METHOD OF FORMING UNDERGROUND COMMUNICATION BETWEEN BOREHOLES

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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 deposits and the like.

The oil industry has employed certain processes or techniques for increasing the porosity and permeability of an underground formation. Generally stated, these techniques involve the process of shooting or hydraulically fracturing the formation adjacent an oil producing borehole to bring about increased flow of oil. These techniques are applicable in recovering underground formations, such as oil bearing sands, and where the fracturing is to extend into the formation for a short distance. Furthermore, in fracturing an oil field adjacent an oil well it is not required that the line of fracture be substantially continuous in the same horizontal plane.

Likewise, a method for recovering soluble or liquescent deposits, such as salt, potash, trona, sulfur and like materials, it is desirable to open an underground passage between two or more boreholes. The terms "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 borehole and an outcrop as well as between wells or drill-holes.

Thus, in mining a substantially non-permeable underground formation containing deposits such as salt, potash, trona, sulfur 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 economically 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, the more efficient is the mining operation.

Heretofore, when boreholes were placed substantial distances apart, it was impossible to communicate between the holes by hydraulically fracturing from one of the boreholes.

Furthermore, even when a borehole is disposed so as to normally be within the line of fracture extending from an adjacent borehole, natural faults, cracks and cleavages may result in a divergence of the direction of fracture away from the selected portion of the borehole it is sought to interconnect.

An object of this invention is to provide a method for the fluid mining of an underground deposit.

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 preselected horizontal plane.

A still further object is to provide a means for interconnecting two boreholes when the line of fracture from one of the boreholes has diverged in a direction away from the other borehole.

Other objects will appear to those skilled in the art as the description of this invention unfolds.

Generally stated, this invention provides for the creation of an underground interconnection between two boreholes by hydraulically fracturing the formation adjacent each of the boreholes. The length and direction of the fracture from any borehole will vary and be affected by the type formation and the pressure thereon, as well as the depth of the formation at the point of fracturing. However, in porous deposits such as oil bearing sands as described above, the fracture length is limited by the porosity of the deposit to about 200 feet as an average. Therefore, communication between holes more distant than 200 feet cannot be brought about by the teachings of the prior art.

However, in solution or thermal mining between two or more boreholes in a solid, substantially non-porous underground formation, such as a trona or salt formation, it is desirable to space the boreholes 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. If it is desired to operate with only two boreholes, the wells should, however, be located sufficiently 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 be pre-determined in order to give the maximum distance between boreholes and still insure that the fractures from each borehole will intercommunicate. For a third, or more if necessary, borehole may be drilled intermediate the two boreholes and the formation adjacent this third borehole fractured so as to communicate with the fractures from the first two boreholes. By plugging or sealing the intermediate borehole, a communication between the first two boreholes is established.

Even, however, where the second borehole is within the extent of the line of fracture from the first borehole this invention may be used to create an underground communication between boreholes with greater facility. The fracture from the first 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 borehole the thickness of the fractured zone is increased, said increase allowing the flow of liquid between boreholes with substantially less resistance.

Furthermore, due to the presence of natural crevices, joints and fractures in the formation, the line of fracture may deviate in a path away from the second borehole and only by fracturing from both boreholes may the formation be solution or thermally mined at a preselected horizontal plane for the entrance and exit of the mining liquid to and from the formation.

I have further discovered that if, when fracturing from the second borehole, to intercommunicate with the fracture from the first borehole, a substantial pressure is maintained along the line of fracture from the first borehole, communication between the boreholes is established with greater facility.

In general, the process of hydraulic fracturing an underground formation comprises drilling a borehole into the formation to the desired depth, sealing off the bottom of the borehole if the bottom lies in relatively permeable or porous formation, perforating the formation in the area desired to be fractured and pumping a fluid into the
borehole to generate sufficient pressure on the formation at the area of perforation to cause a parting of the formation. The well may or may not be cased, but generally is cased and the casing perforated or perforated at the depth where the fracture is to be initiated.

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. of from 1 to 1.8 times the depth of the point of fracture in feet to the point of fracture is sufficient. The fracture 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.

As stated previously, 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 borehole 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 two boreholes 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 and establish underground connections therebetween.

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.

Fig. 1 is a diagrammatic illustration in cross section through an earth formation showing intercommunication between boreholes placed substantial distances apart which have been hydraulically fractured according to the teachings of this invention.

Fig. 2 is a diagrammatic illustration showing how interconnection between boreholes may be brought about when the line of fracture from one borehole deviates from the horizontal.

In recovering trona as shown in Fig. 1 according to the methods of this invention, wells A and B 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 400 feet or more. The wells are cased and cemented according to conventional practices. After the wells are completed, the fracture 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, C 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 D which is shown in Fig. 1, as communicating with fracture C. Having performed the dual fracture, communication between wells A and B is established and the trona formation is now ready for solution mining. If during the fracturing from well B a substantial pressure is maintained along the line of fracture from well A to keep the fracture open, the interconnection of the fractures is brought about with greater facility. This operation may be performed by holding a substantial pressure on well A, after fracturing well A, to keep the formation through which the fracture has penetrated from closing while fracturing from well B. If desired, the pressure may be relieved on well A and then regenerated before fracturing from well B but this is usually undesirable as it tends to cause breaking up of the formation and the production of innumerable small fractures instead of preserving the original wider fracture from well A.

Fig. 2 illustrates the situation which prevails when the fracture from well B is deviated from the desired horizontal plane. By following the teachings of this invention and fracturing from the second well B, after having fractured from well A, interconnection of the fractures E and F will result and thereby establish communication between the wells. Likewise as described in connection with Fig. 1 the interconnection of the two 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. This will occur even if fracture F should also follow the same fault along which fracture E angled. As shown in Fig. 2, fracture E from well A is angled upwardly from trona bed and is extended into the overlying shale formation and intersected well B at the point E' which may be several feet above the trona bed and at a point where the bore of well B is sealed by casing and cementing.

Example

The following is an account of a trona recovery operation at Green River, Wyoming, employing the teachings of this invention. The wells A and B were drilled to a depth of 1780 feet and 1581 feet respectively, at which depth both wells had penetrated the trona formation. The wells were placed at a distance of 400 feet apart.

The formation adjacent the lower interface of the trona bed at each well was perforated for a distance of 1.5 feet from the interface into the lower shale deposit. Well A was drilled to give a borehole of 8% inches inside diameter. A 7 inch outside diameter casing was run into the well and cemented in. A section of well A, lying adjacent the lower portion of the trona formation was then perforated for a distance of about 3 feet by gun perforating or otherwise as is well known in the oil industry. Likewise, well B was drilled to give a borehole of 12% inch diameter. A casing of 8.6 inches diameter was run in and the well cemented. Pressure was applied to the perforated formation adjacent well B by pumping water into the well. The pressure was built up to about 1600 p.s.i.g. in about one minute's time. This pressure was maintained for a few minutes and resulted in the parting or fracturing of the formation as was evidenced by a pressure drop to 1020 p.s.i.g. However, the formation breakdown did not result in communication with well B, as was evidenced by the fact that there was no flow of liquid from well B, even though water was continually pumped into well A. Subsequently, well A was sealed to hold the pressure on the formation at about 925 p.s.i.g. and water was pumped down into well B so as to generate a pressure of 1500 p.s.i.g. on the formation adjacent the perforation at the bottom of well B. After a few minutes of this pressure, there was a parting of the formation adjacent well B as shown by a drop in well B's pressure to 950 p.s.i.g. Water was then continually pumped down well B, the head of well A was opened, and a trona rich liquor recovered from well A demonstrating the establishments of a communication between the wells. The flow from well A increased over a period of several days to a point where the outflow from well A substantially equaled the input into well B.

By proceeding in the above manner with the additional caution of maintaining a pressure of about 900 p.s.i.g. along the line of fracture from well A while fracturing from well B, the channel or passage between wells may be enlarged in a shorter period of time after the breakdown of the formation adjacent well B and thus allow for a greater flow from the output of well B.

While for purposes of illustration the fractures C, D, E and F have been illustrated as spreading substantially horizontally from the bottoms of wells A and B it is to be understood that the actual course a fracture takes is unknown but that wells can be connected over substantial
distances through a dense underground formation by the procedure herein described.

Pursuant to the requirements of the patent statutes, the principle of this invention has been explained and exemplified in a manner so that it can be readily practiced by those skilled in the art, such exemplification including what is considered to represent the best embodiment of the invention. However, it should be clearly understood that, within the scope of the appended claims, the invention may be practiced by those skilled in the art, and having the benefit of this disclosure, otherwise than as specifically described and exemplified herein.

That which is claimed as patentably novel is:

1. A method for forming an underground communication between boreholes in a substantially non-permeable underground formation comprising: drilling boreholes into the formation, perforating a selected portion of the formation adjacent each of the boreholes, pumping a liquid into the boreholes, applying a hydraulic pressure on the liquid and the selected portion of the formation adjacent one of the wells to fracture the formation, maintaining a substantial hydraulic pressure along the line of fracture from said well to keep said fracture open, then applying a hydraulic pressure on the liquid in and on the selected portion of the formation adjacent the second well sufficient to fracture the formation and bring about communication between the boreholes.

2. The method of opening a liquecent bed to solution mining, said bed lying in a substantially non-permeable underground formation which comprises sinking two wells into said formation, casing and cementing said wells and forming openings in said wells adjacent the bottom of said liquecent bed, applying a hydraulic fracturing pressure to one of said wells to fracture the formation adjacent said well and extend the fracture therefrom, sealing said well to maintain the formation separating pressure therein and keep said fracture open and applying a hydraulic fracturing pressure to the other of said wells to fracture the formation adjacent the other of said wells, causing said fractures to communicate and opening the seal on said first well to permit liquid pumped into the one well to flow from the other well and remove dissolved trona from the formation thereby.

4. The method of opening a soluble salt bed lying above an insoluble layer in a dense non-porous formation, to solution mining, which comprises the steps of drilling two wells into the formation substantially to the bottom of the soluble salt formation, injecting liquid into one of said wells under sufficient pressure to effect a stratum fracture adjacent the bottom of said well, maintaining a liquid pressure on said well sufficient to maintain said fracture open, injecting liquid into the other of said wells to open a passage between said wells and releasing the pressure on one of said wells while continuing to pump a dissolution liquid into the other well to dissolve out a passage between said wells.

5. The method of mining a soluble mineral from a stratum between injection wells and production wells, said method comprising the steps of 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 another of said wells under sufficient pressure to produce a fracture at the base of said other well and continuing to pump fluid into said well under sufficient pressure to keep said fracture open while maintaining said first well under sufficient pressure to keep the fracture around said first well open until the said fractures are interconnected and then relieving the fracture, maintaining pressure on one of said wells while continuing to pump a dissolving fluid for said mineral into the other of said wells and through the formation between said wells and out of the other of said wells to dissolve mineral from the formation along the passage thus opened.

References Cited in the file of this patent

UNITED STATES PATENTS

1,960,932  Tracy  May 29, 1934
2,584,605  Merriam et al  Feb. 5, 1952
2,642,142  Clark  June 16, 1953
2,756,653  Desbrow  Aug. 14, 1956
2,780,449  Fisher et al  Feb. 5, 1957
2,780,450  Ljungström  Feb. 5, 1957
2,847,202  Pullen Jr  Aug. 12, 1958
2,850,270  Hanson  Sept. 2, 1958

FOREIGN PATENTS

716,620  Great Britain  Oct. 31, 1954