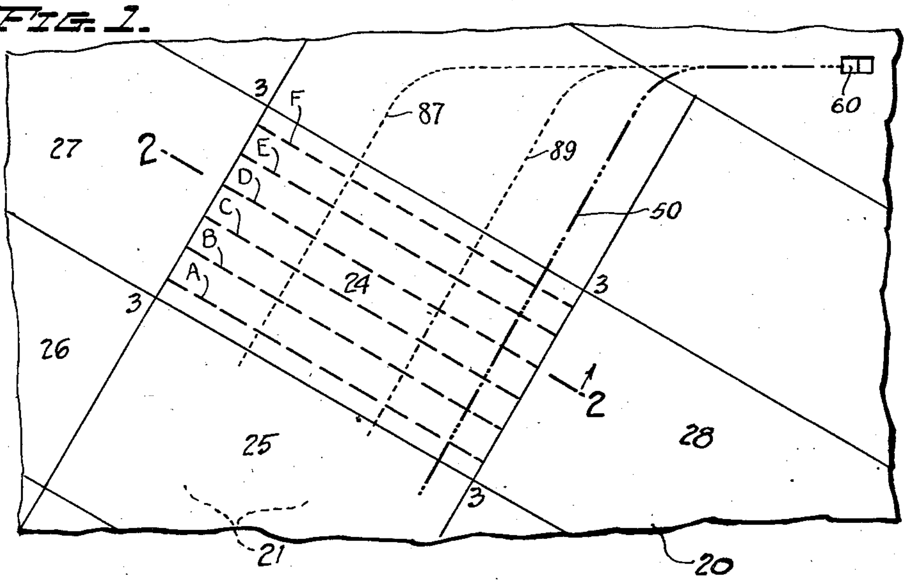
Oct. 13, 1942. M. A. SMITH 2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941 6 Sheets-Sheet 1

FIG. 1.



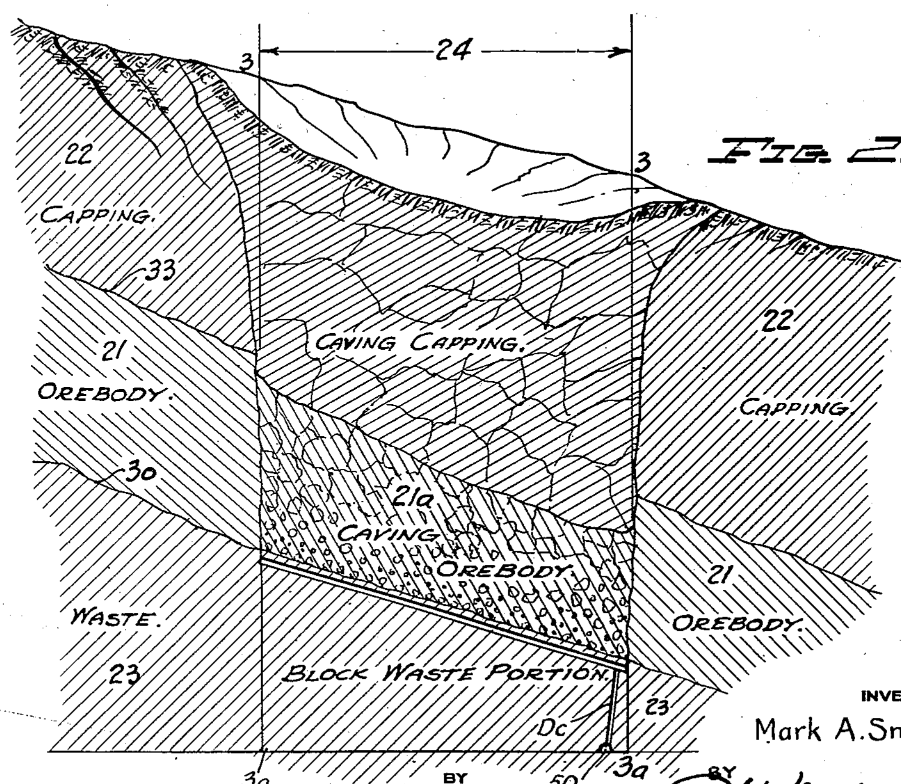


FIG. 2.

INVENTOR
Mark A. Smith

BY
F. H. Mellinbrodt
ATTORNEY

Oct. 13, 1942.

M. A. SMITH

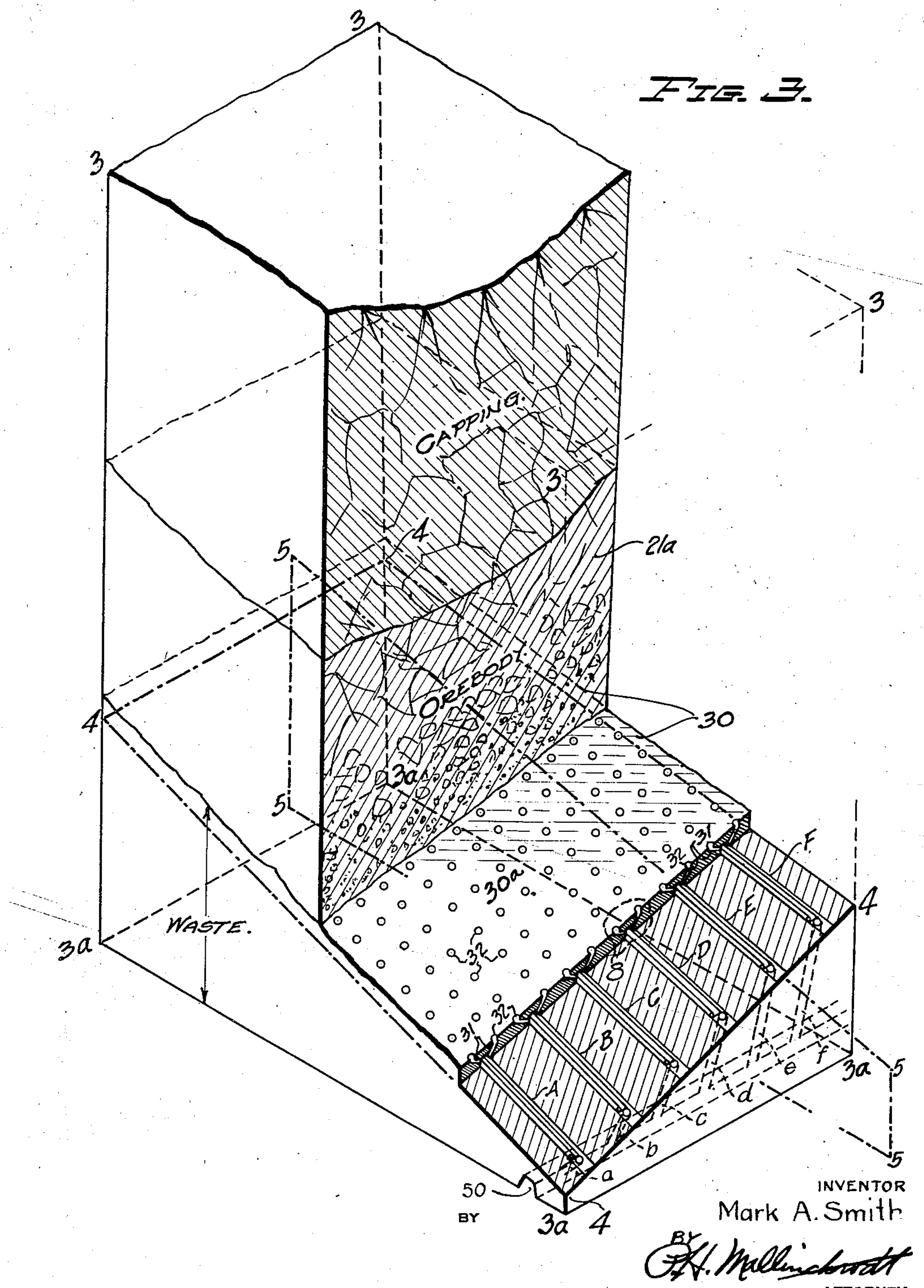
2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941

6 Sheets-Sheet 2

FIG. 3.



INVENTOR
Mark A. Smith

BY
[signature]

ATTORNEY

Oct. 13, 1942. M. A. SMITH 2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941 6 Sheets-Sheet 3

FIG. 4.

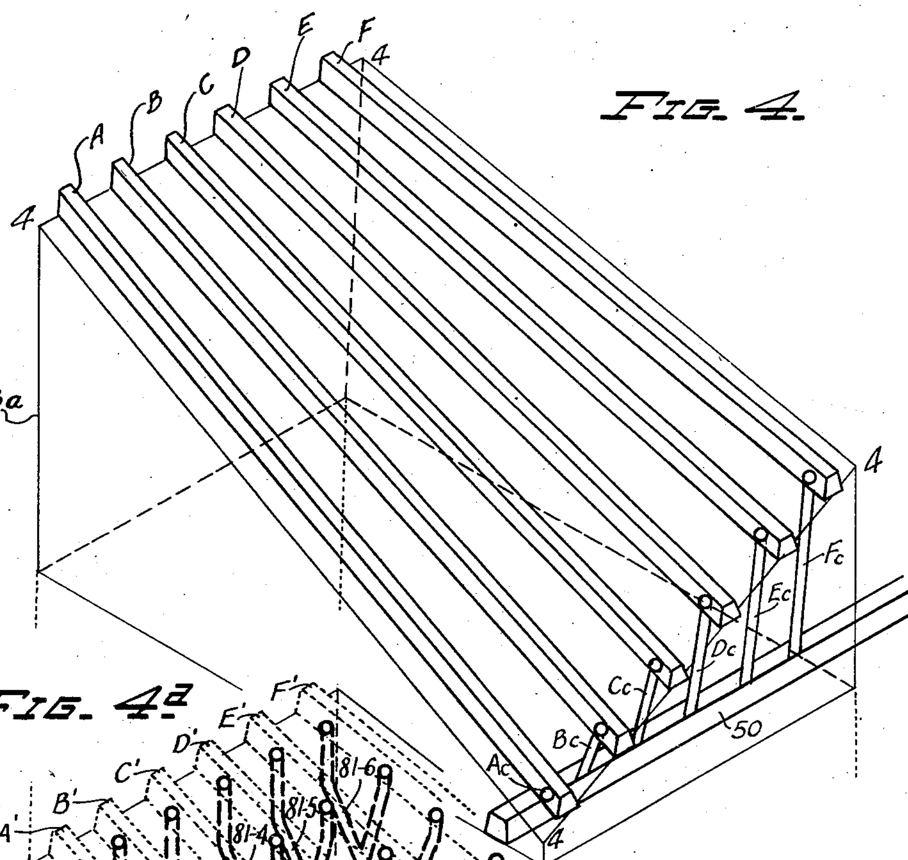
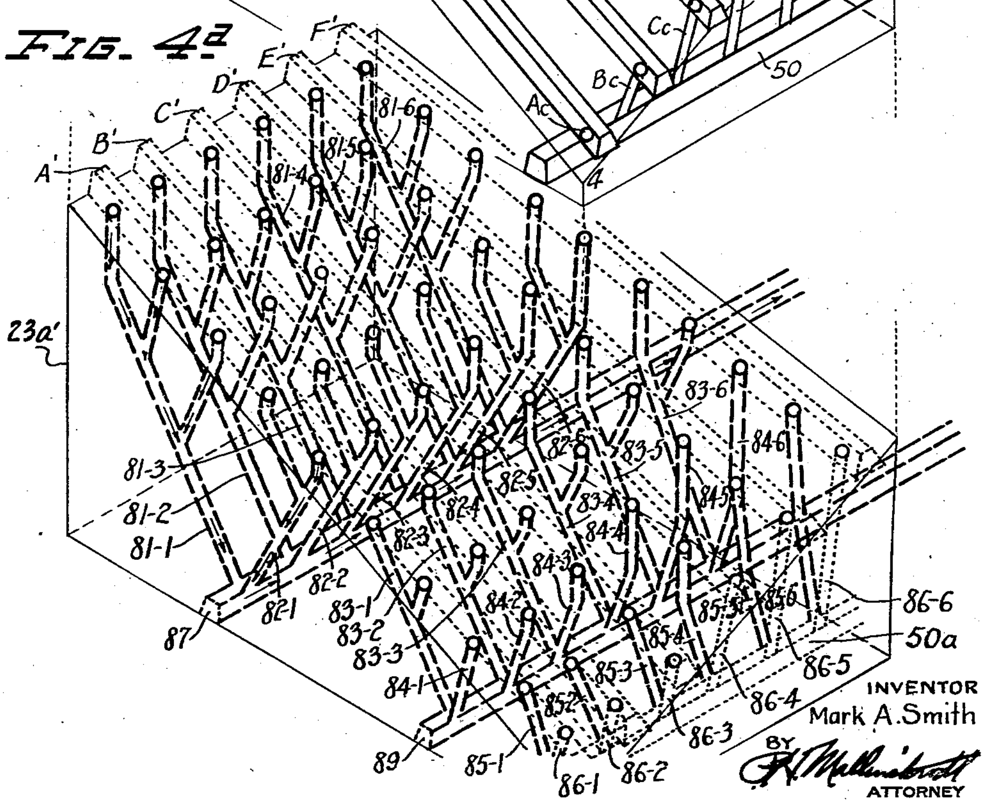


FIG. 4a

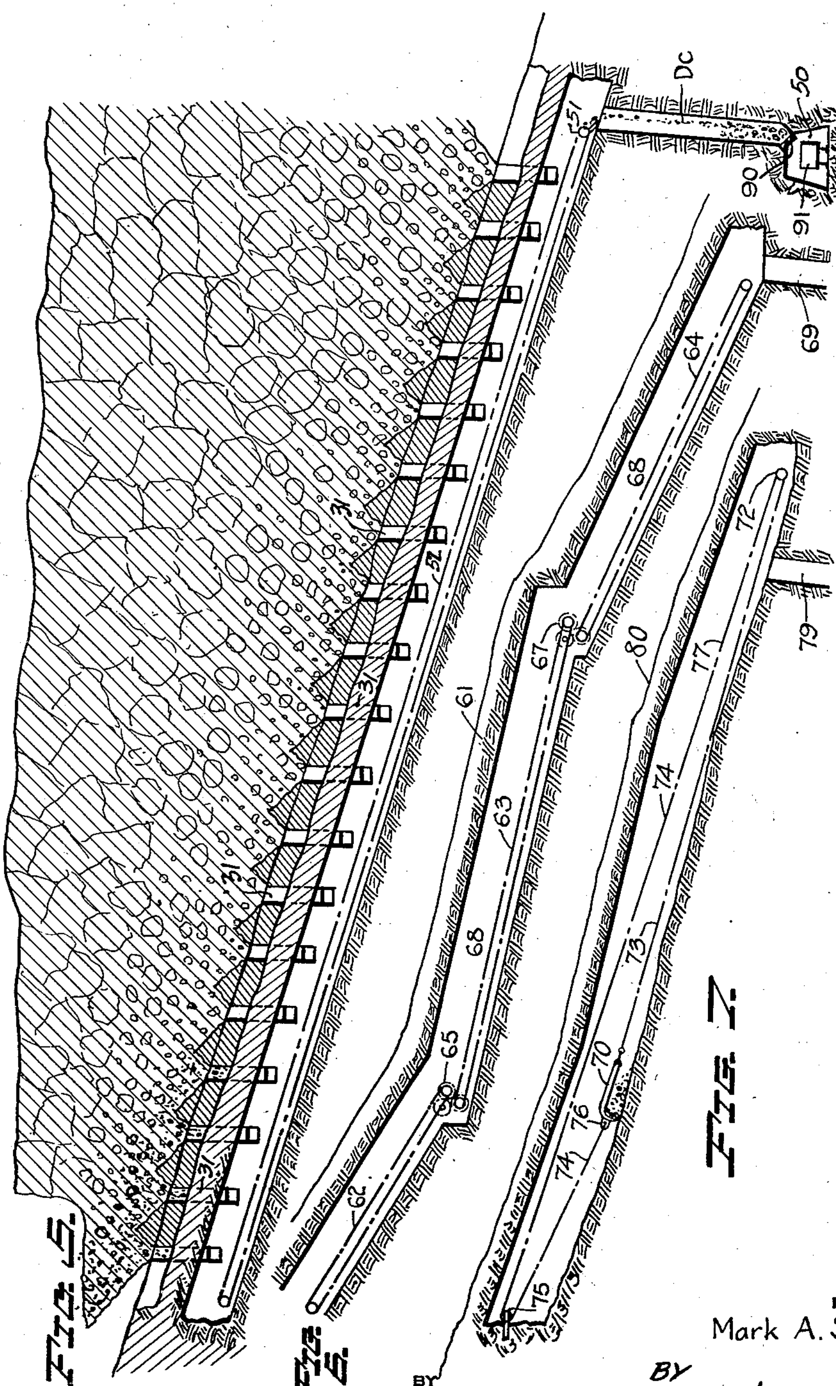


INVENTOR
Mark A. Smith
BY [signature]
ATTORNEY

Oct. 13, 1942. M. A. SMITH 2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941 6 Sheets-Sheet 4



INVENTOR
Mark A. Smith
BY
R. H. Mallinckrodt
ATTORNEY

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941 6 Sheets—Sheet 5

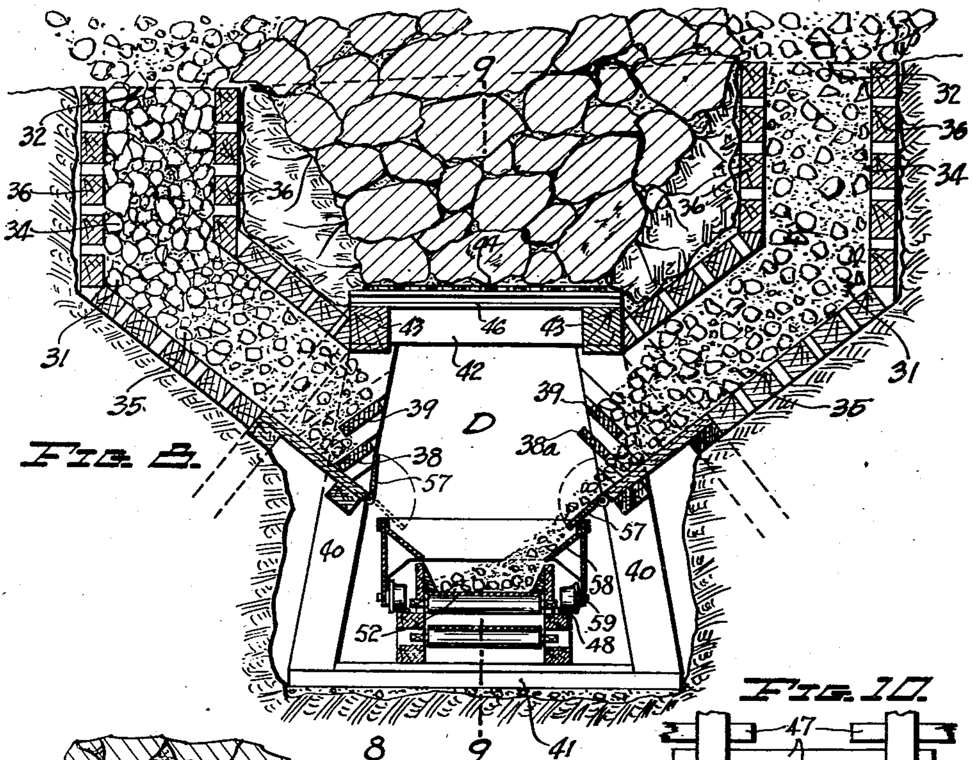


FIG. 8.

FIG. 10.

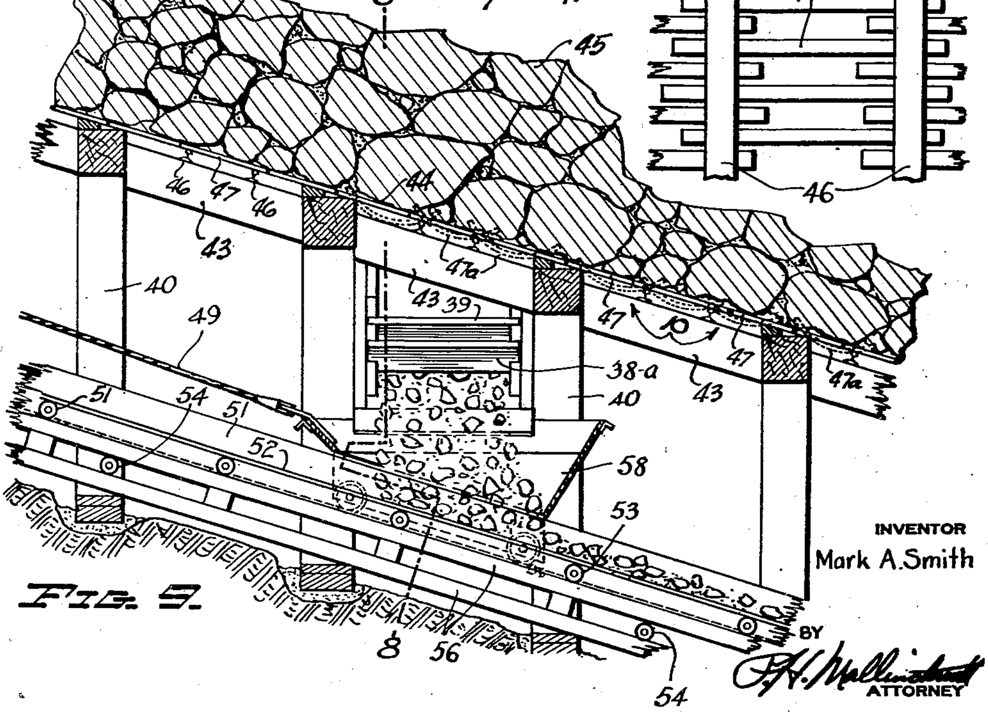


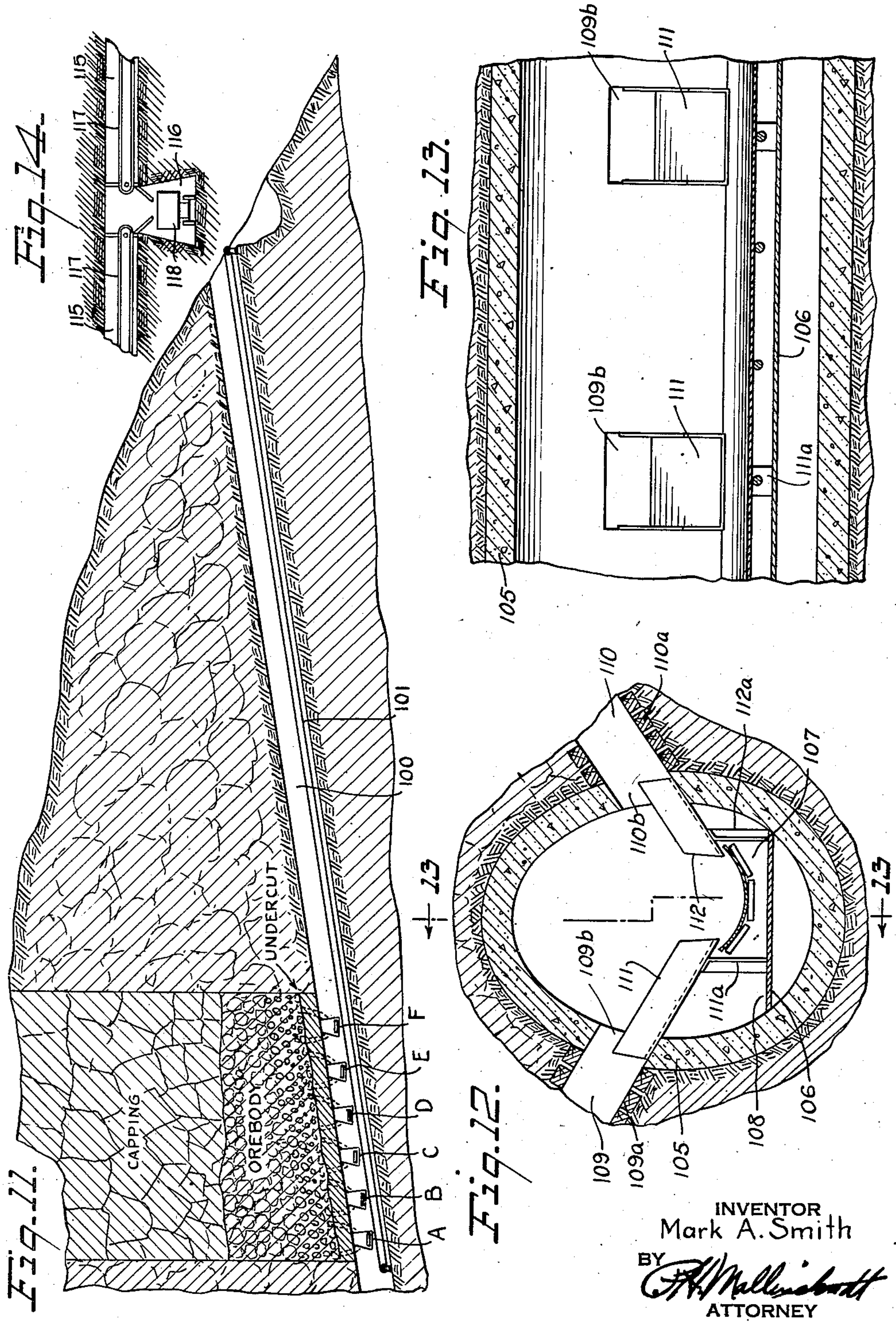
FIG. 9.

INVENTOR
Mark A. Smith
BY
P. H. Mallinckrodt
ATTORNEY

Oct. 13, 1942. M. A. SMITH 2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Filed March 15, 1941 6 Sheets-Sheet 6



INVENTOR
Mark A. Smith
BY
ATTORNEY

Patented Oct. 13, 1942

2,298,599

UNITED STATES PATENT OFFICE

2,298,599

BLOCK CAVE MINING METHOD AND PLANT

Mark A. Smith, Ruth, Nev.

Application March 15, 1941, Serial No. 383,528

16 Claims. (Cl. 262—1)

This invention relates to block cave mining methods and plants, and the present application constitutes a continuation in part of my co-pending application Serial Number 189,840, filed February 10, 1938, and entitled "Cave mining method and plant." This last-named application itself constitutes a continuation in part of my application Serial Number 17,660, filed April 22, 1935, and entitled "Method of mining."

Among the principal objects of the invention are:

To provide a method and plant whereby the draw of caved ore throughout an undercut body of ore may be controlled substantially as desired for eliminating undue pressure on the mining plant by the undercut and descending ore, thus considerably reducing the amount of repair work necessary, and considerably reducing the amount of waste capping mixed with the crushed, caved, and drawn ore, notably by reason of the fact that approximately a horizontal contact may be established and maintained between the top of caved ore and the overlying caved waste;

To reduce enormously, as compared with certain block cave mining methods now commonly employed, the amount of underground excavating necessary for extraction of the ore;

To provide for substantially paralleling the bottom contour of a body of ore with the cave mining operations, if desired, whereby practically all the ore is recovered without resort to customary "scavenger" mining operations following the cave mining of the main body of ore;

To expedite mining operations, thereby reducing materially the total time required to extract the ore from an underground ore body, and resulting in a quick release of invested capital;

To quickly locate points where repairs are necessary, and to provide facilities for promptly making such repairs; (*a*) because of the ease with which material and supplies are delivered to the point where needed; and, (*b*) because of the ease, certainty and rapidity with which caved material that tends to break through the proper restrictive bounds, is released;

To facilitate the breaking up of pillars of ore that may be left in undercutting operations, and the breaking up of large blocks of ore that often settle down on draw points;

To make the undercutting less expensive, faster, safer, and more thorough than has heretofore been possible;

Where churn drill data is incomplete or not conclusive, to follow the bottom contour of the ore to its limits, thus eliminating costly diamond drilling, long hole drilling, churn drilling, prospect raises, prospect drifts and the like;

To hasten the preparation of a block or panel of ore for mining;

To make block cave mining much safer than is possible with branch raising because (*a*) much less raising is required and (*b*) fingers can be blasted electrically, which is not practical in branch raising; and

To reduce total cave mining costs, per ton of ore produced, to a fraction of what they have been in standard practice heretofore.

Various advantages of the invention will appear as the description progresses, one being the ease with which thorough and natural ventilation of the underground workings may be accomplished, another, bringing supplies to the workings.

Block cave mining is distinguished from other types of cave mining by the fact that the ore is broken down by its own weight, or by the weight of overlying rock, or by a combination of both. This method of mining is especially applicable to operations conducted on a large scale in ore bodies of considerable size, but whose structure is comparatively soft and weak. Examples are the porphyry ores of Arizona and Nevada. Its application is not, however, limited thereto; it may be advantageously employed in connection with numerous other types of orebodies.

Block caving involves, in general, the dividing of the orebody into large, high blocks which are usually undercut one at a time and allowed to descend, i. e., cave, on the undercut area. The blocks are caved in proper order, and, under favorable conditions, the ore is crushed, as it descends, due to its own weight and the weight of the overburden or capping, into pieces of suitable sizes for handling. The settling and crushing require time, but the exact length of time varies with the nature of the material constituting the ore body. However, this is a cumulative process, and the rate at which the settling takes place is usually determined experimentally in each individual case. It is desirable in practice that caved ore be removed or drawn from the lower part of the caved portion of the orebody at approximately the rate of caving, so as not to impose extremely heavy stresses upon, and unduly pack, the lower portions of the ore body by the weight of the material above. Packing is objectionable because the ore is consolidated to such an extent that its normal removal becomes difficult or impossible, and results in enormous and often destructive stresses upon the workings below.

Heretofore, various methods of block cave mining have been developed, the one well known as "branch raising," and utilizing gravity chutes as the transporting means, being by far the most important and successful. The one known as "hand tramming," and utilizing hand pushed cars as the transporting means, is not extensively used, and in notable instances has been abandoned after limited use, as being unsuited for extensive operations. The ones known as the "motor haulage" and "modified motor haulage," which utilize self-propelled locomotives hauling cars on tracks as transporting means, have not proved satisfactory, and, for the most part, have been replaced by methods similar, in essential respects, to branch raising.

Pursuant to the present invention, the caved and drawn ore is mechanically conveyed, within the boundaries of a conveyor deck, which is disposed below the undercut and caving ore body, to a relatively localized ore removal zone, wherein the ore is removed from the conveyor deck. The mechanical conveying means may be of the continuous type, such as belt or shaker conveyors, which convey the caved and drawn ore in substantially continuous streams along the conveyor deck, or may be of the intermittent type, such as scraper or slusher conveyors, which scrape the caved and drawn ore along the conveyor deck in successive segregated quantities. The former type has been found to be particularly advantageous.

In the drawings, which illustrate certain mining operations embodying the invention:

Fig. 1 represents a fragmentary portion of the plat plan of an actual mining property, the plat being divided into typical panels or blocks, each of which, when equipped according to the provisions of the invention, may be considered a separate mining plant;

Fig. 2, a vertical section taken on the line **2—2** in Fig. 1;

Fig. 3, an isometric perspective, drawn to an enlarged scale, of the block cut out by four vertical planes indicated by the sides of the rectangle **3—3—3—3**, Fig. 1, and removed bodily, the portion in the foreground having been cut away to show various fragmentary portions of the interior of the block;

Fig. 4, an isometric perspective of that portion of the panel lying below the warped contact surface cutting through the lower part of the block, as indicated by the lines **4—4—4—4** in Fig. 3, drawn to an exaggerated scale, it being assumed that the warped surface coincides with the floor of the conveyor drifts;

Fig. 4A, a typical plant required for working the panel portion indicated in Fig. 4, by means of the branch-raise system; the dotted lines in Fig. 4A, represent for comparison, the plant of the invention;

Fig. 5, a vertical section lying largely in the surface indicated by the quadrilateral **5—5—5—5** in Fig. 3;

Fig. 6, a vertical section similar to Fig. 5, but indicating a conveyor drift following a differently undulating contact surface between an ore body and its underlying waste;

Fig. 7, still another vertical section similar to Fig. 5, but showing a conveyor drift in which is used a slusher dipper or scraper instead of a traveling conveyor;

Fig. 8, a detail of the section enclosed by the broken line **8** in Fig. 3, drawn to a scale greatly enlarged; this figure also represents a section taken on the line **8—8** in Fig. 9;

Fig. 9, a vertical section taken on the line **9—9** in Fig. 8;

Fig. 10, a fragmentary ceiling plan of the back of the conveyor drift, as indicated by the double-pointed curved arrow **10** in Fig. 9;

Fig. 11, a vertical section through a mining plant embodying further features of the invention;

Fig. 12, a vertical section through a conveyor drift of a special construction pursuant to the invention;

Fig. 13, a vertical section taken on the line **13—13** of Fig. 12 showing a fragmentary portion of the length of the conveyor drift of Fig. 12; and

Fig. 14, a fragmentary view in vertical section and on a considerably reduced scale, of a somewhat different type of conveyor-drift layout wherein a main haulage drift is run transversely across the several conveyor drifts, intermediate their lengths, and at a level slightly below the level of the conveyor deck.

Referring to the drawings, the numeral **20**, Fig. 1, indicates a portion of the natural surface of the mining property which is underlaid with a mineral deposit forming the ore body **21**, it being understood that the area has been previously prospected, as by means of churn or diamond drills, in a manner that is well known, and that the orebody has been revealed accordingly.

In developing a mining property by means of any block cave mining method, it is customary to divide the ore body into panels or blocks, such as **24** to **28**, Fig. 1, and to mine each block individually. The size of a block may vary within wide limits. The invention is applicable to all customary sizes, and is also applicable to much longer and higher, i. e., thicker, blocks than have heretofore been usual. A block, inclusive of the capping, several hundred feet high is usual in block caving.

According to the invention, passageways—here termed "conveyor drifts"—are driven adjacent the bottom of the block or ore to form a so-called "conveyor deck" which is substantially similar in area to the horizontal cross-sectional area of the block of ore, and which may, if found desirable in the particular instance, substantially parallel, i. e., follow, the contour of the bottom contact surface of the ore body. The conveyor deck may be substantially horizontal, or sloping as above indicated, and may be above, in substantial coincidence with, or below the bottom contact surface of the block of ore, and the conveyor drifts may be variously arranged thereon. Relatively short passages, i. e., finger raises, usually from 6 to 25 feet in length, are driven upwardly from the conveyor drifts at relatively closely spaced intervals along the lengths thereof, and the block is undercut and caved at the upper ends of these finger raises, above the conveyor deck. Mechanical conveying means, as distinguished from the usual tramming or haulage means heretofore employed, all as is discussed more fully hereinafter, are operatively disposed in the conveyor drifts for transporting the caved ore—as drawn from the finger raises—through the conveyor drifts to suitable disposal passages located within an ore-removal zone which is preferably localized at or along some one comparatively minor portion of the conveyor deck, see the ore-removal zone represented by the upper openings of the chutes Ac, Bc, Dc, Ec, and Fc, in Figs. 2, 4, and 5, and of the chutes 69 and 79 in Figs. 6 and 7, respectively.

To exemplify the invention, its application to mining the block 24 is set forth in the present drawings. For convenience, this block is assumed to be cut vertically by the planes 3—3—3—3, Fig. 1, and lifted out bodily for display, as shown in Fig. 3, the lower parts of the vertical cutting planes being located at the level 3a—3a, Figs. 2 and 3, which at the same time is coincident with the main haulageway.

The mining plant consists of the underground conveyor drifts, including the mechanical conveying means therein, the finger raises leading upwardly from the conveyor drifts, the undercut zone, which is directly above the conveyor deck, and the passageways for ore removal.

The contact surface 30, Figs. 2 and 3, between the lower part of the ore body 21 and the waste portion 23 beneath, and the contact surface 33 between the upper part of the ore body and the capping 22 above, may both be more or less clearly defined, and often are roughly undulating and warped in character. This means that the contact surfaces may and do often have many different degrees of slope in their various parts.

In opening the block 24 by means of the invention, conveyor drifts, such as those illustrated and indicated A to F, Figs. 3 and 4, are driven directly under the ore body portion 21a in its virgin state, the conveyor drifts being here located in close proximity to the lower contact surface 30, and, in the illustrated instance, but not necessarily, as nearly as practical in average parallelism therewith. The floors of the various conveyor drifts here lie in a warped, imaginary surface 4—4—4—4, which forms the "conveyor deck." Finger raises 31, Figs. 3, 5, and 8, are driven upwardly from the conveyor drifts, and undermining and subsequent caving of the ore body portion started in much the ordinary manner. This results in filling the finger raises with broken ore, which is drawn into the conveyor drifts and conveyed to the ore removal zone. The handling of the broken ore is peculiar to the method of the invention.

The intake openings 32, at the top of the finger raises, lie, as closely as it is possible to locate them, in the contact surface 30, and the finger raises lead downwardly into the respective conveyor drifts by means of vertical portions 34 and inclined portions 35. The intake openings are generally referred to as "draw points" and are preferably spaced apart from one another equally in two directions. As a result of practical experience, the spacing has been found to give satisfactory results at 15 feet, center to center. In the fragmentary portion 30a of the surface 30 in the foreground of Fig. 3, the draw openings are indicated by small circles for convenience. Actually, the draw openings are square because of the timbering 36, Fig. 8.

The discharge of ore from the fingers into the conveyor drift may be controlled by suitable closures, such as the louvre gates at the lower extremities of the fingers, as indicated in Fig. 8. The gates may consist of heavy boards 38 and 39, movable up and down in suitable guides in order to increase or decrease the flow of ore out of the respective finger raises as may be required. Since the draw points are spaced on 15 feet centers, each way, in the present example, the spacing of the conveyor drifts A to F, center to center of one another, naturally follows as being 30 feet, these figures, however, being largely arbitrary and possible of variation.

While the detailed showing in Figs. 8 and 9 refers specifically to conveyor drift D, Fig. 3, it is to be understood that the general arrangement of the timbering is similar in the remaining drifts, the only differences being such as are caused by the relatively different degrees of slope of the different conveyor drifts.

A usual and satisfactory way of defining the conveyor drifts may include timber sets composed of battered posts 40 resting on sills 41 and having the caps 42, the successive sets being connected together, at the top thereof, by girts 43 extending longitudinally of the drifts. Supporting the material 45, above the drift, is the back 44 thereof. The latter may consist of steel rails 46 extending from girt to girt crosswise of the drift. Spanning the rails 46 is a light and sensitive lagging means consisting, for example, of small wooden strips 47. The sensitive lagging plays an important part in the control of the caved, descending ore body, because as the pressure of the material on the back of the drift increases, the lagging gradually is distorted downwardly, as indicated approximately by the dotted curved lines 47a in Fig. 9. As the bending of the lagging increases, it indicates dangerously heavy loads, and gives the miners warning that the pressure must be relieved in order to safeguard the drift, and more especially the heavy timbering, against excessive crushing stresses and consequent destruction. Such destruction involves what are ordinarily known as major repairs, for reconstructing the drifts. The manner of accomplishing the necessary relief will presently be described in detail.

In order to convey the broken ore from the finger raises to the main haulageway 50, Figs. 1 to 5, mechanical conveying means, continuous or discontinuous, having large capacities capable of quickly moving their loads, are provided. In the instance of conveyor drift D, the conveying means may consist of a traveling belt conveyor 51, of any usual and suitable construction, including, in general, a traveling belt 52, carrying rollers 53, idlers 54, and a supporting framework 56. The exact nature of the conveying means may vary greatly, and may consist of any standard equipment furnished by manufacturers in the highly specialized field of conveying machinery. It may be stated that ordinary belt conveyors are successfully employed for inclinations up to approximately 18 degrees from the horizontal. Greater inclinations require other types of traveling conveyors, such, for example, as retarding pan conveyors.

In Figs. 8 and 9, broken ore from finger chutes 35 is shown as discharging by gravity from under a lower gate positioned at 38a, while the hinged flap 57 conducts the discharging ore into a traveling or floating hopper 58, which may be suitably spotted longitudinally along a conveyor drift in front of any particular finger raise gate, as shown.

The floating hopper may be provided with flanged wheels 59, which run on a track 48, the hopper being propelled downwardly by gravity, and upwardly, by a cable 49 extending to any usual and appropriate hoisting device (not shown) located at a suitable point in the drift. The hopper guides the ore directly onto the belt 52, which conveys the ore into the chute or raise, where it may be temporarily stored, and discharged through a suitable gate indicated at 90 into electrically propelled cars 91 or other carriers, which ply back and forth through the main haulageway 50, Fig. 5. The main haulageway may lead to a suitable exit such as a shaft 60, Fig. 1, through which the ore is hoisted to the outside surface by any usual hoisting apparatus (not shown). The shaft 60 is preferably located beyond the ore zone.

In cases where a contact surface such as 61, Fig. 6, between the ore and the waste, undulates considerably in the length of a mining panel or block, a series of traveling conveyor sections, 62, 63 and 64 in Fig. 6, may be resorted to in order to avoid objectionable depths of finger raises, it being understood that the undulating drift 68 is provided with finger raises (not shown in this figure) extending downwardly from the contact surface 61, and spaced apart from one another after the manner already described. The conveyor sections 62, 63 and 64 may be geared together at the points 65 and 67, and be driven from any suitable source (not shown) in any customary manner. The conveyor section 64 may discharge into a chute or raise 69, leading to a main haulageway, as previously described herein.

In many cases where the conditions warrant, and the conveyor drifts are not too long, a so-called slusher system of conveying the ore may be employed. Such a system is indicated in Fig. 7, where a slusher dipper 70, having the blade 71, is operated by means of an air tugger 72. A tugger rope 73, attached at one end thereof to the dipper 70, extends to the tugger for pulling down the loads, while a tail rope 74 extends from the tugger around a snatch block 75, down to the back of the dipper at 76.

In the slusher system, the ore discharged through finger gates (not shown in this figure, but which may be similar to those shown in Figs. 8 and 9) falls to the bottom 78 of the drift, and is dragged therealong by the dipper until the discharge chute 79 is reached. Here, the ore drops down into the customary haulageway (not shown). In cases where the slusher apparatus is used, it is to be noted that the conveyor drift 77 may follow the contact surface 80 at the bottom of an ore body, just as closely as do the traveling conveyors hereinbefore described.

Reverting to a feature of the invention as hereinbefore touched upon, the manner in which major repairs may be avoided by watching for danger signals in the lagging 47, Figs. 8 and 9, is to be noted. Elaborating upon this feature, it may be stated that when any lagging members become unduly distorted, the floating hopper may be spotted directly underneath, while the workmen deliberately break out the lagging, a little at a time, and let the burden drop into the hopper to be immediately carried away by the conveyor. Large lumps resting on the lagging, may be broken up by means of bars or the moderate use of explosives. After the relief is accomplished, new lagging strips are easily inserted. The relief measure on the back of a conveyor drift is particularly desirable in mining soft porphyry ores which break into comparatively small, individual masses, as indicated in the figures. In the case of a harder rock formation, the lagging relief may not be needed, since such a material usually retains its original compactness over the back of a drift.

The novel relation which an underground plant of the invention bears to an underground plant embodying the best practice of the usual branch raise system, is made clear by reference to Figs. 4 and 4A, where the salient excavation features of each plant are set forth separately, as applied to cave mining the ore body of block 24.

The upper part 23*a* of Fig. 4 represents the waste portion of the block 24 relative to the conveyor drifts A to F with their depending chutes Ac to Fc, which lead into the main haulageway 50. The reference character 23*a'* of Fig. 4A indicates the same waste portion relative to the raises, grizzly drifts and main haulageways of the branch raise system, some of the parts being shown in heavy, broken lines, and others in lighter dotted lines, for a purpose that will presently appear.

Spaced apart from each other across the waste portion 23*a'*, are six main raises 81—1, 82—2 and so on; also six main raises 82—1, 82—2, and so on; all with their respective upwardly extending branches, as shown. Similarly spaced, are main raises 83—1, 83—2, and so on, each with one branch; also raises 84—1, 84—2, and so on; also raises 85—1, 85—2, and so on; and raises 86—1, 86—2, and so on. The top of each main raise, branch raise and raise, where it opens into the respective grizzly drift, A', B', C', D', E', or F', is indicated by a small circle. Each of these openings is served by four draw fingers similar and corresponding to those shown at 32, Fig. 3. The main branches 81—1 to 81—6, and 82—1 to 82—6, at their lower extremities empty into a main haulageway 87, while the main raises 83—1 to 83—6, and raises 84—1 to 84—6, empty into another main haulageway 89. Similarly, raises 85—1 to 85—6 and 86—1 to 86—6 empty into still another main haulageway 50*a*. Now, the grizzly drifts A' to F' correspond almost exactly to conveyor drifts A to F; raises 86—1 to 86—6 correspond to chutes Ac to Fc, and main haulageway 50*a* corresponds exactly to haulageway 50. Hence, assuming that the grizzly drifts A' to F', raises 86—1 to 86—6, and haulageway 50*a*, indicated in light dotted lines, could be detached from the parts indicated in heavy broken lines, and lifted bodily into 23*a*, the parts in light dotted lines practically coincide with the parts of the invention plant. In other words, since the cost of the equivalent parts is substantially the same in each instance, it follows that the main raises with their branches, as well as raises 84—1 to 84—6, and 85—1 to 85—6, and the two main haulages 87 and 89 are one and all thrown into the discard, and, in the case of a new plant, their cost saved by means of the invention.

It may be stated that the layout at 23*a'* was designed by an engineer whose everyday work has for many years had to do with the branch raise system. The estimated cost of this plant, using standard unit prices, is as follows:

540 feet of haulage drift @ $30.00	$16,200.00
4600 feet of raising @ $17.00	78,200.00
2135 feet of grizzly drift @ $15.00	32,025.00
	$126,425.00

The estimate cost of the plant of the invention at 23*a*, is as follows:

180 feet of haulage drift @ $30.00	$5,400.00
400 feet of raising (chutes Ac to Fc) @ $17.00	6,800.00
2135 feet of conveyor drift @ $15.00	32,025.00
	$44,225.00

This represents a saving in capital plant investment in favor of the invention, of $82,200.00. As soon as the ore body becomes exhausted, the underground passages in both cases are abandoned, and no part of the capital investment can be salvaged. The relative maintenance costs of the two systems as reflected in actual service records, show even a greater contrast.

Frequently, it is possible to advantageously change a branch raise plant over to one of the invention, by simply installing the proper conveying means in the grizzly drifts of the former, provided such grizzly drifts are favorably located.

Standard branch raise statistics show that costs become prohibitive at points where the bottom of the ore body is more than 200 feet above the main haulage level. With the system of the invention, this height may be exceeded indefinitely.

In the case of the invention, as in all cave mining, it is desirable that the width of a caving block be limited as a rule to 200 feet or less, owing to the arching support that the caved ore obtains from the side walls, but the length of the block is limited only by the practicable length of the conveying means. The length of a branch raise is limited by the angle at which the ore body is disposed with the horizontal, so, the greater the angle, the less the length, because the height of the ore above the haulage level is limited, as just previously stated.

It is to be noted that ore in caving has a definite rate of descent, which varies, however, from time to time in the same ore depending on conditions, and also varies in ores of different structures with regard to degrees of hardness. A main purpose of the invention is to draw the ore at a controlled rate, usually as nearly as possible at the rate of its descent. This does not mean however, that the drawing continues in a constant stream over an entire period of time, but rather, that certain amounts of ore must be drawn in certain unit times. For example, if an ore is of such a nature that the amount of the draw should be taken every 24 hours, then the unit of time is 24 hours, but all the drawing may take place in one shift of 8 hours of the 24. Likewise, if the unit is three days, then the drawing may take place in one day. In this way, sufficient time is provided between shifts of drawing for making routine repairs. An important thing is that the conveyors have the capacity to move their requisite amount of material in the unit time or its proper fractional part.

From the standpoint of control in drawing the caved ore, the invention makes possible a much greater degree of control than has hitherto been possible. The actual drawing of the ore will, however, depend upon the requirements in the particular instance as determined by competent engineers, the draw always being under a supervised control.

In Fig. 11 is illustrated a form of the invention wherein the conveyor drifts—here, as in the prior figures, indicated A, B, C, D, E, and F—communicate directly with a main haulageway **100**, which slopes gradually upward to the surface. The layout of the conveyor drifts, forming a so-called conveyor deck, may be such as is illustrated in the prior figures, although other satisfactory layouts, within the generic purview of the invention, may be employed.

The main haulageway **100** extends transversely across the width of the conveyor deck, preferably, but not necessarily, at one end thereof, the several conveyor drifts directly intersecting the same, and then slopes gradually upwardly to the surface. Mechanical conveying means are positioned along the length of the main haulageway for receiving the ore which is drawn from the finger raises (not shown) of the several conveyor drifts, A, B, C, D, E, and F, and which is conveyed to the localized zone of conveyor drift and main haulageway intersections.

It is preferable that the bottom of the main haulageway **100** be at a slightly lower level than the bottoms of the several conveyor drifts A, B, C, D, E, and F, so that the mechanical conveying means, of whichever type, continuous or discontinuous, found suitable in the particular instance, and operative in the stated conveyor drifts will be at a higher level than the mechanical conveying means operative in the main haulageway **100**. The grade of ascent of the haulageway **100** must, of course, be determined in accordance with the operative characteristics of the conveying means employed.

In most instances, the length of the main haulageway will necessarily be long in order to reach the surface along a gradual incline. In such instances, a continuous type of mechanical conveying means, such as belt or shaker conveyors, should be employed. As illustrated, several belt conveyor units, each indicated **101**, are indicated as collectively extending the length of the main haulageway **100**, one discharging onto the next advanced, etc. It is preferable that the grade not exceed eighteen per cent (18%) in this instance. Other types of endless conveyors, such as bucket and retarding pan conveyors, may, however, be employed for operating along a greater angle of ascent.

In special instances, the surface contour of the earth relative to the ore body may make it possible to utilize a main haulageway extending substantially horizontally, that is, without upward incline, or, such condition may make it possible to make the main haulageway comparatively short, i. e., less than 200 feet. In all such instances, the continuous type of mechanical conveying means, such as belt or shaker conveyors, should be employed, although, where the main haulageway is comparatively short, the discontinuous type of mechanical conveying means, such as slushers, may be used if desired.

In Figure 12 is illustrated a conveyor drift construction in the form of a tube provided by a pipe-like shell of reinforced concrete. Such drift construction is especially advantageous in connection with the method and plant of the invention, since the individual drifts may be made much smaller in cross section than would otherwise be the case. In soft ground, where it is desired to follow the bottom contact surface of the ore body, and where that bottom contact surface is of an undulating character, or pitches sharply either upwardly or downwardly, this type of conveyor drift construction may be the only practical type, since the usual timbering has been found impractical in particular instance of this kind.

The reinforced concrete shell **105** may be installed by well known methods of construction. It preferably has a transverse cross section which tapers arcuately upwardly, substantially as illustrated, for increasing its resistance to the load of the caving ore body. A floor **106**, of any suitable material, such as wooden planking, may be laid at the bottom of the tube and along the length thereof.

In this embodiment of the invention, only the continuous type of mechanical conveying means, e. g., belt and shaker conveyors, are practical. As in the instance of the illustrated belt conveyor 107, such mechanical conveying means are preferably disposed adjacent one side wall of the tube, leaving a walk 108 for miners along the other side wall.

Finger raises. indicated 109 and 110, communicate with the tube along the length thereof. As in the conventional drift construction, timber cribbing 109a and 110a, respectively, may lead into the respective apertures 109b and 110b provided in the reinforced concrete walls of the shell.

For conducting the caved ore directly to the conveyor 107 during the drawing operation, individual portable chutes 111 and 112, desirably of sheet metal, and having the supporting legs 111a and 112a, respectively, may be removably placed between the apertures 109b and 110b, respectively, and the conveyor 107, the respective supporting legs 111a and 112a resting on the planking 108 and the upper part of the chutes resting in their respective apertures.

In the construction of the tube, as above described, it may be found desirable to form the walls of sections of steel plate, together with suitable reinforcing pieces, and either with or without a cementitious grouting placed between the outer walls of the shell and the earth materials through which it extends. Regardless of the particular construction of the tube per se, however, the remainder of the plant will be substantially as described above.

It has been convenient to describe the general characteristics of block cave mining specifically in connection with the specific embodiments of the invention here illustrated. It should be realized, however, that whatever particular dimensions and particular procedures, relating to the art in general, are set forth, are merely explanatory in nature. The invention is not to be limited thereby, for the invention, as set forth in the claims hereof, may be employed in connection with any general block cave mining procedure found practical in particular instances.

The general layout of conveyor drifts constituting the conveyor deck may be varied considerably to adapt the system to particular instances of use, as may, also, the disposition of the ore-removal zone relative to the conveyor deck. As shown in Fig. 14, the conveyor drifts 115, making up the conveyor deck, intersect the upper part of a transversely extending haulage drift 116, which is driven at a slightly lower level than the conveyor deck. The mechanical conveyors 117, here shown as of the endless belt type, discharge directly into the cars 118 of the ore-removal system, which, it should be noted, occupies a zone of minor extent as compared to the extent of the conveyor deck.

Whereas the invention is illustrated and described with respect to preferred embodiments thereof, many changes may be made without departing from the spirit and scope of the invention as set forth in the claims that here follow.

I claim:

1. A block cave mining plant comprising an ore body having a caving ore zone of relatively great length therein, a conveyor deck substantially parallel to the bottom surface of the caving zone, and a plurality of conveyor drifts spaced apart from one another side-by-side on the conveyor deck and extending along substantially the length thereof; mechanical conveying means disposed in each of the said conveyor drifts, for operation along substantially the length thereof, means operative to feed ore from the caving zone to the said conveyors, and disposal means positioned to receive the ore discharged from the said mechanical conveying means; the said mechanical conveying means having a capacity at least so large that the tonnage of ore conveyed from the loading points in the loading zone, to the disposal means, in unit time, is at least equal to the tonnage rate of caving in the caving zone in the same unit time.

2. A cave mining plant associated with an underground block of ore, comprising a plurality of conveyor drifts disposed relatively closely side-by-side and extending along substantially the length of the block on a conveyor deck which is located in close proximity to and substantially parallel with the lower contact surface of said block of ore; a plurality of mechanical conveyors operatively disposed in the respective conveyor drifts; means operative to transfer caved ore onto the respective mechanical conveyors at rates at least equal to the rate of descent of the caved ore respectively tributary thereto; the mechanical conveyors being capable of transporting their respective quantities of transferred ore at least at the same respective rates at which the ore is transferred to them; and main haulage means disposed to receive the loads discharged by the respective mechanical conveyors.

3. A method of block cave mining comprising driving a plurality of conveyor drifts side-by-side along relatively great length adjacent the bottom surface of an ore body and substantially parallel therewith; disposing mechanical conveying means in and along the conveyor drifts; caving the ore; drawing the caved ore into the conveyor drifts along the lengths thereof and supplying said ore to said mechanical conveying means at a rate which is substantially no less than the tonnage rate of descent of the caved ore; mechanically conveying the caved and drawn ore through the conveyor drifts at a rate which is substantially no less than the tonnage rate of descent of the caved ore; and discharging from the conveyor drifts the said caved and drawn ore which is conveyed therethrough.

4. A method of block cave mining comprising driving a plurality of conveyor drifts side-by-side along relatively great length adjacent the bottom surface of an ore body and substantially parallel therewith; disposing mechanical conveyors in and along the conveyor drifts; caving the ore; drawing the caved ore into the conveyor drifts along the lengths thereof and onto the said mechanical conveyors at a rate which is substantially no less than the rate of descent of the caved ore; conveying the caved and drawn ore through the conveyor drifts at a rate which is substantially no less than the rate of descent of the caved ore; and discharging from the conveyor drifts the said caved and drawn ore which is conveyed therethrough.

5. A mining plant for block cave mining, comprising an undercut area in an ore body; conveyor drifts disposed directly below said undercut area and extending transversely of the vertical dimension of said ore body, each of said conveyor drifts having continuous, reinforced walls forming a continuously reinforced hollow tube which is approximately circular in right cross-

section and is considerably smaller in right cross-section than corresponding drifts customarily employed in mining of the said type; apertures formed through said walls at relatively closely spaced intervals along the lengths of said conveyor drifts; finger raises leading upwardly from said apertures to said undercut area; continuous type mechanical conveyors positioned within said conveyor drifts and extending along the lengths thereof; and chute means leading from said apertures to the receiving surfaces of said continuous type mechanical conveyors.

6. A mining plant for block cave mining, comprising an undercut area in an ore body; conveyor drifts disposed directly below said undercut area and extending transversely of the vertical dimension of said ore body, each of said conveyor drifts having continuous walls of reinforced concrete forming a continuously reinforced hollow tube which is approximately circular in right cross-section and is considerably smaller in right cross-section than corresponding drifts customarily employed in mining of the said type; apertures formed through said walls at relatively closely spaced intervals along the lengths of said conveyor drifts; finger raises leading upwardly from said apertures to said undercut area; continuous type mechanical conveyors positioned within said conveyor drifts and extending along the lengths thereof; and chute means leading from said apertures to the receiving surfaces of said continuous type mechanical conveyors.

7. A method of block cave mining, comprising driving a plurality of conveyor drifts beneath a block of ore to form a conveyor deck substantially coextensive, horizontally, with the said block; driving finger raises upwardly from the conveyor drifts and at relatively closely spaced intervals along the lengths thereof; establishing an ore-removal zone which extends over only a minor portion of said conveyor deck; positioning mechanical conveying means within the conveyor drifts; undercutting the said block from the upper portions of the finger raises for caving the block; drawing the caved ore through as many of the finger raises as required, wherever located, when and for as long a period as required, and at whatever rates of speed required for properly controlling the caving of said block and for preventing excessive weight from developing upon the conveyor drifts; supplying the drawn ore to said mechanical conveying means; and conveying the drawn ore along the lengths of the conveyor drifts to said ore-removal zone, for discharge, by operation of said mechanical conveying means, the said supplying and the said conveying being accomplished at rates of speed such that the caving of said block may be properly controlled and excessive weight may be prevented from developing upon the conveyor drifts.

8. A method of block cave mining, comprising driving a plurality of conveyor drifts beneath a block of ore to form a conveyor deck substantially coextensive, horizontally, with the said block; driving finger raises upwardly from the conveyor drifts and at relatively closely spaced intervals along the lengths thereof; establishing an ore-removal zone which extends over only a minor portion of said conveyor deck; positioning mechanical scraper conveyors within the conveyor drifts; undercutting the said block from the upper portions of said finger raises for caving the block; drawing the caved ore into the respective conveyor drifts and onto the floors thereof through as many of the finger raises as required, wherever located, when and for as long a period as required, and at whatever rates of speed required for properly controlling the caving of said block and for preventing excessive weight from developing upon the conveyor drifts; and mechanically scraping the drawn ore along the said floors of the conveyor drifts to the said ore-removal zone for disposal, the said scraping being carried out at rates of speed such that the caving of said block may be properly controlled and excessive weight may be prevented from developing upon the conveyor drifts.

9. A method of block cave mining, comprising driving a plurality of conveyor drifts beneath a block of ore to form a conveyor deck substantially coextensive, horizontally, with the said block; driving finger raises upwardly from the conveyor drifts and at relatively closely spaced intervals along the lengths thereof; establishing an ore-removal zone which extends over only a minor portion of said conveyor deck; positioning continuous type mechanical conveyors within the conveyor drifts to form substantially continuous conveying surfaces along the lengths of the respective conveyor drifts; undercutting the said block from the upper portions of the finger raises for caving the block; drawing the caved ore into the respective conveyor drifts and onto the conveying surfaces of said mechanical conveyors through as many of the finger raises as required, wherever located, when and for as long a period as required, and at whatever rates of speed required for properly controlling the caving of said block and for preventing excessive weight from developing upon the conveyor drifts; and moving said conveying surfaces for conveying the drawn ore to the said ore-removal zone for disposal, the said conveying being carried out at such rates of speed that the caving of said block may be properly controlled and excessive weight may be prevented from developing upon the conveyor drifts.

10. A block cave mining plant, comprising a plurality of conveyor drifts disposed beneath a block of ore to be caved and forming a conveyor deck which extends substantially coextensive, horizontally, with the said block; and undercut area disposed substantially directly above the conveyor deck; a plurality of finger raises leading upwardly from the conveyor drifts to said undercut area at relatively closely spaced intervals along the lengths of the conveyor drifts; ore-removal passage means intersecting the respective conveyor drifts within an ore-removal zone which extends over only a minor portion of said conveyor deck; and mechanical conveying means operatively positioned within said conveyor drifts and adapted to convey ore, which is drawn from the finger raises along the lengths of the conveyor drifts, to ore-removal passage means for disposal at controlled rates which are substantially no less than the natural rate of descent of the caved ore.

11. A block cave mining plant as recited in claim 10, wherein the mechanical conveying means positioned within the conveyor drifts are scraper conveyors adapted to scrape drawn ore along the lengths of the respective conveyor drifts to discharge at the ore-removal passage means.

12. A block cave mining plant as recited in claim 10, wherein the mechanical conveying means positioned within the conveyor drifts are of the continuous type and extend substantially continuously along the lengths of the respective

conveyor drifts to discharge at the ore-removal passage means.

13. A block cave mining plant as recited in claim 10, wherein the ore-removal passage means constitutes a main conveyor drift which extends transversely across the plurality of conveyor drifts and on out to the surface, and wherein mechanical conveying means are operatively disposed in said main conveyor drift for conveying the ore discharged from said plurality of conveyor drifts to the said surface.

14. In block cave mining practice wherein a body of ore is undercut over a considerable transverse area thereof and caused to cave, the method of extracting the caved ore which comprises, drawing the caved ore from the undercut to below the undercut substantially throughout the said transverse area, and moving the drawn caved ore, by mechanical conveying means, from where the ore is drawn to a zone of ore removal which extends over only a minor portion of the said transverse area of the body of ore, the said moving of the drawn caved ore being carried out transversely of the said body of ore throughout an area substantially commensurate with and disposed below the said transverse area of the undercut, the said mechanical conveying means operating along paths which are relatively closely spaced and of considerable lengths, and the said drawing of the caved ore and the said moving of the drawn caved ore being at controlled rates such that the body of ore caves uniformly and that the caved ore is extracted at a rate which is substantially no less than the natural rate of descent of the caved body of ore.

15. In block cave mining practice, the method of extracting the caved ore as recited in claim 14, wherein the mechanical conveying means are scraper conveyors.

16. In block cave mining practice, the method of extracting the caved ore as recited in claim 14, wherein the mechanical conveying means are of the continuous type.

MARK A. SMITH.