

United States Patent [19]

Janssen

[11] 3,917,348

[45] Nov. 4, 1975

- [54] **METHOD OF DEVELOPING PERMEABLE UNDERGROUND ZONES**
- [75] Inventor: **Albert T. Janssen**, Englewood, Colo.
- [73] Assignee: **Atlantic Richfield Company**, Los Angeles, Calif.
- [22] Filed: **Aug. 22, 1974**
- [21] Appl. No.: **499,696**
- [52] U.S. Cl. **299/13; 299/2; 299/19**
- [51] Int. Cl.² **E21C 41/10**
- [58] Field of Search..... **299/2, 19, 13**

[56] **References Cited****UNITED STATES PATENTS**

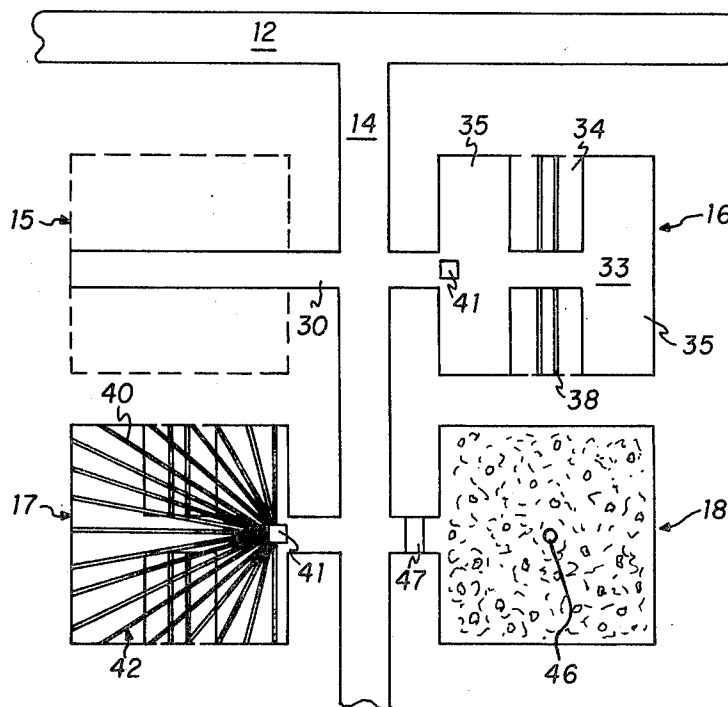
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Primary Examiner—Ernest R. Purser
Attorney, Agent, or Firm—Robert M. Betz

[57]

ABSTRACT

A parallel array of generally horizontal access entries communicating with the surface extend at a level beneath the top of an underground ore body or deposit. Zone entries are driven transversely from each access entry at this level, penetrating the deposit. A plurality of short crosscuts are driven in turn from each zone entry so that in combination each such zone entry and its associated crosscuts define a cavity of predetermined areal extent. The deposit overlaying each cavity is partially supported by the ribs which separate adjacent crosscuts and which project into the cavity from its side walls. Upon removal of these ribs, designated blocks of each of the overlaying deposits may be expanded into their associated undercutting cavities to form a series of adjacent permeable zones.

11 Claims, 3 Drawing Figures

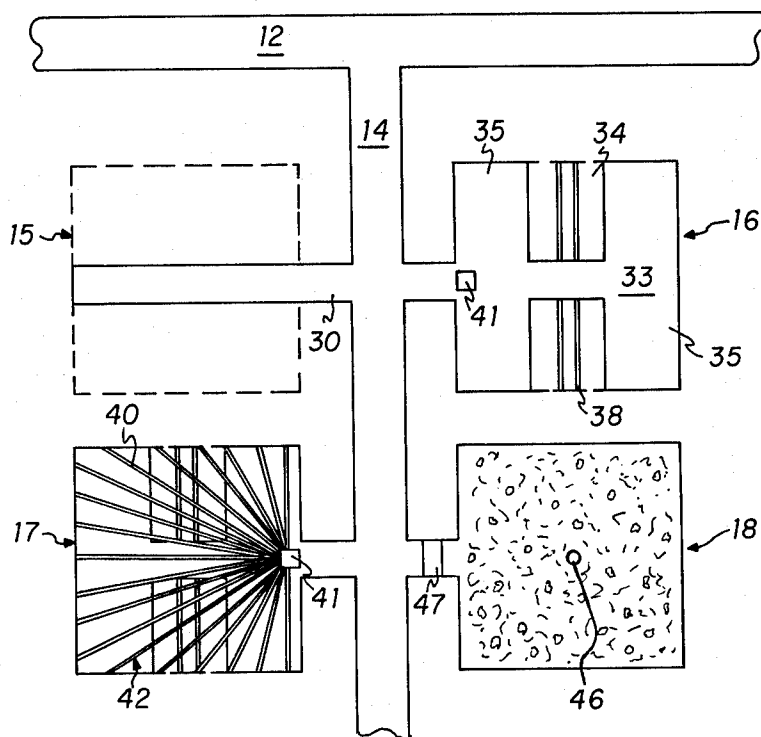


FIG. 3

METHOD OF DEVELOPING PERMEABLE UNDERGROUND ZONES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to mining operations and in particular to a mining method which can be used to develop underground chambers or zones of fragmented or permeable mineral deposits such as oil shale.

2. Description of the Prior Art

Because of the developing worldwide energy shortage, the need for a supplementary supply of fuel from oil shale has now become critical, and thus it has become imperative to devise means for exploitation of oil shale reserves which maximize the efficiency of the various steps involved.

In recent years much attention has been directed to processing of oil shale by retorting in place with hot gases, which promises to become a technologically and economically feasible method for producing shale oil. Since the permeability of oil shale is essentially zero, a technique must be developed which will create sufficient permeability in an oil shale formation to allow the hot retorting gases to pass through the bed of fragmented material. Furthermore, a mining method and layout must be devised which lends itself to inexpensive, large scale progressive permeable zone or chamber development and to retorting operations wherein operating personnel may be easily protected from rock falls, noxious gases, and other similar hazards. At the same time, the overall system should function with efficiency and relative low cost. It is with these general objectives in mind that the method of the present invention has been evolved.

In accordance with a known prior art mining method, subterranean zones of fragmented mineral deposits such as oil shale may be developed by undercutting a designated cross-sectional area of the deposit and thereafter expanding a block of overlaying material so that it forms a permeable mass which fills the void space beneath. This may be done by explosively breaking such overlaying block so that it caves into the undercut space in the form of discrete particles.

In U.S. Pat. No. 3,661,423, for example, a cavity undercutting an oil shale deposit is excavated except for plurality of separate small support pillars, the cavity being connected to a vertical shaft through a short horizontal tunnel. Thereafter, the overlayer is explosively caved into the cavity to form a retortable mass of particles. The patent envisages the formation of pillars, each of which is completely surrounded by the void space of the cavity. Consequently, roof bolting and scaling will be required throughout, which represents a significant expense if the cavity is of any appreciable size. A further problem, peculiar to oil shale, results from the selection of a conventional room and pillar mining technique in the context referenced above if multiple adjacent zones of the character described are to be in progressive stages of development. The laminated structure of oil shale together with the high magnitude of vibrations encountered during blasting operations may result in weakening of pillar structures adjacent to the blasting areas. Where adjacent permeable zones are in progressive stages of development, therefore, blasting operations in one zone may create a safety hazard within a neighboring zone. Even though such weakened pillars may not fail altogether, they may transmit such

vibrational effects to the roof of the undercutting cavity and contribute to the possibility of hazardous roof falls or cave-ins.

U.S. Pat. No. 3,001,776 teaches a pattern of associated upright, underground retorts in progressive stages of operation. In this system the bottom of each permeable zone is interconnected by means of a downwardly directed stope to a common tunnel which serves as a conduit for evolved retort products and also as a passage for removal of loosened shale. The layout is, however, ill-suited to progressive development and retorting of adjacent zones because there is no logical flow pattern available for men and equipment or for a supply of ventilating air.

SUMMARY OF THE INVENTION

The present invention is based on the concept that efficient exploitation of underground mineral reserves, particularly in connection with the in situ retorting of deep underground deposits of oil shale, is enhanced by the creation of a large scale mining layout incorporating multiple adjacent production zones of manageable size.

Accordingly, it is a general object of this invention to devise an efficient method for developing a system of multiple adjacent permeable zones within an underground mineral deposit with maximum safety and economy.

It is a more specific object of this invention to devise a method for developing a system of multiple adjacent retort zones within an underground deposit of carbonaceous material.

It is yet another object of this invention to devise an improved method for developing an undercutting cavity within a subterranean mineral deposit in preparation for expansion therein of an overlayer supported above such cavity.

A method is described for developing a permeable zone within an underground deposit comprising in general the steps of driving an access entry at a level below the top of the deposit, driving a zone entry transversely from said access entry in a substantially horizontal path to penetrate the deposit for a predetermined distance, driving a series of spaced apart crosscuts from said zone entry so as to form in combination therewith a void volume of predetermined areal extent and dimensions, the unmined ribs separating adjacent crosscuts constituting a partial support for the deposit overlaying the void volume, and finally expanding a designated block of the overlaying deposit to fill the void and form said permeable zone.

In another embodiment the method of this invention includes the development of a system of such permeable zones comprising the steps of driving at least one pair of spaced apart main entries below the top of an ore deposit along similarly directed substantially horizontal paths and at approximately the same levels, said pair of main entries defining in plan the boundaries of the system, interconnecting said pair of main entries by a spaced apart series of substantially parallel access entries, driving substantially horizontal zone entries in a transverse direction from each of said access entries into the deposit, driving a plurality of crosscuts from each of the zone entries in the manner referenced above so as to form a series of adjacent deposit undercutting voids or cavities arranged along one or both sides of each of the access entries, and explosively fragmenting a designated block of the deposits respectively

overlying these cavities so that these designated blocks expand into the cavities below to form a series of adjacent permeable zones.

It should be emphasized that there is no intention to limit the scope of the method to be described to any particular end use of the permeable zones thereby created or to any particular character of underground deposit. The technique of this invention may find application, therefore, not only in *in situ* retorting of underground deposits of oil shale and other carbonaceous materials but may also be a preliminary to excavation and removal of such deposits for surface retorting. The technique may further be of value in solution mining and in processing and recovery of sulphur and other minerals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration showing a plan view of a mining layout in accordance with the method of this invention.

FIG. 2 is an isometric view, partly broken away, of a permeable underground zone in progress of development in accordance with the method of this invention.

FIG. 3 is an illustration showing a plurality of permeable zones in various stages of development in accordance with the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, there is illustrated a mining layout within a subterranean ore body, for example, an oil shale formation, which has been developed in accordance with the method of this invention.

At least one pair of similar vertical shafts 10 and 11 are driven at suitably spaced intervals from the surface or from an upper mining level to a selected lower level beneath the top of an ore body. A corresponding pair of main entries 12 and 13 are then driven laterally from the bottom of the shafts 10 and 11 respectively so that they extend in substantially the same direction and in approximately horizontal relation to each other. The main entries 12 and 13 may be of any desired length and spacing, and the permeable zones to be developed all lie between these entries. Thus entries 12 and 13 define the perimeter or areal boundaries of the operation. If desired in connection with specific mining activities, either of main entries 12 or 13 may function as a bleeder or haulage drift.

Interconnecting adjacent main entries 12 and 13 are a series of substantially parallel spaced apart access entries 14, only two of which are shown in FIG. 1 for purposes of illustration. The length and number of such entries 14 are governed by the distance separating adjacent main entries 12 and 13, the longitudinal extent of such main entries, and the selected spacing between adjacent access entries 14. Additional shafts 10 or 11 and main entries 12 or 13 may be added if the mining layout is to be continued into contiguous areas.

Each of the access entries 14 constitutes the common trunk from which a plurality of designated permeable zones such as, for example, 15, 16, 17, 18, 19, 20, 21, and 22 are to be developed and through which subsequent retorting operations or the like may be monitored and controlled.

Each of the zones 15 through 22 is interconnected with the access entry 14 as shown through one of a plurality of zone entries 30, driven transversely from the access entry 14. Within the scope of this invention,

more than one zone entry 30 may conveniently communicate with a single permeable zone. It should further be understood that the mining layout of FIG. 1 may constitute one of a series of vertically spaced layouts of similar form within the same general mining operation wherein the operation may be conducted sequentially from one layout to the next.

Any of the plurality of permeable zones to be developed in the mining layout of FIG. 1, such as, for example, zone 17, may conveniently assume the form illustrated in FIG. 2. In this view, the rectangular or cube-shaped zone 17 is represented partially in dashed outline, as seen from the access entry 14, to which it is interconnected by one of the zone entries 30. The zone 17, shown partially developed prior to expansion comprises generally a block of ore 32 partly broken away overlaying a cavity 33 which has been mined out from the zone entry 30 in the manner to be described, leaving only one or more supporting ribs 34.

In order to better understand the details of the mining operation whereby permeable zones may be developed in accordance with this invention, attention is now directed to FIG. 3. Here several of the zones shown in FIG. 1, such as, for example, zones 15, 16, 17, and 18, are shown, for illustrative purposes, in successive stages of development, the internal features of all such zones being identical. A zone entry 30 may be driven from the access entry 14 along a horizontal or slightly elevated path for a predetermined distance into the base of the ore body until a boundary of a designated zone, for example, zone 15, (shown in dotted outline) is reached.

A plurality of crosscuts 35 are then driven into the deposit from the side walls of the zone entry 30 approximately at right angles thereto as shown in the view of zone 16 in FIG. 3. The crosscuts 35 terminate within the ore body, also at boundaries of the designated zone 16. The crosscuts 35 may be made short enough so that they can be conveniently mined and excavated with the use of gathering arm loaders or other equipment which is advanced within crosscuts 35 without the entry therein of personnel. Thus, the need for roof bolting and scaling within the crosscuts 35 is obviated. The spacing between the crosscuts 35 and the number of such crosscuts is optional; and if the total area of the cavity 33 is sufficiently small, the ribs 34 may be eliminated altogether. However, preferentially the spacing should be such that the separating ribs 34 are wider than they are high for maximum stability, as such ribs 34 partially support the overlying block 32. The fact that the ribs 34 are integral with the side walls of the undercutting cavity 33 into which they project enhances their strength and resistance to vibration. The number of the ribs 34 is, of course, determined by the number of the crosscuts 35 which are driven from each of the zone entries 30.

The undercutting cavity 33 which is formed in the manner described above is areally coextensive with the zone to be prepared such as, for example, zone 17, less the cross-sectional area of the supporting ribs 34, which will be removed prior to expansion of the overlying deposit. The height of the cavity 33 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 32 and, if necessary, to avoid ultimate subsidence of the overburden. If the floor of the cavity 33 is to be slanted or funneled to a liquid gathering sump 36 as, for

example, in collecting shale oil, the paths of the zone entry 30 and associated crosscuts 35 may be deviated appropriately from the horizontal. Also, within the scope of this invention, the cross-sectional area of the cavity 33 may be modified so that it assumes a circular, or other desired shape.

Within the framework of this invention, the block 32 may be expanded by methods well known to the mining art. A preferred method involves explosive removal of the ribs 34 followed by sequential explosive fragmentation of successive layers of the overlaying block 32. A technique for accomplishing such explosive fragmentation is more particularly described in copending application Ser. No. 499,697 incorporated by reference herewith. In accordance with such preferred method, blasting hole patterns for explosive implantation in overlaying block 32 are illustrated in FIGS. 2 and 3. A plurality of blasting holes 38 may, for example, be drilled along approximately horizontal paths through the ribs 34. Additionally, blasting holes 40 may be drilled into the overlaying block 32, horizontally or at a slight elevation, from a raise 41 extending upwardly into the deposit 32 from the roof of the undercutting cavity 33. Such blasting holes 40 may be conveniently drilled in a fan-shaped pattern 42 as illustrated in dotted outline on the top surface 43 of the block 32 at each of any desired number of spaced apart vertical levels ranging from a bottom level 44 to a top level 45.

Following the properly timed detonation of the explosive charges within the blasting holes 38 and 40, the block 32 fragments and expands into the undercutting cavity 33 to create a permeable zone such as zone 18 in FIG. 3; such zones are then available for further operations such as in situ retorting, excavation, etc. In an oil shale retorting operation, for example, an air hole 46 may be drilled from the surface or an upper mining level into the top of any of the permeable zones typified by zone 18 to accommodate a source of oxygen and fuel to ignite and support combustion of the oil shale. At the same time, the zone entry 30 leading into each such zone may be sealed with a bulkhead 47 during retorting operations to eliminate passage of noxious gases into the access entry 14. Suitable conduits (not shown) for recovery of carbonaceous values may easily be introduced from the access entry 14 into each zone 18 through such bulkhead 45. If desired, any of the zone entries 30 may be extended so as to interconnect adjacent access entries 14 so that the resultant permeable zones may be operated from either of two sides.

If the mining of the zones described herein commences in inverse order with zones 21 and 22 and continues in sequence therefrom through zones 15 and 16, then shaft 10 and main entry 12 may be used for haulage of excavated ore while shaft 11 and main entry 13 bleed off properly directed ventilation air. Thus, for example, in a complete system for developing and operating retort zones in an oil shale formation, zones 15 and 16 may be in an initial stage of cavity development, zones 17 and 18 undergoing expansion of the overlaying deposit, zones 19 and 20 in process of retorting, and zones 21 and 22 filled with spent shale and abandoned. Ventilation air flow progresses along access entry 14 from main entry 12 to main entry 13 to insure that noxious gases are carried away from operating personnel at all times.

In order to better appreciate the practical aspect of the method described above as applied to a large scale in situ oil shale retorting operation, the following illus-

trative values are given. A series of four spaced apart main entries such as entries 12 and 13 may be extended equally from the bottom of a like number of vertical shafts similar to shafts 10 and 11 to form an overall square cross section mining layout of 14,880 feet on a side. This covers roughly an area of 5,000 acres. Such a layout will accommodate approximately 204 access entries, such as entry 14, each of which interconnects a pair of main entries and from each of which two rows of 56 permeable retortable zones, of which zone 17 is illustrative, may be developed, each approximately 75 feet on a side for a total of 22,848 retortable zones. Progressive development of such a mining layout realistically permits simultaneous operation of over 100 retortable zones over a period of 15 years.

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. A method of developing a permeable zone within an underground mineral deposit comprising the steps of:
 - a. driving an access entry at a level below the top of the deposit,
 - b. driving a zone entry transversely from said access entry at said level into the deposit,
 - c. driving a plurality of crosscuts from said zone entry to form in combination with said zone entry a cavity undercutting the deposit, and
 - d. expanding a designated block of the deposit overlaying said cavity to fill said cavity and form said permeable zone.
2. A method as in claim 1 wherein said plurality of crosscuts are spaced apart to form a series of ribs projecting into said cavity and partially supporting the overlaying deposit.
3. A method as in claim 1 wherein said crosscuts extend along approximately parallel equidistant paths on both sides of said zone entry.
4. A method as in claim 1 wherein said deposit is a carbonaceous material.
5. The method of claim 1 wherein said deposit is oil shale.
6. A method of developing a mining layout of multiple adjacent permeable zones within an underground deposit comprising the steps of:
 - a. driving at least one access entry at a level within the deposit, said at least one access entry being in communication with the surface at at least one of its ends;
 - b. driving a plurality of spaced apart zone entries transversely from said at least one access entry at said level, said zone entries penetrating said deposit and terminating therein;
 - c. driving at least two spaced apart crosscuts from each of said zone entries into said deposit and terminating therein so that said at least two crosscuts in combination with a respective one of said plurality of zone entries form a cavity of predetermined areal extent undercutting said deposit, thereby forming a plurality of separate adjacent cavities separately undercutting said deposit; and
 - d. expanding designated blocks of said deposit respectively overlaying said separate cavities into

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said cavities to form said permeable zones.

7. A method of developing a system of adjacent permeable zones within a subterranean deposit comprising the steps of:

- a. driving at least two substantially horizontal spaced apart main entries along parallel paths at the base of the deposit, said main entries forming the boundaries of the system;
- b. driving a plurality of parallel access entries interconnecting said main entries;
- c. driving a plurality of zone entries transversely from each of said access entries into said deposit;
- d. driving at least two crosscuts from each of said transverse zone entries at spaced intervals so that said at least two crosscuts in combination with a respective one of said plurality of zone entries form a cavity undercutting said deposit, thereby forming a plurality of adjacent cavities separately undercutting said deposit; and
- e. explosively fragmenting designated blocks of said deposit respectively overlaying said adjacent cavities so that said designated blocks are expanded respectively into said cavities to form said permeable zones.

8. A method of developing a system of adjacent permeable zones within a subterranean deposit comprising the steps of:

- a. driving at least a pair of spaced apart vertical shafts from the surface to a level below the top of a subterranean deposit;
- b. driving a main entry from the bottom of each of said at least two vertical shafts respectively, said main entries generally extending in a similar direction and along generally horizontal paths;
- c. driving at least two substantially parallel access entries each interconnecting and communicating with said main entries;
- d. driving a plurality of zone entries transversely from each of said at least two access entries into said deposit;
- e. driving at least two crosscuts from each of said plurality of transverse zone entries at spaced apart intervals, said at least two crosscuts penetrating said deposit and terminating therein, each of said at

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least two crosscuts forming with a respective one of said plurality of zone entries a cavity undercutting said deposit thereby forming a plurality of separate adjacent cavities separately undercutting said deposit; and

- f. explosively fragmenting designated blocks of said deposit respectively overlaying said plurality of separate cavities so that said designated blocks are expanded respectively into said plurality of separate cavities to form said permeable zones.

9. A method as in claim 8 wherein said plurality of zone entries extend between and interconnect said at least two access entries.

10. A method of preparing underground retorts for in situ combustion operations within an underground mineral deposit comprising the steps of:

- a. driving at least one access entry at a level below the top of said underground deposit, said access entry being in communication with the surface at at least one of its ends;
- b. driving a plurality of zone entries transversely from said at least one access entry at said level into and terminating within said deposit;
- c. driving at least two spaced apart crosscuts from each of said plurality of zone entries into said deposit and terminating therein so that said at least two crosscuts in combination with a respective one of said plurality of said zone entries form a cavity undercutting said deposit, thereby forming a plurality of separate adjacent cavities separately undercutting said deposit;
- d. explosively fragmenting designated blocks of said deposit respectively overlaying said separate adjacent cavities so that said designated blocks are expanded respectively into said separate cavities to form a plurality of permeable zones; and
- e. providing a plurality of air inlet means communicating respectively with the top of each of said permeable zones.

11. A method as in claim 10 further comprising means for sealing the zone entries respectively interconnecting each of said permeable zones and said at least one access entry.

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