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Lampard

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[54] **CONTROLLED IN SITU LEACHING OF ORE DEPOSITS UTILIZING PRE-SPLIT BLASTING**

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[52] **U.S. Cl.** **299/4,** 102/23, 166/299

[51] **Int. Cl.** **E21b 43/28**

[58] **Field of Search** ..... 102/21, 22, 23, 24 R; 166/299; 299/4, 5, 13

[56] **References Cited**

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[57] **ABSTRACT**

In-situ leaching of various underground minerals, especially ores of base metals, such as copper, is controlled by pre-split blasting to create fracture planes wholly or partially surrounding a block of ore to be leached, and often within such block as well. The fracture planes are employed as part of an injection and recovery system for a leaching solution and as a barrier to prevent loss of such solution to surrounding areas.

10 Claims, 4 Drawing Figures

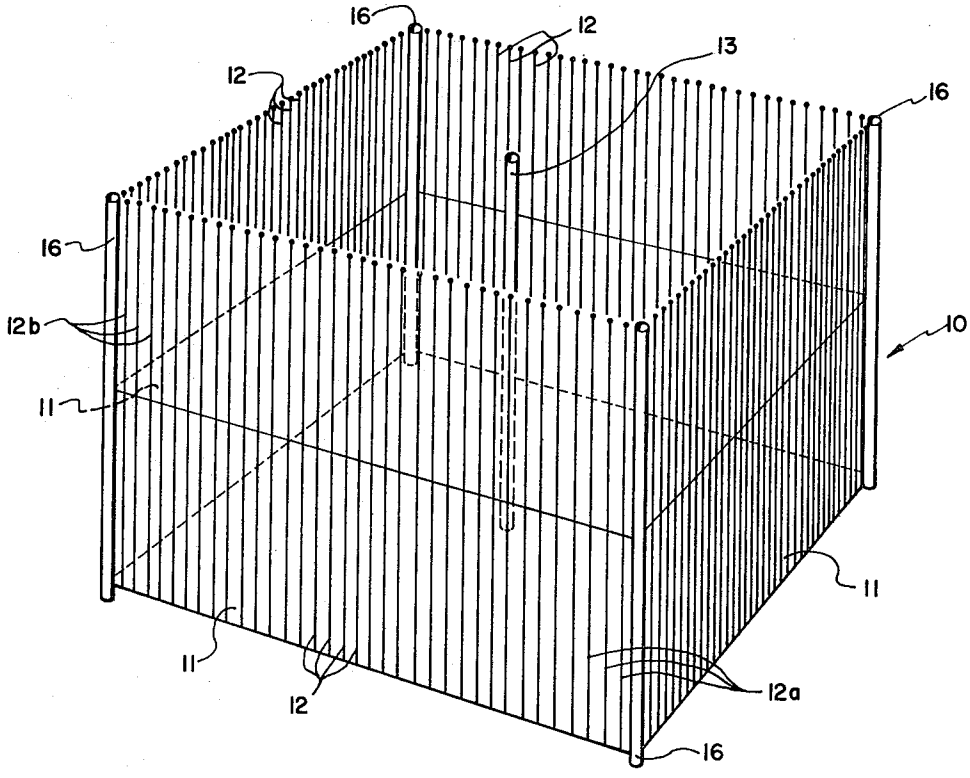


FIG. 1

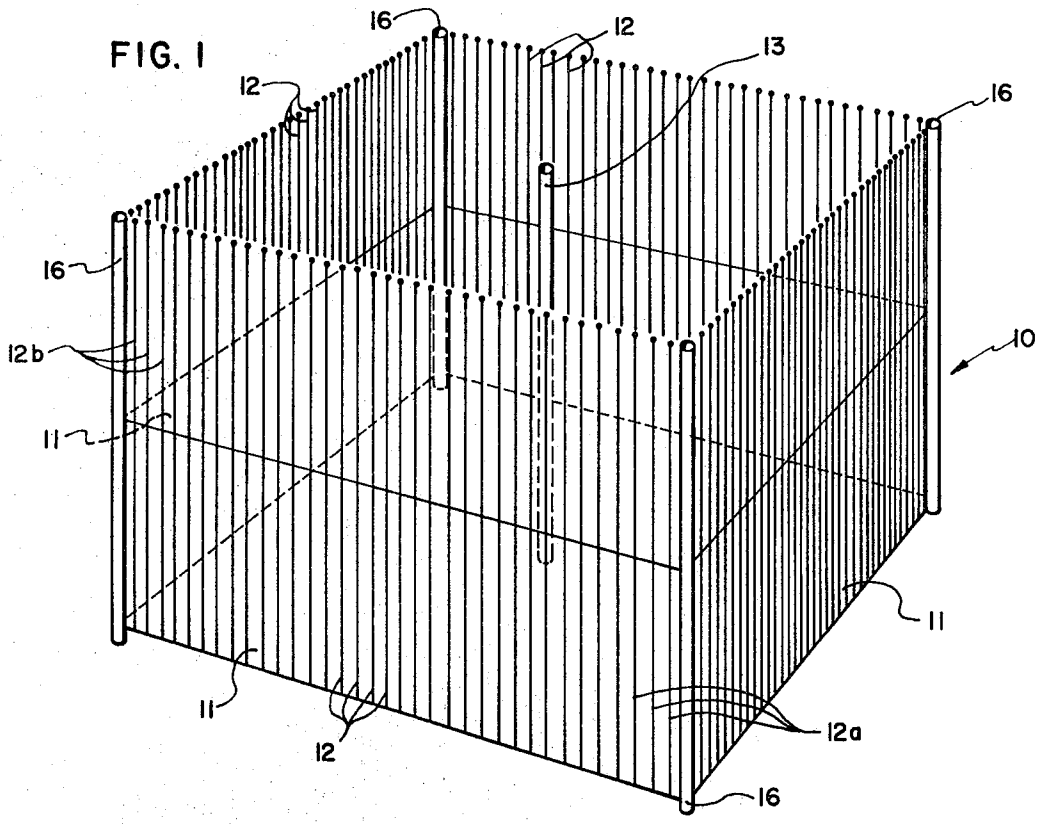


FIG. 2

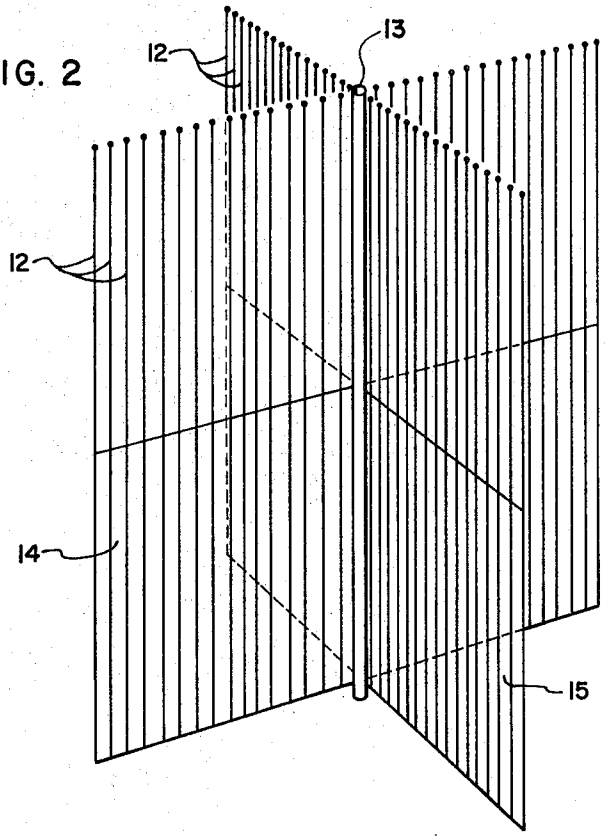


FIG. 3

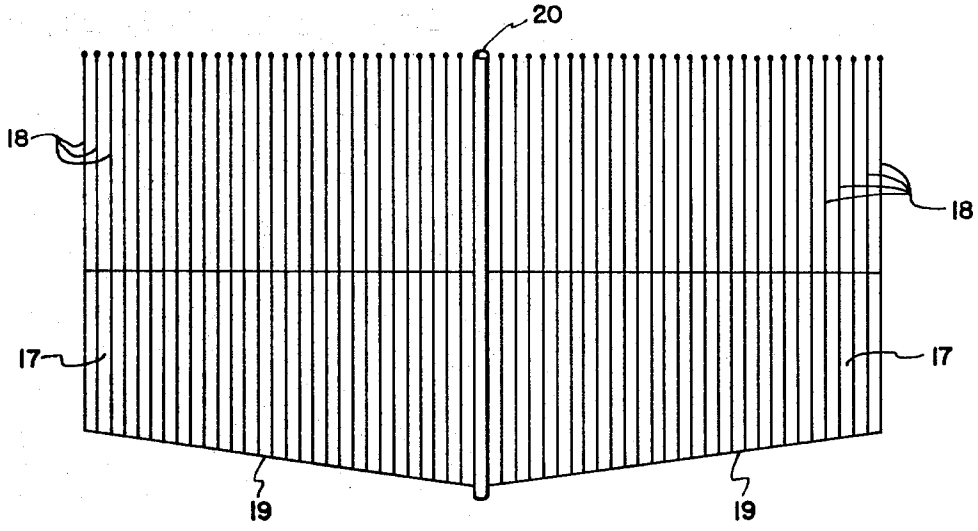
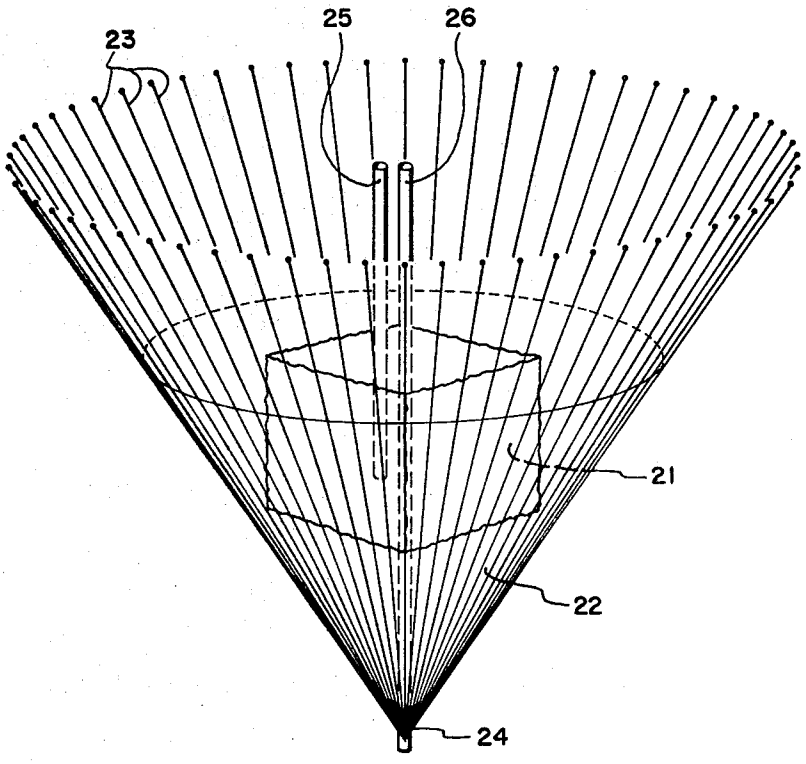


FIG. 4



CONTROLLED IN SITU LEACHING OF ORE DEPOSITS UTILIZING PRE-SPLIT BLASTING

BACKGROUND OF THE INVENTION

1. Field:

The invention is in the field of in-situ extraction of mineral values by injection of a leach solution into an underground deposit of such mineral values and by recovery of the resulting pregnant solution.

2. State of the Art:

Although it is customary to recover such readily soluble salts as sodium, potassium, and uranium from underground deposits of same by so-called "solution mining" techniques, ores of base metals, such as copper, are ordinarily bodily removed from the ground by either underground or open pit mining methods and subjected to treatment thereafter for extracting the metal values therefrom.

In order to avoid the necessity of removing ore from its natural location and of transporting it, treatment of the ore in place by leaching for the extraction therefrom of only its contained values has been proposed heretofore, see U.S. Pat. Nos. 2,919,909 and 2,952,449. However, problems not normally present in solution mining as heretofore carried out are encountered, primarily difficultly of controlling flow into, retention within, and recovery of the leach solution.

Since base metal ore minerals are usually sparsely disseminated through bodies of largely non-porous rock materials, proper distribution of an injected leach solution within the ore deposit and prevention of loss thereof through natural flow channels extending beyond the area being worked and outside the effective recovery zone, become of considerable importance.

Pre-split blasting has been developed in the mining and construction industries in order to produce a relatively smooth surface for rock remaining in place after the blasting, with minimum damage to such rock, thereby maximizing roof control, overbreak prevention, and safety. For this purpose, it is customary to drill a single line of holes along a border of the required excavation, and to lightly load and blast the holes before the adjoining main blast. Such an operation is based on the theory that, when two charges are shot simultaneously in adjoining holes, collision of the shock waves between the holes places the intervening rock in tension and causes fracturing along a zone of shear between the holes.

With proper spacing and charge (depending upon rock strength and structure) and with a line of holes in simultaneous detonation, the fracture zone between the holes can be made a narrow shear plane for producing a relatively smooth wall upon excavation. Such a technique has been used heretofore in the construction of land cuts, canals, tunnels, underground chambers, and in some aspects of underground mining.

Objectives: Principal puposes in the making of the present invention were to enable various underground minerals, especially the ores of base metals, to be effectively and efficiently mined in situ by means of suitable leach solutions; to effectively accomplish penetration of a leach solution throughout a body of mineral in a predetermined space or block; to largely confine the leach solution to such space or block; to recover the pregnant leach solution from such space or block with minimum loss to surrounding areas; and to lessen the possibility of pollution to the ground water of the district.

SUMMARY OF THE DISCLOSURE

In accordance with the invention, so-called "pre-split" blasting techniques are employed to create fracture planes as barriers for preventing loss of a leach solution injected into a mineral deposit and for providing solution distribution channels. Such fracture planes may and preferably are utilized both as solution-injection and solution-recovery zones, and advantageously partially or wholly surround an underground mineralized area to be leached. Such area may be substantially commensurate with a mineral deposit in instances where the deposit is relatively small, or may be restricted to any conveniently workable portion of the deposit, and may be of any shape dictated by the geological formation and slopes involved. Where so restricted, the entire deposit will usually be blocked out and worked in manageable, side-by-side sections. It is desirable that the pre-split blasting also be carried out internally of the area, partially but not entirely across the same, e.g., across the area in opposite directions so as to intersect centrally thereof.

The leach solution is advantageously injected through one or more wells drilled within the fracture plane or planes, thereby enabling such solution to permeate and pass through the entire body of ore blocked out for leaching and enabling the resulting pregnant solution to be recovered through other wells similarly drilled with respect to the boundary fracture planes. To keep costs down, the number of wells is minimized consistent with optimum injection and maximum recovery of the solution. The pre-split fracture planes are usually arranged to intersect as many natural fractures as possible, so as to obtain maximum distribution of the leach solution at minimum expense.

In the pre-split blasting, a blasting design is employed which establishes the upper line of the shear zone sufficiently below the surface that the collars of most of the blasting drill holes can be plugged, with only a few appropriately spaced holes left open for injection or recovery of the leach solution.

Instead of injection and recovery wells, either existing or specially driven mine openings can be employed to intersect the fracture planes produced by the pre-split blasting; or the pre-split blasting can originate wholly or partially from mine openings. Thus, mine drifts may be driven along the lower edges of fracture planes, with the gradient being such as to ensure gravity flow out of the entry adit, or drilling for pre-split blasting may be done upwardly from a mine drift to meet similar drilling from the surface downwardly.

The rate of injection of solvent via a well or mine opening into a body of non-porous rock material depends partly on the pressure applied but mostly on the number of natural fractures and pores intersected by such well or mine opening. The greater the surface area of the injection system, the faster the solvent can be forced into the rock material. Any injection system utilizing solely wells or mine openings will have a relatively small surface area, but, with one or more pre-split fracture planes cutting across the rock body as a distribution channel or channels, a relatively large number of natural fractures and pores are intersected and a much more effective flooding of the rock body can be achieved.

The injection plane can be one of the boundary planes or a special plane of any appropriate configuration situated more ore less centrally within the area to be leached. If a block of ore, for example, can be surrounded wholly or in part by boundary fracture planes intersecting open fractures, leach solution flowing more less radially away from an injection plane or points within the block will meet the pre-split boundary planes, and, finding less resistance, will flow within such planes rather than across them to escape into surrounding areas.

Studies of natural fracture intensity, orientation, and size, and of other factors contributing to a "flow net", will determine the need for and positioning of pre-split boundary planes in any given situation. Thus, a cut-off plane would not be required across a direction of low flow in an anisotropic environment, but would be required across a direction of high flow. In an isotropic environment of more or less equal flow in all directions, an entire block might have to be surrounded by pre-split planes to prevent excessive escape of solution.

Once the solution has been captured by a pre-split plane, it will flow in the direction of least resistance, i.e., toward the nearest recovery well or mine opening within the plane. Locations of recovery wells and/or mine openings will be dependent upon the geometry of the pre-split fracture planes. Wells can be located at the ends of such planes, at intersections of two or more planes, at the center of a plane, etc. The fracture planes can be pre-split so the lower lines thereof slope toward a well or wells, upwardly or downwardly depending upon whether the well is an injection or recovery well.

In the case of a recovery well, it is advantageous that it be drilled after the pre-split fracture plane is blasted, so as to use a pre-split hole as a pilot to ensure that the well follows the already established shear plane. Underground mine openings are advantageously driven prior to the pre-split blast, so as to gain the advantage of extra knowledge of rock characteristics, the opportunity to drill part of the holes for the pre-split fracture plane from underground, and the ability to drain water from any wet drill holes intercepted. Such mine openings will not be destroyed by the blast if the blasting is done in sections of, say, twenty holes at a time.

Contrary to normal uses of pre-split blasting techniques, there is no need to establish a smooth boundary fracture plane for in-situ leaching, and damage to the surrounding rock will generally be beneficial rather than the reverse. Thus, accepting some deviation and including the possibility of greater explosive loadings, pre-split depths to the order of 300 feet to 500 feet are possible in many instances, and greater depth may be feasible.

Though drilling for the establishment of vertical pre-split fracture planes is easiest, there may well be distinct advantages in using inclined pre-split planes in certain circumstances in order to meet design criteria imposed by geologic conditions. Thus, for example, for small orebodies it is possible to drill the holes for the fracture plane in the form of a cone, with the point down, such that all leach solution will be collected at a central point or ring, requiring a minimum number of recovery wells.

For a large orebody, where more than one block of ore is to be leached in situ, double use of many of the pre-split planes can be made by laying out the system in a rectangular or polygonal grid. This will provide substantial cost savings in both the pre-splitting and the provision of injection and recovery wells or mine openings.

THE DRAWINGS

The best mode presently contemplated of carrying out the invention in practice is typified by the preferred embodiments illustrated in the accompanying drawings, in which:

FIG. **1** is a schematic isometric view of a typical layout of bore holes utilized for pre-split blasting to split off a block of ore from an underground deposit in preparation for in situ leaching, and of wells adapted for the injection and recovery of a leach solution;

FIG. **2**, a similar view of pre-split blasting bore holes and of an injection well, such as might be employed in the layout of FIG. **1** to facilitate diffusion of injected leach solution throughout the pre-split isolated block of ore, or in conjunction with appropriately located recovery wells;

FIG. **3**, a similar schematic elevational view of a single line of pre-split blasting bore holes and of a recovery well showing an arrangement useful, with or without underlying intersected mine drifts or other openings, to facilitate collection of injected leach solution at the intake end of the recovery well; and

FIG. **4**, a view similar to that of FIG. **1**, but illustrating a layout of pre-split blasting bore holes and injection and recovery wells arranged for maximum effectiveness with respect to a small ore body to be leached.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

The invention may be applied in various ways depending upon the nature and topography of the underground area containing the mineral values to be recovered.

As illustrated in FIG. **1**, a block of ore **10** is split from the remainder of a large ore deposit by the establishment of rectangular pre-split fracture planes **11** peripherally defining the block as the lateral boundaries thereof.

Such fracture planes **11** are established by utilizing the ordinary pre-split blasting technique of driving a series of pre-split blasting bore holes **12** along a line at the surface corresponding to the desired line of split, by inserting a suitable explosive in the lower portion **12*a*** of each bore hole **12** to a height substantially corresponding with the desired height of the block of ore to be split off from the remainder of the ore deposit, and by detonating such explosive. This leaves the upper portions **12*b*** of the bore holes substantially intact.

The bore holes **12** are usually quite closely spaced, e.g., from three to five feet apart depending upon the character of the underground ore material.

Having established the several pre-split planes **11** defining and, in effect, isolating the block of ore **10**, and having capped the several pre-split blasting bore holes **12** in any suitable manner, as by plugging (not shown) their collared upper ends, a leach solution is injected into the block intermediate its height and breadth through a suitably placed injection well **13**, which may be drilled and cased before or after the pre-split blasting, depending upon circumstances.

If the block of ore is sufficiently pervious to the flow of the leach solution therethrough, no aid to diffusion of such solution through the ore material need be pro-

vided. If not, suitable corrective measure may be employed, which might well be the establishment of a cruciform pre-split layout, as shown in FIG. **2**, the injection well **13** being located at the intersection of the crossed pre-split fracture planes **14** and **15**. Various other configurations of pre-split fracture planes may be similarly employed in order to facilitate flow of the leach solution throughout the block of ore. In all instances, however, such intermediately located pre-split fracture planes should terminate short of the boundary pre-split fracture planes, so the leach solution will not short circuit around, rather than through, the block.

In order to effectively recover the pregnant solution in the layout of FIG. **1** following its extraction of values to be recovered, recovery wells **16** are provided at strategic locations along the pre-split boundary fracture planes **11**. As illustrated, such recovery wells are located at the four corners of the rectangular area blocked out by such boundary fracture planes. If the cruciform pre-split layout of FIG. **2** or corresponding pre-split layout is used alone as a solution injection pattern, and is not used in combination with the layout or one similar to that of FIG. **1**, recovery wells are strategically located around such first-mentioned, solution injection layout. This, of course, would not have the advantages of confinement within a given blocked out zone, but might well prove useful in special situations.

A pre-split solution-recovery layout is shown in FIG. **3** to exemplify many situations in which it is desirable to facilitate recovery of the pregnant solution by running it to a common collection point. As illustrated, pre-split fracture planes **17** are provided in the usual manner by driving a series of pre-split blasting bore holes **18** and by blasting as previously indicated and as is well understood by those skilled in the art. In this instance, such holes **18** will terminate along downwardly sloping lines **19** leading to and converging on the intake end of a recovery well **20** driven at the midpoint of the single line layout of blasting bore holes **18**. Other configurations could, of course, be used. Thus, the recovery well **20** could be located at either end of a single slope, rather than at the convergence of a plurality of slopes; and it should be borne in mind that such a recovery layout can be used for any one or more of several fracture plane layouts, rectilinear as shown or curved, making up an overall block or other three-dimensional type of layout, as in FIG. **1**.

A useful layout for relatively small ore deposits is shown in FIG. **4**, wherein such an ore deposit **21** is enclosed by a conical fracture zone **22** made up of the usual blasting bore holes **23** driven around a circle at the surface and sloping downwardly to convergence at a common collection point **24** constituting the apex of the cone. An injection well **25** is driven near the center of the circle of blasting bore hole collars at the surface down to an appropriate location immediately above or in the ore body **21**, e.g., to a point intermediate the depth of such ore body as shown, and a recovery well **26** is driven nearby, preferably right at the center of the circle so as to terminate at or somewhat below the apex **24** of the cone.

This layout of FIG. **4** can be employed for large orebodies as well as small, as, for example, in place of the layout of FIG. **1**, although it should be realized that the latter is better suited to sectional operation in which blocks of ore to be leached are laid out side-by-side for individual leaching.

Whereas this invention is illustrated and described with specific reference to embodiments representing the best mode presently contemplated of putting it into practice, various other embodiments are possible within the inventive concepts here disclosed and claimed.

I claim:

1. A method of in-situ leaching of mineral deposits, comprising driving a series of pre-split blasting bore holes into or near an underground area to be leached for the recovery of mineral values therefrom; blasting a pre-split fracture along said series of bore holes to provide a barrier to fluid flow; injecting a leach solution into or near said area for diffusion through said area, said barrier limiting flow of said fluid; and recovering pregnant leach solution from parts of said area into which said pre-split fracture has directed the flow of solution.

2. A method according to claim **1**, wherein the leach solution is injected substantially into the pre-split fracture for distribution throughout the area.

3. A method according to claim **1**, wherein the pregnant leach solution is passed into and through the pre-split fracture to a location of recovery.

4. A method according to claim **3**, wherein the recovery is effected by driving a recovery well into the location of recovery.

5. A method according to claim **1**, wherein the pre-split fracture surrounds the underground area laterally and blocks off said area from surrounding areas.

6. A method according to claim **5**, wherein the area blocked off is of rectangular configuration.

7. A method according to claim **5**, wherein the area blocked off is of conical configuration having its apex directed downwardly.

8. A method according to claim **7**, wherein a recovery well is driven into the apex of the cone, and recovery of the pregnant leach solution is effected through said recovery well.

9. A method according to claim **1**, wherein the pre-split fracture is of substantially cruciform configuration, an injection well is driven at and along the cruciform intersection, and the leach solution is injected through said injection well.

10. A method according to claim **1**, wherein the bottom of the fracture slopes toward a location of recovery of the pregnant leach solution.

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