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Janssen

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[54] METHOD OF BLASTING A
SUBTERRANEAN DEPOSIT

[75] Inventor: Albert T. Janssen, Englewood, Colo.

[73] Assignee: Atlantic Richfield Company, Los
Angeles, Calif.

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[51] Int. Cl.² E21C 41/10

[58] Field of Search 299/2, 13, 19, 11

[56] References Cited

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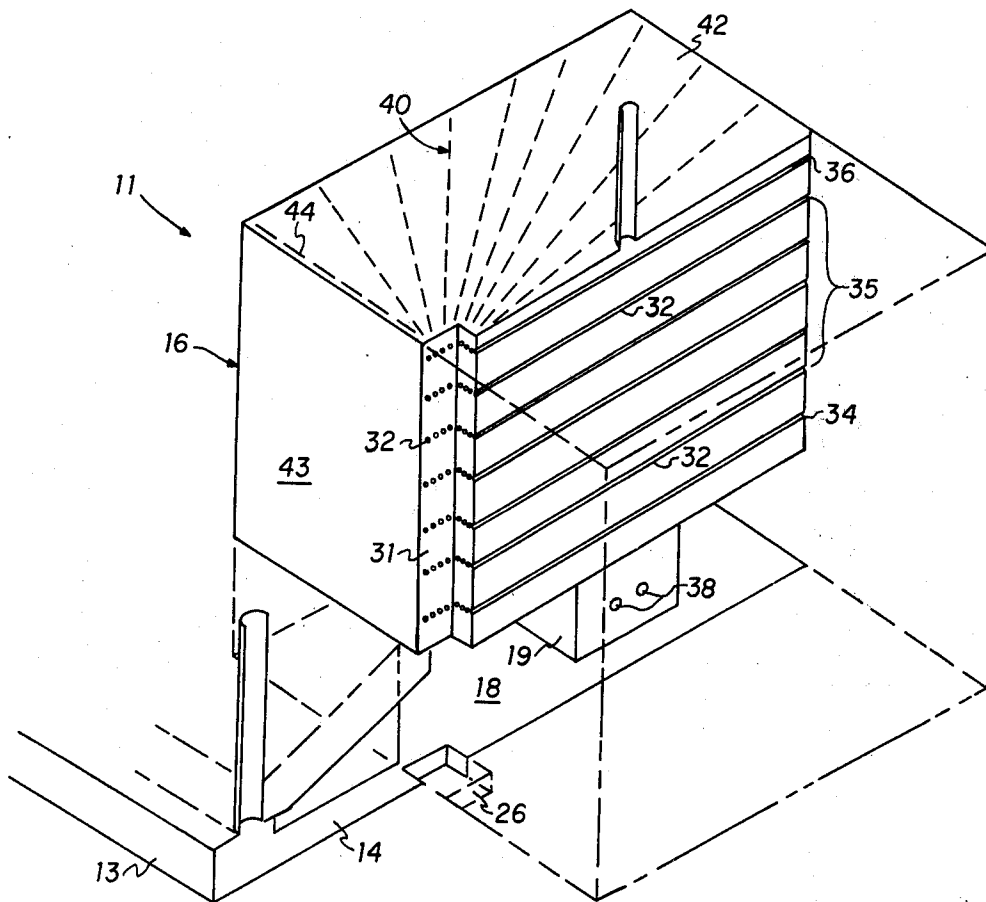
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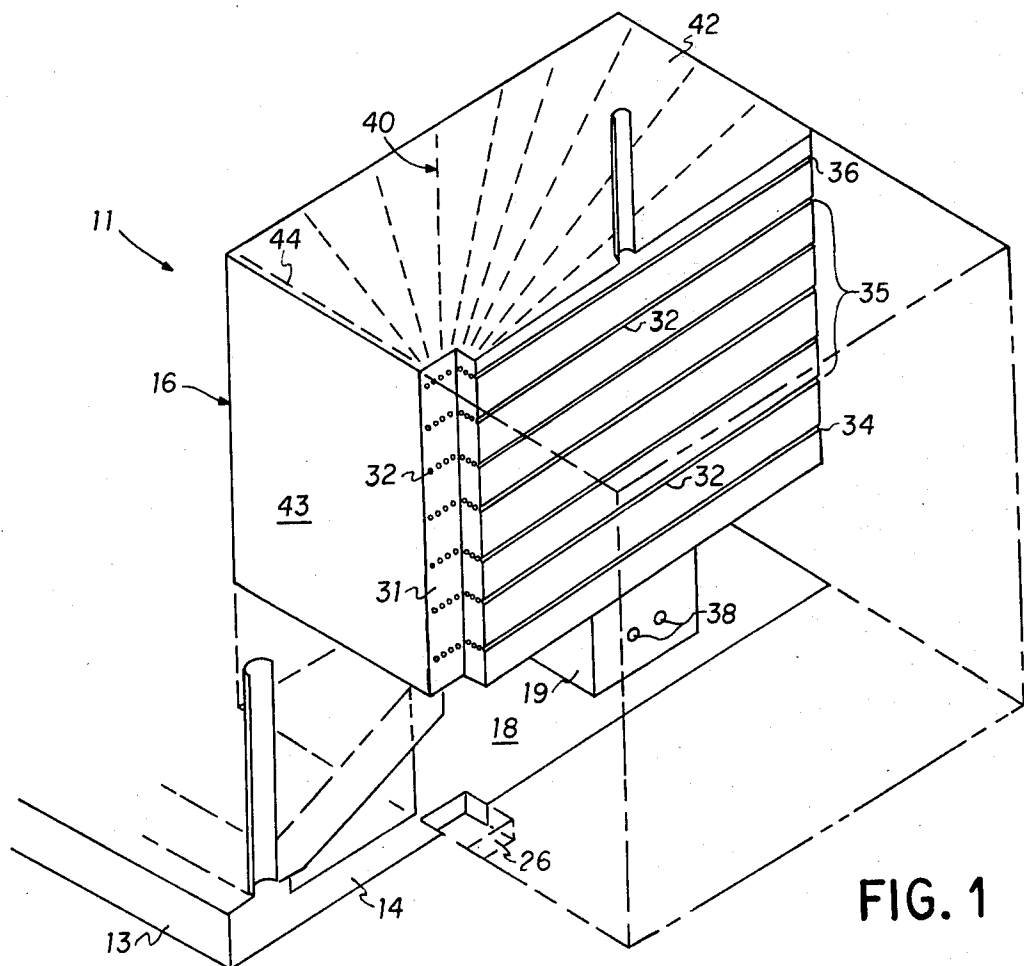
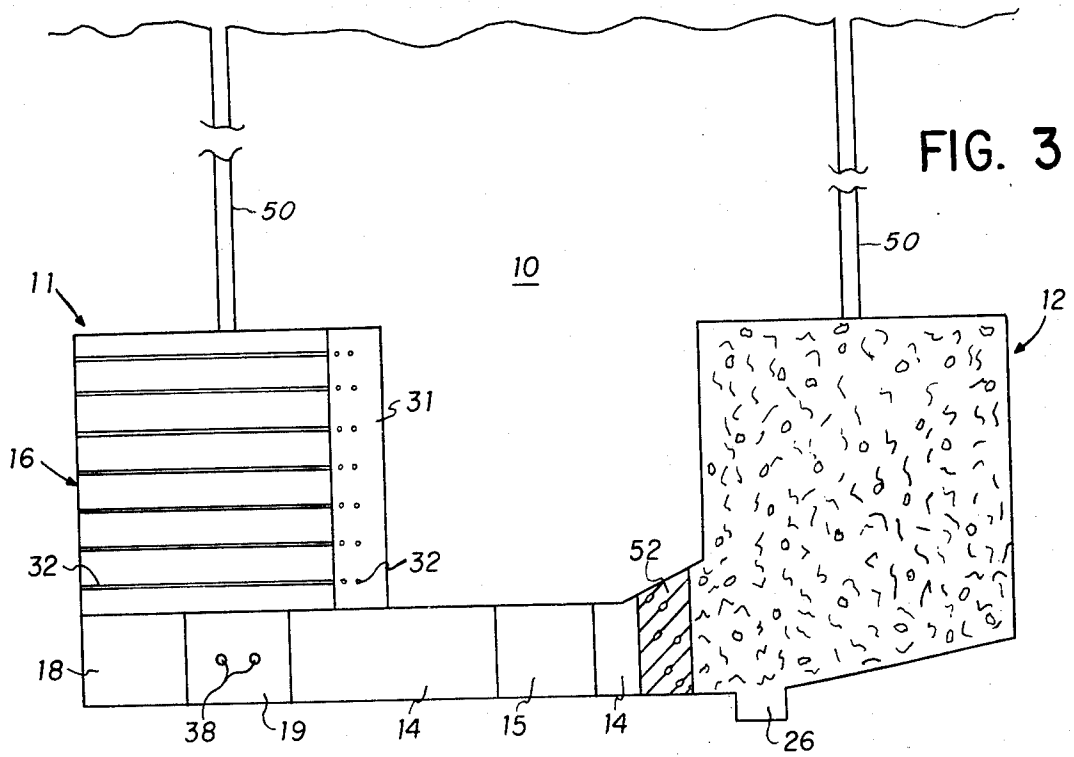
Primary Examiner—Ernest R. Purser
Attorney, Agent, or Firm—Robert M. Betz

[57] ABSTRACT

A raise is driven upwardly into a designated block of a subterranean mineral deposit from the roof of an undercutting cavity. A plurality of blasting holes are driven substantially horizontally into the block from the raise in a fan-shaped pattern at each of a plurality of vertically spaced levels and at least partially loaded with explosives. The charges are detonated sequentially in an upward progression to effect fragmentation and expansion of the overlying block into the undercutting cavity.

11 Claims, 3 Drawing Figures





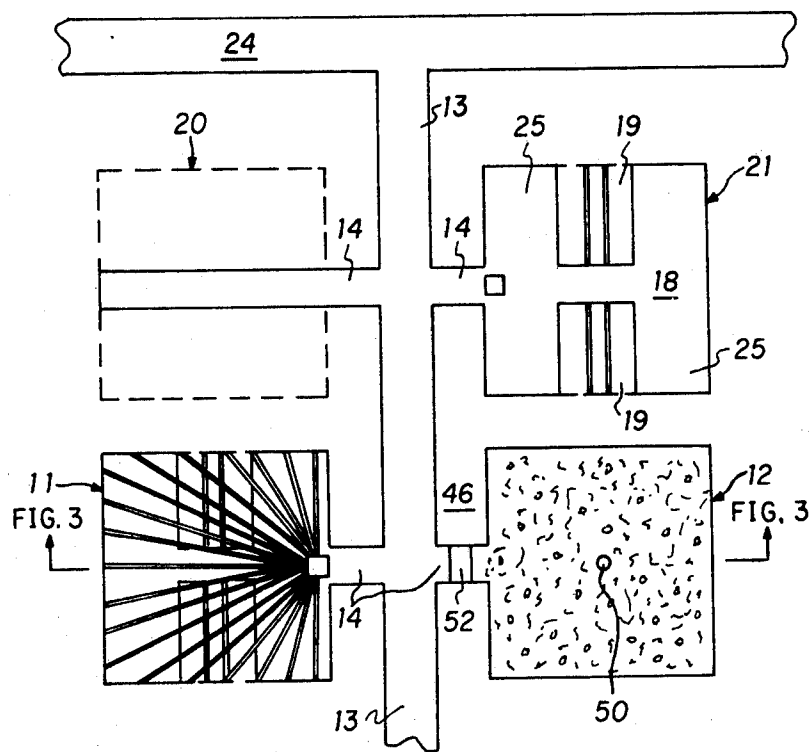


FIG. 2

METHOD OF BLASTING A SUBTERRANEAN DEPOSIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to mining operations and more particularly to the blasting of subterranean mineral deposits in carrying out such operations.

2. Prior Art

In accordance with a well-known prior art mining method, a permeable subterranean zone within a mineral deposit, such as oil shale, may be developed by undercutting the deposit and thereafter expanding a block of overlying material, such as by explosive fragmentation, so that it forms a permeable porous mass filling the void volume beneath.

An example of the application of this technique is found in U.S. Pat. No. 3,661,423 which describes an underground formation undercut by a cavity mined out by the room and pillar method. The pillars are explosively broken, and thereafter explosive charges in the overlayer are sequentially detonated from the bottom up so that the overlayer fragments and expands into the undercutting void. Although the method of this patent requires placement of explosive charges in the overlayer, it does not disclose from what vantage point the blasting holes are to be drilled nor does it indicate how such holes are to be oriented. However, when explosive fragmentation is employed in the preparation of a permeable zone in an underground ore deposit, it is essential that a method of blasting hole placement be devised which minimizes the working space required and which is of maximum effectiveness.

In a mining layout of multiple adjacent permeable zones, it is also desirable that this step should involve minimum interference between adjacent zones in progressive stages of development, such as in preparation for an in situ oil shale retorting operation.

SUMMARY OF THE INVENTION

It is, therefore, a general object of this invention to devise a blasting method for use in the subterranean mining of an ore deposit.

It is a further object of this invention to devise an improved blasting method for use in the mining of a subterranean oil shale deposit.

It is a more specific object of this invention to devise an improved method for the placement of blasting holes in the development of adjacent permeable zones in a subterranean ore deposit.

In accordance with a preferred embodiment of this invention, an access entry is driven at a level beneath the top of an underground ore deposit. From this access entry a tunnel is driven transversely along a horizontal or slightly elevated path into and terminating within the ore deposit. A portion of the tunnel spaced from the access entry is further enlarged to form a cavity of predetermined areal extent undercutting the deposit. A raise is driven upwardly from the roof of the cavity into a designated block within the overlying deposit. From this raise, blasting holes are driven substantially horizontally in a fan-shaped pattern at each of a plurality of vertically spaced levels so that these holes extend adjacent the boundaries of the designated block. Explosive charges are distributed within the blasting holes so as to achieve a desired powder ratio and fragmentation. After removal of the ribs, these

charges are progressively detonated in upward sequence so that the designated block of overlying deposit fragments and expands to occupy the void volume of the undercutting cavity and the raise.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view, partly broken away, of a zone in an underground deposit being developed in accordance with this invention.

FIG. 2 is an illustration showing zones within an underground deposit in various stages of development in accordance with the method of this invention.

FIG. 3 is a sectional view taken along the line 3—3 in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 3 of the drawings, there is illustrated, within an ore deposit 10, such as oil shale, a subterranean zone 11 in progress of development in accordance with the method of this invention and a similar zone 12 fully developed in accordance therewith. The zones 11 and 12 are interconnected with an access entry 12 extending horizontally at a level below the top of the ore deposit by means of transverse zone entries 14. Internally the zone 11 at this stage comprises a block 16 of ore overlying a void or cavity 18 into which one or more supporting ribs 19 project. In zone 11, a similar overlying block has been fragmented and expanded.

In order to better understand the details of an operation whereby the zone 10 may be undercut and excavated, attention is directed to FIG. 2. Here a portion of a mining layout is shown in plan including in addition to the zones 11 and 12, zones 20 and 21, at earlier stages of development, as more particularly described in co-pending application Ser. No. 499696. The access entry 13 communicates with at least one main entry 24 which in turn leads through a vertical shaft (not shown) to an upper mining level or to the surface of the earth. Each of the zones 11, 12, 20, and 21 is interconnected with the access entry 12 by means of one of the transverse tunnels 14.

Initially, a zone entry 14 may be driven from the access entry 12 along a horizontal or slightly elevated path for a predetermined distance into the base of the deposit until a boundary of one of the designated zones, for example, zone 20, is reached. Since it is contemplated that men will be working throughout the tunnel 14, it may be desirable to provide roof bolting along its length. However, the remainder of the deposit undercutting cavity 18 which is mined out from the zone entry 14, may be conveniently formed without the entry of mine personnel.

In order to prepare an undercutting cavity 18 of desired areal extent, a plurality of spaced apart crosscuts 25 are driven into the deposit from the sidewalls of the tunnel 14 in opposite directions approximately at right angles thereto as illustrated in the view of zone 21 in FIG. 2. Adjacent crosscuts 25 on either side of the tunnel 14 are separated by one of the aforementioned ribs 19. The crosscuts 25 terminate within the ore body, also at boundaries of the designated zone 21. The crosscuts 25 may be made short enough so that they can conveniently be mined and excavated with the use of gathering arm loaders or other equipment which is advanced within crosscuts 25 without the entry therein of personnel. Thus, the need for roof bolting and scal-

ing within the crosscuts 25 is obviated. The spacing between the crosscuts 25 and the number of such crosscuts 25 is optional. If the total area of the cavity 18 is sufficiently small, the ribs 19 formed between adjacent crosscuts 25 may be eliminated altogether. However, preferentially the spacing should be such that the separating ribs 19 are wider than they are high for maximum stability, as such ribs 19 partially support the overlaying block 16. The fact that the ribs 19 are integral with the sidewalls of the undercutting cavity 18 into which they project enhances their strength.

The undercutting cavity 18 which is formed in the manner described above is areally coextensive with the zone to be prepared such as, for example, zone 11, less the crosssectional area of the supporting ribs 19 which will be removed prior to expansion of the overlaying of the deposit 16. The height of the cavity 18 should be selected, in accordance with well known principles, unnecessary to detail here, so that its void volume is sufficient to permit a desired degree of expansion of the block 16 and, if necessary, to avoid substantial subsidence of the overburden. With further reference to FIG. 3, if the floor of a developed zone such as zone 12 is to be slanted or funneled to a liquid gathering sump 26, as, for example, in collecting liquid shale oil, the path of its zone entry 14 and/or associated crosscuts 25 may be deviated appropriately from the horizontal. Also, within the scope of this invention, the cross-sectional area of the cavity 18 may be modified so that it assumes a circular or other desired shape.

The blasting method of this invention will now be described in detail with further reference to FIGS. 1 and 2. From the roof of the cavity 18 at the point of its juncture with the tunnel 14, a raise 31 is driven upwardly to a point adjacent the top level of the overlaying block 16. The raise 31 may be driven from a so-called raise drilling platform which supports an operator. Such an operator will be conveniently positioned at various levels to drill horizontal blasting holes to be described. The raise 31 may also be driven by means of a so-called raise driver which is a form of self-propelled earth boring machine. Such machines are described, for example, in U.S. Pat. No. 3,399,738; and their construction and operation form no part of this invention. The common practice is to first drill a pilot hole through the earth's formation between the two points to be connected by a raise, after which the pilot hole is reamed out to the desired diameter of the finished raise.

A plurality of blasting holes 32 are drilled from the raise 31 along nearly horizontal paths into the block 16 at a plurality of vertically spaced apart levels, including a bottom level 34, a plurality of intermediate levels 35, and a top level 36. Additional horizontally extending blasting holes 38 are drilled into and at least partially through the ribs 19. As a practical matter, blasting holes 32 and 38 are driven at a slight upward slant to facilitate flushing out of cuttings and to eliminate standing water.

The blasting holes 32 at each of the levels 34, 35, and 36 extend radially from the raise 31 so that each blasting hole 32 is angularly separated from the most nearly adjacent blasting hole 32 at such level. Also, the blasting holes 32 at any given level preferably extend or are projected to the periphery of the block 16. A typical arrangement for the blasting holes 32 is illustrated by a fan-shaped pattern 40 superimposed for illustrative purposes in dotted outline on the top surface 42 of the block 16.

The blasting holes 32 may be charged with suitable explosives so as to permit effective fragmentation of the block 16. In order to achieve relative uniformity in the distribution of explosive charge over the cross-sectional area of the block 16, it will be necessary to take account of the fact that the physical separation between adjacent blasting holes 32 increases with their distance from the raise 31. One approach which may be employed is to limit the explosive loading of alternate blasting holes 32 at any level so that the concentration of explosive charge in the vicinity of the raise 31 is not excessive.

Upon detonation of the explosive charges in the block 16 and the ribs 19, the void volume available for expansion thereof consists of the cavity 18 increased by the additional void volume of the raise 31. Well-known calculations have dictated the percentage of a given type of ore deposit which must be undercut in order to leave sufficient volume for expansion. For oil shale, for example, this undercut percentage is usually expressed as somewhere between five and thirty percent of the block 16, with optimum values varying with the degree of permeability and porosity to be achieved.

The explosive charges in blasting holes 32 and 38 may now be detonated in upwardly progressing timed sequence. Thus, the ribs 19 may be explosively removed first, after which the blasting holes 32 at levels 34, 35, and 36 may be detonated in order. The result is that the expanding shock front at each such level experiences least resistance in a downward direction. The vertical separation of the successive patterns 40 of blasting holes should be less than a critical depth, so that as each explosive level is detonated cratering to the free surface below occurs. It is also preferable that the maximum horizontal spacing between adjacent blasting holes 32 within any of the patterns 40 shall not greatly exceed such critical depth.

At least two of the blasting holes 32 at each level 34, 35, and 36 extend in a direction parallel to the face 43 such as along line 44 in the fan-shaped pattern 40. This insures that the face 43 of the resultant permeable zone 11, after detonation, will be smooth blasted to give added strength to the columns of deposit 46 (FIG. 2) separating zone 11 and other like zones respectively from the access entry 13.

Clearly within the scope of the method of this invention, the raise 31 may be positioned at other locations within the undercutting cavity 18. And also, if desirable, more than one raise 31 may be employed in the development of a single zone 11. However, the use of a single raise 31 located adjacent the entrance to the cavity 18 from the tunnel 14 is the most economical and preferred arrangement. It also minimizes hazard to personnel due to rock fall, caving, etc.; but perhaps most importantly it facilitates the installation of the necessary ducting for ventilation during mining operations.

In FIG. 3 the zone 12 is shown completely fragmented as a result of the detonation sequence described within the zone 11. If it is desired to use the zone 12 as a retort chamber, for example, in situ retorting of oil shale, an air hole 50 may be drilled from the surface or an upper mining level into the top of the zone 12 to accommodate a source of oxygen and fuel to ignite and support combustion of the shale. At the same time, the tunnel leading into the zone 12 may be sealed with a bulkhead 52 during retorting operations to eliminate passage of noxious gases into the access entry 13. Concentric conduits (not shown) for recovery of car-

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bonaceous values from the zone 12 may easily be introduced from the access entry 13 into the zone 12 through the bulkhead 52, as more particularly described in copending application Ser. No. 499,694.

Although this method has been described and illustrated with respect to a preferred embodiment thereof, many variations or modifications in relative proportions, arrangement, and orientation of specific elements will occur to those skilled in the mining art without departing from the scope and spirit of the invention as set forth more particularly in the appended claims.

What is claimed is:

1. In the development of a permeable zone within a subterranean ore deposit wherein the deposit is undercut to form a cavity therebeneath communicating with the surface and a designated block of the overlaying deposit is thereafter expanded to form said permeable zone, the method of blasting said overlaying block comprising the steps of:

- a. driving at least one raise upwardly into said block from the roof of said cavity to a position adjacent the top level of said block,
- b. drilling a plurality of blasting holes extending from said raise along substantially horizontal paths into said block in a plurality of similar radially expanding patterns, said patterns being situated respectively at each of a like plurality of vertically spaced apart levels disposed from adjacent the top of said raise to adjacent the bottom thereof,
- c. at least partially filling said plurality of blasting holes with explosive charges, and
- d. detonating said explosive charges to effect fragmentation of said overlaying block and expansion thereof to fill said undercutting cavity.

2. The method of claim 1 wherein said raise is contiguous with said block.

3. The method of claim 1 wherein the upwardly extending surface of said raise is entirely surrounded by said block.

4. The method of claim 1 wherein the convergent ends of said blasting holes are distributed substantially

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uniformly over the interface between said at least one raise and said block.

5. The method of claim 1 wherein said at least one raise is driven in a vertical direction.

6. The method of claim 1 wherein each of said blasting holes extends to the areal limits of said block at each of said plurality levels.

7. The method of claim 1 comprising disposing said explosive charges within said blasting holes so as to achieve a substantially uniform distribution thereof over the areal limits of said block at each of said plurality of levels.

8. The method of claim 1 wherein the maximum spacing between adjacent blasting holes in any of said fan-shaped patterns does not exceed a critical depth.

9. The method of claim 1 wherein the explosive charges in alternate nonadjacent blasting holes in each of said fan-shaped patterns are confined to a predetermined fraction of the respective lengths thereof.

10. The method of developing a permeable zone within a subterranean ore deposit comprising the steps of:

- a. driving a tunnel into said deposit at a level below the top thereof,
- b. enlarging one end of said tunnel at said level to form a cavity undercutting said deposit,
- c. driving a raise upwardly into said deposit adjacent the juncture of said cavity and the remainder of said tunnel,
- d. drilling a plurality of blasting holes from said raise into a designated block of the deposit overlaying said cavity, said plurality of blasting holes being oriented so as to achieve a desired charge distribution throughout said block, and
- e. detonating said blasting holes to effect explosive fragmentation of said block and expansion thereof into the void volume of said cavity.

11. The method of claim 10 wherein said plurality of blasting holes are oriented to provide a smooth blasted face for said permeable zone extending upwardly from said juncture in a plane transverse to the direction of said tunnel.

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