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[54] **PROCESS TO ESTABLISH COMMUNICATION
BETWEEN WELLS IN MINERAL FORMATIONS**
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ABSTRACT: A solution mining operation is established by drilling a well into a soluble salt formation, hydraulically creating and maintaining a fracture pool, defining the area of the fracture pool by surface measurement and drilling at least one other well in the defined fracture pool area to establish communication.

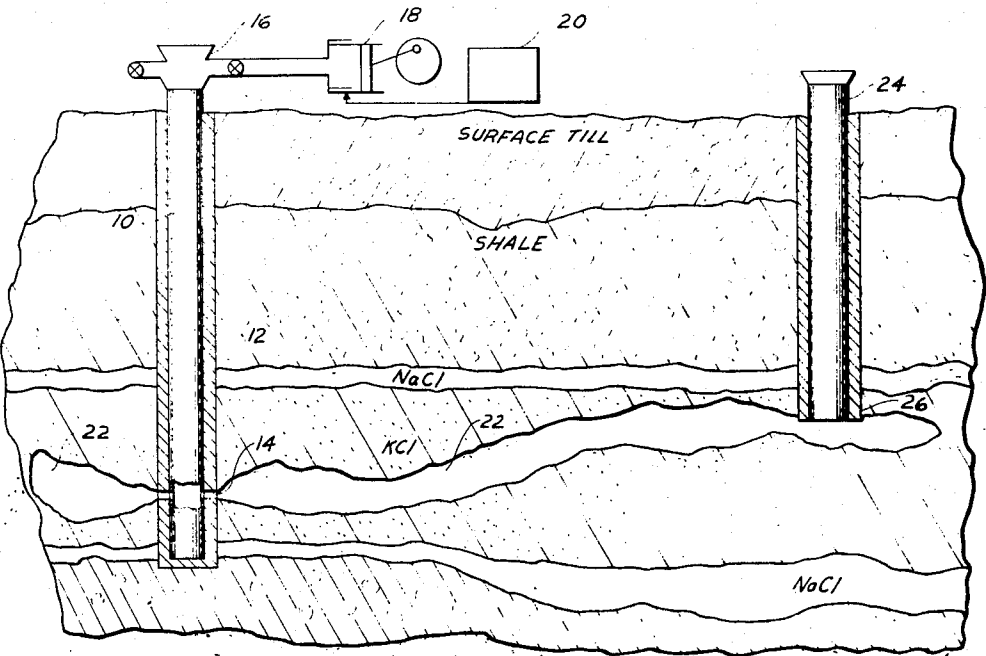
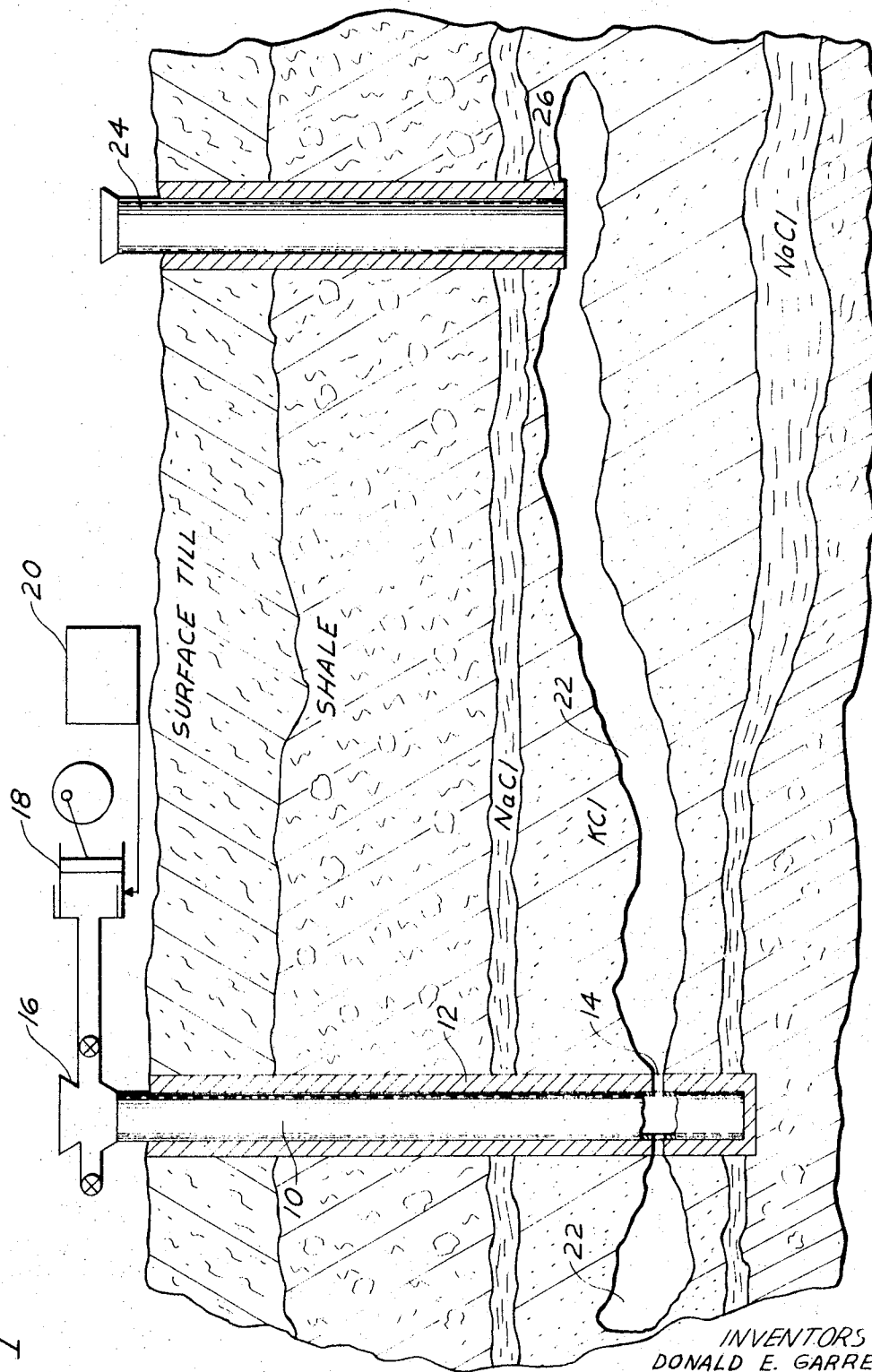
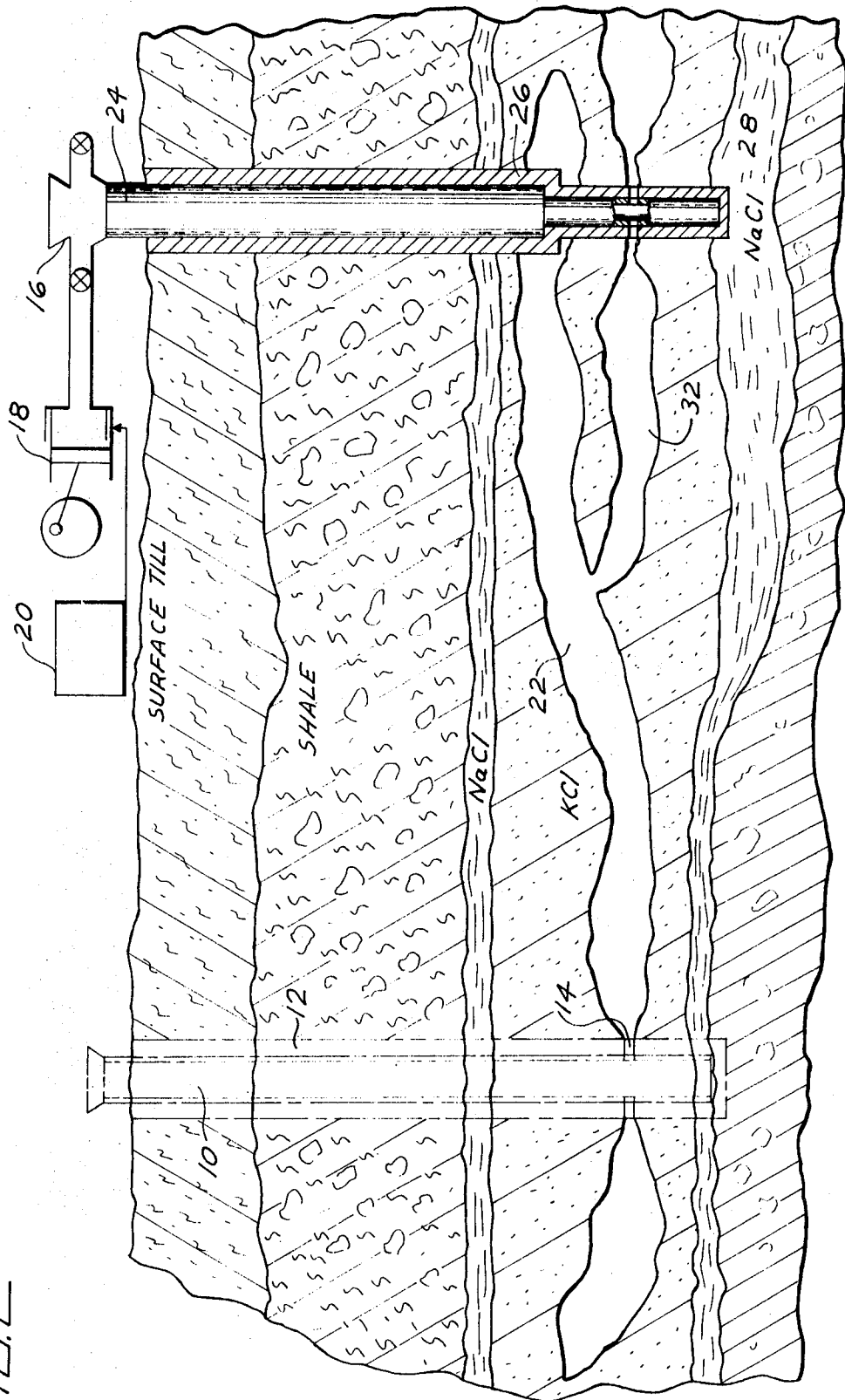


FIG 1



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FIG. 2



PROCESS TO ESTABLISH COMMUNICATION BETWEEN WELLS IN MINERAL FORMATIONS

BACKGROUND OF THE INVENTION

This invention relates to the recovery of underground deposits of soluble minerals by solution mining and particularly to establishing an aqueous solution mining operation in formations containing layers of different salts of similar crystal structure.

It is known that underground formations can be hydraulically uplifted or fractured by injecting a fluid into predrilled bores. The oil industry, for instance, frequently uses this method to increase the permeability of oil-bearing formations. In the mining of soluble salt deposits, the practice has been to drill two wells in relatively close proximity, typically not more than 600 to 800 feet in separation, and then to create a connecting fracture at a natural zone of cleavage between the soluble salt and insoluble overlying or underlying strata.

In U.S. Pat. Ser. No. 2,847,202, which is indicative of such prior art practices, a salt-shale boundary at the base of the salt deposit is used as the zone of fracture to establish communication between wells drilled to approximately this salt-shale boundary.

Some salt systems, however, are not amenable to the creation of a solution mine using such prior art techniques. For example, underground potassium salt deposits are typically contained between layers of halite. Such formations have ill-defined boundaries which are weak because the crystal structures of the salts are almost identical and no technique has been established to obtain controlled communication between predrilled wells bored into such deposits.

SUMMARY OF THE INVENTION

It has now been found that subsurface communication can be established in a desired soluble salt formation by drilling a first well into a water soluble salt formation, injecting a fluid at a pressure greater than static overburden pressure and sufficient to initiate and propagate the formation of a fracture pool and drilling at least one additional well into the fracture pool area to establish communication between the wells, while maintaining the fracture pool under a pressure greater than static overburden pressure.

This method is particularly useful in establishing communication in water soluble salt formations in the absence of definable zones of cleavage. In addition, positive intersection with the fracture pool can be obtained with the communication well no matter how thin or at what horizon it exists with respect to the first well.

DRAWINGS

FIG. 1 is an illustration of a solution mine created according to the practice of this invention.

FIG. 2 is an illustration of an expanded solution mine operation according to the practice of this invention.

DESCRIPTION

The present invention relates to a process for creating a solution mine in underground mineral formations in the absence of definable zones of cleavage.

The process of this invention is accomplished, in general, by drilling a first borehole or well into a soluble mineral deposit, hydraulically creating a fracture pool by pumping a fluid into the well, determining to the extent possible the area of the fracture pool while it is maintained under a positive pressure, then drilling a second borehole or well within the defined area to communicate with the fracture pool.

More particularly, and with reference to FIG. 1, the first borehole or well 10 is drilled into the soluble mineral salt deposit sought to be recovered, then typically cased to its total depth with a casing 12 of a strength sufficient to withstand the fracture pressures to be employed. The casing is then normally notched or perforated at point 14 in the region where it is

desired to initiate the fracture. Alternately, methods such as plugging the hole below the casing may be used to define the area in which the fracture is to be initiated.

The well is then fitted with wellhead equipment 16 designed to withstand the estimated pressures needed to establish the fracture pool, which is, in general, from about 0.7 to about 1.5 p.s.i. per foot of depth between the surface and the depth at which the fracture is to be initiated. Injection equipment 18 and a fluid reservoir 20 of sufficient capacity are then connected to the wellhead equipment. The fracture pool 22 is formed by injecting a fracturing or lifting fluid into the well until a fracturing pressure is reached, typically from about 10 to about 40 percent greater than static overburden pressure, and, when fracture has initiated, then propagating the fracture through the formation. The fracturing or lifting fluids useful for such impermeable formation may be liquids or gases and include water; brines; acidic solutions, such as sulfuric acid, hydrochloric acid and the like; caustic solutions, such as sodium carbonate; inert hydrocarbon liquids; inert compressed gases and the like, with water or brine being preferred. When inert hydrocarbon liquids or compressed gases and the like are used, they are supplanted by a suitable salt solvent once communication between wells is established. The quantity of fluid injected to establish the fracture pool may be varied widely from several thousand to many millions of gallons, depending on the extent of fracture desired. Normally, however, from about 1 to about 10 million gallons will be required to establish a pool in a potash ore system.

As indicated in FIG. 1, the fracture created according to the practice of this invention will extend from the point of initiation in all directions and can be expected to propagate towards the surface. The growth of the fracture pool and any anomaly in it may be continuously monitored by measuring changes in surface elevation or inclination of the areas surrounding the first well by using surveying instruments, tilt meters and similar geological measuring devices.

When a fracture pool of desired area is established, the injection of fluid is stopped and the well is "shut in." The shut-in pressure of the well will ordinarily be substantially the same as the injection pressure with some allowance for pressure drop due to termination of fluid flow. In this static condition the wellhead pressure is approximately equal to the static overburden pressure. With the pool sealed, a communicating borehole or well 24 is then drilled in the area designated as containing the fracture pool until it communicates with the pool by intersecting it at point 26. When communication is established, the pressure of the fracture pool will normally cause the second well to "blow in." The pressure in the newly drilled well will decrease rapidly as the well is allowed to flow until it is only slightly greater than the hydraulic head of the well and fluid flow is reduced to a relatively low level, typically of the order of from about 2 to about 50 gallons per minute. At this point the well can be further drilled, if desired, and normal completion, such as running and cementing casing in the well, can be carried out.

When construction of the second well is completed, mining is carried out by typically pumping a fluid solvent, such as water or brine, into the original injection well and withdrawing saturated brine from the second well. When desired, this flow procedure may be reversed. Additional wells may also be drilled within the fracture pool area and may be operated in cooperation with the original injection well or any other wells feeding to the fracture pool. Further, wells drilled close to the edge of the fracture pool may be used to extend the fracture pool or create new fracture pools by a repetition of the procedures set forth above.

The conveniences of the practice of this invention are several. There is no dependency on a cleavage zone and there is less dependence on the axial or radial path of the fracture as is necessary with other systems. Further, the fracture may be allowed to propagate in any fashion determined by the natural condition of the formation as the second well will intersect the fracture at any horizon no matter how thin the fracture pool may be at that point.

As indicated above, the fracture pool often will tend to drift upwards as it grows and when mined with the original combination of wells, much valuable ore may be bypassed. A method of exposing this valuable ore to recovery is depicted in FIG. 2. With reference thereto, the bore of the second well is extended downward to the base of the ore deposit 28 or at least to the level of the original point of fracture 14. Well 10 is then temporarily sealed and the second well equipped with injection head equipment 16, pumping means 18 and fluid reservoir 20. Injection fluid is then pumped into well 26 until a second fracture pool 32 forms and intersects with the original fracture pool. By this method a labyrinth of harvesting zones may be readily created to allow complete and thorough recovery of the mineral values in the formation.

In establishing communication in a potash deposit by this method, flow can be established with the initial injection well and production flow maintained in this reverse direction, especially employing, air, immiscible fluid layer or a magnesium chloride fortified brine. This reverse flow should be initially established very slowly so that the formation will not plug due to the cooling of and crystallization from the warmer brine out in the formation returning to the cool zone where the injection brine or water had cooled the formation.

A solution mine created in accordance with the practice of this invention may be typically mined by continuously injecting or pumping water or a brine dilute with respect to the components to be dissolved into the ore formation. The density of the water or brine normally used is unavoidably light compared to that of the brine which will be formed after it is saturated. It has been found that this causes the incoming water or brine to stratify and travel along the upper limits of the deposit until saturated. This causes the ceiling to dissolve preferentially and the cavity to grow in an upward direction. Often there is such rapid growth near the point of brine or water injection that a barrier or pad has been customarily inserted to prevent this uncontrolled dissolving action. It has been found, however, that the need for installing a barrier or pad can be conveniently avoided by suitably loading the dissolving water or brine with a heavy salt component of low value, such as magnesium chloride, to raise its density to a level sufficiently high that it will not change appreciably with dissolution of the desired salts within the formation. Using a brine of this character allows uniform dissolution of the ore or, where the brine is heavily loaded, preferential dissolution in a downward direction. This could allow forming the fracture pool near the upper contact between a potash ore zone and the overlying salt mass and dissolving the potash ore in a downward direction.

Using a brine loaded with a heavy salt component of low value is particularly effective where a mining operation is established through the use of two fracture zones as described above, which are used to expose the lower zones of a deposit. The brine heavily loaded with the salt of low value can then be pumped into the second well and carried away in the first well and selectively mine the lower portion of the formation before insoluble clays and the like settle and occlude further mining and before the cavity is allowed to grow in an upward direction.

The use of heavily loaded brines is also effective in establishing communication between the first well and otherwise unavailable potash formations below the second well, in that the second well can be drilled to the bottom of such a formation in the manner set forth below, and the second well operated as a countercurrent flow single well until a cavity, which communicates with the first fracture pool, is established. This can be carried out concurrently with the mining of the fracture pool between the initial well and upper level of the second well.

It should also be understood that included within the practice of this invention is the formation of any number of fracture pools within a given site. These pools may be operated independently or progressively created and interconnected through the use of a combination of wells in which the first fracture pool is communicated with the second fracture pool

by drilling another well and creating a joining fracture with the first pool, etc., until the desired number of interconnecting fracture pools are realized.

The following example is illustrative of the practice of this invention:

EXAMPLE

An injection well was drilled into a soluble salt formation containing sylvinitic and halite layers. The top of the formation was determined to be at a depth of 4,800 feet and a fracture initiation point selected at 4,932 feet. For this depth casing and wellhead equipment was selected which would withstand the pressure of 5,000 p.s.i. The casing was installed to within a foot of the bottom of the drill hole and subsequently cemented with sodium chloride and potassium chloride saturated cement. The casing was notched at the fracture initiation depth by means of a fluid abrasive jet which was used to cut a circumferential notch in the casing. Wellhead fittings were installed and suitable pumping equipment for injection was rigged to the well. Approximately 1,600,000 gallons of a sodium chloride and potassium chloride containing brine was injected into the well. A surface pressure of 4,000 p.s.i. was reached before a breakdown or fracture occurred. At breakdown, the pressure dropped in a few minutes to 3,200 p.s.i. and during the hours of subsequent injection gradually decreased to about 2,700 p.s.i. After the well was shut in, the static pressure was 2,600 p.s.i.

A second well was then drilled which intersected the fracture pool at a depth of 4,875 feet. Intersection was evidenced by blow-in of the well which lasted about 15 minutes until flow reduced to a level of about 5 gallons per minute. The fluid which flowed from the second well was estimated to be about 50,000 gallons or less; only a small portion of the fluid content of the fracture pool. Flow between wells was continuously maintained with pressures of 30 to 100 p.s.i. above the static head in the secondary well and yielded brines at a flow rate of 40 to 120 gallons a minute. Additional wells could be drilled to intersect the fracture pool.

What is claimed is:

1. A process for establishing a multiwell solution mine in a soluble mineral formation which comprises:

- a. drilling a first well into the soluble mineral formation, said well containing a zone for initiating a fracture in said formation;
- b. injecting a fracturing fluid to a pressure sufficient to initiate a fracture at said fracture zone;
- c. pumping additional fluid into the well to propagate the fracture to form a fracture pool;
- d. determining the extent of the fracture pool; and
- e. drilling at least one other secondary well into the defined fracture pool area to at least the upper level of the fracture to establish communication between the wells while maintaining the fracture pool under positive pressure.

2. The method of claim 1 in combination with the subsequent steps of recovering the soluble minerals in the formation by injecting a solvent for said minerals into one of said wells while withdrawing brine containing dissolved minerals from the other of said wells.

3. A process as claimed in claim 1 in which additional wells are drilled into the fracture pool.

4. A process as claimed in claim 1 in which the fracture is initiated at a pressure which is from about 10 to about 40 percent greater than static overburden pressure.

5. A process as claimed in claim 1 in which the fracture pool is maintained at a positive pressure at least equal to static overburden pressure while at least one secondary well is drilled into the fracture pool area.

6. A process as claimed in claim 1 in which the fracturing fluid is selected from the group consisting of water, brines, acidic solutions, caustic solutions, inert hydrocarbon liquids and inert compressed gases.

7. A process as claimed in claim 2 in which the solvent is water.

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8. A process as claimed in claim 2 in which the solvent is a brine containing a heavy salt, which is different from the soluble salt, in a quantity at least sufficient to make the density of the brine at least substantially equal to the density of the brine in the fracture pool.

9. A process as claimed in claim 8 in which the heavy salt is magnesium chloride.

10. A process as claimed in claim 1 in which the fracture pool area is determined by surface measurement prior to drilling the secondary well.

11. A process as claimed in claim 10 in which the fracture pool area is determined with a tilt meter.

12. A process as claimed in claim 1 in combination with the steps of:

- a. drilling said secondary well to a depth at least equal to the point of fracture initiating from said first well while brine is withdrawn from said secondary well at the zone of communication with said fracture pool;
- b. temporarily sealing said first well;
- c. pumping a fracturing fluid into said second well to create a second fracture pool; and
- d. pumping additional fracture fluid into said second well until the fracture pool communicates with said first fracture pool.

13. The method of claim 12 in combination with recovering soluble salts in the formation by injecting a solvent for said salts into the joined fracture pools through one of said wells while withdrawing brine containing dissolved salts from the other of said wells.

14. A process as claimed in claim 12 in which the fracturing fluid is selected from the group consisting of air and immiscible fluid or magnesium chloride fortified brine.

15. A process as claimed in claim 13 in which the solvent is a brine containing a heavy salt which is different from the soluble salt in a quantity at least sufficient to make the density

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of the brine at least substantially equal to the density of the brine in the joined fracture pools.

16. A process as claimed in claim 1 in combination with the steps of:

- a. extending said secondary well to a base which is at a depth at least equal to the point of fracture initiating from said first well;
- b. operating said extended secondary well as a single cavity, countercurrent well until communication is established with said fracture pool; and
- c. thereafter maintaining a flow of solvent between said first well and the base of said secondary well.

17. A process as claimed in claim 16 in which the solvent flow is maintained in said fracture pool concurrently with operating said extended secondary well as a single cavity, countercurrent well.

18. A process for establishing a multiwell solution mine in a soluble mineral formation which comprises:

- a. drilling a first well into the soluble mineral formation, said well containing a zone for initiating a fracture in said formation;
- b. injecting a fracturing fluid to a pressure sufficient to initiate a fracture at said fracture zone;
- c. pumping additional fluid into the well to propagate the fracture to form a fracture pool;
- d. determining the fracture pool area by surface measurement; and
- e. drilling at least one other secondary well into the defined fracture pool area to at least the upper level of the fracture to establish communication between the wells while maintaining the fracture pool under a positive pressure.

19. A process as claimed in claim 18 in which the fracture pool area is determined with a tilt meter.

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