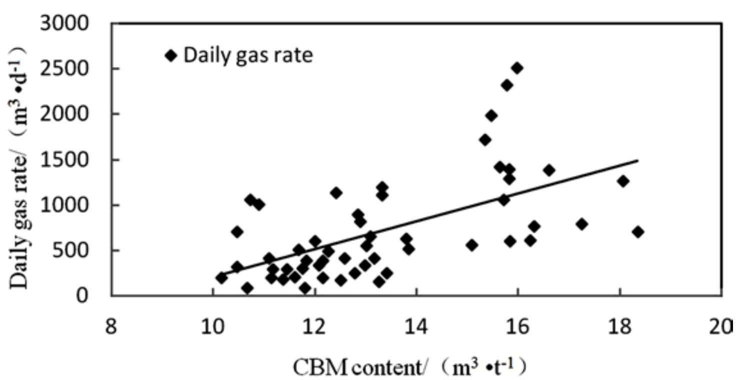

Figure 2
Plot Between CBM Content and Gas Rate

1.1.2 Fault

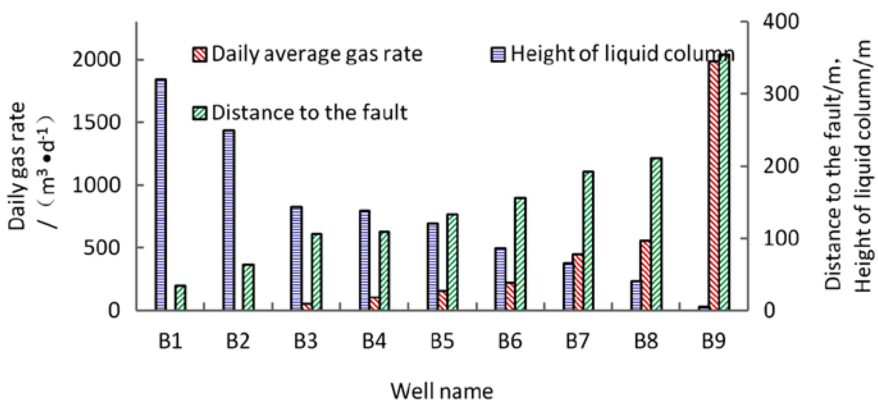

Figure 3
Wells' Yield Distribution Around Faults

As shown in Figure 3, wellbores' liquid column will be higher while their position is closer to faults, whose height changes from 5 to 320 meters. Faults provide passage for interlayer water or edge water's invasion to wells. As for wells that are far away from faults they often have higher gas rate and lower water yield.

1.1.3 Subsided Column

Figure 4 shows statistics of well data that are nearby the collapse column.

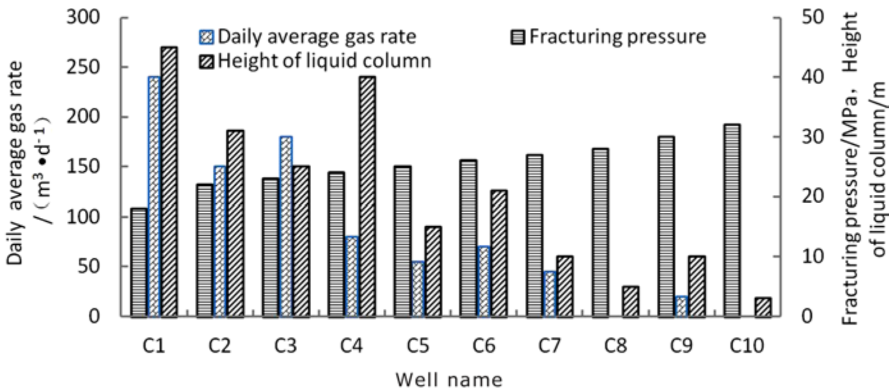

Figure 4
Wells' Yield Around Subsided Column

From Figure 4 it is found that wells around subsided column have poor productivity with their liquid height from 30 to 45 meters and gas rate from 0 to 240 m^3/d. Due to collapse of coalbed reservoir fluids' channel is destroyed, and gas dispersion loss is greatly serious.

1.2 Engineering Factors

1.2.1 Wellbore Enlargement Effects

Due to coal's fragile feature, wellbore diameter is easily enlarged during the drilling process.

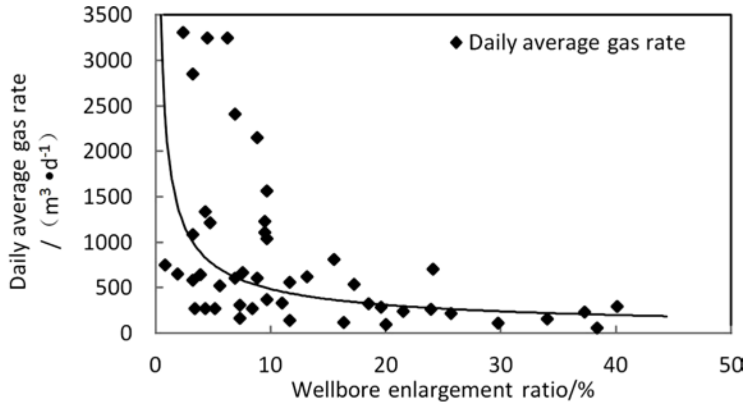

Figure 5
Wells' Yield Under Different Wellbore Enlargement Ratios

As shown in Figure 5, when wellbore diameter enlargement ratio is bigger gas rate declines faster, if its value overcomes 20%, wells' productivity will be less than 450 m^3/d.

1.2.2 Soaking Time of Fracturing Fluid

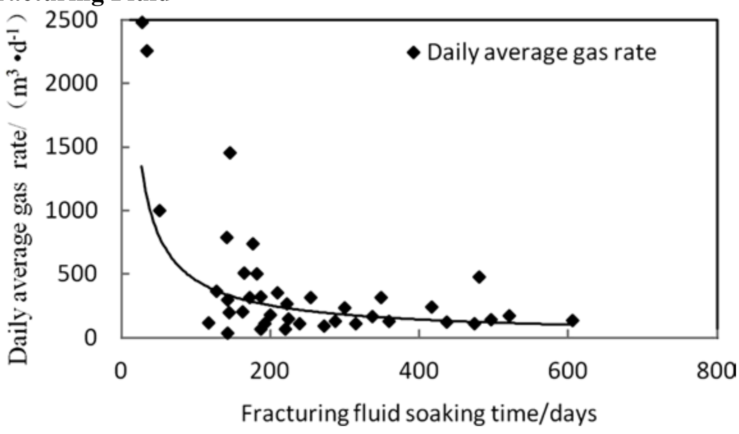

Figure 6
Wells' Yield Under Various Fracturing Fluid Soaking Time

Longer soaking time of fracturing fluid will cause the damage to reservoir such as water lock effects, coal powders' blockage, etc. From Figure 6 it can be seen that wells' gas rate will be lower than 500 m^3/d as soaking days' number >200.

1.2.3 Drainage Time Interval

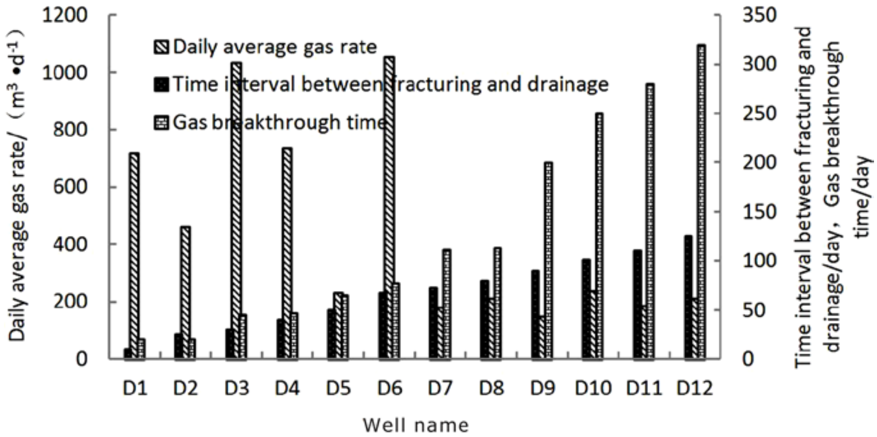

Figure 7
Drainage Intervals' Effect on Gas Production

Gas output will be later as when drainage interval is greater in Figure 7. Because of coal powders' or ashes' deposit during fluids' drainage it may cause formation damage and lead to wells' poor productivity.

1.3 Drainage Factors

1.3.1 Low Production Efficiency

There are many factors that affect wells' production efficiency such as coal powder migration, pump efficiency, discontinuous working system of technical equipment and so on. These wells' productivity performance is shown in Figure 8.

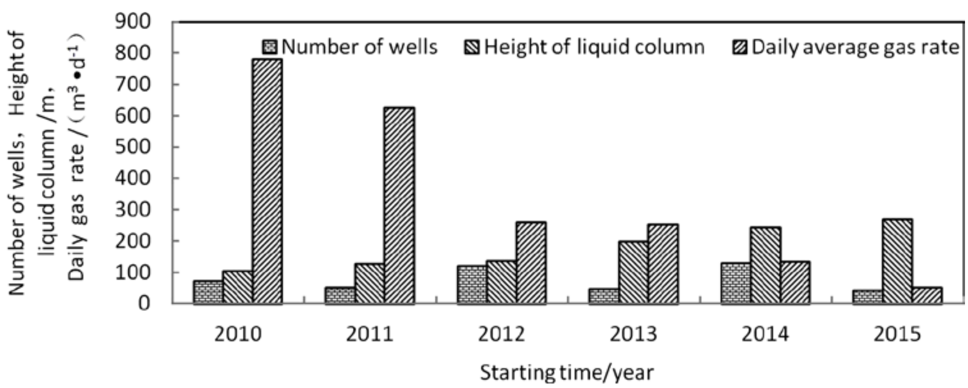

Figure 8
Inefficient Wells' Yield Distribution Statistics

1.3.2 Liquid Falling Rate

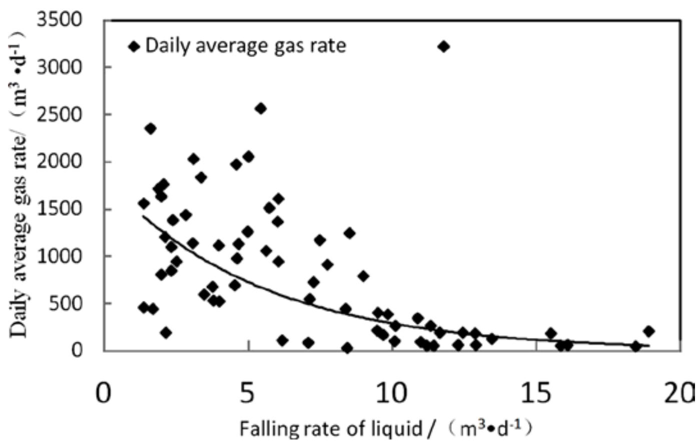

Figure 9
Fluid Falling Rate's Effects on Wells' Yield

As can be seen from Figure 9, as with greater liquid drop rate wells' productivity declines more. Due to wellbore liquid level's dynamic changes, it may cause coal-powders' precipitation and formation pollution.

1.3.3 Pump Efficiency

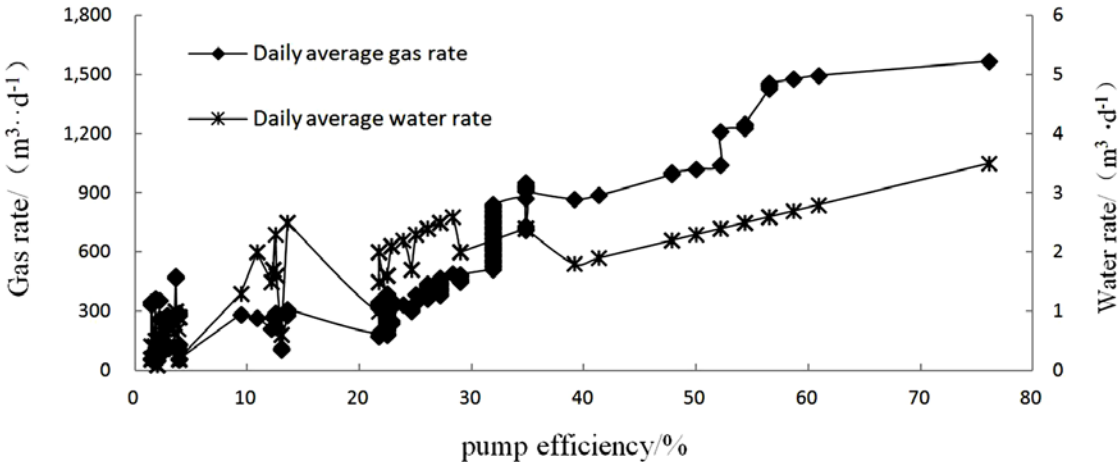

Figure 10
Pump Efficiency Effects on Wells' Yield

From Figure 10 it is found that wells with better pump efficiency may have higher water or gas rate. Weaker pump efficiency may lead to wellbore liquid loading. Major factors of weakening pump efficiency are as follows: (a) due to wellbore tubing's corrosion, scrap iron's accumulation does harm to pump; (b) coal powders or sands that are carried by formation fluids easily block up pump inlet, which will weaken pump efficiency greatly.

2. DYNAMIC TYPICAL CBM CURVES

Various factors' damaging degrees on the reservoir are different, and wells' performance characteristics are also diverse from each other, whose parameters' changing features can gradually reflect the dynamic information of reservoir.

Through 40 wells' production statistics and analysis, typical curves are established to display wells' productivity performance, which will provide references for studying reasons of wells' poor performance.

2.1 Coal Powder Blockage

During the early drainage stage this kind of wells' water rate is high, coal ashes and powders migration in pore may lead to reservoir pollution, water and gas yields decline quickly. Wells' production performance is shown in Figure 11.

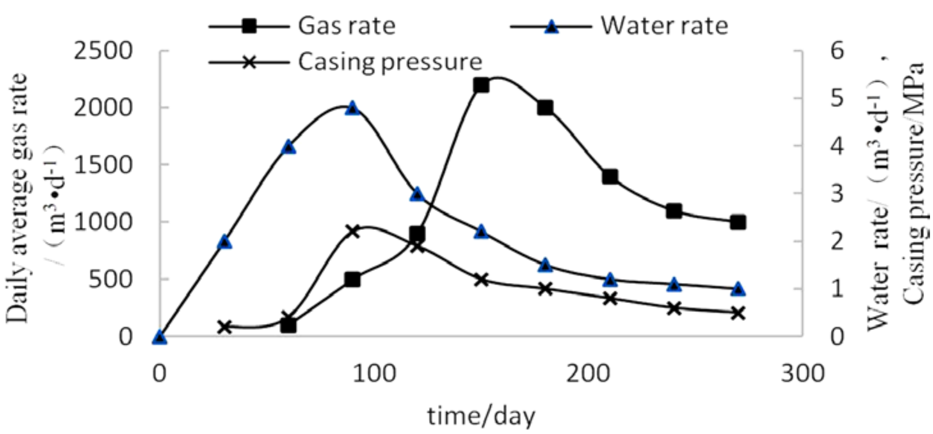

Figure 11
Typical Curve Under Coal Powder Blockage

2.2 Water Lock

In the early days of production, water and gas rates are high, but later gas-liquid interfacial tension in the micro pore increases which may suppress gas output. As a result of water lock damages casing pressure and gas rate will have obvious decreases as shown in Figure 12.

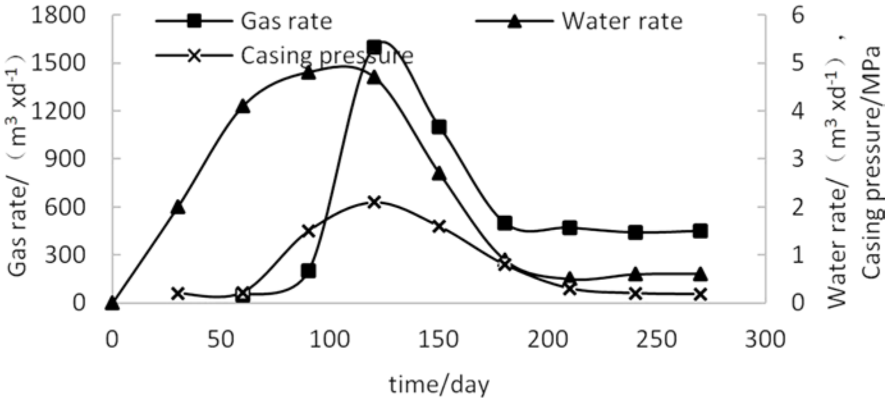

Figure 12
Typical Curves Under Water Block Damages

2.3 Stress Closure

Coal is brittle, which can be easily embedded by proppant during the fracturing. With formation fluids' output and producing pressure differences increasing, hydraulic fracture may partly close as a result of pressure sensitive effect. After pressure-sensitivity effects water yield decreases to 0, and gas rate declines significantly. The typical curve is drawn in Figure 13.

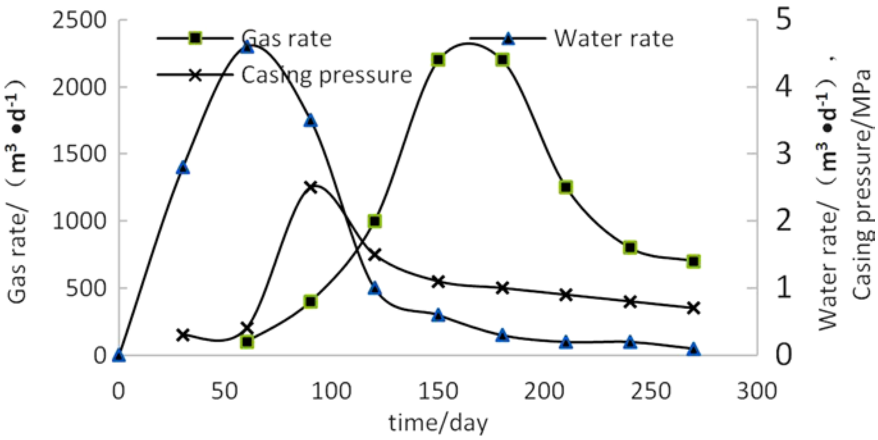

Figure 13
Typical Curves With Stress Sensitivity Effects

2.4 Fracturing Problems

Due to the sand blockage or bridge problems in the field fracturing process, major crack with high conductivity can't be formed in the formation. Because of poor fracturing effects, in the early production stage casing pressure is high but later declines quickly; both water and gas yields are few. Wells' typical performance is shown in Figure 14.

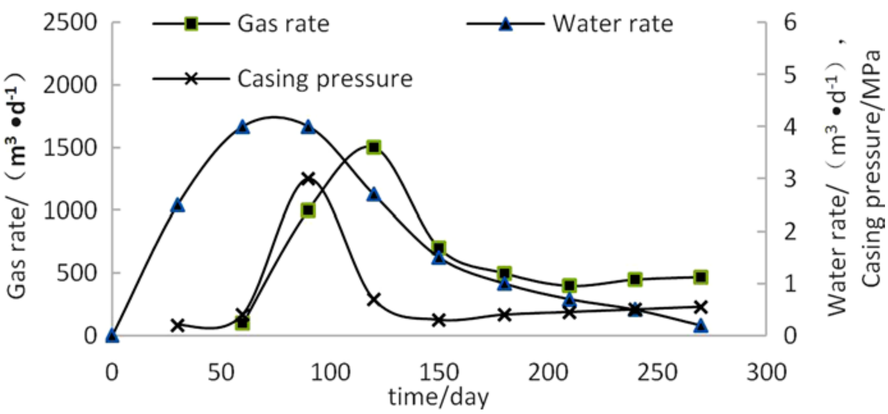

Figure 14
Typical Curve With Poor Fracturing Effects

Some reservoir stimulating measures are advised to deal with different kinds of wells' poor productivity as follows: (a) coal powder blockage: Cyclic nitrogen foam stimulation technology is applied on eliminating particle pollution near wellbore area; (b) water locking damage: Chemicals against water lock are used to reduce the interracial tension and change rock wettability, and weaken fluid's flow resistance; (c) fracturing damage: For some wells with bad fracturing effects, hydraulic jet and technology can be applied on reservoir stimulation.

3. CASE STUDY

Through the study of reservoir damage factors and types, some stimulating measures are applied on reservoir of poor performance to increase well's productivity. Layer selection criteria is established as follows: (a) coalbed with high gas content, good quality and yield potential; (b) lower production capacity in comparison with adjacent wells "yield; (c) wells" production affected by discontinuous work system or pump efficiency problems; (d) abnormal hydraulic fracturing such as sand plug or sand bridge etc. but neighboring wells with good productivity performance.

By CBM reservoir damage diagnosis and layer refracturing criteria, one preferred well's initial site fracturing and production dynamic curves are shown in Figures 15, 16.

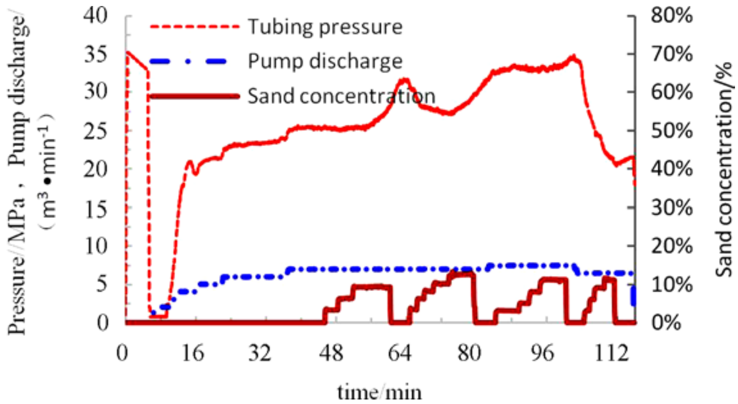

Figure 15
Hydraulic Fracturing Curve of Well S1

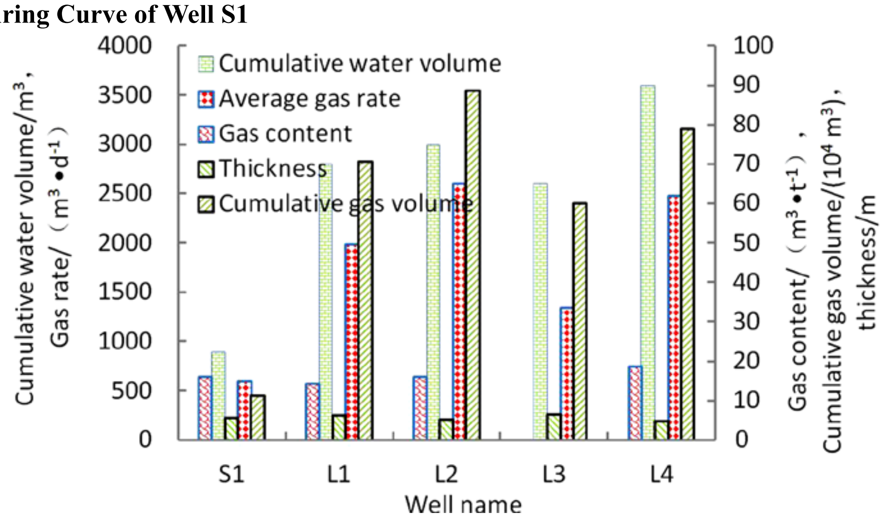

Figure 16
Statistics of S1 and Its Adjacent Wells

In Figure 15 by the contrast with neighboring wells: L1, L2, L3, L4 on reservoir parameters such as thickness, cumulative gas production, and gas content, S1 shows worse production performance: cumulative gas volume as $11.2\times10^4 m^3$, cumulative water volume as $1.2\times10^4 m^3$.

In Figure 16 it can be found that during the fracturing procedure S1's pump pressure is continuously increasing due to sand blockage, and number of actual proppant and fracturing fluid volume have not met the requirements of fracturing scheme.

By the comprehensive analysis of S1's production and fracturing, it is found that poor fracturing effects mainly leads to poor productivity of S1, but actually it has good potential.

The incrementary ratio of well S1 after refracture is 5.1, and its yield reaches 1,200 m^3/d that exceeds the earlier maximum rate as shown in Figure 17.

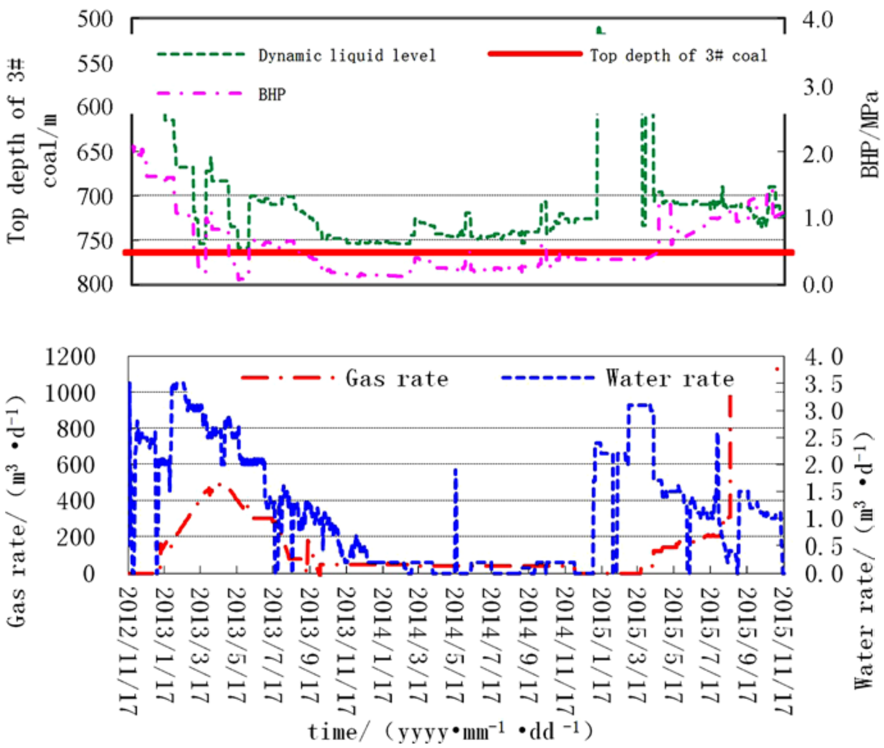

Figure 17
Well S1 Production Curve After Refracturing

CONCLUSION

(a) Through geology, engineering and drainage parameters' study on CBM wells' productivity, it can be found that geological factors have great influences on CBM wells' performance, such as CBM content, fault and coalbed subsided columnetc; engineering damage factors contain fracturing fluid soaking time, fracturing fluid drainage time interval, fracturing practice problems; during the production pump efficiency, production efficiency, and liquid loading rate have certain impacts on reservoir capacity;

(b) According to the dynamic production characteristics of CBM wells, from the perspective of geology, engineering and drainage, this paper establishes typical production model that studies water block, coal powder blockage, stress closure factors' influences on production performance such as casing pressure, water and gas rate, and it offers judgment criteria for inefficient wells' reservoir pollution types. Meanwhile based on field test and application results, reservoir stimulation measures are advised to eliminate formation damage.

(c) Through candidate wells and layers ' optimization, well S1 uses refracturing technology to improve productivity, and obtains satisfying fracturing effects. After refracturing, the incrementary rate ratio of well S1 is 5.1 that greatly exceeds the earlier maximum gas rate.

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