

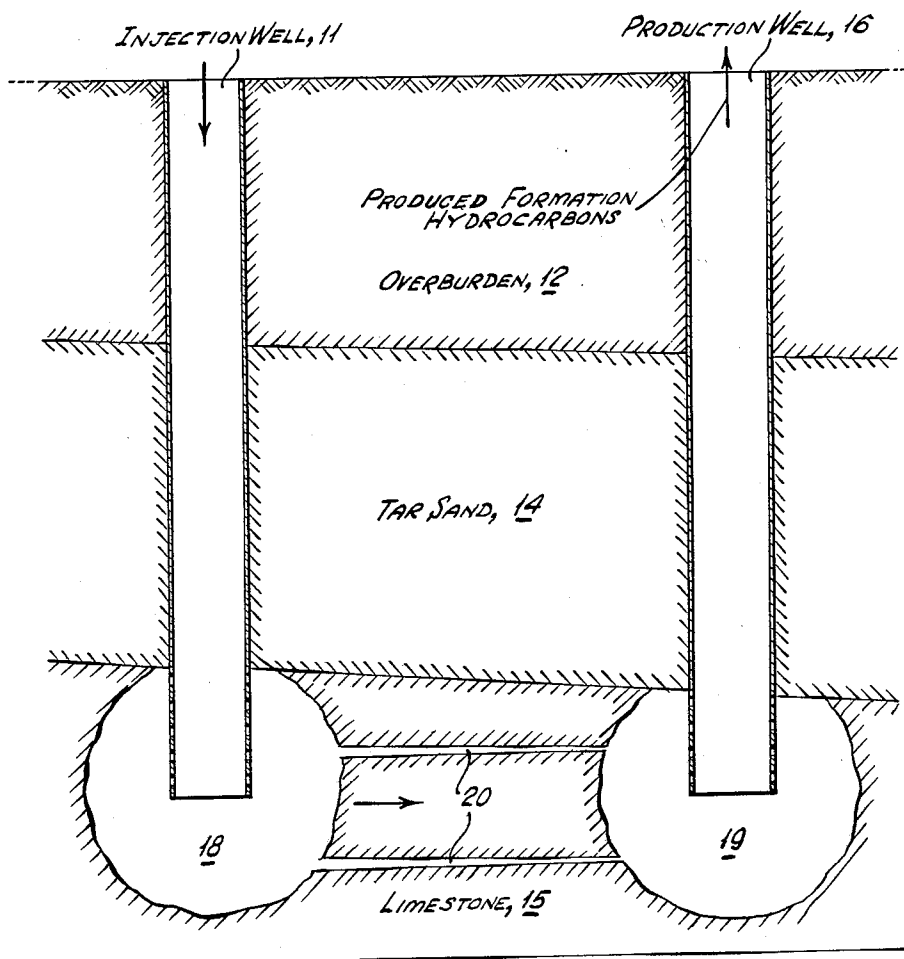
May 28, 1963

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3,091,292

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Filed Feb. 12, 1959



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3,091,292

RECOVERING HYDROCARBONS FROM SUB-SURFACE FORMATIONS

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Filed Feb. 12, 1959, Ser. No. 792,904
16 Claims. (Cl. 166-11)

This invention relates to the recovery of hydrocarbons from subsurface formations. In accordance with one embodiment this invention is directed to the recovery of hydrocarbons from the Athabasca tar sands. In accordance with another embodiment this invention is directed to the recovery of viscous petroleum or bituminous material from underground formations. In accordance with yet another embodiment this invention is particularly directed to the recovery of petroleum, bituminous or hydrocarbon material and the like from an underground formation adjacent an underlying limestone formation.

In the recovery of petroleum and/or bituminous material from underground formations, such as the Athabasca tar sands, because of the rather high viscosity of the in place hydrocarbons and/or bituminous material and in formations where because of the absence of a substantial natural driving force the production of hydrocarbons therefrom is difficult, various methods have been proposed to improve the production and recovery of these hydrocarbons from these formations. Methods which have been proposed include in situ combustion of underground formations containing these hydrocarbons, the displacement of hydrocarbons from underground formations by contact with hot water, in situ solvent extraction processes and the like. None of the methods proposed heretofore have been completely satisfactory.

Accordingly it is an object of this invention to provide a method for the recovery of viscous petroleum and/or bituminous material and the like from underground formations.

Another object of this invention is to provide a method for the recovery of petroleum and the like from underground formations, such as the Athabasca tar sands.

Still another object of this invention is to provide a method for the recovery of petroleum and similar material from an underground formation adjacent an underlying limestone formation.

How these and other objects of this invention are accomplished will become apparent in the light of the accompanying disclosure and drawing which schematically illustrates the practice of this invention as applied to a particular hydrocarbon-containing formation, such as the Athabasca tar sand. In at least one embodiment of the practice of this invention at least one of the foregoing objects will be achieved.

In accordance with this invention an improved method for the recovery of hydrocarbons or bituminous material and the like from underground formations is provided by creating or forming within said formation, especially in a different formation adjacent thereto but in communication with said hydrocarbon-containing formation, a relatively high temperature and relatively high pressure zone whereby formation fluids within said hydrocarbon-containing formations are heated and pressured. The resulting heated and pressured hydrocarbons are then displaced and recovered from the hydrocarbon-containing formation at a location relatively remote from said high pressure, high temperature zone via a production well.

In accordance with a practice of this invention particularly applicable to the production and recovery of petroleum or bituminous material and the like from the Athabasca tar sands, wherein the hydrocarbon-containing formation or tar sand is adjacent an underlying limestone (calcium-magnesium carbonate) formation, an injection

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well is formed to penetrate the hydrocarbon-containing formation or tar sand and the adjacent, underlying limestone formation and a production well, at a location removed from said injection well, is formed to penetrate said hydrocarbon-containing and said underlying limestone formation. A relatively high temperature and high pressure zone is then formed within said formations, desirably within said limestone formation, in the vicinity of said injection well. The resulting heated formation fluids, hydrocarbons and the like, within said hydrocarbon-containing formation are then displaced under the influence of said high temperature and pressure zone in the direction of said production well. These displaced formation fluids are then produced and recovered via said production well.

Various methods may be employed in the practice of this invention for the creation of a relatively high temperature, high pressure zone in the vicinity of the injection well to displace hydrocarbons from the hydrocarbon-containing formation toward a production well. In accordance with one embodiment the formation, such as the limestone formation, is fractured either by setting off an explosive charge (explosive fracturing) or by application of hydraulic pressure (hydraulic fracturing) to create a zone of relatively high permeability within the limestone formation in the vicinity of said injection well adjacent the hydrocarbon-producing formation. A displacing fluid, preferably a hot displacing fluid, is then introduced into the hydrocarbon-containing formation and into the fractured limestone formation to heat the formation fluids within said hydrocarbon-containing formation in the direction of the production well. Suitable displacing fluids include steam, hot air, hot flue gases, combustion gases, or mixtures or combinations thereof, either injected simultaneously or consecutively.

In accordance with one preferred embodiment of the practice of this invention the limestone formation in the vicinity of the injection well is fractured, e.g. explosively fractured, and the resulting fractured formation then contacted with a suitable acid, preferably a mineral acid whose calcium salt is water soluble, such as sulfuric acid, hydrochloric acid and the like. The acid upon contact with the fractured limestone formation reacts with the limestone with the resulting formation of normally gaseous carbon dioxide. Since the heat of reaction between the acid and the limestone is substantial the resulting acid-treated formation increases in temperature. The heat of reaction, besides increasing the temperature of the acid-treated limestone formation, also heats the adjacent overlying hydrocarbon-containing formation or tar sand. The carbon dioxide generated during the acid treatment of the limestone formation in addition to pressuring the limestone formation and the adjacent hydrocarbon-containing formation and displacing hydrocarbons therefrom carries heat to the hydrocarbon-containing formation and the formation fluids therein with the result that the formation fluids within the hydrocarbon-containing formation are heated and are more readily displaced toward the production well. As a result of the fracturing and acid treatment of the limestone formation in the vicinity of the injection well adjacent the hydrocarbon-containing formation there tends to be created or is created within the limestone formation a cavern or cavernous-like zone or a zone of very high porosity and permeability. This zone is particularly useful for the subsequent injection of a treating or displacing fluid, such as hot water, steam, and the like, and/or for the transfer of the carbon dioxide generated during the acid treatment step to heat and/or to displace the hydrocarbons within the hydrocarbon-containing formation adjacent the cavernous-like zone in the direction of the production well.

Desirably a cavern or cavernous-like zone or zone of

high permeability is also established within the limestone formation in the vicinity of the production well penetrating the same. The thus-formed cavernous or highly permeable zone in the vicinity of the production well serves as a sump or collection point for the hydrocarbons within the hydrocarbon-containing formation displaced in the direction from the injection well toward the production well.

Referring now to the accompanying drawing which schematically illustrates a practice of this invention as applied to the recovery of hydrocarbons or bituminous material from tar sands, such as Athabasca tar sand which overlies an adjacent limestone formation, an injection well 11 penetrates the overburden 12, the hydrocarbon-containing formation or tar sand 14 and the limestone formation 15. Similarly, a production well 16 penetrates the overburden 12, the tar sand 14 and the limestone formation 15. The limestone formation 15 in the vicinity of injection well 11 is fractured, either explosively fractured by exploding a charge of explosive therein or hydraulically fractured by the application of hydraulic pressure.

The resulting fractured limestone formation is then treated with acid introduced into fractured limestone formation 15 via injection well 11 to form a cavernous zone or cavern 18. Suitable acid for treatment of the limestone formation 15 to form cavern 18 therein include the mineral acids whose calcium salts are water soluble, such as sulfuric acid, hydrochloric acid and nitric acid or mixtures thereof. Upon introduction of the acid into limestone formation 15 via well bore 11 the acid reacts with the limestone (calcium carbonate) therein with the resultant generation of normally gaseous carbon dioxide. The heat of reaction between the acid and the limestone causes the temperature of the limestone formation 15 in the vicinity of injection well 11 to increase. The heat of reaction, at least in part, is carried away from the acid-treated portion of limestone formation 15 in the vicinity of injection well 11 by the gaseous carbon dioxide which, under a relatively elevated pressure, penetrates or invades the tar sand 14 adjacent cavern 18, the acid-treated portion of limestone formation 15, and increases the temperature of tar sand 14 in the vicinity of injection well 11. The gaseous carbon dioxide which invades or penetrates tar sand 14, and/or subsequently injected extraneous displacing fluid, serves to displace the formation hydrocarbons within tar sand 14 in the direction of production well 16.

Desirably while cavern 18 is being formed within limestone formation 15 in the vicinity of injection well 11 another cavern or cavernous-like zone or high permeability zone 19 is likewise being created within limestone formation 15 in the vicinity of production well 16. The cavernous zone 19 within limestone formation 15 in the vicinity of production well 16 may be formed in substantially the same manner as cavern 18 was formed. The cavern or high permeability zone 19 serves as a sump or collecting point for the hydrocarbons displaced within tar sand 14 in the direction from injection well 11 to the production well 16.

As indicated in the accompanying drawing fractures or high permeability zones or streaks 20 are shown extending between cavern 18 and cavern 19. These high permeability streaks or fractures, formed by properly spacing injection well 11 and production well 16 and by suitably carrying out the explosive or hydraulic fracturing of limestone formation 15 for the formation of cavernous zones 18 and 19, enable ready fluid communication between cavern 18 and cavern 19 and make possible rapid heating of the limestone formation 15 intermediate caverns 18 and 19 by the passage of a suitable heating fluid therethrough. The heating of limestone formation 15 intermediate caverns 18 and 19 serves to heat tar sand 14, at least that portion thereof overlying and immediately adjacent limestone formation 15, there-

by expediting the recovery of the formation fluids therefrom.

To further expedite the recovery of the formation fluids, petroleum and the like, from tar sand 14 there may be introduced via injection well 11 into cavern 18 an extraneous heating fluid such as hot water, hot combustion gases and the like. The thus-injected hot extraneous fluid upon penetration into tar sand 14 would serve to displace the formation fluids therefrom in the direction of cavern 19 and production well 16.

It is mentioned that since caverns 18 and 19 are formed within limestone formation 15 in the vicinity of injection well 11 and production well 16, respectively, fluid communication directly between these caverns and the tar sand 14 is effected. If desired, the formation of caverns 18 and 19 can be effected to such a radial extent that caving or collapse of a portion of the tar sand 14 in the vicinity of the wells into caverns 18 and/or 19 can be effected. By operating in the aforesaid manner, i.e. cavern creation and, if desired, collapse of a portion of tar sand 14 into the cavern, a large amount of surface area is opened up within tar sand 14 for the injection thereinto of a displacing fluid to displace formation fluids from tar sand 14 in the direction of production well 16.

One feature which makes this invention particularly applicable to the recovery of petroleum from the Athabasca tar sands resides in the recovery of sulfur from the petroleum recovered from tar sand 14. This petroleum has a relatively high sulfur content. When this sulfur, after recovery by suitable known methods, is oxidized and converted to sulfuric acid the thus-formed sulfuric acid can be employed for the formation of additional caverns to promote the production of additional petroleum from the tar sand. If sulfuric acid is not desired, the presence of salt beds in the vicinity of the Athabasca tar sands suggests that the sulfuric acid can readily be chemically converted by reaction with sodium chloride to hydrochloric acid which can then be employed as the acid for the formation of caverns.

Although the drawing indicates the practice of this invention with respect to a single injection well and a single production well any number of injection wells and any number of production wells in any suitable pattern may be employed.

As will be apparent to those skilled in the art many changes, modifications and substitutions are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A method of producing hydrocarbons from a sub-surface hydrocarbon-containing formation in contact with an underlying contiguous limestone formation, said hydrocarbon-containing formation and said limestone formation each being penetrated by at least one common injection well and at least one common production well, which comprises fracturing said limestone formation in the vicinity of said injection well and in the vicinity of said production well, introducing a mineral acid whose calcium salt is water soluble via said injection well and said production well into the fractured limestone formation adjacent the wells to react with the limestone therein to form a zone of high permeability, introducing a hot displacing fluid via said injection well into said hydrocarbon-containing formation and said fractured, acid-treated limestone formation to displace in situ hydrocarbons from said hydrocarbon-containing formation toward said production well, and producing the resulting displaced hydrocarbons from said hydrocarbon-containing formation via said production well.

2. A method in accordance with claim 1 wherein said acid is hydrochloric acid.

3. A method in accordance with claim 1 wherein said acid is sulfuric acid.

4. A method in accordance with claim 1 wherein said displacing fluid is a hot gaseous fluid.

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5. In the method of producing hydrocarbons as defined in claim 1, the additional formation of a cavern-like zone in the fractured limestone formation adjacent the wells.

6. A method of producing hydrocarbons from a subsurface hydrocarbon-containing formation in contact with an underlying contiguous limestone formation which comprises penetrating the formations with at least one injection well and with at least one production well, fracturing said limestone formation in the vicinity of said injection well and in the vicinity of said production well, introducing acid whose calcium salt is water soluble via said injection well into the fractured limestone formation in the vicinity of said injection well whereby said acid by reaction with the limestone forms a relatively high temperature zone in said fractured limestone formation due to chemical heat of reaction and forms a relatively high pressure zone therein due to the release of carbon dioxide by reaction between said acid and said limestone, heating in situ hydrocarbons in the vicinity of said injection well and displacing said in situ hydrocarbons toward said production well by the thus-produced chemical heat of reaction and the released carbon dioxide, and producing the resulting displaced hydrocarbons via said production well.

7. A method in accordance with claim 6 wherein acid whose calcium salt is water soluble is introduced also via said production well into the fractured limestone formation in the vicinity thereof prior to the production of hydrocarbons from said hydrocarbon-containing formation via said production well.

8. A method in accordance with claim 6 wherein said acid is sulfuric acid.

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9. A method in accordance with claim 6 wherein said acid is hydrochloric acid.

10. A method in accordance with claim 6 wherein there is introduced via said injection well into the formations a displacing fluid to aid in the displacement of the in situ hydrocarbons from said hydrocarbon-containing formation toward said production well.

11. A method in accordance with claim 10 wherein said displacing fluid comprises relatively hot gaseous products of combustion.

12. A method in accordance with claim 10 wherein said displacing fluid is steam.

13. A method in accordance with claim 10 wherein said displacing fluid is hot water.

14. A method in accordance with claim 10 wherein said displacing fluid is hot air.

15. A method in accordance with claim 7 wherein said acid is sulfuric acid.

16. A method in accordance with claim 7 wherein said acid is hydrochloric acid.

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