

[54] **IN-SITU EXTRACTION OF MINERAL
 VALUES FROM ORE DEPOSITS**

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[51] Int. Cl. E21b 43/28

[58] Field of Search. 299/4; 166/299

[56] **References Cited**

UNITED STATES PATENTS

2,847,202	8/1958	Pollen	299/4
2,952,449	9/1960	Bays	299/4
3,565,173	2/1971	Anderson	166/299 X
3,718,366	2/1973	Hill	299/4

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[57] **ABSTRACT**

There is disclosed a method for the in-situ extraction of metal/mineral values from metalliferous and/or nonmetallic ores occurring in substantially impermeable ore deposits of the laminar gneiss or schist or conglomerate types, or the like. The invention is particularly adaptable for example to the mining of copper and nickle and manganese carbonate or sulphide type ores. In accordance with this invention, the geologic formation containing the ore is first penetrated by two or more, suitably spaced-apart openings, such for example bore holes extending from the earth's sur-

face to the bottom level of the deposit. There is then established a liquid-permeable "base" fractured zone interconnecting the lower ends of the bore holes within the ore body by means of a hydraulic-fracturing technique such as described in my U.S. Pat. No. 3,064,957; the base fracture being propped open by means of any suitable agent such as described for example in U.S. Pat. No. 2,645,291. An explosive material of liquid or slurry form is then flowed into the cavitated U-tube system comprising the bore holes and the "base" fractured zone, thereby replacing the hydraulic fracturing fluid by an explosive material of fluidized powder or liquid or slurry form. This operation is conducted under only substantially the earth's-surface-ambient atmospheric pressure conditions, thereby eliminating serious prior art hazards. The explosive is then detonated so as to fracture the overlying ore body according to the petro-fabrics of the ore deposit and/or the stress patterns of the mineral constituents thereof. The ore body is thereby rendered permeable, and a suitable solvent/reactive material (such as sulphuric acid in the case of the metal carbonates) for recovery of the desired value-containing salt solution is then caused to percolate through the permeabilized ore deposit. The invention also contemplates a specific geometry for the solvent/reactive flow pattern through the ore body, featuring a vertical migration and "floating" of the solvent/reactant on top of the more metal concentrated fraction of the product flow stream; thereby maintaining an optimum reactant-to-ore status progressively upwardly within the lateral confines of the ore body. If sulphide type ores are involved oxygen or air and water may be employed as an in-situ solvent/reactant.

8 Claims, 5 Drawing Figures

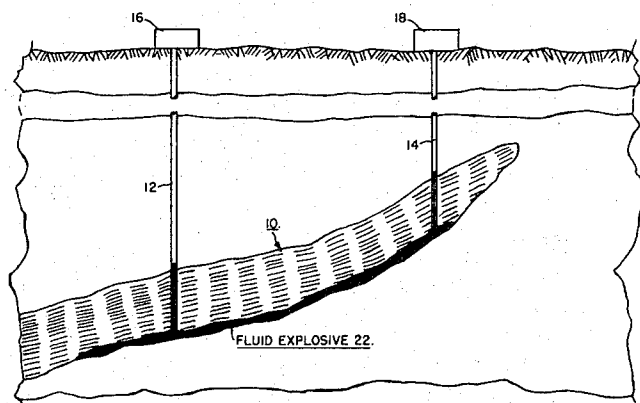


FIG. 1

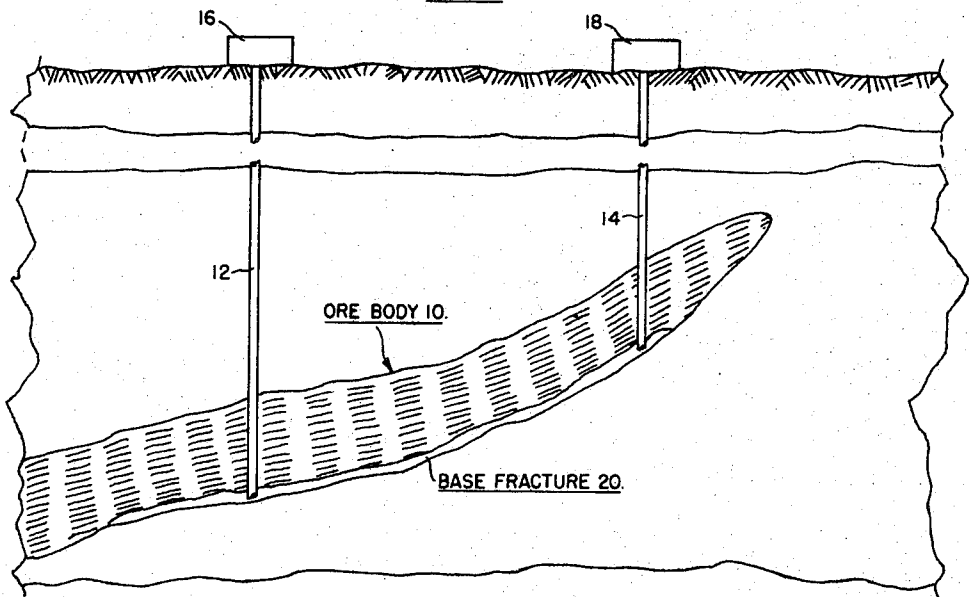


FIG. 2

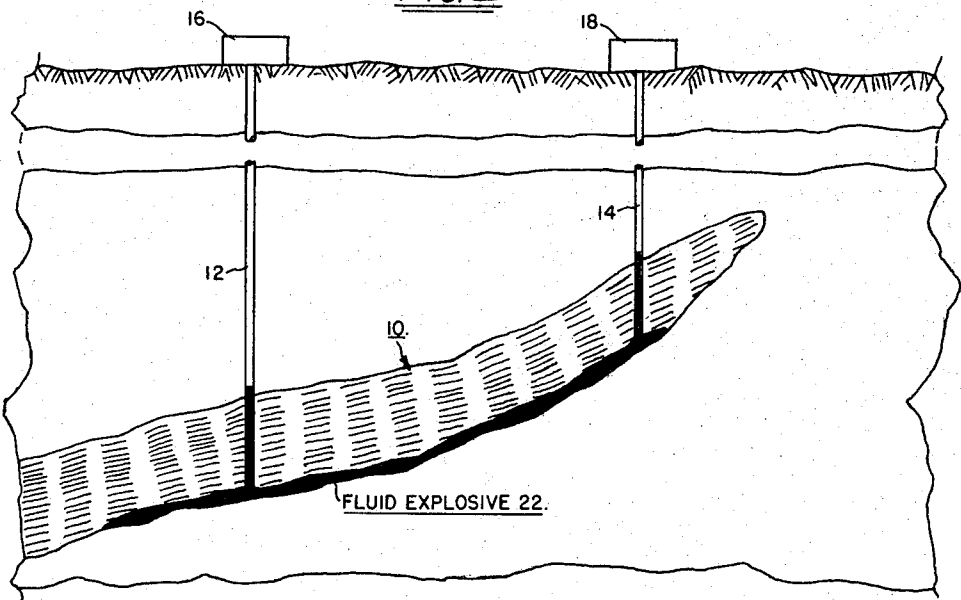


FIG. 3

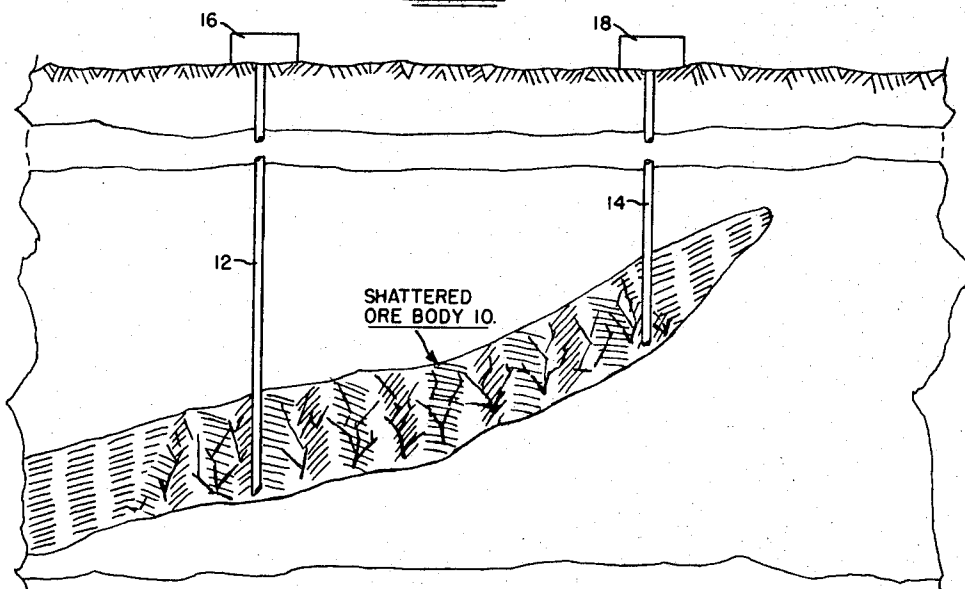


FIG. 4

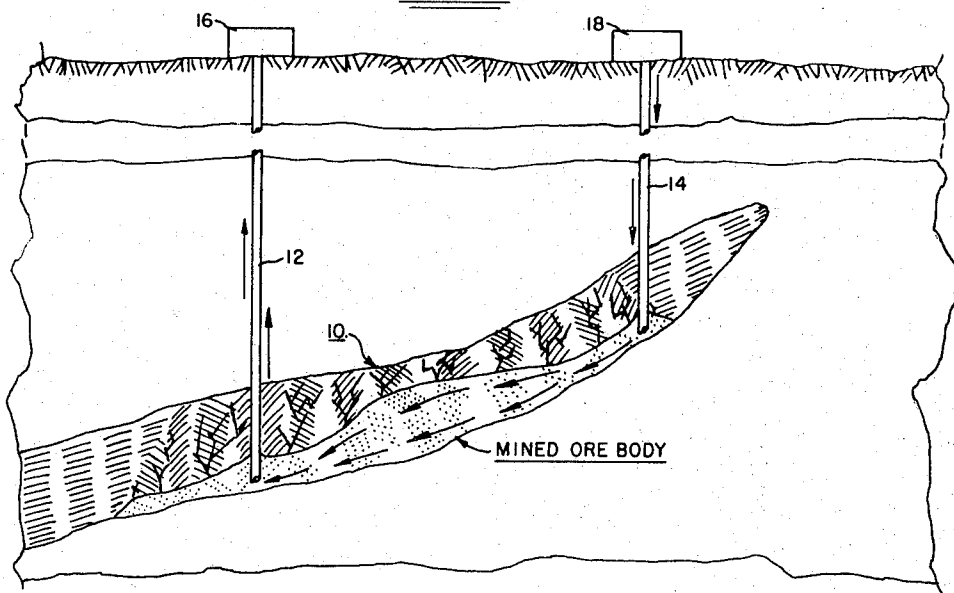
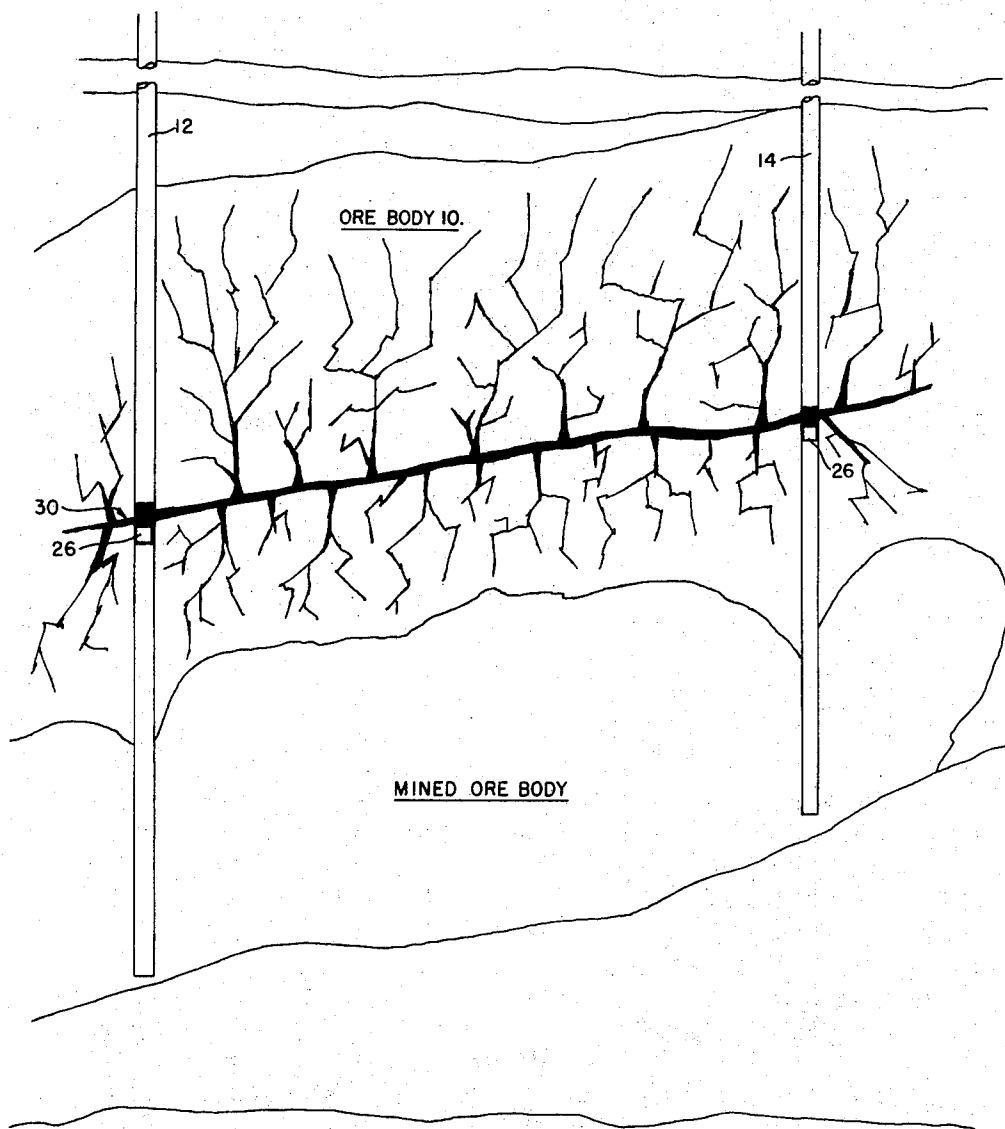


FIG. 5



IN-SITU EXTRACTION OF MINERAL VALUES FROM ORE DEPOSITS

BACKGROUND OF THE INVENTION

Economically successful methods for the in-situ mining (as by leaching) of ores have long been sought, as illustrated for example by way of U.S. Pat. No. 3,574,599; but such methods have proved to be economically and/or otherwise inadequate for various reasons. For example, previously proposed and employed methods for underground fracturing utilizing liquid explosives have necessitated supply and underground distribution of the liquid explosive under extremely high pressures (in order to overcome the hydrostatic pressures at depths below the earth's surface) thereby inherently rendering such operations highly hazardous, while at the same time being inefficient from the standpoint of optimum placement of the liquid explosives. Also, problems associated with solution-mining gallery maintenance have heretofore rendered such previously proposed methods economically impracticable; and it is an object of the present invention to provide an improved method and system whereby an ore can be reacted in-situ with a suitable solvent and/or reactant to produce a product solution of the sought-for mineral such as will flow continuously through a "production-well" to the earth's surface metal recovery plant, while leaving behind the residual insoluble gangue material. The invention also contemplates an improved solvent/reactant solution flow pattern through the ore body which is operatively maintained in accordance with specific parameters as disclosed hereinafter, and as illustrated by way of example in the accompanying drawing, wherein:

THE DRAWING

FIG. 1 is a symbolical illustration of vertical geological section type, illustrating a typical ore-bearing schist, gneiss, dike, sheet, lode, lens, sill or the like which is of limited or varying vertical thickness; and showing diagrammatically how the initial ore-body penetration and base fracturing-propping operations are performed;

FIG. 2 is a view corresponding to FIG. 1, illustrating how the base fractured zone of the ore-body is subsequently loaded with a liquid (or slurry) type explosive;

FIG. 3 illustrates how the ore deposit is then beneficially three-dimensionally fractured so as to accommodate a dissolution/reaction flowage system in accordance with the invention;

FIG. 4 illustrates how a leach/ion-reaction mining and value-recovering operation may then be carried on in accordance with the present invention; and

FIG. 5 is a view illustrating how the system of the invention is conducted when operating upon an ore-body of substantially greater vertical extent than as illustrated at FIGS. 1-4.

SPECIFICATION

It is well known that many copper ore deposits of value occur at such depths within the earth-surface's geology as to render their exploitation by typical mechanical mining methods to be not economically feasible; and it is a primary object of the present invention to provide a practicable system whereby such deposits may be economically recovered. As illustrated by the

drawing herein, the method of the present invention is applied to an inclined dike or other type copper or manganese or the like ore deposit such as is indicated generally at 10. Such deposits occur at various depths and distances underground, and are only economically mined by conventional mechanical mining methods whenever they occur relatively close to the earth's surface and when they contain relatively high-grade recoverable mineral values.

According to the present invention as illustrated by way of example by the drawing herewith, the mineral deposit 10 may be intersected by a pair of bore holes 12, 14, which extend substantially to the lower levels of the ore-bearing body and communicate at their upper ends with appropriate surface plant processing facilities as indicated at 16, 18. The bore holes are preferably "cased" (as is well known in the well drilling art) by means of casings fabricated of or lined with material which is non-reactive relative to the fluids to be handled. Thus, the bore holes 12, 14, provide means for ingress to the ore deposit; and preferably the bore hole 12 which intersects the deposit at a lower level than the bore hole 14 is used as the site to "base-fracture" the ore body as indicated at 20 (FIG. 1) thereby utilizing the "uplift" effect of the hydraulic operation to optimum advantage. The fracturing operation may be performed in accordance with any suitable hydraulic fracturing technique; and as previously mentioned it may be performed as disclosed for example in my U.S. Pat. No. 3,064,957. As shown therein, the result of such an operation provides a solution-permeable region designated 20 extending radially from the bottom of the bore hole 12 toward the bottom of the bore hole 14. In the case of a copper carbonate ore the fracturing operation is preferably performed by utilizing a dilute sulfuric acid solution containing in suspension a fracture "propping" agent such as sand, glass beads, or the like. Such propping devices are well known in the art; and a passageway between the lower ends of the bore holes for introduction of liquid or slurry type explosive is thereby established.

In event the "base" fracturing process referred to hereinabove does not operate to coalesce the two or more bore holes the situation may be remedied by repeated attempts to hydraulically re-fracture the zone between the bore holes, or by extending the propped cavity by means of a liquid or slurry type explosive. This may be done simply by pumping the explosive into the cavity under relatively low pressure such as is sufficient to displace the hydraulic "frac" liquid ahead of the explosive. By way of example, the fluid explosive may be fed into the system by a low pressure pump through the bore hole 12, supplemented if preferred by use of a suction pump operatively connected to the upper end of bore hole 14.

The explosive is then detonated, thereby propagating a "base" fracture toward the target well; but in event this operation still does not provide an open communication between the bottom ends of the wells the operations may be repeated as often as may be necessary (from the same well, or alternatively from either well) in order to complete an inter-connection between the lower ends of the wells. The system including the propped base-fractured zone may now be purged of the residual "frac" liquids and replaced by an explosive material of liquid or slurry form as shown at 22 (FIG. 2) simply by flowing it into the system under only sub-

stantially atmospheric pressure condition. This explosive is subsequently detonated so as to vertically fracture the valuable mineral containing ore body thereabove, as illustrated at FIG. 3.

The mining process is then conducted by passing a solvent or reactant liquid and/or gas through the system so as to extract the desired mineral values from the deposit. For example, as shown at FIG. 3 the ore-reactant fluid is preferably injected into the ore body through the bore hole 14 which terminates at a higher elevation than the other bore hole (s) of the system. The fluid initially percolates through the lower level of the ore body to the bottom of the lowermost bore hole 12 for withdrawal to the surface; the operation being readily controlled by means of a suction pump or the like located in conjunction with the bore hole 12, and/or a pressure pump located in conjunction with the bore hole 14 operating to inject the solvent into the system.

The chemical content of the ore-reactant solution will of course be prescribed and/or adjusted according to the nature of the mineral content of the ore body from which it is required to extract the sought-for mineral values. As the ore-reactant operation progresses the reacting solution forms progressively enlarging voids and/or passageways through the ore body; the leaching action operating to "honeycomb" the ore body of the mineral values therein.

Note that the invention contemplates circulation of the leach/reactant liquid (or gas) through the ore body commencing from the bottom of the bore hole which stands at the highest elevation of the group of bore holes involved; the product liquid (or gas) being withdrawn from the bottom of the deepest bore hole involved. By virtue of this system advantage is taken of the phenomenon that the mineral-laden liquid (or gas) will be of higher specific gravity than the fresh solvent/reactant and will automatically migrate down towards the bottom of the bore hole 12, while the fresh solvent/reactant fractions will float on top so that the leach/reaction process automatically progresses vertically from along the lower level of the mineral deposit upwardly therefrom and to the top level thereof. Otherwise stated the mineral-value-laden liquid (or gas) will automatically keep migrating toward the entrance to the product withdrawal bore hole, while the relatively fresh leach/reactant input is automatically disposed to percolate through progressively higher (still mineral-value laden) levels of the ore body.

Should the above described system operate to mine only the lower portion of the ore body (such as in the case of an ore deposit of substantial vertical extent as illustrated for example at FIG. 5 herein) the system may be repeated as many times as necessary to fracture and mine successively higher levels of the ore body. To this end the same bore holes may be employed after first mining the lower portion of the ore body by temporarily blocking off the lower end of the bore hole/casing system as shown at 26; perforating the system at a substantial elevation above the blocking 26; hydraulically fracturing a vertically intermediate portion of the ore body as indicated at 30; and then repeating the above described fluid explosive replacement and detonating operations so as to shatter and permeablize the vertically intermediate portion of the ore body.

Note that as illustrated at FIG. 5, herein, detonation of the fluid explosive occupying the fractured zone 30 will operate to fracture the ore body both downwardly

and upwardly therefrom; the downward fracturing effects being facilitated by reason of the previous honeycombing of the underlying portion of the ore body as explained hereinabove. Thus, it will be understood that in the case of an ore body of extreme vertical extent the above described progressive level fracturing and mining operations may be repeated until mining of the entire ore body is completed.

I claim:

1. The method for extracting metalliferous values from a laminar type impermeable metalliferous ore body comprising:

A. penetrating the ore body to provide two or more spaced apart clear openings extending from the earth's surface and terminating in portions of the ore body at different elevations;

B. fluid-pressure fracturing the ore body from the bottom end of the opening terminating at the lowest elevation upwardly to the bottom end of another of said openings in the laminar direction of the ore body to provide a permeable zone underlying a higher portion of the ore body of substantial vertical thickness, thereby establishing a substantially closed fluid circulation system including said openings and said permeable zone;

C. flowing a fluid type explosive under pressure less than the fracturing pressure into said circulation system so as to fill said permeable zone;

D. detonating said explosive so as to permeablize the ore body thereabove; and

E. then flowing a sought-for metalliferous solvent/reactant fluid through another of said openings downwardly and through said circulation system so as to percolate through the permeabilized portions of the ore body to produce a product fluid containing the sought-for metalliferous values from the opening terminating at the lowermost elevation.

2. A method as set forth in claim 1 wherein said openings into said ore body are provided by two or more horizontally spaced apart bore holes terminating at their bottom ends at different elevations.

3. A method as set forth in claim 2 wherein said base fracturing process is repeated as many times as may be necessary to coalesce the lower ends of at least two bore holes.

4. A method as set forth in claim 1 wherein said base fracturing process is performed by means of a hydraulic fracturing technique.

5. A method as set forth in claim 4 wherein said base fracturing process is conducted initially by means of a hydraulic fracturing technique, and is supplemented by an explosive fracturing technique.

6. A method as set forth in claim 1 wherein said fluid type explosive is flowed into said circulation system by means of a low pressure pump operating to deliver explosive through the opening hole terminating at the lowest level.

7. A method as set forth in claim 6 wherein a suction pump is operably connected to another one of the openings to supplement flowage of fluid explosive into said system.

8. The method for extracting metalliferous values from a laminar type impermeable metalliferous ore body comprising:

A. penetrating the ore body to provide two or more spaced apart clear openings extending from the

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earth's surface and terminating in lower portions of the ore body at different elevations;

- B. fluid-pressure fracturing the ore body from the bottom end of the opening terminating at the low-
ermost elevation upwardly to the bottom end of another of said openings in the laminar direction of the ore body to provide a permeable zone underlying a higher portion of the ore body of substantial vertical thickness, thereby establishing a substantially closed fluid circulation system including said openings and said permeable zone; 10
- C. flowing a fluid type explosive under pressure less

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than the fracturing pressure into said circulation system so as to fill said permeable zone;

- D. detonating said explosive so as to permeabilize the ore body thereabove; and
- E. then flowing a sought-for metalliferous solvent-/reactant fluid through one of said openings, upwardly and through said circulation system so as to percolate through the permeabilized portions of the ore body to produce a product fluid containing the sought-for metalliferous values from an opening terminating at a higher elevation.

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