IN SITU COMBUSTION FOLLOWING SAGD

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ABSTRACT

There is provided herein a method for recovering petroleum from a formation, wherein said formation is intersected by at least one wellpair consisting of a horizontal production well and a horizontal injection well, and wherein said formation comprises at least one steam chamber developed by a steam-assisted process, said method comprising: providing an oxidizing agent near the top of said formation; initiating in situ combustion (ISC); and recovering petroleum from said at least one production well.
IN SITU COMBUSTION FOLLOWING SAGD
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. 61/448,868 filed Mar. 3, 2011, entitled "In Situ Combustion Following SAGD," which is hereby incorporated by reference in its entirety.

FEDERALLY SPONSORED RESEARCH STATEMENT

[0002] Not applicable.

FIELD OF THE INVENTION

[0003] The invention relates to recovery of petroleum from a petroliferous formation, in particular to in situ processing of a reservoir containing heavy oil and/or bitumen.

BACKGROUND OF THE INVENTION

[0004] Production of heavy oil and bitumen from a subsurface reservoir can be quite challenging, especially when the viscosity of the oil at reservoir temperature is often greater than one million centipoise (cP). High viscosity oil cannot be pumped out of the ground using typical methods, but must be mined or processed in situ. Surface mining is limited to reservoirs to a depth of about 70 meters. Greater depths are not economical to access and most reserves are not accessible by mining. Since only a relatively small percentage of bitumen and oil sand deposits (such as the Athabasca oils sands of Alberta, Canada), are recoverable through open-pit mining, the majority of reservoirs require some form of in situ extraction.

[0005] In situ combustion (ISC) is an enhanced oil recovery method for both light oil and heavy oil reservoirs, wherein the heat to liquefy the deposits is provided bycombusting some of the fuel in situ. ISC typically involves injection of an oxidant into a formation, and the oil present in the reservoir serves as fuel for combustion once ignited. Heat, oxygen and fuel must be readily available to sustain the reaction, but in a bitumen reservoir, combustion can be interrupted by immobile fuel. Therefore, combustion gas products (CO, CO₂, H₂S, etc.) and mobilized oil can be trapped in the reservoir, extinguishing the combustion front.

[0006] Furthermore, interwell fluid communication must be established for ISC to work. Heating rods and other approaches can achieve this outcome, but they are not as yet economical.

[0007] U.S. Pat. No. 7,516,789 and WO0674555 describe a hydrocarbon recovery process comprising, among other things, injecting an oxidizing gas into a formation through an injection well to support in situ combustion and mobilize hydrocarbons in the heavy oil, producing fluids from a combustion gas production well, to direct combustion gases to the combustion gas production well, and recovering the mobilized hydrocarbons from the reservoir through a hydrocarbon production well. These publications also suggest that the method can be applied to a reservoir that has been depleted or partially depleted by a petroleum recovery process, leaving a residual oil deposit in the reservoir. U.S. Pat. No. 7,516,789 and WO0674555 require a separate combustion gas production well, and fail to teach or suggest disposition of the oxidizing gas injection well within the formation relative to the overburden and/or to the hydrocarbon production well.

[0008] US20070187094 and US20090449490 describes a method referred to as Combustion Assisted Gravity Drainage (CAGD), wherein oxygen is co-injected with steam into a SAGD steam chamber, thereby reducing the amount of steam required to produce a barrel of oil. In particular, US20090449490 describes a method for producing oil comprising: providing a steam chamber within an oil formation wherein the steam chamber defines steam chamber walls; injecting oxygen into the steam chamber and initiating combustion of oil at the steam chamber walls; allowing heated and cracked oil to drain toward a production well, and recovering oil through the production well. These applications fail to teach or suggest use of in situ combustion after a formation is developed with a steam-assisted process, and describe recovery only at steam chamber walls rather than from the formation as a whole, such as edges of the formation and residual oil within the steam chamber.

[0009] There thus exists a need to overcome fuel immobility in petroliferous formations so that ISC can be applied as an improved recovery and/or secondary recovery method. Such a method is especially needed to recover residual oil from a steam chamber and at the boundaries of a petroliferous formation after a SAGD process reaches its economic end.

SUMMARY OF THE INVENTION

[0010] Steam-assisted gravity drainage (SAGD), a leading recovery method already in use for heavy oil and bitumen in Canada, can be used to condition a reservoir prior to ISC implementation. The steam chamber generated by a SAGD wellpair provides two of the main requirements for ISC: oil mobility and established communication between wells. By drilling a horizontal well near the top of the reservoir and injecting an oxidizing agent, such as air, oxygen, or oxygen-enriched air, ISC recovers residual oil in the steam chamber and provides heat to recover residual oil at the edges of the steam chamber and from the boundaries of the formation. Using ISC after a SAGD pattern has matured can recover additional reserve past the normal SAGD economic limit, and the compression equipment used in ISC can be used to repurify the reservoir before abandonment.

[0011] This application provides a method for recovering petroleum from a formation, wherein said formation is intersected by at least one wellpair consisting of a horizontal production well and a horizontal injection well, and wherein said formation comprises at least one steam chamber developed by a steam-assisted process, said method comprising: providing an oxidizing agent near the top of said formation; initiating in situ combustion (ISC); and recovering petroleum from said at least one production well.

[0012] The petroleum can comprise heavy oil and/or bitumen. The oxidizing agent can be selected from the group consisting of air, oxygen and oxygen-enriched air, preferably oxygen. The duration of the process can be, for example, 5 years of SAGD followed by 5 years of air injection, but obviously, the time will vary with the size and conditions of the reservoir.

[0013] The ISC can heat the formation or parts of the formation to a temperature of; for example, 500° C. to 1000° C. The steam-assisted process can be selected from the group consisting of steam-assisted gravity drainage (SAGD) (with
or without solvents), steam-assisted gravity push (SAGP), and cyclic steam stimulation (CSS). For example, the at least one wellpair can be a SAGD wellpair.

[0014] The oxidation agent is provided 1-10 meters below the overburden of said formation. The wellpairs can be at any distance relative to one another determined, for example, by details for the formation and economic concerns. The oxidizing agent is provided through a horizontal oxidant injection well. In some embodiments, an oxidant injection well is placed at the top of a formation between sets of SAGD wellpairs. This configuration allows the oxidant injection wells to supply an oxidizing agent to two steam chambers simultaneously. For example, the formation can comprise at least two wellpairs and at least two steam chambers, and the oxidant injection well can be disposed so that said oxidizing agent is supplied to said at least two steam chambers.

[0015] In addition to recovering more oil, the method herein also allows repurification of the formation. Some governments require that a reservoir produced using a SAGD method must be pressurized back to reinjected reservoir pressure before abandonment, so as to avoid subsidence and other post-production complications.

[0016] In a particular embodiment, there is provided a method for recovering heavy oil and/or bitumen from a formation, comprising: providing an oxidizing agent through a horizontal oxidant injection well disposed 1-10 meters below the overburden of said formation, wherein said formation is intersected by at least one steam-assisted gravity drainage (SAGD) wellpair consisting of a horizontal production well and a horizontal injection well, wherein said formation comprises at least one SAGD steam chamber, and wherein said oxidizing agent is selected from the group consisting of air, oxygen and oxygen-enriched air; initiating in situ combustion (ISC); and recovering petroleum from said at least one production well. The formation can comprise at least two SAGD wellpairs and at least two SAGD steam chambers, and said oxidant injection well is disposed so that said oxidizing agent is supplied to said at least two SAGD steam chambers.

[0017] In another embodiment, a method of enhanced oil recovery is provided using at least one horizontal production well and at least one horizontal injection well, said production well being at or near a bottom of a hydrocarbon reservoir, and said injection well being above said production well and at or near a top of said hydrocarbon reservoir. The method can include additional injection or production wells, arranged as is known in the art. The first step is injection steam (or solvents and/or gases) into said injection well and recovering a first amount of hydrocarbon from said production well. The second step is injecting an oxidant into said injection well when steam assisted hydrocarbon production begins to decrease, and initiating combustion. Finally, the remaining hydrocarbon can be produced using the additional heat produced by in situ combustion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1. Typical SAGD wellpair, wherein an injection well is above a production well. The SAGD process forms a steam chamber in a formation between the overburden and the underburden, mobilizing oil to gravity drain at the production well.

[0019] FIG. 2. Oil saturation of a formation containing a SAGD wellpair at the pattern’s economic limit.

[0020] FIG. 3. Air injector layout for ISC after a SAGD process.

[0021] FIG. 4. Temperature profile for ISC that shows the combustion front moving toward the production well.

[0022] FIG. 5. Oil saturation of a SAGD-treated formation after ISC, which creates a bank of oil that moves toward the producer as the combustion front progresses.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0023] The following abbreviations are used herein:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOE</td>
<td>barrel of oil equivalent</td>
</tr>
<tr>
<td>CAGD</td>
<td>combustion assisted gravity drainage</td>
</tr>
<tr>
<td>cP</td>
<td>centipoise</td>
</tr>
<tr>
<td>cSOR</td>
<td>cumulative steam-to-oil ratio</td>
</tr>
<tr>
<td>CSS</td>
<td>cyclic steam stimulation</td>
</tr>
<tr>
<td>CWE</td>
<td>cold water equivalent</td>
</tr>
<tr>
<td>DSG</td>
<td>direct steam generation</td>
</tr>
<tr>
<td>GOR</td>
<td>gas-oil ratio</td>
</tr>
<tr>
<td>MPa</td>
<td>megapascals</td>
</tr>
<tr>
<td>NCG</td>
<td>non-condensable gas</td>
</tr>
<tr>
<td>SAGD</td>
<td>steam-assisted gravity drainage</td>
</tr>
<tr>
<td>SOR</td>
<td>steam-to-oil ratio</td>
</tr>
</tbody>
</table>

[0024] “Formation” as used herein refers to a geological structure, deposit, reserve or reservoir, which includes one or more hydrocarbon-containing layers, one or more non-hydrocarbon layers, an overburden and/or an underburden. The hydrocarbon layers can contain non-hydrocarbon material as well as hydrocarbon material. The overburden and underburden contain one or more different types of impermeable materials, for example rock, shale, mudstone, wet carbonate, or tight carbonate. A “petrolierous formation” is a formation that contains or yields petroleum.

[0025] “Petroleum deposit” refers to an assemblage of petroleum in a geological formation. The petroleum deposit can comprise light and heavy crude oils and bitumen. Of particular interest for the method described herein are petroleum deposits that primarily comprise heavy petroleum, such as heavy oil and/or bitumen.

[0026] “Injection well” or “injector” refers to a well from which a fluid is injected into a geological formation. The injected fluid can comprise, for example, a gaseous mixture of steam, non-condensable gas (NCG) and/or hydrocarbon solvent. The injected fluid can also comprise a liquid solvent, such as a liquid hydrocarbon solvent or CS<sub>2</sub>.

[0027] “Production well” or “producer” refers to a well from which a produced fluid is recovered from a geological formation. The produced fluid can comprise, for example, a petroleum product, such as heavy oil or bitumen.

[0028] “Horizontal drilling” refers to a process of drilling and completing a well, beginning with a vertical or inclined linear bore, which extends from the surface to a subsurface location in or near a target reservoir (e.g., gas, oil), then bears off at an arc to intersect and/or traverse the reservoir at an entry point. Thereafter, the well continues at a horizontal or nearly horizontal attitude tangent to the arc, substantially or entirely remaining within the reservoir until the desired bottom hole location is reached. (Of course, the “bottom hole” of a horizontal well is the terminus of the horizontal wellbore rather than the gravitational bottom of the vertical wellbore.)

[0029] A “horizontal well” is a well produced by horizontal drilling. Horizontal displacements of more than 8000 feet (2.4 km) have been achieved. The initial linear portion of a horizontal well, unless very short, is typically drilled using...
rotary drilling techniques common to drilling vertical wells. A short-radius well has an arc with a 3-40 foot (1-12 m) radius and a build rate of as much as 3° per 100 feet (30 m) drilled. A medium-radius well has an arc with a 200-1000 foot (61-305 m) radius and build rates of 8-30° per 100 feet drilled. A long-radius well has an arc with a 1000-2500 (305-762 m) foot radius. Most new wells are drilled with longer radii, while recompletions of exiting wells tend to employ medium or short radii. Medium-radius wells are the most productive and most widely used.

[0030] Horizontal wells confer several benefits. Operators are often able to develop a reservoir with fewer horizontal wells than vertical wells, since each horizontal well can drain a larger rock volume about its bore than a vertical well could. One reason for this benefit is that most oil and gas reservoirs are more extensive in their horizontal (areal) dimensions than in their vertical (thickness) dimension. A horizontal well can also produce at rates several times greater than a vertical well, due to a higher wellbore surface area within the producing interval.

[0031] “Multilateral well” refers to a well that is one of a plurality of horizontal branches, or “laterals”, from a vertical wellbore. Such wells have at least two such branches and allow access to widely spaced reservoir compartments from the same wellbore, thus saving the cost of drilling multiple vertical wellbores and increasing the economy of oil and gas extraction. For example, a well with a fishbone configuration has a single vertical wellbore and a plurality of non-vertical (e.g., horizontal), deviated portion connected to the vertical wellbore and extending into the formation. The non-vertical portions of a fishbone-configured well can further progress through the reservoir at angles different from the original angle of deviation.

[0032] “Ex situ processing” refers to petroleum processing which occurs above ground. Oil refining is typically carried out ex situ.

[0033] “In situ processing” refers to processing which occurs within the ground in the reservoir itself. Processes include heating, combustion, pyrolysis, steam cracking, and the like. In situ processing has the potential of extracting more oil from a given land area than ex situ processes since they can access material at greater depths than surface mines can. Examples of in situ processing include SAGD and ISC.

[0034] “Steam-assisted process” refers to any method wherein heated water or steam, used alone or in combination with other solvents and/or gases, is injected into a petroleum formation so as to produce petroleum from that formation. Solvents may include hydrocarbon solvents, such as methane, ethane, propane, butane, pentane, hexane, acetylene, and propane, or solvents containing heteroatoms, such as carbon disulfide (CS₂). Other gases may include non-condensable gases (NCGs) such as nitrogen (N₂), oxygen (O₂), air, CO₂, CO, hydrogen (H₂), flue gas and combustion gas. Examples of steam-assisted processes include, but are not limited to steam-assisted gravity drainage (SAGD), steam-assisted gravity push (SAGP), and cyclic steam stimulation (CSS).

[0035] “Steam-assisted gravity drainage” or “SAGD” refers to an in situ recovery method which uses steam to assist in situ processing, including related or modified processes such as steam-assisted gravity push (SAGP), and the original SAGD method as described by Butler in U.S. Pat. No. 4,314,485. In general, the method requires two horizontal wells drilled into a reservoir. The wells are drilled vertically to different depths within the reservoir then, using direction drilling, the wells are extended horizontally, resulting in horizontal wells vertically aligned to and spaced from each other. Typically the production well is located above the base of the reservoir but as close as possible to its bottom, for example between 1 and 3 meters above the base of the oil reserve. The injection well is placed above (or nearly above) the production well, and is supplied steam from the surface. The steam rises, forming a steam chamber that slowly grows toward the reservoir top, thereby increasing reservoir temperature and reducing viscosity of the petroleum deposit. Gravity pulls the petroleum and condensed steam through the reservoir into the production well at the bottom where the liquid is pumped to the surface. At the surface, water and petroleum can be separated from each other.

[0036] “In situ combustion” or “ISC” refers to a process wherein an oxidizing agent is introduced into a formation and a combustion reaction is initiated to consume fossil fuel that is present in the formation. ISC can be controlled, for example, by metering the volume of oxidizing agent introduced to the formation, adjusting the pressure of the oxidizing agent or overall pressure of the formation, and/or producing combustion gases and/or petroleum from the formation. ISC can be used over the period of years to heat and pressurize a petrolierous formation in order to mobilize, liquify, upgrade, and/or produce petroleum. Time can depend on economic limits, for example simulations were run for 5 years of SAGD followed by 5 years of air injection.

[0037] Oxidizing agents include, but are not limited to, oxygen, air, oxygen-enriched air, and the like. Oxygen is preferred because of its relatively low cost and effectiveness in the ISC process. ISC can be catalyzed, for example for upgrading purposes. Although upgrading is not ISC per se, upgrading can result from an ISC process. Temperatures in the formation should be below the melting temperature of well completion to avoid well failure, for example from 500°C to 1000°C. The entire formation need not attain the target combustion temperature for the process to be effective, but different portions of the formation or hydrocarbon reservoir can attain the target temperature at different times.

[0038] Temperature can depend on asphaltene content of the bitumen and air injection rates. Air injection duration depends on air injection rate, which depends in part upon economic factors that have had been investigated. Speed of the front can be controlled by the rate of oxidizing agent injection and pressure at which it is injected. A balance between front speed and compression cost is determined on a reservoir-by-reservoir basis. Pressure and volume can be adjusted and area determined, for example, by economic factors associated with each reservoir.

[0039] “Cumulative steam-oil ratio” or “cSOR” refers to the ratio of cumulative injected steam (expressed as cold water equivalent, CWE) to cumulative petroleum production volume. The thermal efficiency of SAGD is reflected in the cSOR. Typically a process is considered thermally efficient if its SOR is less than 3, such as 2 or lower. A cSOR of 3.0 to 3.5 is usually the economic limit, but this limit can vary project to project and with oil prices.

[0040] “Steam chamber”, “vapor chamber” or “steam vapor chamber” refers to the pocket or chamber of gas and vapor formed in a geological formation by a steam-assisted process. In other words, the steam chamber is the volume of the reservoir which is saturated with injected steam and from which mobilized oil has at least partially drained. As the
steam chamber expands upwardly and laterally from the injection well, viscous hydrocarbons in the reservoir are heated and mobilized, especially at the margins of the steam chamber where the steam condenses and heats a layer of viscous hydrocarbons by thermal conduction. The mobilized hydrocarbon and aqueous condensate drain under gravity toward the bottom of the steam chamber, where a production well can be located.

[0041] A steam chamber can be in fluid communication with one or more injection wells, for example, two injection wells. During initiation of a SAGD process, overpressurized development conditions can be imposed to accelerate steam chamber development, followed by prolonged underpressurization to reduce the steam-to-gas ratio. Maintaining reservoir pressure while heating advantageously minimizes water inflow to the heated zone and to the wellbore. When petroleum is continuously recovered and the eSOR is under 4, a steam chamber has likely formed. An eSOR of less than 4 implies that heat from the injected steam reaches the petroleum at the edges of the chamber and that the mobilized bitumen is flowing under gravity to the production well.

[0042] "Recovery" refers to extraction of petroleum from a petroleum deposit or hydrocarbon-containing layer within a geologic formation.

[0043] The present invention is exemplified with respect to an in situ combustion following SAGD in a bitumen-containing formation. However, this method is exemplary only, and the invention can be broadly applied to any petrolierous formation, wherein the petroleum was mobilized prior to ISC or wherein a combustion process is used in connection with a steam-assisted process. The following examples are intended to be illustrative only, and not unduly limit the scope of the appended claims.

Example 1

In Situ Combustion after SAGD

[0044] In a typical oil saturation of a SAGD well pattern at the end of its economic life, about 10% of the original oil still remains in the steam chamber, with very high saturation on the edges of the SAGD pattern (FIG. 2). Please note that in this figure and in others like it (FIGS. 3, 4, & 5), the producer and injector and/or their labels are superimposed to one another.

[0045] The residual oil can be removed from the steam chamber by in situ combustion following the SAGD process. Oxidant injection wells are placed at the top of the reservoir at the edge of the SAGD pattern or, if the reservoir contains multiple SAGD wellpairs, between SAGD wellpairs. This placement allows the oxidant injection wells to supply an oxidizing agent to two steam chambers simultaneously.

[0046] After combustion initiates, the combustion front proceeds from the oxidant injectors to the SAGD wellpair, having maximum temperatures of about 500° C. (FIG. 4). Temperature of the combustion front depends on asphaltene content of the bitumen. Red and yellow indicate propagation of the combustion front toward the production well at the bottom of the formation. As the combustion front advances, it creates a bank of oil that is swept toward the production well. At this same time step, oil saturation increases ahead of the combustion front as the residual oil is removed from the rock matrix (FIG. 5). Heat from the combustion front also reduces the viscosity of the unproduced oil on the edges of the SAGD pattern, allowing it to flow toward the production well.

[0047] Simulations were run using properties of a typical Athabasca-type reservoir with bitumen viscosities representative of that area, for example, Surmont 1. A process using ISC after SAGD can increase recovery factors by about 10% and reduce cumulative steam oil ratios by about 15%.

[0048] The use of the word "a" or "an" when used in conjunction with the term "comprising" in the claims or the specification means one or more than one, unless the context dictates otherwise.

[0049] The term "about" means the stated value plus or minus the margin of error of measurement or plus or minus 10% if no method of measurement is indicated.

[0050] The use of the term "or" in the claims is used to mean "and/or" unless explicitly indicated to refer to alternatives only or if the alternatives are mutually exclusive.

[0051] The terms "comprise", "have", "include" and "contain" (and their variants) are open-ended linking verbs and allow the addition of other elements when used in a claim.

[0052] The following references are incorporated by reference in their entirety:


1. A method for recovering petroleum from a formation, wherein said formation is intersected by at least one wellpair consisting of a horizontal production well and a horizontal injection well, and wherein said formation comprises at least one steam chamber developed by a steam-assisted process, said method comprising:

a) providing an oxidizing agent near the top of said formation;

b) initiating in situ combustion (ISC); and

c) recovering petroleum from said at least one production well.

2. The method of claim 1, wherein the petroleum comprises heavy oil and/or bitumen.

3. The method of claim 1, wherein said oxidizing agent is provided 1-10 meters below the overburden of said formation.

4. The method of claim 1, wherein said oxidizing agent is selected from the group consisting of air, oxygen and oxygen-enriched air.

5. The method of claim 1, wherein said steam-assisted process is selected from the group consisting of steam-assisted gravity drainage (SAGD), steam-assisted gravity push (SAGP), and cyclic steam stimulation (CSS).

6. The method of claim 1, wherein said at least one wellpair is a SAGD wellpair.

7. The method of claim 1, wherein said oxidizing agent is provided through a horizontal oxidant injection well.

8. The method of claim 7, wherein said formation comprises at least two wellpairs and at least two steam chambers, and said oxidant injection well is disposed so that said oxidizing agent is supplied to said at least two steam chambers.

9. The method of claim 1, wherein said formation attains a temperature of 500° C. to 1000° C. during said ISC.

10. The method of claim 1 further comprising, repressurizing said formation to its virgin pressure after recovering the petroleum is complete.
11. A method for recovering heavy oil and/or bitumen from a formation, comprising:
   a) providing an oxidizing agent through a horizontal oxidant injection well disposed 1-10 meters below the overburden of said formation,
   wherein said formation is intersected by at least one steam-assisted gravity drainage (SAGD) wellpair consisting of a horizontal production well and a horizontal injection well,
   wherein said formation comprises at least one SAGD steam chamber, and
   wherein said oxidizing agent is selected from the group consisting of air, oxygen and oxygen-enriched air;
   b) initiating in situ combustion (ISC); and
   c) recovering petroleum from said at least one production well.

12. The method of claim 11, wherein said formation comprises at least two SAGD wellpairs and at least two SAGD steam chambers, and said oxidant injection well is disposed so that said oxidizing agent is supplied to said at least two SAGD steam chambers.

13. The method of claim 11 further comprising, repressurizing said formation to its virgin pressure after recovering the petroleum is complete.

14. The method of claim 11, wherein said formation attains a temperature of 500° C.-1000° C. during said ISC.

15. A method of enhanced oil recovery comprising:
   a) providing at least one horizontal production well and at least one horizontal injection well, said production well being at or near a bottom of a hydrocarbon reservoir, and said injection well being above said production well and at or near a top of said hydrocarbon reservoir;
   b) injecting steam into said injection well and recovering a first amount of hydrocarbon from said production well;
   c) injecting an oxidant into said injection well when hydrocarbon production in step b) begins to decrease;
   d) initiating combustion; and
   e) recovering a second amount of hydrocarbon from said horizontal production well.

16. The method of claim 15, comprising a second horizontal injection well, wherein step e) uses said second horizontal injection well.

17. The method of claim 15, comprising a second horizontal injection well, wherein step e) uses both horizontal injection wells.

18. The method of claim 15, further comprising, repressurizing said hydrocarbon reservoir to its initial pressure after recovering said hydrocarbons is complete.

19. The method of claim 15, wherein said hydrocarbon reservoir attains a temperature of 500° C.-1000° C. during said combustion.

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