ENHANCED HYDROCARBON RECOVERY FROM LOW MOBILITY RESERVOIRS

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Appl. No.: 13/334,679
Filed: Dec. 22, 2011

Provisional application No. 61/429,628, filed on Jan. 4, 2011.

Publication Classification
Int. Cl. E21B 43/22 (2006.01)

ABSTRACT
Methods are provided using heated fluids along with combined/drive cyclical injection/production profiles to enhance hydrocarbon recovery from shallow and/or low mobility reservoirs. In certain embodiments, injection and production flow rates to and from the reservoir are varied to beneficially modulate certain pressure drive profiles between a minimum pressure and a maximum pressure. During these drive profile modulations, heated water, solvent, and surfactant are injected into the reservoir. The combination of injected fluids and cyclical pressure drive profiles beneficially enhances hydrocarbon recovery from the reservoir. Other optional variations include using multiple injection and/or production wells. Advantages include accelerated hydrocarbon recovery, higher production efficiencies, and lower costs. These advantages ultimately translate to higher production and/or reduction of total hydrocarbon extraction time. These methods are particularly advantageous when applied to shallow reservoirs (e.g., reservoirs having depths less than or equal to about 150 meters).
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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a non-provisional application which claims the benefit of and priority to U.S. Provisional Application Ser. No. 61/429,628 filed Jan. 4, 2011, entitled “Enhanced Hydrocarbon Recovery From Low Mobility Reservoirs,” which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to methods and systems for enhancing hydrocarbon recovery from low mobility reservoirs. More particularly, but not by way of limitation, embodiments of the present invention include methods and systems using heated fluids with combined/ drive cyclical injection/production profiles using two or more wells to enhance hydrocarbon recovery from shallow and/or low mobility reservoirs.

BACKGROUND

[0003] The production of hydrocarbons from low mobility reservoirs presents significant challenges. Low mobility reservoirs are characterized by high viscosity hydrocarbons, low permeability formations, and/or low driving forces. Any of these factors can considerably complicate hydrocarbon recovery.

[0004] Extraction of high viscosity hydrocarbons is typically difficult due to the relative immobility of the high viscosity hydrocarbons. For example, some heavy crude oils, such as bitumen, are highly viscous and therefore immobile at the initial viscosity of the oil at reservoir temperature and pressure. Indeed, such heavy oils may be quite thick and have a consistency similar to that of peanut butter or heavy tar, making their extraction from reservoirs especially challenging.

[0005] Conventional approaches to recovering such heavy oils often focus on methods for lowering the viscosity of the heavy oil so that the heavy oil may be produced from the reservoir, such as heating the reservoir to lower the viscosity of the heavy oil. Commonly used in-situ extraction thermal recovery techniques include a number of reservoir heating methods, such as steam flooding, cyclic steam stimulation, and Steam Assisted Gravity Drainage (SAGD). SAGD is an enhanced oil recovery technology for producing heavy crude oil and bitumen. It is an advanced form of steam stimulation in which a pair of horizontal wells is drilled into an oil reservoir, one a few meters above the other. Steam is continuously injected into the upper wellbore to heat the oil and reduce its viscosity, causing the heated oil to drain into the lower wellbore, where the oil is then pumped out. While SAGD technology has proven effective in improving hydrocarbon recovery in many types of reservoirs, SAGD unfortunately suffers from relatively high energy consumption, which in some cases results in low efficiencies due to the resulting amount of water contamination in the recovered hydrocarbons.

[0006] Low driving forces can also adversely affect hydrocarbon recovery. Where sufficient reservoir pressure is lacking to motivate hydrocarbons to the surface, hydrocarbon production rates may be limited to an economically unpractical production flow rate. Secondary recovery operations are sometimes used to motivate hydrocarbons suffering from low driving forces toward a production well. One example of a secondary recovery is the use of steam flooding to sweep hydrocarbons toward a production well. Steam flooding involves the use of injected steam to heat and physically displace hydrocarbons to encourage production of the hydrocarbons.

[0007] Another related production enhancement technique is known as cyclic steam stimulation. Cyclic steam stimulation, also known as the huff and puff method, involves three stages, injection, soaking, and production. Steam is first injected into a well for a certain amount of time to heat the oil in the surrounding reservoir to a temperature at which it flows. After a sufficient injection of steam, the steam is usually left to “soak” for some time afterward (typically not more than a few days). Then oil may be produced out of the same well. Steam assisted gravity drainage, on the other hand, involves continuously injecting steam into an upper wellbore to heat the surrounding heavy crude oil and reduce its viscosity, causing the heated oil to drain into a lower wellbore, where the oil may be pumped out.

[0008] These conventional approaches are highly disadvantageous in that they are all significantly energy intensive. In some cases, these thermal recovery techniques are so inefficient that they are often not economically viable for recovering heavy crude oil. Indeed, these conventional thermal recovery techniques are especially economically disadvantageous when applied to shallow reservoirs. This inefficiency is attributable in large part to high heat loss inherent in shallow reservoirs as compared to deeper reservoirs due in part to heat loss to the surface. This heat loss in shallow reservoirs along with other factors such as well cost and well spacing makes conventional thermal recovery methods economically infeasible as applied to shallow, thin zone reservoirs.

[0009] These energy-intensive conventional methods are also highly disadvantageous in particularly colder regions such as permafrost regions (e.g. especially high or low latitude geographic regions) due to the high heat loss that necessarily occurs in these regions.

[0010] Another example of a conventional method for recovering heavy oil is surface mining. Surface mining may be infeasible or at least highly inefficient under certain circumstances, such as when the desired hydrocarbons are not located near the surface. Additionally, in some of the conventional approaches, surface mining may require significant surface reconstitution.

[0011] Low permeability of subterranean formations can also adversely affect hydrocarbon recovery. Various types of stimulation operations are often used to improve formation permeability such as fracturing and acid matrix stimulation. In some types of formations, however, such as shallow reservoirs, fracturing is not feasible due to the risk of propagating fractures to the surface, which could result in the undesirable release of hydrocarbons to the surface. Another type of stimulation, acid matrix stimulation, is limited in that it is only effective on some types of formations.

[0012] Accordingly, there is a need for enhanced recovery methods for recovering heavy oils from shallow and/or low mobility reservoirs that address one or more of the disadvantages of the prior art.

SUMMARY

[0013] The present invention relates generally to methods and systems for enhancing hydrocarbon recovery from low
mobility reservoirs. More particularly, but not by way of limitation, embodiments of the present invention include methods and systems using heated fluids with combined/ drive cyclical injection/production profiles using two or more wells to enhance hydrocarbon recovery from shallow and/or low mobility reservoirs.

An example of a method for enhancing hydrocarbon recovery from a low mobility reservoir having an injection well and a production well intersecting the low mobility reservoir comprises the steps of: (a) providing water; (b) providing a solvent; (c) providing a surfactant; (d) heating at least one of the water, the solvent, and the surfactant to its saturation temperature; (e) introducing the water, the solvent and the surfactant into the low mobility reservoir at an injection rate by way of the injection well; (f) allowing the pressure of the low mobility reservoir to increase until reaching a first maximum pressure of the low mobility reservoir; (g) upon substantially reaching the first maximum pressure of the low mobility reservoir, producing from the production well at a production rate; (h) allowing the reservoir pressure to reduce until the low mobility reservoir reaches a first minimum pressure.

(i) upon reaching the first minimum pressure, substantially reducing production from the production well; and (j) repeating steps (e)-(i) a plurality of times.

One example of a method for enhancing hydrocarbon recovery from a low mobility reservoir having one or more injection wells and one or more production wells intersecting the low mobility reservoir comprises the steps of: (a) providing water; (b) providing a solvent; (c) providing a surfactant; (d) heating at least one of the water, the solvent, and the surfactant to its saturation temperature; (e) introducing the water, solvent and the surfactant into the low mobility reservoir at a total injection rate by way of the one or more injection wells; (f) allowing the pressure of the low mobility reservoir to increase until reaching a dilation pressure of the low mobility reservoir; (g) upon substantially reaching the dilation pressure of the low mobility reservoir, producing from the one or more production wells at a total production rate; (h) allowing the reservoir pressure to reduce until the low mobility reservoir reaches a first minimum pressure; (i) upon reaching the first minimum pressure, substantially reducing production from the one or more production wells; and (j) repeating steps (e)-(i) a plurality of times.

The features and advantages of the present invention will be apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying figures, wherein:

FIG. 1 illustrates an example of an enhanced heavy oil recovery system in accordance with one embodiment of the present invention.

FIG. 2 illustrates an example of a cyclic pressure profile of a low mobility reservoir during execution of one embodiment of the present invention.

FIGS. 3A-3E illustrate aerial views of example well configurations in accordance with certain embodiments of the present invention.

While the present invention is susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

The present invention relates generally to methods and systems for enhancing hydrocarbon recovery from low mobility reservoirs. More particularly, but not by way of limitation, embodiments of the present invention include methods and systems using heated fluids with combined/ drive cyclical injection/production profiles using two or more wells to enhance hydrocarbon recovery from shallow and/or low mobility reservoirs.

In certain embodiments, injection and production flow rates to and from the reservoir are varied to beneficially modulate certain pressure drive profiles between a minimum pressure and a maximum or dilution pressure. During these drive profile modulations, heated water, solvent and surfactant are injected into the low mobility reservoir. The combination of injected fluids and cyclical pressure drive profiles beneficially enhances hydrocarbon recovery from the low mobility reservoirs. Other optional variations and enhancements include, for example, using multiple injection and/or production wells, which are described further below.

Advantages of such enhanced heavy oil recovery processes include, but are not limited to, accelerated hydrocarbon recovery, higher production efficiencies, and lower costs. These advantages ultimately translate to higher production and/or a reduction of total extraction time of in-situ hydrocarbons. The methods disclosed herein are particularly advantageous in shallow reservoirs (e.g. reservoirs having depths less than or equal to about 150 meters), because conventional methods suffer from a variety of disadvantages when applied to shallow reservoirs due in part to the energy losses to the under or over burden of the shallow reservoirs.

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation of the invention, not as a limitation of the invention. It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations that come within the scope of the invention.

FIG. 1 illustrates an example of an enhanced heavy oil recovery system in accordance with one embodiment of the present invention. Low mobility reservoir 120 is shown residing in submeraneous formation 110. Injection well 130 and production well 140 both intersect low mobility reservoir 120. Injection well 130 is provided for introducing injected fluid 135 into low mobility reservoir 120 by way of injection
well 130, whereas production well 140 is provided for extracting production fluid 145 by way of production well 140.

[0028] Reservoir 120 suffers from low mobility of the hydrocarbons therein due in part to high viscosity of the hydrocarbons therein, low permeability, and/or low driving forces. Furthermore, where low mobility reservoir 120 is a shallow reservoir, heat loss to the surface becomes significant thus reducing the efficiency of many conventional methods. In some geographic regions such as in the permafrost, cooler formation temperatures also adversely affect the economics of using steam flooding due to the heat loss that is exacerbated by the cooler formation temperatures.

[0029] Low reservoir pressures can also adversely impact hydrocarbon recovery. Often, lifting equipment is required to provide the necessary driving forces to motivate the hydrocarbons to the surface. Additionally, where the low mobility reservoir is a shallow low permeability reservoir, even with low viscosity oil, the permeability of the formation is too low to allow production of the oil at any practical rate. In such cases, fracturing the reservoir to enhance the permeability is not a viable option since fracturing the reservoir risks propagating the fractures to the surface, which could result in the undesirable loss of injected fluids or hydrocarbons to the surface. All of these factors tend to impair the efficiency of hydrocarbon recovery from low mobility reservoirs.

[0030] Introducing one or more heated fluids into the formation by way of injection well 130 can enhance hydrocarbon recovery. The heated fluids may comprise water, solvent, and a surfactant. The heated fluids and solvent can provide this beneficial effect by both acting as a diluent to reduce the viscosity of the hydrocarbons and by increasing the temperature of hydrocarbons. Because viscosity is highly temperature dependent, heating the hydrocarbons will beneficially reduce the viscosity of the hydrocarbons, thus making the hydrocarbons more mobile.

[0031] In certain embodiments, the heated fluids may be at any temperature above the formation hydrocarbon temperature up to approximately the solvent’s saturation temperature. In this way, the heated fluids advantageously warm the formation hydrocarbons so as to reduce the viscosity of the hydrocarbons. Because the latent heat capacity of a solvent usually far exceeds its specific heat capacity, one can realize tremendous energy savings by avoiding further heating the solvent once the solvent reaches its saturation temperature. Other conventional processes such as Steam Assisted Gravity Drainage (SAGD) technology would be highly inefficient in shallow low-permeability reservoirs due to the additional heat losses that would result. In this way, one can avoid the considerable expense of further heating the solvent once its saturation temperature is reached.

[0032] Any solvent may be used that provides some dissolution of the heavy oil and/or lowering of the viscosity of the heavy oil. Examples of solvents suitable for use in conjunction with the present invention include, but are not limited to, a wide variety of condensing solvents including C4-C30 or mixtures thereof, naphtha, diluent, syncrude, diesel, aromatic solvents such as toluene, benzene, and xylene, and any other solvent known in the art, or any combination thereof. Other solvents could include carbon dioxide or flue gas as well. In embodiments where the solvent is combined with the water and the surfactant, concentrations of the solvent in water may vary from about 0 wt % to about 50 wt %, and the active surfactant concentration in water may vary from about 0 wt % to about 20 wt %.

[0033] In some embodiments, the water may be fresh water, sea water, formation water, or any combination thereof. In certain embodiments, the water may be recovered from the mixture withdrawn from low mobility reservoir 120, which in certain embodiments may be a flash drum, one or more distillation columns, any suitable process separations technology, or any combination thereof. In some embodiments, the recovered water may be recycled back to the reservoir for additional use.

[0034] One or more surfactants may also be introduced into low mobility reservoir 120 by way of injection well 130. Surfactants can lower the interfacial tension and hence the capillary forces that hold the oil in the sand matrix and further enhance hydrocarbon mobility, especially when combined with the beneficial effects of the heated solvent. Any surfactant may be used that tends to reduce the interfacial tension and capillary forces of the hydrocarbon. Examples of surfactants suitable for use in conjunction with the present invention include, but are not limited to, a number of commercially available interfacial tension reducing surfactants such as petroleum sulfonates, aliph olefin sulfonates, or synthetic alkylaryl sulfonates.

[0035] The surfactants may be combined with one or more of the aforementioned solvents, in some cases, in combination with an emulsifying agent. When combined with the heated water and solvent, concentrations of surfactant in the resulting fluid mixture may vary from about 0 wt % to about 20 wt % of surfactant to mixture in certain embodiments.

[0036] Low mobility reservoirs are reservoirs that are practically limited to production rates of about 1 to about 5 barrels of oil per day. This low production limit is often due to the limitation that the injection flow must be limited below the fracture pressure of the reservoir to avoid fracturing the formation. Normally, higher injection pressures would be desirable to increase the driving force from injection well 130 to production well 140, but the driving force from injection well 130 to production well 140 is necessarily limited by the desire to avoid undesirably fracturing the formation. This maximum pressure limitation of the injection fluids thus limits the driving force available to motivate or “sweep” hydrocarbons from injection well 130 to production well 140. This driving force from injection well 130 to production well 140 is referred to herein as the “sweeping driving force.”

[0037] A countervailing concern of increased injection pressure over time is that the pressure of low mobility reservoir 120 will also necessarily increase over time. Because the flow rate of injection fluid 135 is determined in part by the difference in the injection pressure of injection fluid 135 and the pressure of low mobility reservoir 120, any increase in the pressure of low mobility reservoir 120 will necessarily decrease the sweeping driving force from injection well 130 to production well 140. On the other hand, an increased pressure of low mobility reservoir 120 is advantageous in that it results in higher flow rates of production fluid 145. This driving force from production well 140 to the surface is referred to herein as the “production driving force.”

[0038] Therefore, higher pressures of low mobility reservoir 120 is advantageous for maximizing the production driving force (e.g., flow rates of production fluid 145 to the surface), but disadvantageous in that the higher pressures of low mobility reservoir 120 adversely reduces the sweeping driv-
ing force (e.g. the flow of injection fluid 135 from injection well 130 to production well 140). Conversely, lower pressures of low mobility reservoir 120 are advantageous for maximizing the sweeping driving force but disadvantageous as to maximizing the production driving force. Accordingly, the methods described herein vary the flow rates injection fluid 135 and production fluid 145 to alternatively achieve each of the aforementioned advantages of alternately maximizing the production driving force and maximizing the sweeping driving force.

Fig. 2 illustrates an example of a cyclic pressure profile of low mobility reservoir 120 during execution of one embodiment of the present invention. Here, cyclic pressure profile 201 varies alternatively from crests 252 to troughs 262.

In certain embodiments, heated fluids are introduced into low mobility reservoir 120 by way of injection well 130. Injected fluid 135 will necessarily increase the pressure of low mobility reservoir 120 as illustrated by pressurization cycles 250. Thus, the pressure of low mobility reservoir 120 may be allowed to increase until reaching a first maximum pressure (e.g. the maximum pressure illustrated by crests 252). At this first maximum pressure, the production driving force is maximized, resulting in maximum production flow from low mobility reservoir 120. Where the first maximum pressure is approximately the dilation pressure of low mobility reservoir 120, the production driving force is at its highest without fracturing the formation. Upon reaching the first maximum pressure, the flow of production fluid 145 may be commenced or increased in such a way as to allow the pressure of low mobility reservoir 120 to reduce until reaching a first minimum pressure (e.g. the minimum pressure illustrated by troughs 262). In certain embodiments, upon reaching the first maximum pressure, the flow of production fluid 145 is increased to about the same rate as the flow of the injection fluid 135. The resulting depressurization phase of low mobility reservoir 120 is illustrated in Fig. 2 as production cycle 260. When the pressure of low mobility reservoir 120 is at trough 262, the sweeping driving force is at its maximum while the production driving force is at a minimum.

Upon reaching the first minimum pressure, the flow of production fluid 145 may be substantially reduced or substantially ceased so as to allow the pressure of low mobility reservoir 120 to increase once again to the first maximum pressure (e.g. crest 252). In this way, the pressurization cycles and production cycles may be successively repeated so as to alternatively maximize the sweeping driving force and the production driving force.

The dilation mechanism creates additional pore space and is thought to provide additional porosity and permeability enhancement to the formation. Weak geological formations such as unconsolidated sand formations are particularly susceptible to dilation and therefore the methods described herein. The dilation mechanism easily occurs in these formations because they have weak rock shear strength of low internal friction angle and low cohesion.

In certain embodiments, the first minimum pressure, illustrated by troughs 262, is the minimum lifting pressure of the hydrocarbon lifting equipments such as lifting pumps. The minimum lifting pressure may be any pressure above the minimum lifting pressure but less than the fracture pressure.

The pressure cycles shown in Fig. 2 may be achieved by any suitable differential flow rate between the flow rate of injection fluid 135 and production fluid 145. In certain embodiments, the flow rate of injection fluid 135 remains constant while production fluid 145 is varied to achieve the desired cyclic pressure profile. While a continuous pressure profile is depicted in Fig. 2, it is recognized that a pressure profile comprising step-changes in pressure may also be used in lieu of a gradually changing pressure profile.

Fig. 3A-3E illustrate aerial views of example well configurations in accordance with certain embodiments of the present invention. While some embodiments have heretofore been described with respect to one injection well and one production well, it is recognized that any number of injection wells and production wells may be used to exploit a low mobility reservoir.

Fig. 3A illustrates a five-spot well configuration, showing injection wells 371 surrounding production well 372. Fig. 3B illustrates a seven-spot well configuration, showing injection wells 375 surrounding production well 376. Fig. 3C illustrates a nine-spot well configuration, showing injection wells 377 surrounding production well 378. Fig. 3D shows a line arrangement of alternating injection wells 381 and production wells 382. Fig. 3E illustrates a row of injection wells 385 opposite a row of production wells 386.

It is recognized that each of the patterns above may be repeated successively adjacent to one another to create repeating fields of the above well configurations. Indeed, the methods herein contemplate any suitable arrangement of injection wells and production wells which optimize field exploitation. In certain embodiments, the injection wells and the production wells depicted in Figs. 3A-3C are swapped so as to provide one injection well for a number of production wells.

It is explicitly recognized that any of the elements and features of each of the devices described herein are capable of use with any of the other devices described herein with no limitation. Furthermore, it is explicitly recognized that the steps of the methods herein may be performed in any order except unless explicitly stated otherwise or inherently required otherwise by the particular method.

Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations and equivalents are considered within the scope and spirit of the present invention. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

What is claimed is:

1. A method for enhancing hydrocarbon recovery from a low mobility reservoir having an injection well and a production well intersecting the low mobility reservoir, the method comprising the steps of:
   (a) providing water;
   (b) providing a solvent;
   (c) providing a surfactant;
(d) heating at least one of the water, the solvent, and the surfactant to its saturation temperature;
(e) introducing the water, the solvent and the surfactant into the low mobility reservoir at an injection rate by way of the injection well;
(f) allowing the pressure of the low mobility reservoir to increase until reaching a first maximum pressure of the low mobility reservoir;
(g) upon substantially reaching the first maximum pressure of the low mobility reservoir, producing from the production well at a production rate;
(h) allowing the reservoir pressure to reduce until the low mobility reservoir reaches a first minimum pressure;
(i) upon reaching the first minimum pressure, substantially reducing production from the production well; and
(j) repeating steps (e)-(i) a plurality of times.

2. The method of claim 1 wherein step (d) comprises heating the water to its saturation temperature;
   wherein the first maximum pressure is a dilation pressure of the low mobility reservoir;
   wherein step (f) comprises the step of continuously increasing the pressure of the low mobility reservoir until reaching a dilation pressure of the low mobility reservoir in step (f);
   wherein the production rate is substantially equal to or greater than the injection rate during step (h); and
   wherein the first minimum pressure is a pre-determined pressure below the dilation pressure.

3. The method of claim 2 further comprising combining the water, the solvent, and the surfactant to produce an injection fluid wherein step (e) further comprises introducing the injection fluid into the low mobility reservoir at the injection rate by way of the injection well.

4. The method of claim 2 wherein step (i) further comprises substantially ceasing production from the production well.

5. The method of claim 2 wherein step (i) further comprises continuing step (i) during steps (f)-(i).

6. The method of claim 4 further comprising the step of substantially ceasing step (e) upon substantially reaching the dilation pressure of the low mobility reservoir.

7. The method of claim 2 wherein the production rate is substantially equal to the injection rate during step (h).

8. The method of claim 2 wherein the first minimum pressure is the minimum lifting pressure of the low mobility reservoir.

9. The method of claim 1 wherein the low mobility reservoir is a shallow reservoir having a depth of about 80 meters to about 150 meters and wherein the low mobility reservoir is unconsolidated.

10. The method of claim 9 wherein the first minimum pressure is from about 130 psi to about 250 psi.

11. The method of claim 2 wherein the low mobility reservoir is a shallow reservoir having a depth of about 80 meters to about 150 meters, wherein the first minimum pressure is from about 130 psi to about 250 psi.

12. The method of claim 11 wherein the solvent is wherein the solvent is carbon dioxide, flue gas, an aliphatic hydrocarbon having 4 carbons to 30 carbons, naphtha, syn crude, diesel, an aromatic solvent, toluene, benzene, xylene, or any combination thereof.

13. The method of claim 11 wherein the surfactant is petroleum sulfonates, alpha olefin sulfonates, synthetic alkylaryl sulfonates, or any combination thereof.

14. The method of claim 11 wherein the heated solvent has not been heated beyond its saturation temperature at the pressure of the low mobility reservoir.

15. The method of claim 14 wherein the heated solvent has been heated to a temperature that is less than its saturation temperature at the pressure of the low mobility reservoir.

16. A method for enhancing hydrocarbon recovery from a low mobility reservoir having one or more injection wells and one or more production wells intersecting the low mobility reservoir, the method comprising the steps of:
   (a) providing water;
   (b) providing a solvent;
   (c) providing a surfactant;
   (d) heating at least one of the water, the solvent, and the surfactant to its saturation temperature;
   (e) introducing the water, solvent and the surfactant into the low mobility reservoir at a total injection rate by way of the one or more injection wells;
   (f) allowing the pressure of the low mobility reservoir to increase until reaching a dilation pressure of the low mobility reservoir;
   (g) upon substantially reaching the dilation pressure of the low mobility reservoir, producing from the one or more production wells at a total production rate;
   (h) allowing the reservoir pressure to reduce until the low mobility reservoir reaches a first minimum pressure;
   (i) upon reaching the first minimum pressure, substantially reducing production from the one or more production wells; and
   (j) repeating steps (e)-(i) a plurality of times.

17. The method of claim 16 wherein the one or more injection wells comprises a plurality of injection wells.

18. The method of claim 17 wherein step (f) comprises the step of continuously increasing the pressure of the low mobility reservoir until reaching a dilation pressure of the low mobility reservoir in step (f);

19. The method of claim 16 wherein the one or more production wells comprises a plurality of production wells.

20. The method of claim 17 wherein the one or more production wells comprises a plurality of production wells.

21. The method of claim 20 wherein step (f) comprises the step of continuously increasing the pressure of the low mobility reservoir until reaching a dilation pressure of the low mobility reservoir in step (f);

22. The method of claim 21 wherein step (i) further comprises substantially ceasing production from the one or more production wells.