Oct. 16, 1962 C. A. BAYS **3,058,730**

METHOD OF FORMING UNDERGROUND COMMUNICATION BETWEEN BOREHOLES

Filed June 3, 1960 2 Sheets-Sheet 1

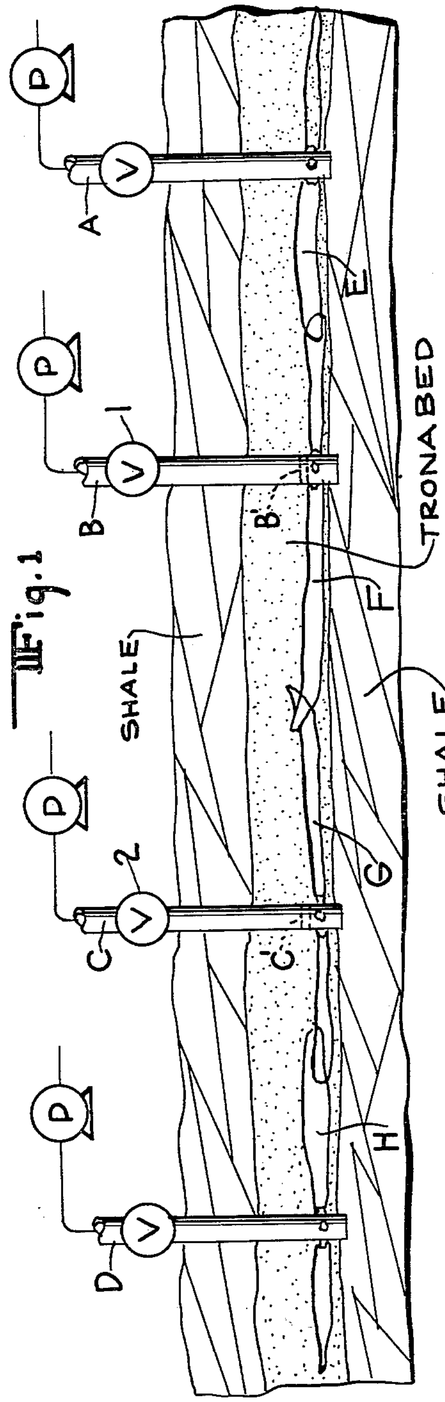

Fig. 1

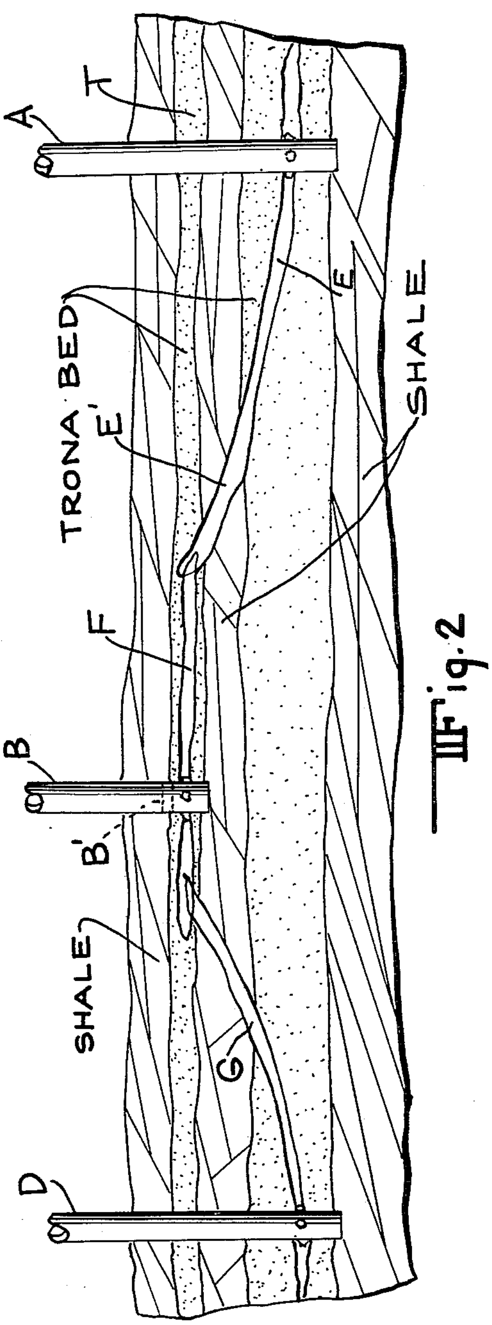

Fig. 2

INVENTOR
CARL A. BAYS
BY
Hammond & Littell
ATTORNEYS

Oct. 16, 1962 C. A. BAYS 3,058,730

METHOD OF FORMING UNDERGROUND COMMUNICATION BETWEEN BOREHOLES

Filed June 3, 1960 2 Sheets-Sheet 2

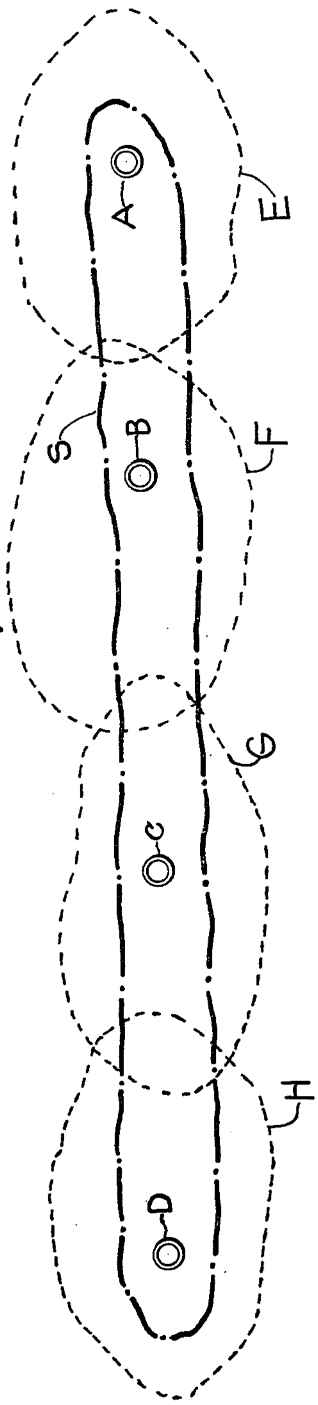

Fig. 3

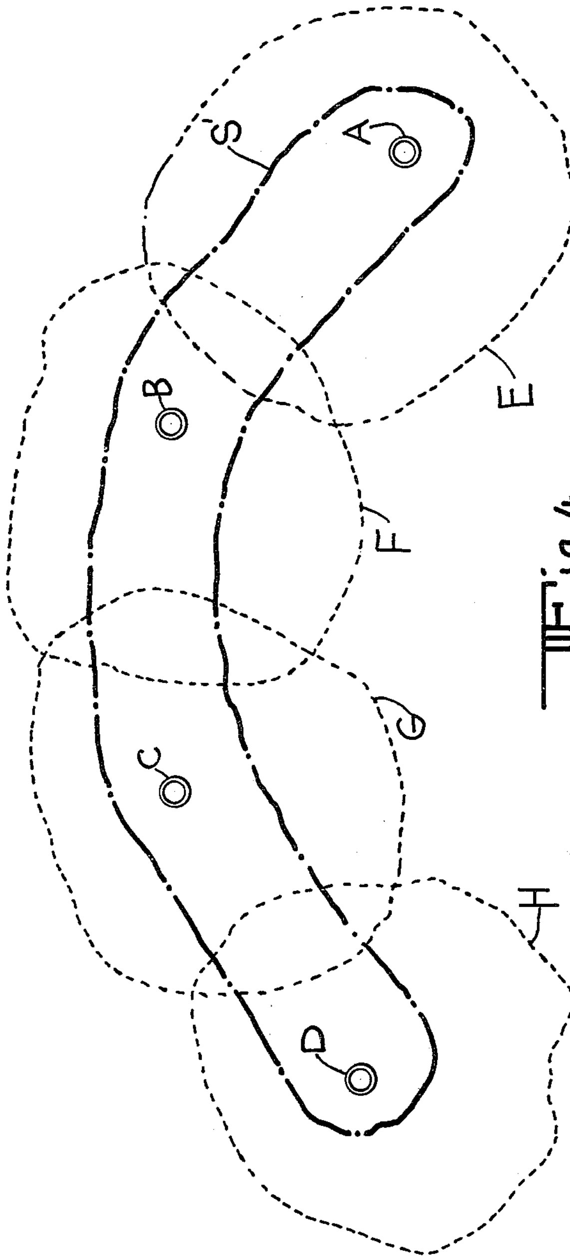

Fig. 4

INVENTOR
CARL A. BAYS
BY
Hammond & Littell
ATTORNEYS

United States Patent Office

3,058,730

Patented Oct. 16, 1962

3,058,730

METHOD OF FORMING UNDERGROUND COMMUNICATION BETWEEN BOREHOLES

Carl A. Bays, Urbana, Ill., assignor, by mesne assignments, to FMC Corporation, a corporation of Delaware

Filed June 3, 1960, Ser. No. 33,738
6 Claims. (Cl. 262—3)

This invention relates to a method of opening solid underground formations containing soluble or liquescent constituents therein for fluid mining. Examples of materials which may be mined by this process are salt, potash, trona, sulfur, mineral ores and the like. This application is a continuation-in-part of my prior applications Serial No. 637,684, filed February 1, 1957, now Patent No. 2,952,449, and Serial No. 628,485, filed December 17, 1956, now abandoned.

The terms of "borehole" or "boreholes" when used in this application refer broadly to any borehole or point of entry into an underground formation. For example, a fracture may be between a plurality of boreholes and an outcrop or between a borehole and a previously opened mine, as well as between a plurality of wells or drill-holes in a solid formation.

In mining a substantially non-permeable underground formation containing deposits such as salt, potash, trona, sulfur, mineral ores and like materials, it is desirable to open an underground passage between two or more adjacent boreholes to permit the flow of liquid therebetween. The greater the distance between these boreholes the more technically and substantially feasible the mining operation becomes, as the cost of drilling the boreholes is many times that of hydraulically fracturing the formation. From a technical standpoint, the longer the retention time of the fluid within the underground cavity, and the greater the area of contact of the removal fluid with the formation to be removed, the more efficient is the mining operation. A long solution path, with a large area of contact with the formation to be removed provides a greater degree of saturation in passing from an input to an outlet well. This is particularly true in the solution mining of relatively thin salt and mineral beds, such as trona beds, potash beds, copper veins, etc., where it is impossible to get a large solution exposure in a vertical direction. There is a limit, however (differing for each formation) to the distance over which a single pair of wells can be brought into communication by hydraulic fracturing.

An object of this invention is to provide a method for the fluid mining of an underground deposit, whereby an elongated narrow fracture path may be produced through the formation, through which a dissolving or extraction fluid may pass to extract mineral values from the formation.

Another object is to provide a method for creating an underground connection between boreholes which are spaced a substantial distance from each other.

A further object is to provide a means for interconnecting boreholes so that a fluid may be flowed between boreholes from a pre-selected horizontal plane to another pre-selected horizontal plane through a plurality of interconnected fractures formed at the base of a plurality of separate boreholes or wells drilled into the formation.

A still further object is to provide a means for interconnecting fractures at the base of a plurality of boreholes when the line of fracture from one of the boreholes has diverged in a direction away from another borehole.

Various other objects and advantages will appear to those skilled in the art as the description of this invention proceeds.

Experience indicates that in the future an increasing proportion of the workable salt deposits and ore bodies adjacent to or readily accessible to centers of civilization or markets will be at greater and greater depths and that economical methods of reaching and extracting these salt and ore bodies at greater depth must be used. The methods herein described are applicable to secure these results.

Generally stated, this invention provides for the creation of an underground interconnection between fractures at the base of a plurality of boreholes by hydraulically fracturing the formation adjacent each of the boreholes and interconnecting the fractures, while maintaining the fracture open, adjacent the base of each of a plurality of boreholes, until the fractures adjacent the base of each borehole have been washed through and a clear passage formed from the first borehole in the series to the last borehole in the series. The length and direction of the fracture from any borehole will vary and be affected by the type of formation and the pressure thereon as well as the depth of the formation at the point of fracturing.

In solution or thermal mining between two or more boreholes in a solid, substantial, non-porous underground formation, such as a trona or salt formation, a mineral deposit, it is often desirable to space the inlet and outlet wells as far apart as possible and preferably at such a distance apart that the area of the fracture initially produced adjacent one well will not extend to the other well, but if it is desired to open the formation to solution mining by flowing between only two boreholes, the wells must be located sufficently close together that the line of fracture from each of the boreholes will intercommunicate.

I have discovered that it is not of absolute necessity that the maximum fracturing distance between boreholes in a given formation be predetermined in order to give the maximum distance between boreholes and still insure that the fractures from each borehole will intercommunicate. For a third, fourth or more boreholes, if necessary, may be drilled intermediate two end boreholes and the formation adjacent this third or fourth or more borehole fractured so as to communicate with the fractures from the first two or end boreholes. By plugging or sealing the intermediate borehole or boreholes, a communication between the first two or end boreholes of a series is established.

Even, however, where the third or more borehole is within the extent of the line of fracture from the first borehole, this invention may be used to create an extended underground communication between boreholes with greater facility. The fracture from a borehole becomes narrow and tapers to a feather edge as it progresses farther away from the borehole being fractured. This presents frictional restraint to the flow of liquid through the underground channel. By fracturing from the second, third, fourth or more boreholes, the thickness of the fractured zone is increased, said increase allowing the flow of liquid between spaced boreholes at the end of the series with substantially less resistance.

I have further discovered that if, when fracturing from a second, third or more boreholes to intercommunicate with the fracture from a first borehole, a substantial pressure is maintained along the line of fracture from the first fractured boreholes to keep the fracture in the formation open, communication between the end boreholes is established with greater facility.

A desirable way to maintain such elongated, interconnected fractures open while a clear solution path is washed through between an input and an output well is to maintain a pressure in the fractures sufficient to prevent closing or resettling of the fractured formation until a clear solution path has been established through the formation. This may be done by continuing to pump a fracturing and dissolving liquid into the fractures adjacent the base of a plurality of three or more wells at a pressure sufficient to float or hydraulically support the formation above the fracture upon the fracturing liquid or to seal the fracturing liquid in each fracture under a pressure sufficient to float or hydraulically support the formation above the fractures. After the fractures have been interconnected at a pressure sufficient to float or hydraulically support the overlying formation on the fracturing fluid and a clear solution path washed through between the input and output wells, the formation may be permitted to return to its normal environmental pressure, in other words, to resettle, and the clear solution path will still remain open for the passage of a dissolving or liquefying fluid from the input to the output well at only sufficient pressure to overcome the static head and frictional resistance of the fluid path.

The pressure required to part the formation is dependent on the type of formation, but it has been found that a pressure in p.s.i.g. (pounds per square inch gauge) of from 1 to 1.8 times the depth of the formation in feet to the point of fracture is sufficient. The fracture, when initiated in a horizontal plane, will generally form more or less of a circular pattern about the borehole with the zone of fracture being of greatest thickness adjacent the borehole and tapering off to a feather edge along the outer circumference of the circle. If the fracture is at an interface between a soluble and an insoluble stratum, a fracture of this type exposes a large roof area of the formation to solution mining and if the fracture is wholly within a soluble stratum, both a large roof area and a large floor area is exposed to solution mining.

Vertical or diagonal fractures may be initiated in specified formations where desired and the fractures may be initiated at different depths in the formation so as to bring the fractures into communication at different elevations, to connect portions of a mineral or salt bed lying at different depths in the formation or vertically displaced relative to different portions thereof by faults in the formation.

The fracture may not extend in the same horizontal plane due to the presence of natural faults or irregularities in the formation, so that a fracture adjacent the bottom of one borehole may intersect the second or third boreholes several feet above or below the desired fracture point of the other borehole.

While the process of this invention will be described with reference to the drilling of three or more boreholes in a substantially straight line and the opening of a passage therebetween, it is to be understood that the process is equally applicable to situations where it is desired to drill a plurality of boreholes into the formation in a circle, semicircle, rectangle, triangle or the like, and establish underground connections therebetween by fracturing the formation adjacent the base of three or more boreholes and interconnecting the fractures.

For purposes of illustrating an embodiment of this invention, reference will hereafter be made to the recovery of an underground trona deposit found in Green River, Wyoming, where the main trona bed is approximately 12 feet in thickness and lies in a substantially horizontal plane.

It will be understood, however, that the principles of this invention are applicable to various salt beds and ore bodies located in dense, non-permeable formations where fractures may be initiated and propagated for substantial distances without loss of pressure on the formation, due to dissipation of the fracturing fluid into pores in the formation, as happens where a fracturing fluid is pumped into a porous oil sand formation and no substantial pressure can be maintained on the fracturing fluid due to its rapid leakage or penetration into the pores of the oil sands or into other pores in a porous formation or where sealing against such natural permeability can be practiced by use of plugging materials.

In the accompanying drawings:

FIG. 1 shows a series of four boreholes drilled into an earth formation, containing a trona bed, and hydraulically fractured at the base of each borehole to form an interconnected fracture from the first to the fourth borehole.

FIG. 2 is a diagrammatic illustration showing how interconnection between different boreholes may be brought about at different levels when the line of fracture from one or more boreholes deviates from the horizontal.

FIG. 3 is a plan view illustrating diagrammatically how a solution path is formed in a substantially straight line through hydraulic fractures at the base of four boreholes.

FIG. 4 is a plan view illustrating a semi-circular arrangement of boreholes.

In recovering trona as shown in FIG. 1 according to the methods of this invention, wells A, B, C and D are drilled into the formation to a depth preferably just beyond the lower interface of the trona bed. The wells are spaced a substantial distance apart, for example, a distance of 600 to 800 feet or more. The wells are cased and cemented according to conventional practices and care is taken to use cement slurries that will not shrink on setting and will bond with the rock materials that may be present, such as oil shale, anhydrite, and the like. The formation may be underreamed at the base of each well, if desired. After the wells are completed, the formation is perforated by conventional means at the lower interface of the trona bed. If the formation at the bottom of the well is permeable, it may be necessary to seal off the bottom of the well before fracturing. After sealing, if necessary, and perforation, the trona bed adjacent well A is fractured by subjecting the perforated formation to a pressure sufficient to part the formation. The initial parting of the formation is marked by a sudden drop in pressure. As shown in FIG. 1, E represents the fracture adjacent well A.

Due to the distance between wells, a communication cannot be made by fracturing from well A alone. The next step is to similarly fracture from well B to create fracture F which is shown in FIG. 1, as communicating with fracture E. In a similar manner the formation at the base of well C is fractured to form the fracture indicated diagrammatically at G and the formation adjacent the base of well D is fractured to form the fracture H, with each of the fractures E, F, G and H communicating with the next adjacent fracture or fractures so that communication is formed through the formation from well A to well D.

During the fracturing from well B a substantial pressure is maintained along the line of fracture from well A to keep the fracture open so that the interconnection of the fractures E and F is brought about with greater facility. This operation may be performed by holding a pressure on well A high enough to support the overburden above the fracture, after fracturing well A, to keep the formation through which the fracture has penetrated from closing while fracturing from well B. If the fracture formed at the base of any well is permitted to close by relief of the pressure on the formation at this fracture, the resettling of the formation tends, in some formations, to reseal the fracture or to break up the formation adjacent the fracture and to cause the production of innumerable small fractures instead of preserving the original wider fracture. The pressure on fracture E adjacent the base of well A may be kept up by continuing to pump a fracturing fluid into well A under sufficient pressure to hydraulically support or float the overlying formation on the fracturing fluid in the fracture E or by sealing the head of well A to maintain a formation floating pressure on the fluid in fracture E.

In a similar manner the fractures at the base of wells B, C and D are kept open until all the fractures are interconnected, and the formation floating pressure is maintained on the fractured formation from wells A to D during a wash through period in which a dissolving or liquefying fluid is pumped through the formation between wells A and D until a clear channel has been dissolved out or formed through the formation after which the overburden supporting pressure may be relieved and the formation permitted to settle without fear that the passage between wells A and D will be blocked.

After a clear passage has been formed between wells A and D, wells B and C may be plugged by inserting packers B′ and C′ or other sealing means at the bases thereof, or by sealing at the surface as by closing valves 1 and 2, or by cementing, or the like, to shut off these wells and cause a dissolving or liquefying solution to flow between wells A and D to dissolve or liquefy and remove trona, salt, sulfur or the like from the underground formation.

In situations where the intermediate wells are to be used only for hydraulic fracturing and are not to be used in later production, the intermediate wells, such as B and C may be uncased boreholes, and may be of smaller diameter than the production wells or end wells A and D. The formation at the bottom of the uncased intermediate wells may be hydraulically fractured by inserting a packer or packers at the point of the desired fracture and applying the fracturing pressure between the packer and the base of the well or between two packers in the well.

FIG. 2 illustrates the situation which prevails when the fracture from a well deviates from the desired horizontal plane or when it is desired intentionally to form intercommunicating fractures at different depths in the formation. As therein illustrated, the fracture E from the base of well A has angled upward, or has been intentionally angled upward, as indicated at E′ into a higher trona bed T. The well B has been drilled into the bed T and fracture F formed to communicate with fracture E and a third well D has been drilled into the lower trona bed and the formation fractured at G to communicate with the other two fractures. Likewise, as described in connection with FIG. 1, the interconnection of the three fractures may be brought about with greater facility by maintaining pressure on well A to keep the fracture E open while fracturing from well B and from well D. This will occur even if fracture G should also follow the same fault along which fracture E angles.

After a clear solution path has been formed between wells A and D, well B may be sealed by inserting a packer B′ at the base thereof or by closing the valve at the top, or by cementing or otherwise sealing to cause dissolving solution to flow through the formation between wells A and D.

While it is preferred to fracture wells A, B, C and D in sequence and to keep the fracture adjacent the bottom of each well open by maintaining a separating or floating pressure on the fractured formation while the next adjacent well is being fractured, and during any wash through period, the exact order of fracturing and washing through is not critical and two or more of the wells may be simultaneously fractured if desired.

In fracturing and interconnecting a plurality of wells it is sometimes desirable to drill two wells, namely, an input and an output well, into the formation and to fracture each of said wells and maintain the fluid in each of said wells under sufficient pressure to keep the fractures at the base of said wells open and to drill one or more intermediate wells and after the end wells have been fractured if the fractures do not interconnect to fracture the intermediate well or wells and maintain sufficient pressure on the intermediate well or wells to keep the fracture adjacent the base of the intermediate well or wells open and continue to pump fluid into the intermediate well or wells until the fracture at the base of the intermediate well or wells is interconnected with the fracture at the base of the input and output wells and to maintain the separating or floating pressure on the fractured formation during any wash through period and then seal the intermediate well or wells and pump the removal liquid through the formation between the input and output wells.

By fracturing at the base of three or more spaced wells, a longer initial flow circuit is established and the initial flow path is narrower. Thus, as indicated in FIG. 3, a series of wells A, B, C and D have been drilled in a substantially straight line and interconnected as described above. The outlines of the original fractures E, F, G and H are indicated in dotted lines and the solution or flow path between wells A and D has been indicated at S by dash dot lines. When a clear solution path has been established between wells A and D and the floating pressure has been relieved to permit the formation to resettle, the outer edges of fractures E, F, G and H tend to reseal themselves and confine the flow to the clearly washed solution path S.

By having a long and relatively narrow solution path S between wells A and D, the velocity of flow is higher, there is less stratification and stagnation of the solution than if it spread into the outlines of fractures E, F, G and H and the longer flow path provides a higher degree of saturation of the output solution. Where a heated solution is circulated between wells A and D, there is less loss of heat to the formation.

FIG. 4 shows wells A, B, C and D drilled in a semicircle and interconnected for flow between the base of wells A and D as previously described. The outlines of the original fractures are indicated at E, F, G and H and a curved solution path S′ between wells A and D has been shown. When the dissolving or removal liquid is pumped at high velocity between wells A and D it tends to even more turbulent flow through a curved path than through a straight path, with the advantages recited above.

Example

Wells A, B, C and D were drilled into a trona formation to varying depths of between 1500 and 1750 feet at which depth the wells penetrated the main trona bed lying approximately 1500 feet underground. The wells were placed at a distance of 600 feet apart. The thickness of the main trona bed was about 12 feet. The wells were drilled and cased to a point slightly below the main trona bed and the casings cemented into place and the wells and the formation adjacent the lower interface of the trona bed at each well were perforated substantially at the lower trona-shale interface.

Pressure was applied to the formation adjacent well A by pumping water into the well. Pressure was built up to about 1600 p.s.i.g. in about 1 minute's time, and after a few minutes resulted in a parting or fracturing of the formation so that two minutes and twenty seconds after the application of pressure was started, the pressure had dropped to 1020 p.s.i.g. and then gradually decreased to about 925 p.s.i.g. After pumping water into well A at a pressure of about 925 p.s.i.g. at the rate of about 200 gallons per minute for sufficient length of time to spread the fracture from the base of well A, well A was sealed to hold the pressure on the formation at about 925 p.s.i.g. and water was pumped into well B to generate a pressure of about 1600 p.s.i.g. on the formation adjacent the perforation at the bottom of well G. After a few minutes' time the pressure dropped, indicating the formation of a fracture adjacent the base of well B. Normally, the pressure required to produce a fracture adjacent the well B is somewhat smaller than the pressure required to produce the initial fracture at the base of well A, and the pressure then drops to about 925 p.s.i.g. Water was continually pumped down well B at a pressure of about 900 p.s.i.g. and at the rate of about 200 gallons per minute to spread the fracture around well B and well B was then sealed or shut in so as to hold the pressure on the fracture at the base of well B at around 925 p.s.i.g. Water was then pumped down well C at a pressure sufficient to fracture the formation adjacent the well C and after a fracture had been formed, as indicated by a drop in pressure, pumping down well C was continued at the rate of approximately 200 gallons per minute and a pressure of about 925 p.s.i.g. until the fracture around the base of well C had spread substantially to intersect the fracture around the base of well B. Well C was then sealed or shut in so as to hold the pressure on the formation at about 925 p.s.i.g. and water was then pumped down well D at a pressure high enough to fracture at the base of well D, and after the fracture had been formed, pumping of water down well D at the rate of about 200 gallons per minute under pressure of about 925 p.s.i.g. was continued until the fracture at the base of well D had spread to intersect the fracture at the base of well C.

The valve at the top of well A was then opened slightly to permit some flow from well A while continuing to maintain the pressure at the base of wells A, B, C and D at the pressure necessary to float or hydraulically support the overburden on the fracturing fluid in the fractures at the base of wells A, B, C and D. As fluid began to flow from the slightly open valve of well A pumping was continued down well D at a rate and pressure sufficient to cause flow from well D to well A, and when the valve of well A could be opened to permit a rate of flow from well A substantially corresponding to the rate of input into well D without a pressure drop in the interconnected wells B and C, the pressure was relieved by opening the valves on wells B and C. This permitted the pressure on the liquid in the fractures E, F, G and H to be reduced and the formation to return to its normal environmental pressure. In the meantime, however, a clear solution path such as indicated at S had been washed through between wells A and D and a dissolving liquid for salt or a hot extraction liquid for sulfur can be circulated between wells A and D to remove the salt or mineral from the formation.

After a clear solution path has been formed between wells A and D, it is sometimes preferable to open wells B and C and insert packers at the base of the well casings to prevent the hot solution from stagnating in the well casing and precipitating and plugging these casings. However, if the valves at the head of wells C and D are maintained slightly open, a sufficient flow of solution from these wells can be maintained to prevent precipitation of salt in the casing of wells C and D while the main flow of the dissolving fluid is still directed between wells A and D.

If wells B and C are not plugged and are kept open as described, they can be used for back flowing or for reversing the flow of solution at any time by merely opening the valve at the head of wells B or C and either permitting the solution to flow therefrom or pumping solution into the open well. In either event, a reversal or partial reversal of flow and change of flow pattern may be accomplished which sometimes has the advantage of opening up new surfaces of the formation being mined to the action of the dissolving or liquefying fluid.

While the invention has been described with particular reference to the recovery of salt, sulfur or mineral deposits, when used in oil bearing formations, or in the recovery of oil from oil shale formations, a longer flow path between an input and an outlet well can be established by the teachings of this invention than by heretofore known methods and a heated removal fluid or a solvent may be circulated through the oil bearing formation to liquefy or remove oil deposits not readily removable by the normal oil recovery techniques.

The invention has been described specifically as covering the connection of four wells, but it will be understood that this is only an illustrative embodiment and that the number of wells can still be further increased and that the length of the solution path can likewise be increased.

Where a saturated solution at the temperature of the solvent or liquefying fluid can be gotten by circulating between wells D and B or between any two wells, the unneeded length of the solution path may be discontinued by plugging or sealing one or more of the wells on either end of the string. By opening a formation to solution mining in this way, a longer solution path giving a substantially saturated solution can be initially formed, and as the size of the cavities become larger and longer solution paths are no longer necessary, the solution path can be readily cut down as described. Thus, by providing a long solution path initially by interconnecting fractures at the base of three or more wells, a saturated solution may be secured from the beginning of the operation of a well string, and a long period of production at low saturation avoided and as the saturation rises, the length of the string may be reduced or the solution path may be divided into two or more separate solution paths while still maintaining the desired degree of saturation.

Various other modifications and changes will be obvious to persons skilled in the art and are within the scope of the appended claims.

I claim:

1. The method of mining a mineral removable in liquid form from an underground formation between input and output wells, which comprises drilling wells into said formation, pumping a fracturing fluid into one of said wells under sufficient pressure to produce a fracture in the formation at the base of said well, maintaining the fluid in said well under sufficient pressure to keep said fracture open, pumping a fracturing fluid into the other of said wells under sufficient pressure to produce a fracture at the base of said other well, maintaining the fluid in said other well under sufficient pressure to keep said fracture open, drilling an intermediate well between the input and output wells, pumping a fracturing fluid into the intermediate well under sufficient pressure to produce a fracture at the base of said intermediate well and continuing to pump fluid into the intermediate well under sufficient pressure to maintain said fracture open until the fracture at the base of said intermediate well is interconnected with the fracture at the base of said input and output wells and then sealing the intermediate well and pumping a removal liquid through the formation between the input and output wells to liquefy and remove mineral from said formation.

2. The method of mining a mineral removable in liquid form from an underground formation between input and output wells, which comprises drilling wells into said formation, pumping a fracturing fluid into one of said wells under sufficient pressure to produce a fracture in the formation at the base of said well, maintaining the fluid in said well under sufficient pressure to keep said fracture open, pumping a fracturing fluid into the other of said wells under sufficient pressure to produce a fracture at the base of said other well, maintaining the fluid in said other well under sufficient pressure to keep said fracture open, drilling a plurality of intermediate wells between the input and output wells, pumping a fracturing fluid into the intermediate wells under sufficient pressure to produce a fracture at the base of each of said intermediate wells and continuing to pump fluid into the intermediate wells under sufficient pressure to maintain said fractures open until the fractures at the base of said intermediate wells are interconnected with each other and with the fracture at the base of said input and output wells and then sealing the intermediate wells and pumping a removal liquid through the formation between the input and output wells to liquefy and remove mineral from said formation.

3. The method of claim 2 in which said wells terminate at different depths in the formation and said communicating fractures are at different levels in the formation.

4. The method of mining a mineral removable in liquid form from an underground formation between input and output wells which comprises drilling three wells into said formation, pumping a fracturing fluid into the first of said wells under sufficient pressure to produce a fracture in the formation at the base of said well, pumping a fracturing fluid into the second of said wells under sufficient pressure to produce a fracture at the base of said second well, to communicate with the fracture at the base of said first well, pumping a fracturing fluid into the third well under sufficient pressure to produce a fracture at the base of said third well to communicate with the fracture at the base of said second well maintaining a sufficient pressure on the fracturing fluid at the base of each of said wells, after the fracturing, to hydraulically support the formation above said fracture on the fracturing fluid, pumping a removal fluid through the formation between said wells until a clear path for a removal fluid has been washed through between the first and the last well in said series and then sealing the second well and pumping a removal fluid through the formation between the first and third wells to liquefy and remove mineral from said formation.

5. The method of mining a mineral removable in liquid form from an underground formation between input and output wells which comprises drilling a series of more than three wells into said formation, pumping a fracturing fluid into the first of said wells under sufficient pressure to produce a fracture in the formation at the base of said well, pumping a fracturing fluid into the second of said wells under sufficient pressure to produce a fracture at the base of said second well, to communicate with the fracture at the base of said first well, pumping a fracturing fluid into the next well in said series under sufficient pressure to produce a fracture at the base of said next well to communicate with the fracture at the base of the preceding well in said series and continuing to fracture each well in said series until all the wells have been fractured and interconnected maintaining a sufficient pressure on the fracturing fluid at the base of each of said wells, after the fracturing, to support the formation above said fractures on the fracturing fluid, pumping a removal fluid through the formation between said wells until a clear path for a removal fluid has been washed through between the first and last well in said series and then sealing the intermediate wells in said series and pumping a removal fluid through the formation between the first and last well in said series to liquefy and remove mineral from said formation.

6. The method of mining a mineral removable in liquid form from an underground formation between input and output wells, which comprises drilling wells into said formation, pumping a fracturing fluid into one of said wells under sufficient pressure to produce a fracture in the formation at the base of said well, maintaining the fluid in said well under sufficient pressure to keep said fracture open, pumping a fracturing fluid into the other of said wells under sufficient pressure to produce a fracture at the base of said other well, maintaining the fluid in said other well under sufficient pressure to keep said fracture open, pumping a fracturing fluid into an intermediate well under sufficient pressure to produce a fracture at the base of said intermediate well, maintaining the fluid in said intermediate well under sufficient pressure to keep said fracture open and continuing to pump fluid into one of said wells until the fracture at the base of said intermedite well is interconnected with the fracture at the base of said input and output wells and then sealing the intermediate well and pumping a removal liquid through the formation between the input and output wells to liquefy and remove mineral from said formation.

References Cited in the file of this patent

UNITED STATES PATENTS

1,960,932	Tracy	May 29, 1934
2,695,163	Pearce et al.	Nov. 23, 1954
2,847,202	Pullen	Aug. 12, 1958
2,850,270	Hanson	Sept. 2, 1958
2,917,296	Prentiss	Dec. 15, 1959
2,952,449	Bays	Sept. 13, 1960