299-13
SR
F360D
OR 3,588,175

[11] 3,588,175

[72] Inventor **Jerry M. Whiting**
Dallas, Tex.

[21] Appl. No **816,249**
[22] Filed **Apr. 15, 1969**
[45] Patented **June 28, 1971**

[73] Assignee **Atlantic Richfield Company**
New York, N.Y.

[54] METHODS FOR MINING DEEP THICK OIL SHALE DEPOSITS

3 Claims, 8 Drawing Figs.

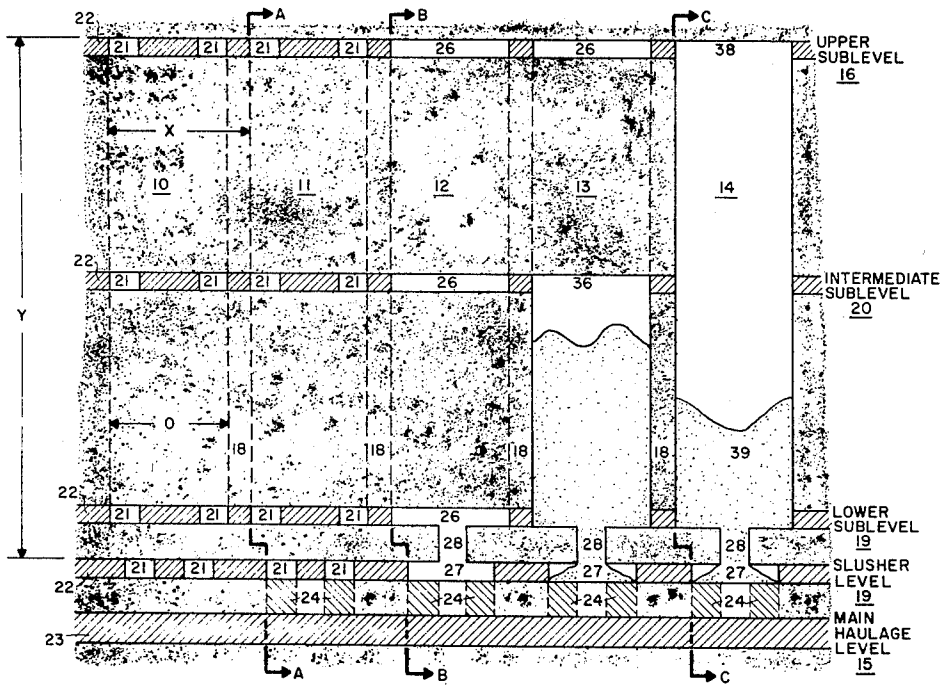
[52] **U.S. Cl.** **299/11,** 299/18, 299/19
[51] **Int. Cl.** **E21c 41/10**
[50] **Field of Search** 299/2, 11, 13

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

473,734	4/1892	Forrester	299/13
1,842,664	1/1932	Elsing	299/11
2,536,869	1/1951	Bucky	299/11
3,001,776	9/1961	Van Poollen	299/2

Primary Examiner—Ernest R. Purser
Attorneys—Blucher S. Tharp and Robert E. Lee, Jr.

ABSTRACT: Mining deep subsurface deposits of oil shale and associated minerals by blasthole stopping. A main haulage level is driven beneath a horizontal series of production blocks and subordinate levels are driven between the vertical limits of the blocks. Outlets for broken ore are created at the bottom of the blocks extending to the main haulage level. The blocks are sequentially drilled and blasted to form a series of stopes in progressive stages of development separated by thin pillars. The broken ore is recovered from the stopes via the main haulage level and the empty stopes are backfilled.



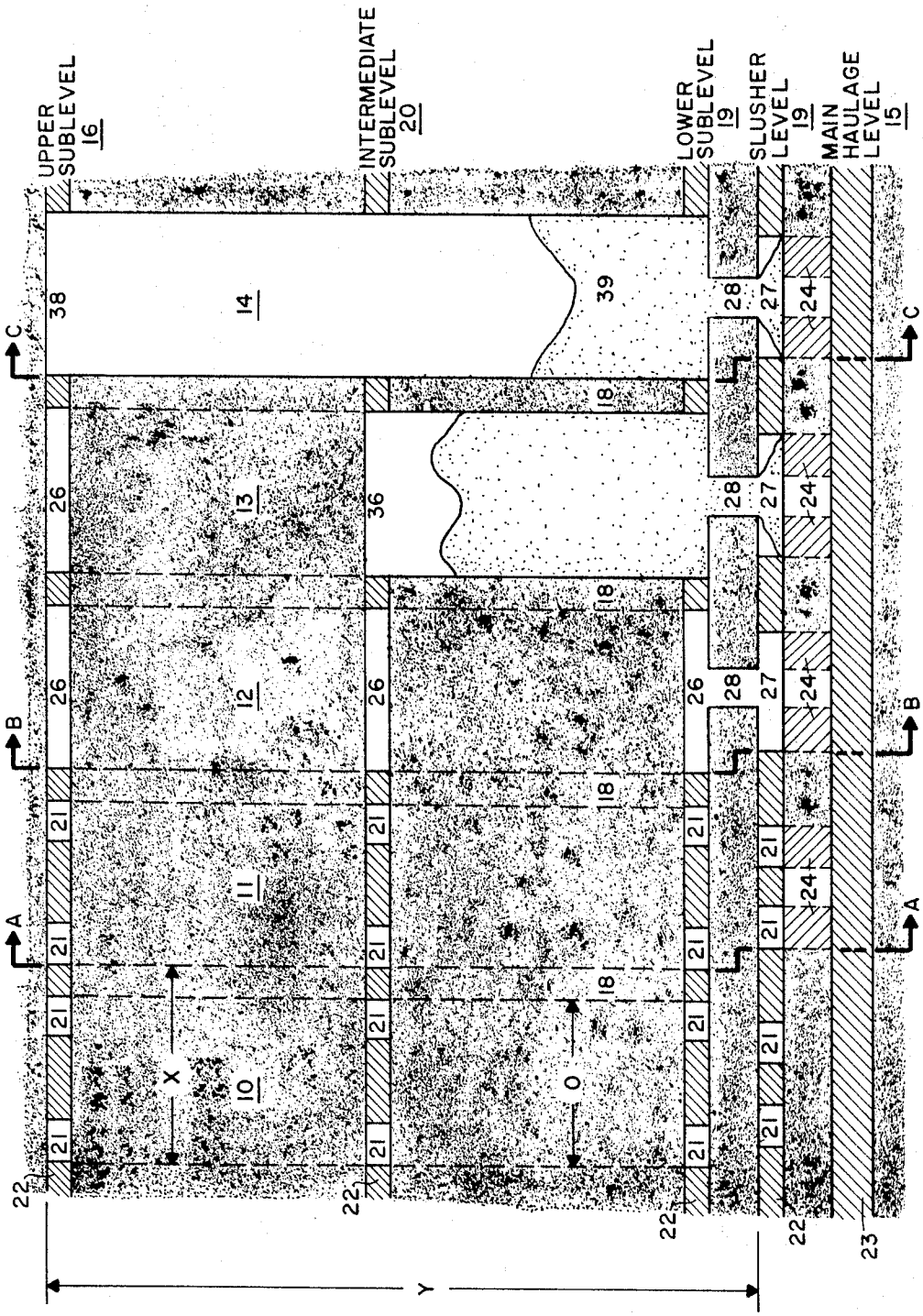


FIG. 1

INVENTOR
JERRY M. WHITING

Robert Ellsworth Lee
ATTORNEY

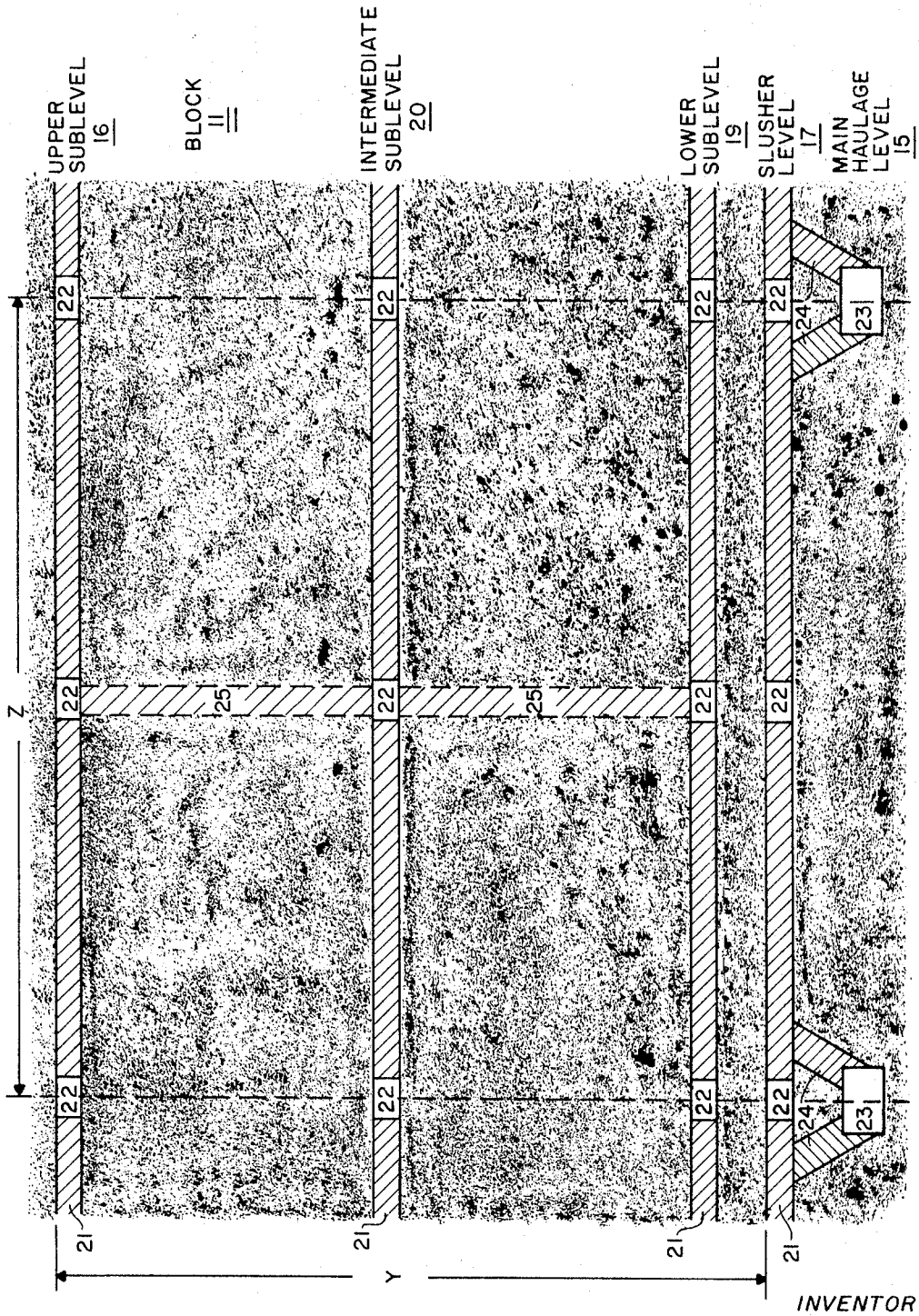


FIG. 2

INVENTOR
JERRY M. WHITING

Robert Elsworth Lee
ATTORNEY

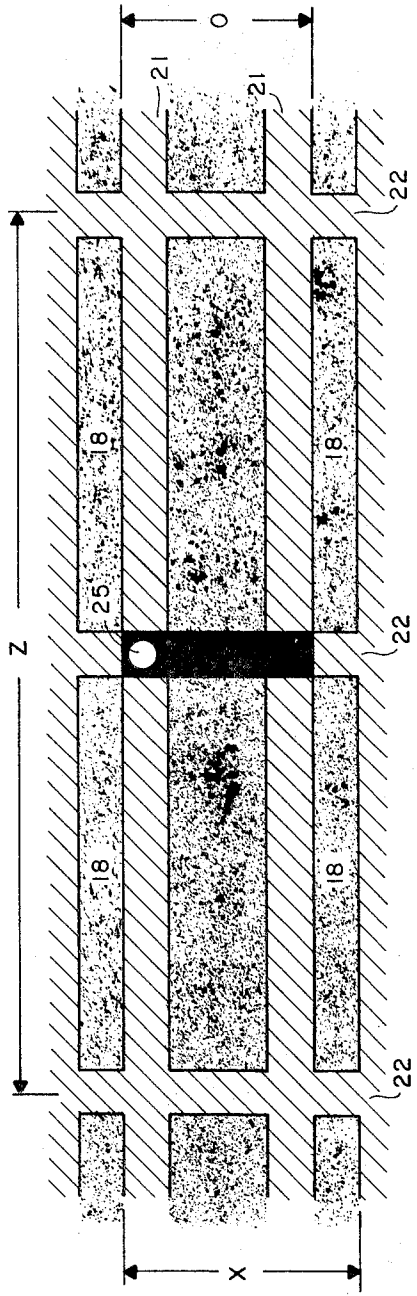


FIG. 3

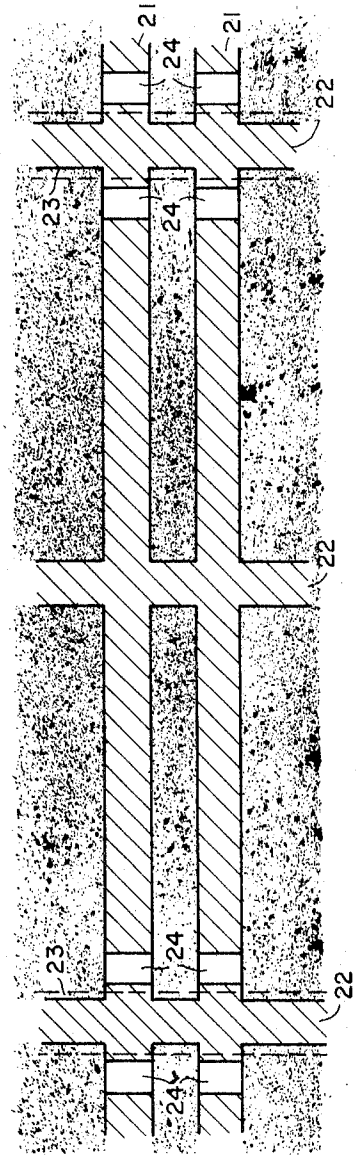


FIG. 4

INVENTOR

JERRY M. WHITING

Robert Elsworth Lee

ATTORNEY

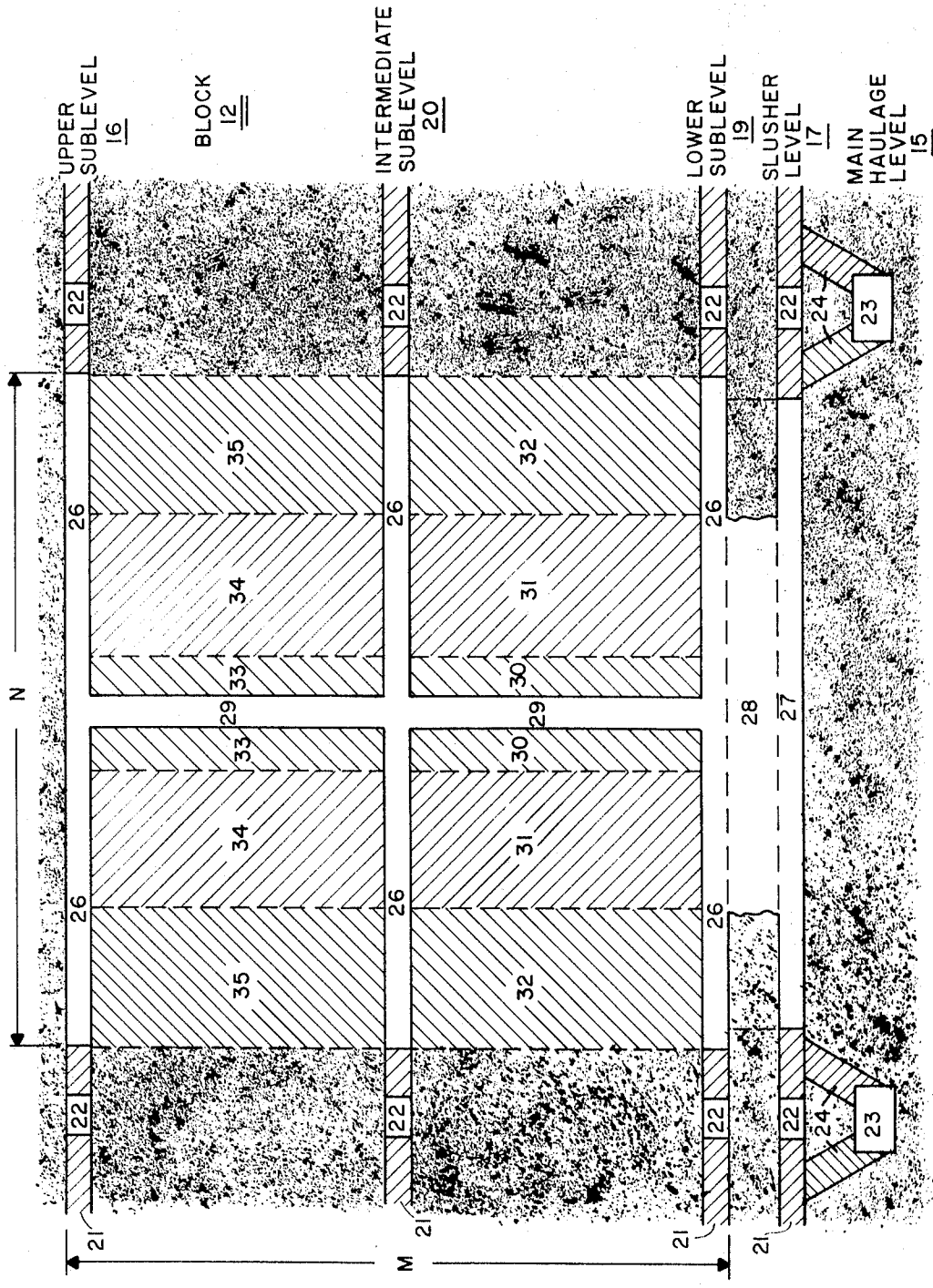


FIG. 5

INVENTOR
JERRY M. WHITING

Robert Elsworth Lee
ATTORNEY

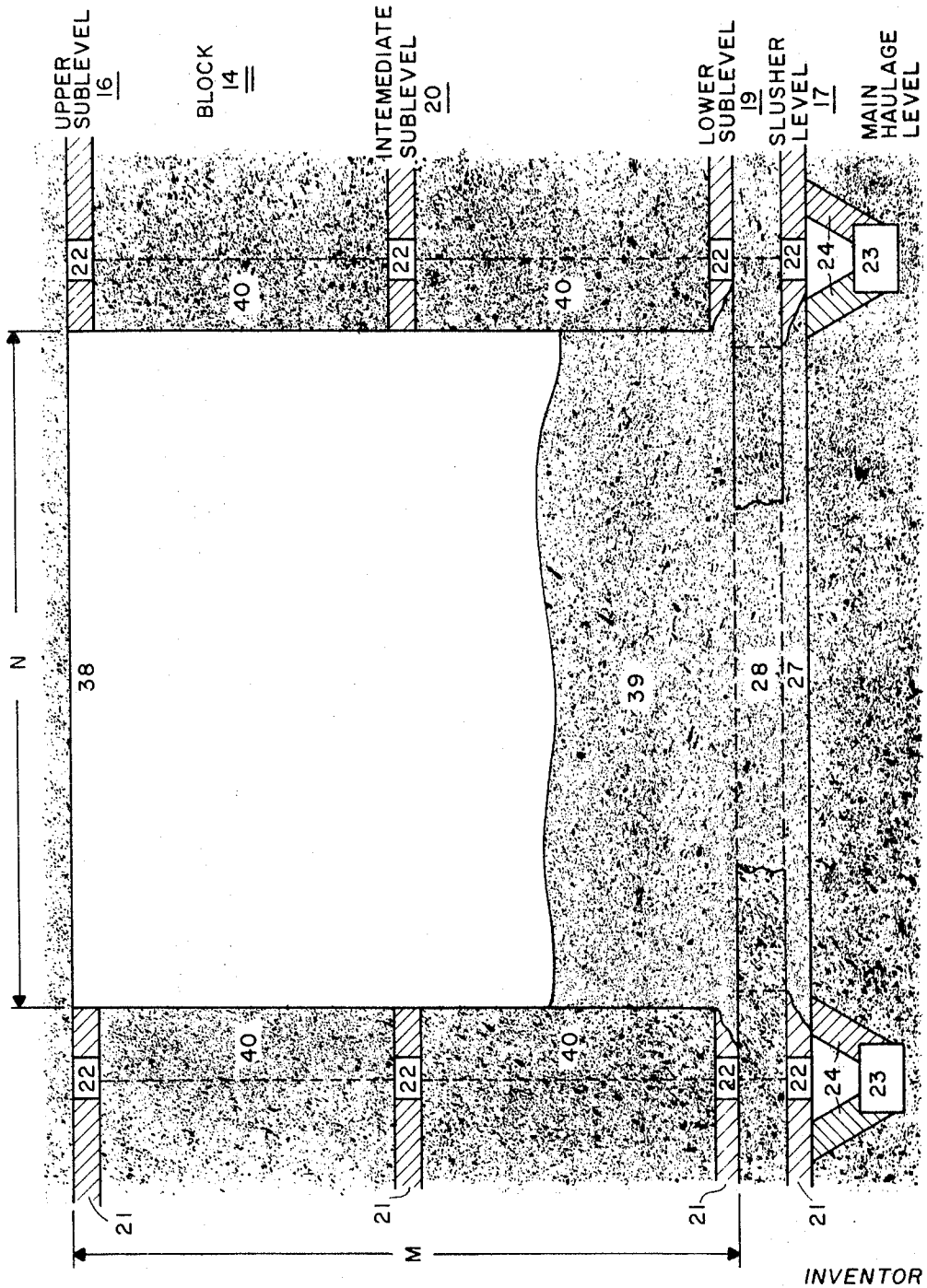


FIG. 6

INVENTOR
JERRY M. WHITING

Robert Elsworth Lee
ATTORNEY

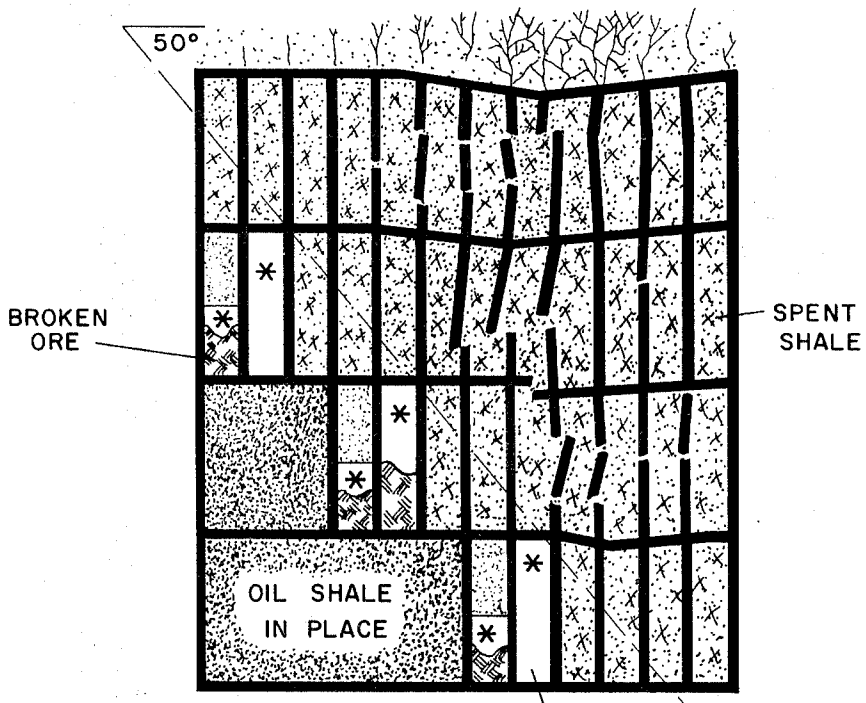


FIG. 7

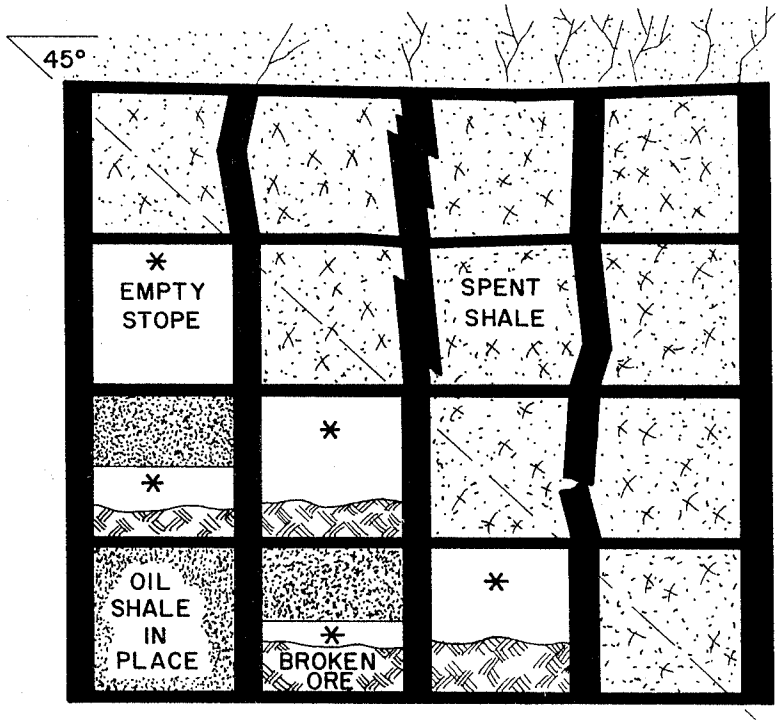


FIG. 8

INVENTOR
JERRY M. WHITING

Robert Ellsworth Lee
ATTORNEY

METHODS FOR MINING DEEP THICK OIL SHALE DEPOSITS

BACKGROUND OF THE INVENTION

This invention relates to the mining of "oil shale" as found in the Piceance Basin, Garfield and Rio Blanco Counties, Northwestern Colorado and in similar deposits found elsewhere.

The term "oil shale" refers to sedimentary deposits of organic-rich argillaceous dolomites. The organically derived component is kerogen, a mineral that when subjected to sufficient heat is converted to a form of crude petroleum. Deposits of oil shale in the United States, principally in the states of Colorado, Utah and Wyoming, contain billions of barrels of crude oil reserves.

The U.S. Bureau of Mines estimates that 81 billion barrels of liquid fuels will be consumed in the period 1966—1980. This is more petroleum than was produced in the United States during the first 100 years after oil was discovered in 1859. (Prospects for Oil Shale Development, Colorado, Utah and Wyoming, U.S. Department of the Interior, Washington, D.C., May 1968). As a result, oil shale is a logical supplementary source for a substantial portion of this required production and, therefore, constitutes one of the country's most important natural resources.

For oil shale to be utilized as a source of crude petroleum, a great effort must be directed to inventing and developing equipment and methods which will allow its exploitation with safety and economy. Considerable effort has been expended to date, but relative to the mining and moving of raw shale ore, the shale deposits have barely been scratched.

Oil shale mining has been carried out to feed pilot plant operations of Union Oil Company, the U.S. Bureau of Mines, the Colony Development Company joint venture, etc. In each case, however, oil shale mining has been restricted to the room-and-pillar method in relatively thin (about 60 feet) peripheral strata. This type of mining method in oil shale has been described thoroughly by the U.S. Bureau of Mines and others in numerous publications and its general application in mining is widely known. References of interest, to name a few, include:

Gardner, E. D., "Mining Program, Bureau of Mines Oil-shale Project, Rifle, Colorado," *U.S. Bureau of Mines Report of Investigations* 4269, U.S. Department of the Interior, Washington, D.C. 1948.

Ertl, Tell, "Oil Shale Mining," American Institute of Mining and Metallurgical Engineers Technical Paper 2359, *Mining Technology*, July 1948.

Sipperelle, E. M., "Oil-Shale Mining Investigations, Rifle, Colorado," *Mines Magazine*, Vol. 38, No. 12, Dec. 1948.

Gardner, E. D., "Innovations in Equipment and Underground Mining Procedures at the Bureau of Mines Oil-Shale Mine, Rifle, Colorado," 1949 *Mining Yearbook*, Colorado Mining Association, Jan. 1949, pp. 29, 31—33.

Wright, F. D., "**Mining Oil Shale at Rifle, Colorado**," *Explosives Engineer*. May—June 1949, pp. 78—81, 86, 92.

Gardner, E. D. and Sipprelle, E. M., "Mechanization at the Bureau of Mines Oil-Shale Mine," *Mining Engineering*, Sept. 1949, pp. 317—323.

Sipprelle E. M. and Teichman, H. L., "Roof Studies and Mine Structure Stress Analysis, Bureau of Mines Oil-Shale Mine, Rifle, Colorado," American Institute of Mining and Metallurgical Engineers Technical Paper 2942, *Mining Transactions*, Feb. 1950.

Wright, F. D., et al., "Equipment Tested at the Bureau's Oil-Shale Mine," *U.S. Bureau of Mines Report of Investigations* 4810, 1951.

Wright, F. D., et al., "Blasting Research at the Bureau of Mines Oil-Shale Mine," *U.S. Bureau of Mines Report of Investigations* 4956, 1953.

Merrill, R. H., "Design of Underground Mine Openings, Oil-Shale Mine, Rifle, Colorado," *U.S. Bureau of Mines Report of Investigations* 5089, 1954.

Obert, L. and Merrill, R. H., "Oil-Shale Mine, Rifle, Colorado, A review of Design Factors," *U.S. Bureau of Mines Report of Investigations* 5429, 1958.

East, Jr., J. H. and Gardner, E. D., "Oil-Shale Mining, Rifle, Colorado, 1944—56," *U.S. Bureau of Mines Bulletin* 611, 1964.

Room-and-pillar mining is applicable to near-surface oil shale deposits which have a thickness from 20 to possibly 100 feet. However, most of the oil shale reserves in the U.S. are contained within strata over 100 feet thick lying under several hundred feet of overburden. While it would be theoretically possible to mine thick beds of this sort by the room-and-pillar method, at least 50 percent of the shale would be unrecoverable. (*Prospects for Oil Shale Development, Colorado, Utah and Wyoming*, U.S. Department of the Interior, Washington, D.C., May 1968, p. 49.)

The main factor tending to prevent higher recovery is that room-and-pillar mining under such conditions would create a complex, open honeycomb pillar structure with questionable stability. To guard against potential unexpected and/or premature failure of this structure, and the attendant safety hazards of roof falls, rock bursts, and violent air displacement, it would be necessary to leave sufficiently large oil shale pillars in place to make such failure impossible which, in turn, minimizes the shale that can be recovered.

It has been suggested that thick strata of oil shale could be mined successfully by open pit methods. While technically feasible, the magnitude of such an undertaking would be beyond the practical capability of any existing organization. Such a mine would have to supply several large oil shale processing plants; furthermore, overburden handling and disposal would pose extraordinary problems. (*Prospects for Oil Shale Development*, ibid.)

A variation of the block caving method has been suggested for extracting deep thick strata of oil shale. (Allsman, P. T., "A Simultaneous caving and Surface Restoration System for Oil Shale Mining," *Quarterly of the Colorado School of Mines*, Golden, Colo., Vol. 63, No. 4, Oct. 1968, pp. 113—126.) However, at least three major potential problems are associated with the block caving method: First, the surface directly above the mine would be extensively broken and would subside to a depth approximating the thickness of extracted oil shale; second, subsidence would involve a volume of overburden extending far beyond the perimeter of the mining horizon; third, withdrawal of the oil shale strata and replacement with randomly broken, poorly consolidated overburden would reduce the lateral confinement on adjacent unmined shale, and thus likely would cause substantial structural deterioration which could adversely affect subsequent mining operations. The first problem might require extensive and costly surface reclamation systems. The second and third problems would require limiting extraction so that final subsidence planes would not extend into adjacent properties, or would require the cooperation of adjacent property owners on matters related to surface and mining strata stability. The latter might be impossible to obtain if exploitation of adjacent properties were to be delayed for several years, or if the ultimate effects of subsidence could not be predicted with certainty. Additionally, oil shale strata might resist caving and fragmentation due to gravitational forces to a degree that would make the method impractical.

Another possible mining method, referred to as "cut-and-fill," has been mentioned briefly as a possible way to extract deep thick oil shale deposits. (*Prospects for Oil Shale Development, Colorado, Utah and Wyoming*, U.S. Department of the Interior, Washington, D.C., May 1968, pp. 54—55.) No detailed information on such a system has been made available to the public, although cut-and-fill mining of steeply dipping, relatively narrow, bed of vein deposits is a well established mining practice, viz:

Peel, R., "Filled Stopes," *Mining Engineers' Handbook*, John Wiley & Sons, Inc., New York, 3rd Ed., 1941, pp. 10—237.

Young, G. J., "Underground Methods," *Elements of Mining*, McGraw-Hill Book Co., Inc. New York, 4th Ed., 1946, pp. 555—607.

Woodruff, S. D., "Timber and Fill Supported Stopes," *Methods of Working Coal and Metal Mines*, Pergamon Press, London, Vol. 3, 1st Ed., 1966, pp. 284—300.

Most recently, leading experts have stated: "[Thick deposits, thick cover, not accessible from surface or outcrop]shale constitutes most of the Federal holdings in Colorado and contains by far the largest potential reserve of shale oil.... We know of no methods for exploiting this type deposit economically at the present time." ("Comments and Suggestions on the Department of Interior Oil Shale Policy Statement of May 1968," *Synthetic Fuels Quarterly Report*, Cameron and Jones, Inc., Denver, Colo.)

Accordingly, the primary object of the present invention is to provide an efficient and practical method for mining deep thick oil shale deposits. Secondary objects of the invention are to prevent or minimize the problems associated with other methods which are outlined above: namely, 1. the creation and maintenance of open, potentially hazardous, mine structures; 2. less than optimum recovery of oil reserves; 3. uneconomical or otherwise impractical overburden removal and handling; 4. catastrophic and/or eventual undesirable subsidence above and adjacent to a mined out region; 5. extensive surface rehabilitation; and 6. the possibility of causing unacceptable damage to contiguous properties. An additional object is to return most of the waste rock, from which oil has been removed, to the mine stopes, thus greatly reducing surface disposal and possible pollution problems. Other additional objects and advantages are discussed below and still other and further objects and advantages will be evident to those skilled in the art from the specification and claims.

SUMMARY OF THE INVENTION

The invention details a new oil shale mining method for deep thick deposits which, for lack of a better description term, could be referred to as a "cut-and-fill" method; it would be more accurately described as "sublevel blasthole stope-and-fill" or, more simply, as "blasthole stoping."

One aspect of the invention is a method of mining a single block of ore; another aspect is a method for mining a horizontal series of contiguous ore blocks; still another aspect concerns the development of a multilevel, three-dimensional mining complex; and still another aspect concerns disposal of spent shale in mine stopes.

Briefly, a mining zone is selected and divided vertically by horizontal haulage levels into a preselected number of production levels. A plurality of subordinate level networks is established above each haulage level to divide each horizontal production level into production blocks of desirable size. Muck raises are driven to create outlets for broken ore at the bottom of each block. Ore remaining at each subordinate level is removed to form horizontal slots or voids. A vertical raise is driven at the longitudinal center of each block and then a slot or void is slashed for the width of block. Volumes of each block are sequentially blasted from the central vertical slot to form a stope of increasing dimensions. Lastly, the broken ore is drawn and removed via the underlying haulage level.

Thin weak pillars are left between adjacent stopes to retain fill and as roof support to temporarily control caving. After suitable bulkheads are constructed, the empty stopes are filled with spent shale and other waste material.

Production is carried out at several horizontal levels at the same time with the active stopes vertically staggered from level to level at such an angle as to minimize stress and strain on adjacent support pillars. Backfilling is accomplished as soon as possible so that each stope remains empty a minimum amount of time. As the development proceeds from level to level, the effect is to create an inverted pyramid-shaped mass of consolidating and subsiding fill.

Advantages of the invention include the following: It is possible to safely recover 50 to 80 percent or more of the oil reserves from oil shale deposits; surface subsidence and attendant restoration problems are minimized; breakdown or weakening of strata and overburden adjacent to the mining limits is prevented or minimized; ground pressures and rock deformation at the periphery of the mined out region are minimized; surface waste disposal requirements are minimized; and hazards such as violent air displacement, rock falls, shock, and dust, caused by sudden breakdown of many large open stopes are eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view at mine level illustrating the application of the present invention.

FIG. 2 is a sectional view taken along line A–A of FIG. 1, illustrating initial mine development.

FIG. 3 is a plan view taken along any of sublevels 16, 19, and 20 in FIG. 2.

FIG. 4 is a plan view taken along slusher level 17 in FIG. 2.

FIG. 5 is a sectional view taken along line B–B of FIG. 1, illustrating further mine development.

FIG. 6 is a sectional view taken along line C–C of FIG. 1, showing broken ore in a partially drawn stope.

FIGS. 7 and 8 are exaggerated views taken at right angles to each other showing a multilevel mining development according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

This invention is primarily suited for recovery of deep thick oil shale deposits. Accordingly, property should be purchased to provide sufficient ore reserves within a single rectangular tetrahedron or prism in order to ensure maximum economy in mine development and transportation.

One or more vertical or inclined entry shafts with adequate capacity are collared near one corner, or near the center of one side of the property, and are driven to the base of the mining zone.

The mining zone is divided vertically into a desirable number of main haulage levels, ranging from 120 to 200 feet apart, adapted to accommodate high-speed, automated rock haulage equipment. Vertical or inclined raises are driven from one main level to the next at predetermined locations, so that subordinate level networks can be established as needed between the main haulage levels. Mining, then, begins at, and retreats from, the property boundary opposite the main shaft installation as set forth below with the very last operation in the life of the mine being recovery of the ore which forms an ever diminishing pillar between the stopping region and the main shaft installation.

Referring to the drawings:

A series of production blocks of oil shale 10, 11, 12, 13, and 14, FIG. 1, representing various stages of development and recovery, are arranged above main haulage level 15. The production blocks have top and bottom boundaries defined by upper sublevel 16 and slusher level 17 and are separated from one another by pillars 18. Lower sublevel 19 marks the lower limit for producing ore from the blocks, i.e. the bottom of the stopes which are to be formed. One or more optional intermediate sublevels such as 20 may be driven between upper and lower sublevels 16 and 19 to divide each block into two or more vertically stacked subblocks that can be separately produced.

As shown in FIG. 1, each production block has a transverse horizontal dimension X and a vertical dimension Y. The longitudinal horizontal dimension Z, which extends into the plane of the drawing, and vertical dimension Y are shown in FIG. 2. (Dimensions X and Z can also be seen in FIG. 3.) Exemplary values for X, Y, and Z are 60, 216, and 240 feet, respectively; however, it is understood that X, Y,and Z must be chosen in each case to effect maximum economy for particular ground conditions and equipment systems.

Proceeding now from left to right across FIG. 1, the first stage of development involves forming a network of interconnecting passageways at each of the subordinate levels. Thus, blocks 10 and 11 are penetrated at subordinate levels 16, 17, 19, and 20 by passageways 21, extending along longitudinal axes of the blocks, and by passageways 22, extending along the common transverse axis of the blocks. It will be seen that, with respect to each block, there are two longitudinal passageways 21 at each level with passageways 21 at slusher level 17 being spaced closer together than passageways 21 at sublevels 16, 19, and 20. Transversely, there are three parallel passageways 22 at each subordinate level, as shown in FIG. 2, passing from block to block with the middle passageways being at the longitudinal center of each block. It will also be seen, FIGS. 1 and 2, that main haulage level 15 is comprised of passageways 23 which run traversely with respect to the production blocks at their longitudinal ends.

Next in order of development, muck raises 24, FIGS. 1 and 2, are driven between main haulage level 15 and slusher level 17. High capacity, remote controlled chutes are installed at the bottom of each raise and a muck moving system (i.e. scrapers and hoists) is established at the slusher level 17 to move ore along haulage passageways 21. Also, vertical raise 25 (FIG. 2) is driven at the longitudinal center of block 11 from lower sublevel 19 to upper sublevel 16 at a convenient location along its transverse axis.

The mine layout at this stage can best be seen by referring to FIGS. 3 and 4. The former shows the makeup of sublevels 16, 19, and 20 and the latter shows the makeup of slusher level 17. Both are comprised of a crisscross pattern of longitudinal passageways 21 and traverse passageways 22. Vertical raise 25 (FIG. 3) can be located anywhere in the shaded area, since, as discussed below, the shaded area will subsequently be slashed to a slot. Muck raises 24 (FIG. 4) lead to haulage passageways 23, shown in broken lines, beneath the slusher level. Finally, it should be noted that passageways 21 on slusher level 17 are closer together than corresponding passageways on levels 16, 19, and 20.

Now, considering block 12, FIGS. 1 and 5, the ore remaining between longitudinal passageways 21 is removed at sublevels 16, 19, and 20 for a distance equal to N forming horizontal slots 26. Ore is also removed between passageways 21 at slusher level 17 for a distance less than N forming slot 27. The width and height of slot 27 must be carefully selected and maintained in relation to the angle of repose of the broken ore in order to avoid overfilling slusher level 17 with muck. Further, the roofs of the rooms at sublevels 16 and 20 are trimmed and bolted as necessary to stand safely through the drilling cycle.

Development of block 12 is continued by drilling and blasting central slot 28 from slusher level 17 to lower sublevel 19. Particular care is taken to avoid fracturing the short pillar cantilevers extending over slot 27 and rock bolts and/or other support means, if needed, are used to provide safe passageways. Next, vertical slot 29 (FIG. 5) is slashed between sublevels 19 and 26 for a distance equal to 0 (FIG. 1) by drilling small diameter holes to raise 25 (FIGS. 2 and 3) and subsequently blasting them. Finally, before block MNO is blasted, parallel small diameter holes (not shown) are bored downward from the floors of sublevels 16 and 20 at sufficiently close centers to ensure adequate fragmentation for trouble-free muck flow through central slot 28 and muck raises 24 to haulage passageways 23.

One sequence of blasting is illustrated in FIG. 5. Volumes 30 adjacent to traverse vertical slot 29 are shot between sublevels 19 and 20 and the broken muck is drawn. Volumes 31 are shot next and drawn and volumes 32, 33, 34, and 35 follow in sequence. (If so desired, volumes 32 and 33 could be blasted at the same time or, alternatively, volumes 33 could be blasted before volumes 32.)

Whatever particular blasting sequence is employed, each volume blasted should have an adjacent void of at least 20 to 25 percent of its magnitude for expansion. Particular care should be taken at the edges of the resulting stope to lessen breakage of pillars 18 (FIGS. 1 and 3) so that they remain sufficiently stabile until the stope is back filled.

Referring to block 13, FIG 1, the results of the first stage of blasting will be seen. The bottom half of block 13 has been fragmented resulting in the formation of stope 36 and broken ore pile 37. The broken ore can be seen pouring through central slot 28 to slot 27 at slusher level 17.

Proceeding now to block 14, FIGS. 1 and 6, the next stage of blasting is shown. Both the upper and lower sections of block 14 have been blasted, resulting in large stope 38 and broken ore pile 39. After all the broken ore has been drawn, stope 38 will have dimensions MNO and will be approximately 200 by 200 by 50 feet. Pillars 18 at the transverse ends (i.e. sides) of stope 38 and pillars 40 at its longitudinal ends represent unrecoverable ore.

The percent recovery of ore from one of the production blocks is calculated as follows:

$$\text{Percent recovery} = \frac{(M)(N)(O)}{(X)(Y)(Z)} \times 100$$

Thus, where X, Y, and Z are 60, 216, and 240 feet, respectively, and M, N, and O are 200, 200, and 50 feet, respectively, the recovery is 64.2 percent. (This will even be greater if the ore recovered from slot 28, FIGS. 1 and 5, is taken into consideration).

In order to present an embodiment of the invention as required by the patent laws, it was necessary to set forth a particular sequence of operation. However, it will be apparent to those skilled in the art that certain steps can be reversed or carried out in a different order and still be within the scope of the present invention. For instance, horizontal slots 26 can be formed prior to driving muck raises 24; vertical raise 29 could be driven after horizontal slots 26 are formed; etc.

Filling of the stopes with waste shale from which the oil content has been removed is another aspect of the invention and begins as soon as practicable. A prime objective is to have a minimum number of empty stopes open at any time.

Assuming that the broken ore has been fully recovered from large stope 38, FIGS. 1 and 6, and that broken shale has been cleaned out of longitudinal passageways 21 on slusher level 17, a suitable bulkhead is constructed across the top of slot 28 between sublevel 19 and slusher level 17 to ready the stope for injection of spent shale. This can be done without exposure of men to the high stope walls by some variations of the following: Set up a small slusher hoist under pillars 18 sublevel 19; drop a rope down slot 28 to slusher level 17; pull the rope and tail block across to the opposite end of slot 28; and lift them to sublevel 19. Then, working under safe cover, construct the bulkhead from prefabricated components and slide it into place with the hoist.

If the spent shale is to be transported hydraulically from the concentrator (retort) to the stope, a suitable water decant system must be provided. A pipe which is perforated at regular vertical intervals is lowered from either of sublevels 16 or 20, depending on the fill level, along the corner of the stope into a base (not shown) installed on sublevel 19. The base connects to drainage pipes which carry the water away from the stope via sublevel 19. Also, small bulkheads are constructed at sublevel 19 to block passageways 21 and 22 in order to retain the spent shale.

Working first from intermediate level 20 and later from upper level 16, spent shale slurry is sprayed into the stope. With proper preparation of the spent shale to provide a particle size distribution that ensures an adequate settling rate, relatively clear water is decanted away rapidly, and negligible hydraulic heads are created. As the height of fill increases, and the fill compacts under its own weight, the reaction from the lateral pressure it exerts against the stope walls tends to support much of the mass. Therefore, the bottom bulkhead is not required to support more than a portion of the weight of the overlying column of fill. If troublesome leaks show up in the bottom bulkhead as filling starts, they can be plugged by work-

ing from slusher level 17. As the fill level reaches sublevels 20 and 16, small bulkheads are constructed to restrict the spread of fill into passageways 21 and 22 as was done in the case of sublevel 19.

After backfilling is complete, slusher level 17, FIG. 1, is widened to full stope width, i.e. distance O, and it becomes the upper sublevel for the production block which is directly below it. Thus, the invention readily permits progressive mining from one main level to the next in a diagonally downward direction.

FIG. 7 and FIG. 8 are schematic drawings which illustrate several important facets of applicant's invention. Each stope depicted therein measures on the order of 200 by 200 by 50 feet and yields 130,000 to 200,000 tons per day would excavate and fill the equivalent of about ¾ to 1½ stopes each day. In a deposit 800 feet thick and 2 or more square miles in area, it is, of course, possible to arrange development work, drilling, blasting, mucking, and filling in numerous ways.

Any mining operation, nevertheless, benefits from systematization, and, in such large oil shale operations, this is especially important. Accordingly, a preferred system of extraction and filling is shown by applicant in FIG. 7 and FIG. 8. The active stops, i.e. those being produced or backfilled, are staggered, both transversely (FIG. 7) and longitudinally (FIG. 8) to create an inverted pyramid-shaped mass of slowly consolidating and subsiding fill. By keeping the active stopes (indicated by asterisks) below a plane inclined about 45° to 50° from the horizontal and keeping the number of open stopes to the least required to provide uninterrupted production, the deformation of rock structures near the edge of the active mining region is minimized. Thin pillars, represented by the broad dark lines, are left between the stopes to temporarily retain fill and enclose access and haulage levels and, therefore, need only be stabile for a relatively short period of time.

As the active mining zone retreats from the mining limits, the thin pillar structure readily breaks up from increasing deformation caused by the weight of overburden and minor movement of the slowly consolidating mass of fill. (Distortion and subsidence have been exaggerated in FIGS. 7 and 8 for illustrative purposes). There is no possibility of a continuing buildup of stresses at the active mining zone as there would be if that zone were acting as an abutment region for the overburden above a huge honeycomb of open stopes. Furthermore, the potential for sudden, violent air displacements caused by stope caving is reduced to that comparable to many other practical mining methods.

The spent shale emplaced according to the invention will undergo very little further consolidation. This reduces surface subsidence to a probably negligible magnitude. Further, the high lateral supports provided by such a relatively solid mass either prevents breakdown of adjoining strata, or allows only minimal, probably negligible, distortion. This is a most important consideration relative to potential damage to adjoining properties.

Again it is emphasized that, while a preferred embodiment of the invention has been shown, it is understood that the invention can be practiced in other ways, and that various modifications and changes can be made in active mining operations which are within the spirit spirit of the invention and the scope of the following claims.

I claim:

1. A method of mining deep subsurface deposits of oil shale and associated minerals by blasthole stopping comprising:
   a. designating a horizontal series of suitable sized blocks of ore for production,
   b. driving a main haulage level beneath the blocks,
   c. driving a plurality of subordinate levels between the vertical limits of the blocks,
   d. creating outlets for broken ore at the bottom of said blocks extending to the main haulage level,
   e. sequentially drilling and blasting said blocks so as to form a series of stopes in progessive stages of development separated by relatively thin pillars,
   f. recovering broken ore from the resulting stopes via the main haulage level, and
   g. backfilling empty stopes as they are formed with spent shale and other waste rock.

2. A method of mining deep subsurface deposits of oil shale and associated minerals by blasthole stopping comprising:
   a. vertically dividing a preselected mining zone into a plurality of production levels by driving horizontal main haulage levels,
   b. establishing a plurality of subordinate levels above each main haulage level to divide each production level into production blocks of desirable size,
   c. driving muck raises to create outlets for broken ore at the bottom of each production block,
   d. removing ore from each subordinate level to from horizontal slots in the production blocks,
   e. driving a vertical raise at the longitudinal center of each block and slashing a central vertical slot for the width thereof,
   f. sequentially blasting volumes of each block from its central vertical slot to form a stope, and
   g. removing broken ore which collects in each stope via the underlying main haulage level.

3. A method of mining deep subsurface deposits of oil shale and associated minerals by blasthole stopping comprising:
   a. vertically dividing a preselected mining zone into a plurality of horizontal producing zones separated by main haulage levels,
   b. dividing each horizontal producing zone into an areal arrangement of production blocks separated by subordinate levels,
   c. drilling and blasting preselected production blocks in said producing zones to form a three-dimensional network of stopes in various stages of development,
   d. recovering broken ore from the resulting stopes, and
   e. backfilling the resulting empty stopes with spent shale and other waste rock,

   wherein steps c., d., and e. are coordinated so that the stopes being produced and backfilled are vertically staggered about an inverted pyramid-shaped mass of slowly consolidating and subsiding fill created by the totally backfilled stopes.

PO-1579
(5/68)

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,588,175 Dated June 28, 1971

Inventor(s) Jerry M. Whiting

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the abstract, line 2, "stopping" should read --stoping--.

Column 7, line 14, "130,000 to 200,000 tons per day" should read --130,000 tons of oil shale. An operation producing 100,000 to 200,000 tons per day--.

Column 8, line 1, delete second "spirit"; line 5, "stopping" should read --stoping--; line 21, "stopping" should read --stoping--; line 30, "from", second occurrence, should read -- form --; line 40, "stopping" should read -- stoping --.

Signed and sealed this 15th day of February 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents