

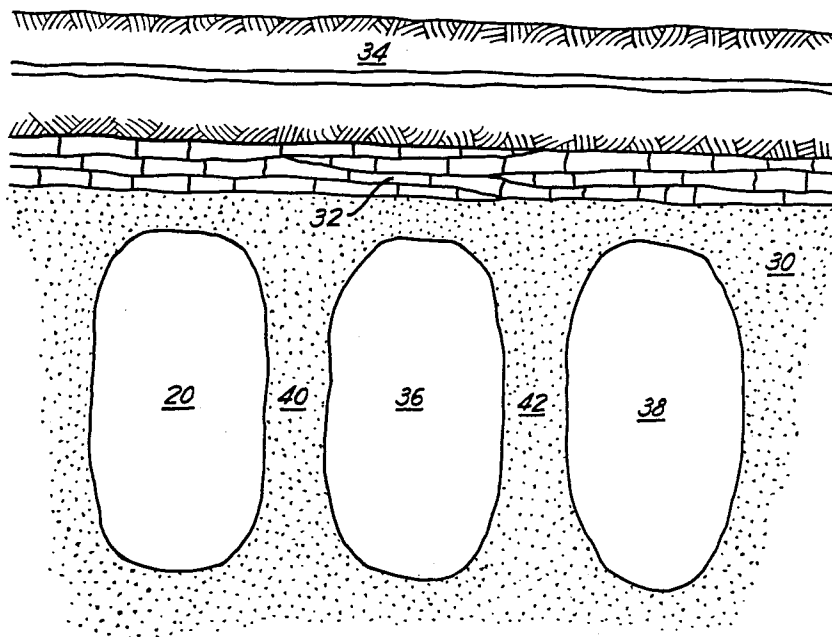
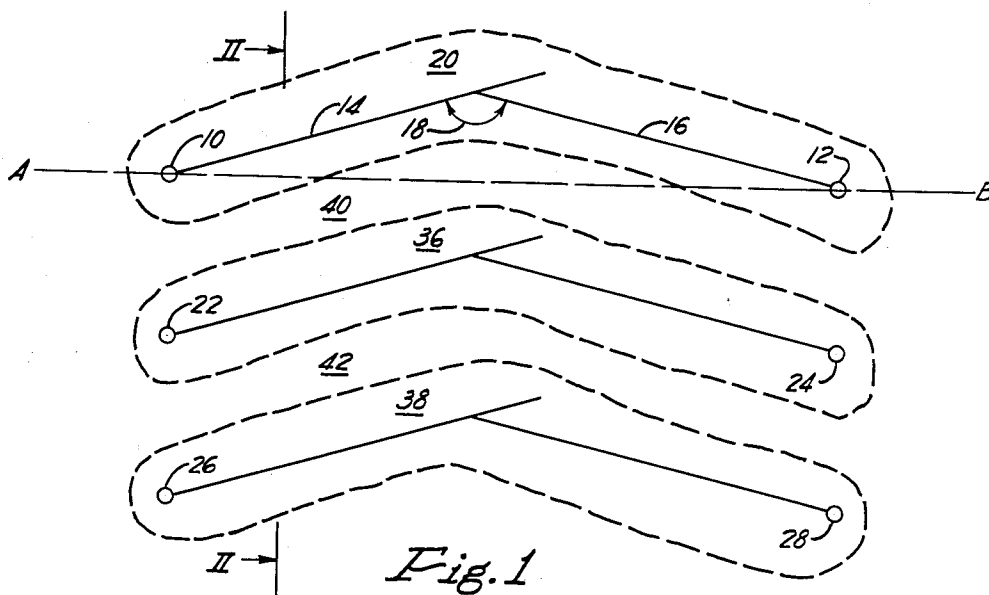
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J. L. HUITT ET AL
PROCESS FOR REMOVAL OF MINERALS FROM
SUB-SURFACE STRATUM BY LIQUEFACTION

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2 Sheets-Sheet 1



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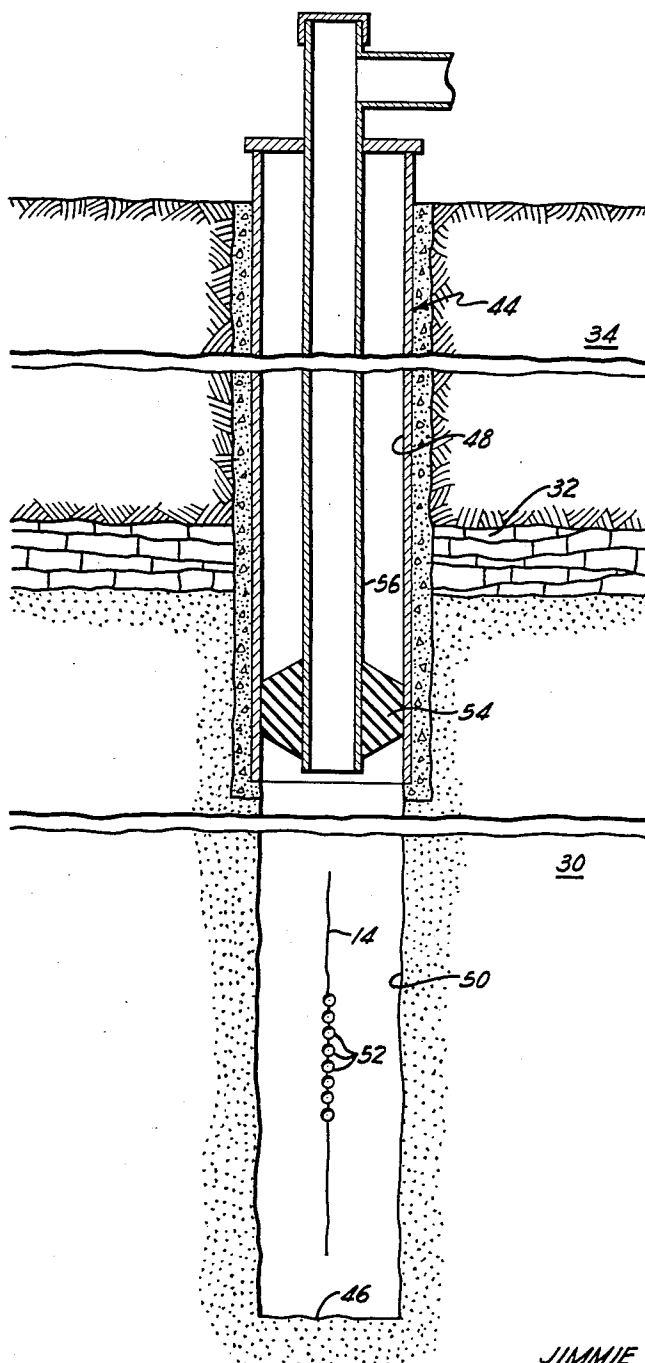


Fig. 3

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PROCESS FOR REMOVAL OF MINERALS FROM SUB-SURFACE STRATUM BY LIQUEFACTION

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10 Claims. (Cl. 262—3)

This invention relates to a method of removing a mineral from a sub-surface stratum of the mineral and more particularly to a method of removing a mineral in the liquid state from a sub-surface stratum in a mining process and of forming a channel through the sub-surface stratum.

One of the methods used for mining minerals in a sub-surface stratum is to convert the mineral from the solid to the liquid state while in the sub-surface stratum and then cause the liquefied mineral to flow to a well from which it can be delivered to the surface. The conversion from the solid to the liquid state may be accomplished in any suitable manner, for example, by melting the mineral in the manner employed in the Frasch process for mining sulfur or by dissolving the mineral as in the solution process for mining salt. Upon continued removal of the mineral from the sub-surface stratum by processes in which the mineral is converted to a liquid, the radius of unsupported rock over the stratum of the mineral increases. Frequently, either during or after the mining operation, the rock over the sub-surface stratum does not have sufficient strength to support the over-burden and the roof of the cavity formed by the mining collapses. As a result of the collapse of the roof the earth subsides over the mined area, frequently causing damage to surface installations.

Cavities dissolved in a sub-surface stratum of soluble minerals are widely used for the storage of volatile hydrocarbons. In order to minimize danger of subsidence, the storage cavities, where possible, are in the shape of long vertical cylinders. Where the stratum of the soluble mineral is relatively thin, it is not possible to form a cavity of the optimum shape. If a cavity of substantial capacity is desired in a thin stratum, the cavity heretofore had to have a relatively large diameter, which greatly increased danger of collapse of the unsupported roof of the cavity.

This invention resides in a process for removing a soluble mineral from a sub-surface stratum of the mineral in a manner to leave supports for the over-burden covering the stratum. In the process, two spaced apart wells are drilled into the sub-surface stratum to be mined. A vertical fracture is formed in one of the wells and made to extend in the general direction of the other well. A vertical fracture is then formed from the second well extending towards the first well to intersect the first fracture. Removal of the mineral from the sub-surface stratum is accomplished by circulating a solvent down one of the wells, through the connecting fractures to the other well, and then to the surface. This invention is useful in the removal of minerals from a sub-surface stratum whenever the mineral can be converted into a liquid phase which allows it to flow from the stratum through suitable conduits to the surface. For example, the mineral may be soluble and converted into a liquid by means of a suitable solvent. The invention can be used in the mining of sulfur, for example, in which the sulfur is converted to the liquid phase by the injection of steam or hot water into the stratum to raise the temperature of the sulfur

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above its melting point. Another type of operation in which the process of this invention is useful is one in which a reagent reacts with the mineral to convert it to a material which is soluble in a liquid and hence can be removed in solution.

Figure 1 of the drawings is a diagrammatic plan view of an arrangement of wells for removing a mineral from a sub-surface stratum by the process of this invention.

Figure 2 is a vertical section along the section line 2—2 in Figure 1 showing the cavities formed by the removal of mineral from the sub-surface stratum by the process of this invention.

Figure 3 is a diagrammatic sectional view of a well during the formation of the vertical fracture.

The description of this invention will be made for the removal of salt from a sub-surface salt deposit. Referring to Figure 1, a well 10 is drilled into the sub-surface stratum of the salt by conventional drilling techniques and casing is set into the upper part of the salt in accordance with conventional practice. A borehole is then drilled farther into the salt below the bottom of the casing. A second well 12 is drilled in a similar manner into the sub-surface stratum at the desired distance from well 10, which distance will depend upon the characteristics of the sub-surface stratum such as the maximum radius of a fracture that can be conveniently made in the stratum. A vertical fracture is then initiated at well 10 below the casing and made to extend outwardly into the formation. The vertical fracture, indicated by reference numeral 14 in Figure 1, is made to extend generally toward well 12, but is deliberately oriented in a direction slightly to one side of a straight line AB from well 10 to well 12. A second vertical fracture is then made from well 12 in the general direction of well 10. The second fracture, indicated in Figure 1 by reference numeral 16, is oriented to extend on the same side of line AB as fracture 14. The fracture 16 is extended until it intersects fracture 14.

The vertical fractures 14 and 16 can be oriented so that they will intersect at an angle 18 which ranges from about 80° to 175°. It is preferred that the angle 18 be near the upper limit of the range to allow the fractures 14 and 16 to be as short as possible for a given well spacing, or, conversely, to allow the wells 10 and 12 to be a maximum distance apart.

Solvent is circulated down one of the wells 10 or 12, through the connecting fractures 14 and 16, and out the other well to dissolve salt from the sub-surface stratum. The circulation is continued to form a cavity 20, the boundaries of which are indicated by the broken line, connecting the two wells. Because of the tendency of the fresh water injected into the well to dissolve salt more rapidly than the substantially saturated water delivered from the fracture into one of the wells for lifting to the surface, it may be desirable periodically to reverse the direction of flow through the cavity 20 to make the width of the cavity more uniform along its length.

Systematic mining of the salt can be accomplished by repeating the process described for wells 10 and 12 with a second pair of wells 22 and 24 and a third pair of wells 26 and 28, and so on. It is preferred to carry out the mining operation from the second pair of wells after it has been completed in the first pair of wells. Then, if the fractures formed from the second pair of wells intersect the cavity formed during the mining from the first pair of wells, there will be no tendency for solvent injected at the input well of one of the pairs of wells to flow to the production well of another pair of wells.

Figure 2 illustrates in vertical section a sub-surface stratum mined by the process of this invention. The sub-surface stratum 30 of salt is covered by an insoluble cap rock indicated by reference numeral 32. Above the cap

rock 32 is an over-burden 34. The cavity 20 formed by circulation of the solvent through the fractures 14 and 16 is of generally oblong shape, having a larger height than width. Similar cavities 36 and 38 are formed by the mining from the pairs of wells 22 and 24, and 26 and 28, respectively. Between cavities 20 and 34 is a wall 40 which provides support for the roof of the cavity, the cap rock 32, and the over-burden 34. A similar wall 42 separates cavities 36 and 38. Walls 40 and 42 support the rock above the mined cavities in a manner similar to the pillars left in mechanical mining techniques. Because of the length of cavity 20 a large amount of salt is removed during its formation, however, the relatively narrow width of the cavity eliminates large unsupported spans.

Figure 3 illustrates a technique for forming the vertical fractures in the salt stratum 30. Referring to that figure, a well indicated generally by reference numeral 44 is drilled through over-burden 34, cap rock 32, and into salt stratum 30. Casing 48 is run into the well and landed in the salt stratum 30 below the cap rock 32. The casing 48 is cemented in place in accordance with conventional practice, after which the well is drilled to total depth 46.

The borehole 50 below the lower end of casing 48 is then prepared for the formation of a vertical fracture. A vertical groove may be made in the borehole wall extending in the direction of the desired fracture to initiate the fracture in the desired direction. Another method of initiating the vertical fracture, illustrated in Figure 3, is to form a vertical series of closely spaced holes 52 extending from the borehole into the stratum 30 in the direction of the desired fracture. The holes 52 may, for example, be formed by explosive jets such as shaped charges. After the holes 52 have been formed to extend in the direction of the desired fracture and in vertical alignment with one another, a packer 54 is run into the well on the lower end of tubing 56 and set in the lower end of casing 48. A hydraulic fracturing fluid, which may be water, is pumped down tubing 56 and the pressure increased until the formation is fractured. The holes 52 initiate a vertical fracture which is extended from the borehole 50 into the stratum 30. The fracture can be extended for a distance as great as about 200 to 800 feet, depending upon the formation being fractured. Fractures having a radius near the upper limit can be made in salt because of the low loss of fracturing fluid into the salt. The procedure is then repeated at the other well in the pair to form intersecting fractures which allow flow from one of the wells in the pair to the other. The formation of oriented fractures is described and claimed in our application Serial No. 721,286, filed March 13, 1958.

After the formation of the fracture, a string of tubing is suspended in one of the wells with the lower end of the tubing below the bottom of the casing. Solvent is pumped down and withdrawn from the other well in the pair through tubing suspended in that well. In order to obtain substantially uniform vertical distribution of the flow, it is preferred that the tubing in the inlet well have a series of perforations or thin slots along the section of tubing placed adjacent the fractured formation.

The process described is especially useful for the mining of a soluble mineral such as salt. It may also be used to form a storage cavity for volatile hydrocarbons in thin layers of salt. By the process of this invention a storage cavity of the desired elongated, relatively narrow shape can be obtained even though the salt stratum is not thick. For example, if it is desired to make a storage cavity of greater length than can be fractured in two fracturing operations, the fracture 16 can be made to continue past the well 12 and intersect with a fracture from still another well. The process of this invention is also useful in forming a channel through pay zones containing crude oil to increase the rate of production of the oil. For example, in a pay zone reactable with acid,

such as a limestone or dolomite formation, vertical fractures can be made to intersect and thereby connect adjacent wells. By pumping an acid, preferably hydrochloric acid, from one well to the other, the capacity of the fractures can be greatly increased. A fluid can then be injected into the intersecting fractures of large capacity to obtain a line drive in a secondary recovery process.

An important advantage of this invention is the ease and certainty with which vertical fractures may be made to intersect. After orienting both fractures on the same side of a line connecting the two wells, it is only necessary to increase the radial extent of the fractures to insure their intersection.

Throughout the description of this invention, the mineral has been described as being in a sub-surface stratum. The term "stratum" is not limited to a single layer of the mineral, or to formations in which the mineral exists in a series of layers intermixed with layers of some other material, but includes all sub-surface deposits of the mineral in which solution mining can be performed. For example, the term "stratum" as used in this application includes salt domes as well as salt beds.

We claim:

1. A method of mining a mineral from a sub-surface stratum thereof comprising drilling a first well from the surface into the stratum, drilling a second well from the surface into the stratum at a location spaced from the first well, forming a first vertical fracture from one of the wells extending to one side of a line connecting the two wells, forming a second vertical fracture from the other well, extending on the same side of the line connecting the two wells as the first fracture to intersect said first fracture, and circulating a solvent down one well through the intersecting fractures and up the other well.
2. A method as set forth in claim 1 in which the mineral is salt.
3. A method of mining a mineral from a sub-surface stratum thereof comprising drilling a first well from the surface into the stratum, drilling a second well from the surface into the stratum at a location spaced from the first well, forming a first vertical fracture from one of the wells extending to one side of a line connecting the two wells, forming a second vertical fracture from the other well extending on the same side of the line connecting the two wells as the first fracture to intersect said first fracture, circulating a solvent down one well through the fracture and up the other well, and repeating the process from a pair of wells spaced from said first and second wells to form a series of washed out channels through the mineral separated by columns of the mineral.
4. A method of mining a mineral from a sub-surface stratum thereof comprising drilling a first well from the surface into the stratum, drilling a second well spaced from the first well from the surface into the stratum, forming a vertical notch along the borehole wall of the first well, said vertical notch being on one side of a straight line from the center of the first well to the center of the second well on the side thereof towards the second well, pumping a liquid into the first well to form a vertical fracture in the formation extending towards the second well, forming a vertical notch in the borehole wall of the second well along the side thereof towards the first well, said notch in the borehole wall of the second well being on the same side of the line joining the centers of the wells as the notch in the borehole wall of the first well, pumping a liquid into the second well to form a vertical fracture extending therefrom in the stratum and intersecting the first fracture, and circulating a solvent down one well through the fracture and up the other well.
5. A method of forming a storage cavity in a relatively thin stratum of salt comprising drilling a first well into the stratum, drilling into the stratum a second well spaced from the first well, forming a first vertical fracture from the first well in a direction generally towards the second well and extending on one side of a straight line con-

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necting the two wells, forming a second vertical fracture from the second well on the same side of the line connecting the two wells as the first fracture and in a direction to intersect the first vertical fracture between the two wells, and circulating water down one well through the fracture and up the other well to form an elongated cavity extending between the two wells.

6. A method of forming a channel of high capacity in a stratum of a mineral reactable with acid comprising drilling a first well into the mineral, drilling a second well spaced from the first well into the mineral, forming a first vertical fracture from the first well through the mineral and extending towards the second well on one side of a straight line connecting the two wells, forming a second vertical fracture from the second well extending through the mineral stratum on the same side of the line connecting the two wells as the first vertical fracture to intersect the first vertical fracture, and circulating an acid from one well to the other through the fracture to dissolve the mineral and form a channel through the mineral between the two wells.

7. A process as set forth in claim 6 in which the mineral is limestone.

8. A process as set forth in claim 6 in which the mineral is dolomite.

9. A method of mining a mineral from a sub-surface

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stratum penetrated by a first well and a second well spaced from the first well comprising forming a first substantially vertical fracture from the first well extending toward the second well on one side of a straight line connecting the two wells, forming a second substantially vertical fracture from the second well extending toward the first well on the same side of the line connecting the two wells as the first fracture, and circulating a fluid adapted to convert the mineral to a liquid phase down one well through the fractures and up the other well whereby the mineral is displaced from the stratum.

10. A method of mining a mineral from a sub-surface stratum thereof comprising drilling a first well into the stratum, drilling a second well spaced from the first well into the stratum, forming a first substantially vertical fracture from the first well extending towards the second well, forming a second substantially vertical fracture from the second well intersecting the first vertical fracture at an angle between about 80° and 175°, and circulating a solvent down one well, through the fractures, and up the other well.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,966,346

December 27, 1960

Jimmie L. Huitt et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 64, for "fromed" read -- formed --;
column 4, lines 56 to 58, strike out ", said vertical notch
being on one side of a straight line from the center of
the first well to the center of the second well" and insert
the same after "well", first occurrence, in line 59, same
column.

Signed and sealed this 20th day of February 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE
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