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(54) **METHOD FOR ENHANCING METHANE PRODUCTION FROM COAL SEAMS**

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(57) **ABSTRACT**

Discloses a three step process to stimulate well production of methane from coal seams, wherein step one provides for injection of a treating gas into a well bore intersecting a coal seam, step two includes a shut-in period and step three comprises the placement of a propped fracture treatment. In step one, the injection of the treating gas physically opens pre-existing paths of weakness in the coal. As the treating gas travels along these planes of weakness, it preferentially adsorbs onto the coal and displaces the methane. This displacement process induces shrinkage of the coal matrix, which further increases the size of the intervening existing fractures. The second step, or shut-in period, allows time for this gas exchange process to substantially complete, thereby maximizing the effect of matrix shrinkage and enhancement of the intervening fractures. The third step provides for placement of a propped fracture treatment into this enhanced fracture system. Propping of the enhanced fractures ensures that they remain open, even as removal of water and methane work to close the fractures by increasing effective stress within the coals. The result is a stimulated coal seam that maintains enhanced permeability during production operations.

METHOD FOR ENHANCING METHANE PRODUCTION FROM COAL SEAMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of application Ser. No. 10/668,019 filed Sep. 23, 2003, now abandoned.

FIELD OF THE INVENTION

[0002] This invention relates to the stimulation of coal seams for methane recovery and more particularly provides for stimulation of methane recovery from coal seams by inducing coal matrix shrinkage and placement of a propped fracture treatment.

BACKGROUND OF THE INVENTION

[0003] Coal seam gas production is primarily dependent on the permeability of the coal seam. Coal seam reservoirs are fractured reservoirs wherein the fractures intervene between essentially impermeable blocks of coal matrix. As the fractures are the only effective pathways for movement of methane through a reservoir to a well-bore for recovery, the size, intensity and connectedness of the fractures determine the permeability and, hence, producibility of the reservoir. No known method exists for artificially creating fracturing within a coal seam on a reservoir wide scale, so techniques and methods for stimulating coal seam permeability are limited to enhancing the near well bore environment with the goal of effectively connecting the well bore to the existing natural fracture system.

[0004] Underground coal seams contain large amounts of natural gas, a significant amount of which is methane. The methane exists in a sorbed state in the coal and several techniques exist for increasing permeability near the wellbore and, hence, methane production. Several challenges exist in creating an open pathway from the coals natural fracture system to the wellbore for the recovery of methane. Firstly, coals are known to possess stress dependent permeability, meaning that the application of additional effective stress upon a coal causes deformation which often closes the fracture system, thus degrading permeability and methane production. A critical challenge in stimulating coalbed methane wells is to design a completion technique that allows the fracture system to maintain an open posture throughout production, thereby minimizing the effect of stress dependence on permeability.

[0005] Secondly, the nature of prior art fracture treatment on coals also serves to damage and degrade coal permeability in some regions of the reservoir while simultaneously enhancing it in others. The intent of the prior art is that the enhanced regions of permeability outweigh the damaged areas, with a net positive effect to the near well-bore environment. In a prior art fracture treatment, proppant is entrained within a foam or water-based slurry into newly created and/or existing fractures within the coal seam. As these fractures are opened, stress is redistributed and other fractures, which may be surrounding the opened fracture, become pressed shut. This effect degrades the reservoir by diminishing the amount of reservoir effectively connected to the hydraulic fracture treatment. The object of the present invention minimizes this degradation by shrinking the coal matrix prior to the introduction of the propped fracture.

[0006] Prior art discloses three main techniques for stimulating coalbed methane wells. All of these techniques disclose injection of a treatment comprising various gases, fluids and/or proppants into the coal seam to fracture the coal.

[0007] The first technique is a chemical bath stimulation in which the coals are subjected to various aqueous-borne chemicals to either increase cleat or fracture development within the coals or to change a chemical characteristic of the coals. U.S. Pat. No. 5,249,627 discloses a method for stimulating methane production from coal seams by treating the coals with various chemicals to improve the removal of water. No disclosures for either gas injection or proppant placement are made. U.S. Pat. No. 5,470,823 discloses a method for stimulating methane production from coal seams by treating the coals with an aqueous acid solution. No disclosures for either gas injection or proppant placement are made. U.S. Pat. No. 5,669,444 discloses a method for stimulating methane production from coal seams by treating the coals with various aqueous chemicals to increase fracture development. No disclosures for either gas injection or proppant placement are made. U.S. Pat. Nos. 5,669,444 and 5,964,290 disclose methods for stimulating methane production from coal seams by treating the coals with various aqueous chemicals to increase fracture development. No disclosures for either gas injection or proppant placement are made. None of these disclosed techniques follow the chemical treatments with a proppant.

[0008] The second type of stimulation is a one-stage completion technique relying on artificially initiating a fracture and/or propagating an existing fracture through the coals through the application of high pressure injection of gas and/or water based fracturing fluids. Hydraulically fracturing coals is difficult given the plastic behavior of many coals, which tend to fracture at a greater treating pressure than the surrounding strata.

[0009] In a one-stage completion, the completion process is one continuous application of pressured fluid, with or without proppant, and the well is placed on production thereafter. No attempts are made to induce shrinkage in the coal. U.S. Pat. No. 3,384,416 discloses a method where a refrigerant fluid containing a proppant is injected into a coal seam to create fracturing. The inducement of matrix shrinkage prior to proppant placement is undisclosed. U.S. Pat. No. 6,412,559 B1 discloses method for recovering methane and/or sequestering fluids in coals whereby a gas more strongly adsorbing than methane with or without a proppant is injected into a coal seam, shut in for a period of time from hours to days and released. The inducement of matrix shrinkage prior to proppant placement is undisclosed.

[0010] The third type of completion is a cycled gas completion, in which gases are repeatedly injected and allowed to flow back, with the intention of causing in-situ failure of the coals and thereby inducing fracturing. U.S. Pat. No. 5,014,788 discloses a method for injecting a gas into a coal seam, which is intended to swell the coals and increase stress within the coal. A rapid depressurization of the coals caused by suddenly releasing the pressurized gas to surface shrinks the coal, removing the induced stress, and mechanically failing the coal. This process is designed to be repeated as many times as necessary. No disclosure is made for following this process with a propped fracture treatment. U.S. Pat. No. 5,417,286 discloses a method for stimulating methane production from carbonaceous subterranean formations be injecting a first fluid to sorb into the formation and subsequently injecting a chemically different second fluid to part the formation and relieving the pressure to produce shear failure within the formation. No claims are made regarding the use of a proppant.

[0011] U.S. Pat. No. 5,566,755 discloses a method for recovering methane from solid carbonaceous subterranean formations through the repeated injection and extraction of an oxygen depleted gas. No claims regarding subsequent placement of a proppant are made. U.S. Pat. No. 6,412,559 B1 discloses a method for recovering methane and/or sequestering fluids in coals whereby a gas more strongly adsorbing than methane and a proppant are simultaneously injected into a coal seam, shut in for a period of time from hours to days and released. U.S. Pat. No. 6,450,256 discloses an enhanced coalbed gas production system whereby gases are injected into a coal seam and released. The injection of the gas increases methane production displacing water within the cleat system, by affecting the gas saturation within the coal and by reducing the partial pressure between the coal and the cleat system. No disclosure of introducing a proppant after release of the injected gas is made.

[0012] U.S. Pat. No. 6,571,874 B1 discloses a method for extraction of in-situ methane from coals whereby gases are injected into a coal seam, shut in for a period of time from days to weeks and released. The process is repeated many times, with the purpose of creating a propped fracture utilizing fines sourced from the coals themselves. This prior art method contains serious drawbacks. Firstly, fines control is considered a major problem in coalbed methane production, as the fines are known to migrate and plug open fractures, rather than maintain open fractures. As well, the low compressive strength of coal makes it a very poor candidate for a proppant, as the fines would be easily crushed into a damaging powder which would cause plugging. This prior art method does not utilize an introduced proppant after release of the injected gas.

[0013] The prior art inventions do not promote matrix shrinkage in coal and fail to take into account the benefits of inducing matrix shrinkage first, followed by the placement of a propped fracture.

SUMMARY OF THE INVENTION

[0014] In one of its aspects, the present invention provides a process to stimulate well bore production of coalbed methane gases. The invention improves on the previously disclosed techniques as it uses the reaction of a predetermined gas with the coal to induce shrinkage within the coal matrix, thus reducing effective stress and enhancing the fracture void volume. This increased fracture void volume increases coal bed permeability and resultant increase in methane gas flows. It also allows placement of proppant within the coals to maintain open fractures in the regions surrounding the propped fracture, thus allowing the enhanced fracture system to communicate more effectively with both the natural fracture system and the wellbore and aiding methane recovery.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] The present invention stimulates and enhances production of methane gas from a coal seam. The coal seam is accessed via one or more well bores that extend into the coal seam. A predetermined gas is introduced into the coal seam, which operates to open the existing natural fracture system by inducing shrinkage of the coal such that when pressure is removed from the system the volume of the coals is less than the volume originally in place. This shrinkage results in additional fracture void volume and serves to create more and better connected pathways through the coal for the methane gas to pass through. The shrinkage lessens effective stress within the coal bed.

[0016] Injecting a treating gas into a well bore that is open to a coalbed stimulates production of methane gas from the coalbed. Once the treating gas has been introduced, the well is shut for a period of time to allow the introduced treating gas to induce shrinkage of the coal seam. The coal seam shrinkage results in enhancement of the intervening natural fractures in the coal seam to increase the permeability of the coal seam to methane gas migration.

[0017] If a coal matrix is considered by analogy as a box packed with methane filled balloons, with each balloon filled to such a capacity such that minimal free space exists between the balloons. Nitrogen introduced into the free space diffuses into the balloons and displaces the methane, which then flows out into the free space. Nitrogen is more "efficient" at filling the balloons than methane, so a lesser volume of nitrogen is required. With this lesser volume, the balloons are smaller, resulting in increased free space between the balloons. This allows greater flow in and around the balloons, allowing for easier and faster recovery of the methane.

[0018] A primary reason for the use of nitrogen is that it displaces methane from the coal matrix and in doing so, causes a net shrinkage of the matrix and an increase in the intervening fractures. The process is a gas exchange process, and it is desirable to place as large a volume of nitrogen as possible into coals to maximize the affected area. This is more a matter of economics than concept. As well, Nitrogen or N_2 gas is preferred as it will not form explosive mixtures with methane and is inherently safer.

[0019] Use of environmental or ambient air itself, that is the air of earth's atmosphere, may be the most desirable injection gas of all. Air from the atmosphere is rich in Nitrogen, and the Nitrogen in the air will shrink the coal matrix. Moreover, the O_2 in the air from the atmosphere can oxidize the matrix, which will hinder reversal of the shrinkage effect of the Nitrogen when the introduced air is dissipated. In order to ensure that explosive mixtures are not created when atmospheric air is used, the residence time of the gas introduced into the coal bed is preferably extended to several days. The length of residency time will depend on the formation parameters such as coal seam type and dimensions as well as the properties of the geologic formation surrounding the coal seam. Experience obtained from performing well treatments with Nitrogen gases, including atmospheric air, against formations with measured and known properties, will establish parameters for optimal treatment processes, including feed pressures, rates, residence times that are established to effect a difference in recovery rates or absolute recovery amounts.

[0020] CO_2 is not preferred as a treating gas or fluid as it causes coal matrix expansion, which will have the undesirable effect of the coals becoming less permeable with injection of such gases. That is, CO_2 injection reduces the inherent permeability of a coal seam and hampers the recovery of methane from it.

[0021] As a further treatment of the coal bed, a propped fracture stimulation is placed into the coal seam into the enhanced intervening fractures to maintain the fractures in an open state. In the preferred process where a proppant is placed in the treated formation, proppant placement should take place immediately after N_2 placement. If the well is allowed to flow back to the surface for any significant length of time, methane from distal portions of the reservoir can again displace the N_2, reversing the matrix shrinkage.

[0022] During the first stage injection of the treating gas, the treating gas travels into the fracture network along the fracture planes where it contacts the coal matrix and begins displacement of the methane contained within the coal matrix. This displacement shrinks the contacted portions of the coal matrix, resulting in an increase in the intervening fracture void volume.

[0023] In the second stage, the well is shut in for a period of time to allow the maximum amount of methane displacement to occur. In this manner, the coal is an active participant in the production of induced fractures and planes of weakness, with the interaction between the coal and the treating gas creating preferential paths of weakness within the coal. The second step, or shut-in period, allows time for this gas exchange process to substantially complete, thereby maximizing the effect of matrix shrinkage and enhancement of the intervening fractures. This differs significantly from most prior art fracture treatments which treat the coal as a static medium and attempt to create new fractures within the coal by introducing formation stresses that exceed it's parting strength. During the shut in period, the supply of treating gas can be completely stopped, allowing the treating gas supplied prior to closing the well for shut in to dissipate into the formation. Alternately, during the shut in period, the supply of treating gas can be continued at suitable rates and pressures, for example, at a rate that maintains a supply pressure above atmospheric pressure at the point of supply over at least a portion of the shut-in period. Or as another example, at a rate that maintains a supply rate or volume of supply at a predetermined rate.

[0024] In one manner of treatment, the shut in period extends until the well head pressure at the point of supply drops to a predetermined pressure. In another manner of treatment, the shut in period extends for a predetermined period of time.

[0025] Another feature of the invention is the maintenance of smaller scale fractures in an open posture surrounding the larger scale induced fractures. The shut in period is related to achieving this effect as the shut in period allows the coal matrix to be bathed in the treating gas. Increasing the shut in period increases the reservoir volume that is treated for induced fracturing. Once the shut-in period has ended, matrix shrinkage will produce a similar effect to removal of matrix as the matrix shrinkage creates additional void spaces in the enhanced fractures within the coal seam. The enhanced fractures facilitate proppant placement when such a stage is warranted. A proppant placement stage is performed to enable the placed proppant to occupy the introduced and enhanced matrix fractures without producing excessively elevated local effective stress fields and collapsing the smaller scale fractures that occupy the region surrounding the propped fracture. In this fashion the propped fracture system maintains an effectively connected posture with both the reservoir's natural fracture system and the well bore and methane collection is enhanced.

[0026] While the invention has been described here with reference to particular embodiments, the invention is not limited to the particular or specific embodiments described, but rather is defined in the appended claims.

We claim:

1. A method for in situ stimulation of a methane production from a coal seam comprising the steps of:

i) supplying a treating gas containing nitrogen into a subterranean methane bearing coal seam via a wellbore intersecting said subterranean coal seam; and

ii) closing the well bore for a shut-in period.

2. The method of claim 1 further including the step of pressing of a fracture treatment containing proppant into said methane bearing subterranean coal seam.

3. The method of claim 1 step of closing includes further supply of treating gas to maintain a predetermined pressure at the point of supply over at least a portion of the shut-in period.

4. The method of claim 1 step of closing includes further supply of treating gas to maintain a predetermined pressure above atmospheric pressure at the point of supply over at least a portion of the shut-in period.

5. The method of claim 1 step of closing includes further supply of treating gas at a predetermined supply rate or over at least a portion of the shut-in period.

6. The method of claim 3 further including the step of pressing of a fracture treatment containing proppant into said methane bearing subterranean coal seam.

7. The method of claim 4 further including the step of pressing of a fracture treatment containing proppant into said methane bearing subterranean coal seam.

8. The method of claim 5 further including the step of pressing of a fracture treatment containing proppant into said methane bearing subterranean coal seam.

9. The method of claim 1 wherein the treating gas is ambient or atmospheric air.

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