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Beard

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[54] **METHOD OF PRODUCING HYDROCARBONS FROM AN OIL SHALE FORMATION CONTAINING HALITE**

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[21] Appl. No.: **75,037**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 770,964, Oct. 28, 1968, abandoned.

[52] **U.S. Cl.** **299/4,** 166/271

[51] **Int. Cl.** **E21b 43/28**

[58] **Field of Search** 299/4, 5; 166/259, 166/261, 271, 272, 307

[56] **References Cited**

UNITED STATES PATENTS

3,481,398	12/1969	Prats	166/251
3,510,167	5/1970	Carmody	299/4
3,502,372	3/1970	Prats	299/5

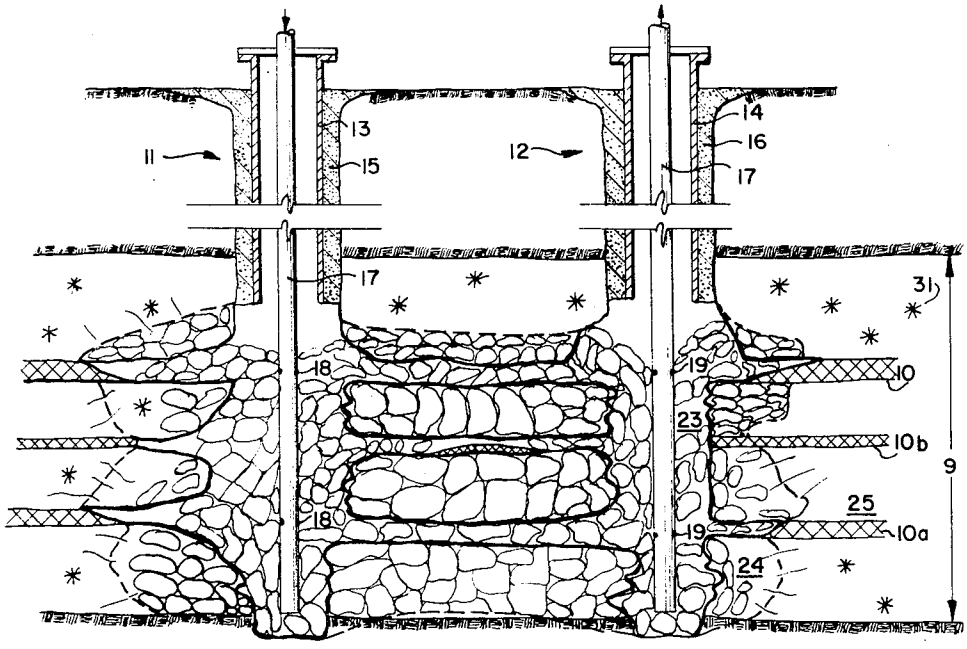
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[57] **ABSTRACT**

A method of producing hydrocarbons and optionally halite from a subterranean oil shale formation containing zone(s) of halite, by penetrating said formation with at least one borehole and leaching or dissolving the halite from the formation with a solvent fluid so as to form a cavern(s) and/or interconnected cavities, followed by fracturization and/or rubblization of the oil shale surrounding the caverns or cavities, and thereafter injecting into the fracturized and/or rubblized zones, a pyrolyzing fluid to effect insitu hydrocarbon recovery therefrom.

5 Claims, 2 Drawing Figures



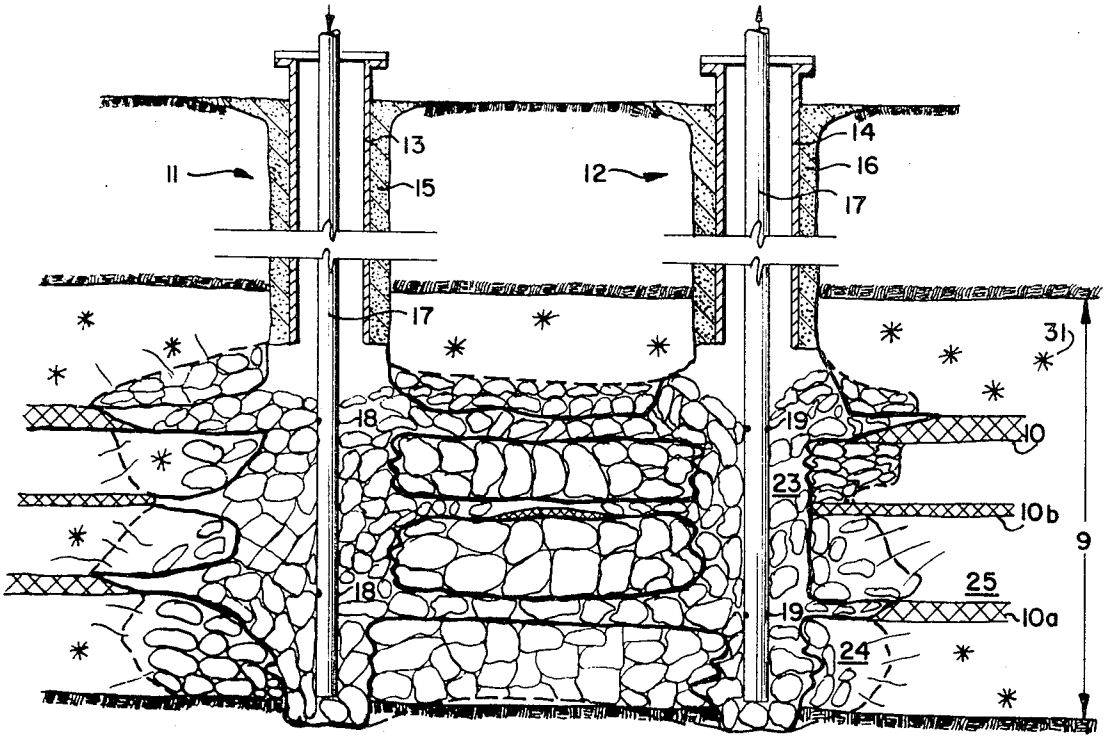


FIG. 1

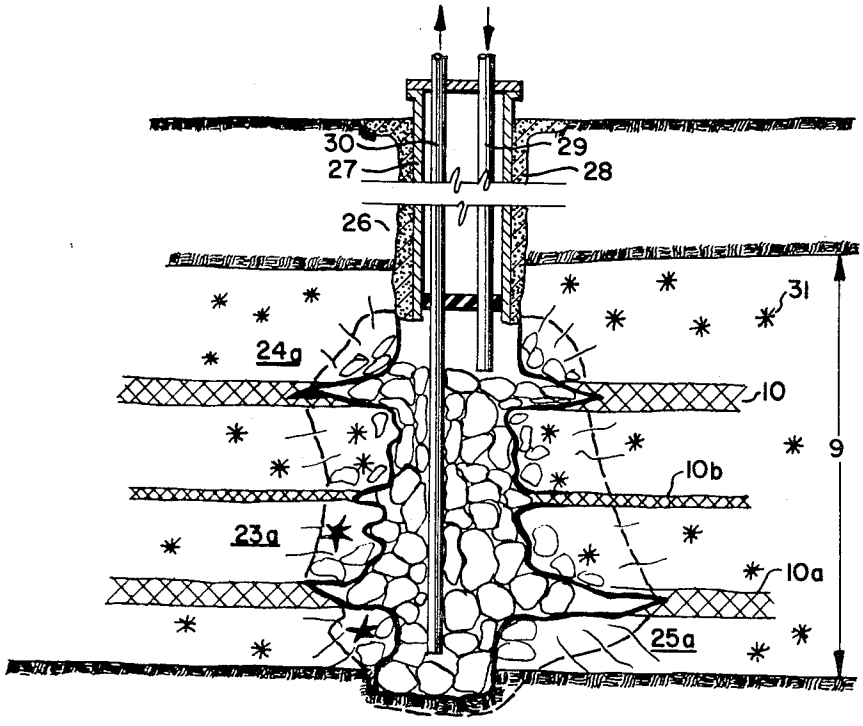


FIG. 2

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METHOD OF PRODUCING HYDROCARBONS FROM AN OIL SHALE FORMATION CONTAINING HALITE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of copending application Ser. No. 770,964, filed Oct. 28, 1968 and now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the recovery of hydrocarbons and optionally halite from underground oil shale formations containing halite deposits. More particularly, it relates to hydrocarbon recovery by in-situ thermal fluid extraction of oil shale within a fracturized and/or rubblized portion of a subterranean oil shale formation in and around a cavern and/or interconnected cavities formed by leaching or dissolving, e.g., solution mining of the halite therefrom.

2. Description of the Prior Art

Large deposits of oil in the form of oil shale are found in various sections of the United States, particularly in Colorado and surrounding states and Canada. Various methods of recovery of oil from these shale deposits have been proposed and the principal difficulty with these methods is their high cost which renders the recovered oil too expensive to compete with petroleum crudes recovered by more conventional methods. Mining the oil shale and removing the oil therefrom by above-ground retorting in furnaces presents a disposal and pollution problem and also such processes are also generally commercially uneconomical. In-situ retorting to convert the oil shale to recover the oil contained therein is made difficult because of the non-permeable nature of the oil shale. The art discloses various means of improving oil recovery of oil from oil shale such as described in U.S. Pat. Nos. 3,400,762 or 3,437,378 or 3,478,825 and particularly various means of increasing permeability of oil shale formations as described in U.S. Pat. Nos. 3,273,649 or 3,481,398 or 3,502,372, or copending application Ser. No. 839,350, filed July 7, 1969. Although these references are directed to an advancement of the art, the basic technique for recovering oil from oil shale still requires rubblization techniques such as by means of explosive devices, e.g., nuclear energy which is expensive, difficult to control and presents a radioactive contamination problem all of which are very undesirable.

OBJECTS OF THE INVENTION

It is an object of this invention to provide an improved method for recovering hydrocarbons from a halite containing oil shale formation by leaching or dissolving the halite such as by solution mining so as to form a cavern and/or interconnected cavities within the oil shale formation.

It is a further object of the invention to effect rubblization and/or fracturization of the halite leached oil shale formation surrounding the cavern and/or cavities so as to form a permeable zone thereby enhancing in-situ thermal fluid extraction (pyrolysis) of hydrocarbons therefrom.

Still another object of this invention is to effect in-situ pyrolysis to produce hydrocarbons from oil shale subjected to leaching, rubblization and fracturization as indicated in the previous two paragraphs, and subsequently recovering the hydrocarbons by suitable means.

Still another object of the present invention is to recover watersoluble minerals from a rich halite containing oil shale formation that may be removed during the leaching and/or solution mining, rubblization and/or fracturization, and/or pyrolysis processes.

Still another object of the present invention is to sequentially and/or simultaneously recover halite and hydrocarbons from halite containing oil shale formations that may be removed during the leaching and/or solution mining, rubblization and/or fracturization and/or pyrolysis processes.

Other objects of the invention will be apparent from the following description.

SUMMARY OF THE INVENTION

The present invention is directed to recovery of hydrocarbons and optionally halite from a halite containing oil shale formation by the following steps: (1) subjecting a rich halite zone(s) of an oil shale formation to a leaching, dissolving or solution mining process so as to remove the halite, thereby creating porosity to allow for thermal expansion of the oil shale and establish communication through the treated zone(s), (2) effecting in said leached zone(s) rubblization and/or fracturization so as to form zone(s) of rubblized and/or fractured oil shale with large surface area for more efficient heat treatment by in-situ thermal fluid extraction (pyrolysis) and (3) injecting into the rubblized and/or fracturized oil shale zone(s) a pyrolyzing fluid to effect hydrocarbon recovery.

The halite and hydrocarbons may be recovered sequentially or simultaneously and if the latter, the two products can be separated by suitable means such as settling or solvent extraction above ground. The oil shale formation may contain more than one zone of rich halite which zones may be separated by impermeable oil shale layers of several feet to several hundred feet and each of these halite layers or zones can be leached or dissolved or solution mined in accordance with the process of the present invention.

The first or initial step should be so designed to create a cavern or interconnecting cavities in the halite bed(s) or zone(s) by dissolving, leaching or solution mining techniques through at least one borehole penetrating said formation. Leaching can be effected by cold or hot aqueous solutions either at atmospheric or elevated pressures. When hot solutions are used such as hot water and/or steam, more rapid dissolution is effected to produce void spaces in the oil shale formation thereby providing and enhancing well communication, space for thermal expansion of the shale, and greater surface contact with subsequent pyrolyzing fluid.

If necessary, fracturing the formation either before or after leaching by conventional means such as hydrofracturing, explosive means, nuclear means, etc., may be desirable. The leaching solutions can contain chemical agents to enhance dissolution of the minerals.

Leaching or solution mining of the halite can be accomplished by a suitable solution mining technique such as described in U.S. Pat. Nos. 2,618,475; 3,387,888; 3,393,013; 3,402,966; 3,236,564; 3,510,167 or Canadian patents 832,828 or 832,276 or as described in copending application Ser. No. 2,765, filed Jan. 14, 1970. Spalling and rubbling can be ac-

complished by the method described in U.S. Pat. No. 3,478,825 or by other means such as by hydraulic explosive, nuclear, electrical means. Preferably rubblization is accomplished by hot fluid circulation through two caverns causing the two walls to spall and fracture. In-situ thermal recovery of oil can be effected by a pyrolyzing fluid such as steam and/or hot water or solvent extraction means.

The circulation of a pyrolyzing fluid not only effects oil recovery but also effects thermal rubbling and/or fracturization. Also, if the pyrolyzing fluid such as steam is used to extract and recover oil, more halite may be dissolved perpetuating the process.

The term "pyrolyzing fluid" is used to refer to a liquid or gas which by means of thermal, chemical and/or solvent action, interacts with the kerogen components of an oil shale to produce and entrain hydrocarbon such as oil. Such a fluid can be comprised of hot fluids such as hot water or steam or mixtures of hot water and steam, hot hydrocarbons and/or mixtures of such fluids with chemicals such as acids, e.g., HCl and/or organic solvents, benzene, toluene, cumene, phenol, etc. The kerogen pyrolyzing fluid can be heated by surface or borehole-located heating devices. The kerogen-pyrolyzing fluid can advantageously comprise or contain a solvent for the halite, such as a steam condensate, having a temperature such as of at least 100°F, such as from about 450°F to above about 1,500°F and preferably from about 550°F to 1,000°F. Where the kerogen-pyrolyzing fluid contains or forms aqueous components, its circulation through the treated oil shale formation can enlarge the cavern, by solution mining the soluble minerals, while shale oil is being produced. Also, simultaneously or sequentially, pyrolyzing and oil extracting fluids can be used such as steam followed by a solvent such as phenol or benzene.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view, partly diagrammatic, of an embodiment of the invention showing a formation penetration by more than one well; and

FIG. 2 is a sectional view of an embodiment of the invention, the formation being penetrated by a single well.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 of the drawing, a plurality of well boreholes are shown penetrating into a subterranean oil shale formation **9** which contain rich zones of halite **10, 10*a*** and **10*b***. An injection well borehole **11** is shown extending into oil shale formation **9** and rich halite zone(s) **10** or multizones such as **10*a*** and **10*b*** that are located within the oil shale formation **9** and are also encountered by well borehole **12**. Well boreholes **11** and **12** are illustrated by having casings **13** through **14**, respectively, cemented in place in their respective boreholes by suitable sealants **15** through **16**, respectively. Although only a single injection well borehole **11** and a single production well borehole **12** have been illustrated, obviously various combinations of one or more injection and production wells may be provided by one skilled in the art.

Fluid communication between well boreholes **11** and **12** (FIG. 1) and the zones rich in halite therebetween may be established by solution mining a cavern or cavities **23**, through the soluble mineral zones. Communication can be enhanced by means of conventional hydraulic, electric, and/or explosive fracturing techniques, all well known in the art. Where, for example, subterranean stresses in and around soluble mineral zones **10, 10*a***, and **10*b*** are conducive to the formation of horizontal fractures, the fluid communication between well boreholes **11** and **12** and the halite can be established by a conventional hydraulic fracturing technique. Referring to FIG. **1**, after fluid communication has been established between a pair of wells, aqueous leaching or solution mining liquid is injected through tubing **17** down well borehole **11**, out through perforations **18** opposite any or all of the soluble beds through the bed **10, 10*a*** and/or **10*b*** up borehole **12** through tubing via perforation **19** creating a leached cavern **23**. The aqueous liquid may comprise water and/or steam or aqueous solutions of acid or acid-forming materials and is circulated at pressures either above or below the over-burden pressure. The circulating aqueous liquid dissolves the halite which is recovered from the fluid flowing out of well borehole **12**, for example, by conventional evaporation and/or precipitation procedures.

Fluid communication can also be established in one borehole between at least two spaced portions of the well borehole and the halite (as for example, in FIG. 2 communication is through the tubing strings, the ends of which are open to the halite and some distance apart). Thus, a single well may be utilized by a dual zone completion arrangement as shown in FIG. 2 such that fluids can be injected at one point of the well and produced from another point of the same well. In FIG. **2**, the wellbore is **26**, the casing is **27**, the sealant is **28**, within the casing are the injection tubing string **29** and production tubing string **30**, the borehole **26** penetrates oil **0**shale formation **9** with halite zone(s) **10** or multizones **10*a*** and **10*b***.

Fracturing pressures are generated within the oil shale formation **9** while lower pressures are maintained within the cavern **23** which is formed within oil shale formation **9** by the removal of the halite. These pressures are preferably generated by merely circulating hot fluid through cavern **23**. As the walls of the cavern(s) **23** (**23*a*** FIG. 2) are heated kerogen is pyrolyzed within the cavern walls and the pressures of the pyrolysis products increase until portions of the walls are spalled into the cavern **23** creating a rubblized zone **24** (**24*a*** FIG. 2) and surrounding fracture area **25** (**25*a*** FIG. **2**).

Alternatively, fracturization and/or rubblization can be accomplished by conventional means such as hydraulic, explosive means and the like. To provide additional void space, if necessary, further leaching can be conducted.

Finally, a kerogen-pyrolyzing fluid such as steam is circulated from well borehole **11** (FIG. **1**) through the rubblized zone **24** and fractured zone **25** of oil shale formation **9** and out of well borehole **12**. Hydrocarbon materials are then recovered from the heated fluid circulating out of well borehole **12** by means well known in the art. Removal of hydrocarbons from the oil shale provides additional void space enlarging the original rubblized zone, perpetrating the process. Similar techniques can be applied to single wells as shown in FIG. **2**.

Conventional equipment and techniques, such as heating means, pumping means, separators and heat

exchangers may be used for pressurizing, heating, injecting, producing and separating components of the heated fluid circulating through the oil shale formation **9**. The production of the fluid may be aided by downhole pumping means, not shown, or restricted to the extent necessary to maintain the selected pressure within the oil shale formation **9**.

The fluid circulated through rubblized zone **24** and fractured zone **25** (FIG. **1**) to recover oil shale from oil shale formation **9** may comprise any heated gas, liquid or steam. Oil shale reactive properties may also be imparted to the circulating fluid as discussed hereinabove.

Where the oil shale formation contains a zone rich in halite in which zone the halite occur in the form of adjacent but discrete nodules or lenses **31**, or the like, the present process is applied as described above. In this situation, the caverns comprise a network of relatively small cavities that are interconnected by fractures.

It is understood that various changes in the detailed described to explain the invention can be made by persons skilled in the art within the scope of the invention as expressed in the appended claims.

I claim as my invention:

1. A method of producing hydrocarbons from a subterranean oil shale formation having halite containing zones therein comprising the steps of:

a. penetrating a well borehole into the halite zone of the oil shale formation;

b. injecting water down the well borehole and into the halite containing zone to leach and withdraw halite thereby creating voids and cavities in the formation;

c. injecting a non-combustible pyrolyzing fluid into the leached voids and cavities to effect extraction of hydrocarbons from the oil shale; and

d. recovering the hydrocarbons from treatment (c) above ground.

2. The method of claim **1** wherein the pyrolyzing fluid comprises steam having a temperature sufficient to thermally fracture oil shale adjacent the leached voids and cavities.

3. The method of claim **1** wherein at least two wells penetrate the formation one of which functions as an injection well and one as a production well.

4. The method of claim **2** wherein the halite is removed by steam used also to effect hydrocarbon recovery.

5. The method of claim **4** wherein the halite and hydrocarbon are recovered simultaneously.

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