Aug. 5, 1958 P. B. BUCKY 2,846,205

MINING METHOD FOR SUPPORTING GEOLOGICAL STRUCTURES

Filed April 19, 1952 3 Sheets-Sheet 1

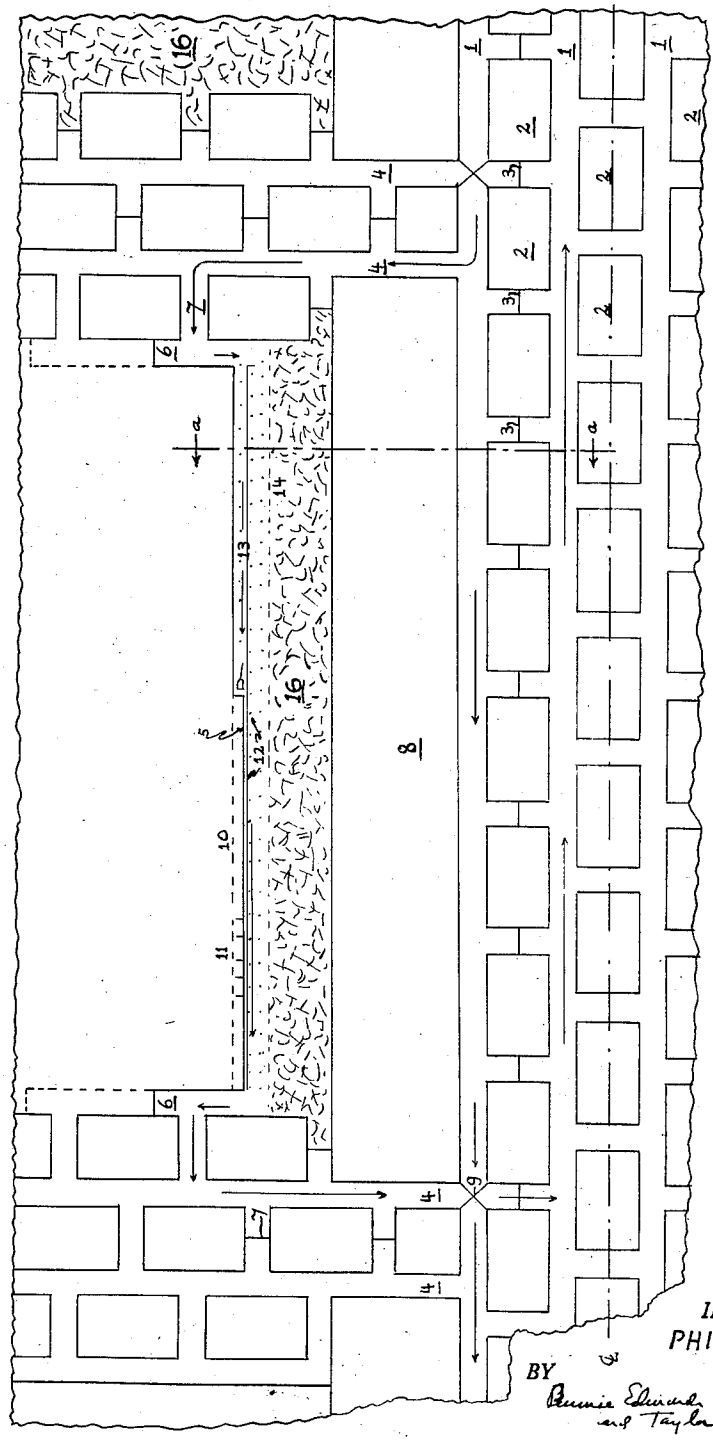


Fig. 1

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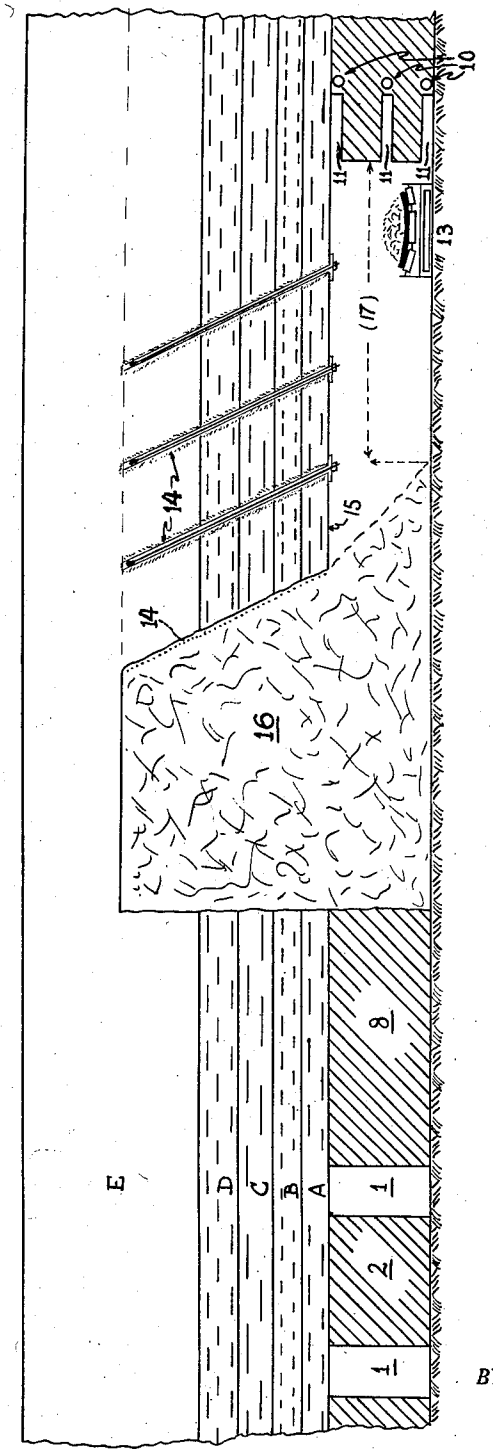


Fig. 2

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MINING METHOD FOR SUPPORTING GEOLOGICAL STRUCTURES

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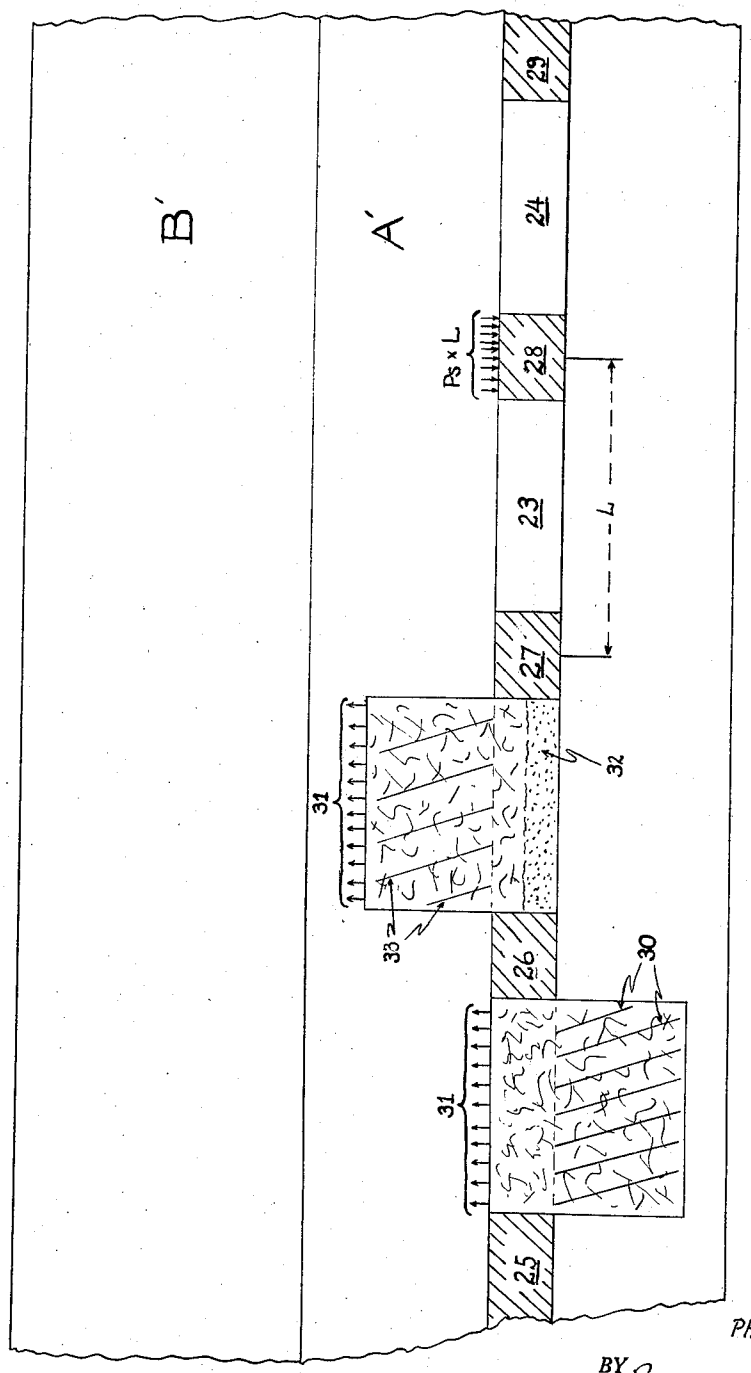


Fig. 3

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MINING METHOD FOR SUPPORTING GEOLOGICAL STRUCTURES

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2 Claims. (Cl. 262—1)

This invention relates to an improved method for supporting geologic structures overlying or adjacent to underground mines or other openings. Essentially the new method, which I have termed "geofragmental support," involves explosively fragmenting (or by equivalent means expanding) a sufficient amount of rock adjacent to the boundaries of the opening so that such rock after being thus expanded is capable of filling and becoming tightly packed into both the opening and the space the rock originally occupied prior to being fragmented or otherwise expanded, and packing the fragmented rock into the opening by the force of the fragmenting explosion or other expanding process.

Experience and history indicate that in the future an increasing proportion of our workable orebodies will be at increasing depths, that the earth's surface is becoming increasingly valuable for living space and agricultural purposes, and that the amount of minerals available per man is decreasing as his demands therefor increase. It therefore becomes increasingly important for those primarily concerned with underground mining to endeavor to find ways and means of mining or extracting minerals from the earth's crust which shall:

(1) Increase the depths at which mining may be carried on;
(2) Provide for the conservation of our mineral resources by
  (*a*) Increasing the percentage of extraction from each orebody mined, and
  (*b*) Mining in such a manner as will result in no harmful effects to other orebodies contained in the same or an adjacent geologic structure; and
(3) Provide for minimum stress and deformation effects at the surface of the ground and in any structures located thereon.

The effect of depth.—As mining depths increase, the load supported by pillars of ore increases and consequently a greater portion of the orebody must be left to support workings while men are there engaged. Artificial support in the form of fill, timber, steel, etc., is in many cases insufficient, in others uneconomic, and in some cases a sheer waste because it is ineffectual. In addition, at considerable depths we are faced with the problem of rock bursts, where the rock in pillars bursts with explosive force because of the great loads which the pillars carry—such bursts sometimes have disastrous effects on men, equipment, and workings. The problem of finding an effective and economic procedure for overcoming rock bursts is among the most pressing of the problems facing the mining industry to-day.

Conservation of mineral resources.—As previously indicated, the greater the mine depth, the more pillars of ore must be left to support shafts, working places and conveyance openings. The result is that at great depths the percentage of orebody extraction is lowered and considerable expenditures are incurred for additional support, for accident and rock bursts insurance, and for labor.

In addition, pillar and roof failures result in distortion and deformation of the adjacent geologic structure, with effects on the other orebodies therein that increase the difficulty of mining them and decrease the percentage of extraction that may be expected from them.

Surface effects.—In highly industrialized areas, in cities and towns, and in agricultural areas, the mining of large orebodies results in disturbing effects on surface topography. Our highly industrialized coal region at Scranton and Wilkes-Barre are illustrative. Surface effects may be minimized at present by the wasteful practice of leaving a high percentage of the ore in pillars for support, or by expensive support methods such as the use of waste fill or timber or steel supports, but even these costly expedients often are not fully effective.

The geofragmental support method of the present invention offers an attractive and effective solution to the foregoing problems in many different specific instances. The new method of providing support to geologic structures overlying or adjacent to an underground opening, in its most generally adaptable and most useful form, comprises explosively fragmenting a portion of the country rock bordering on said opening, the extent of such fragmentation being sufficient to expand the volume of the fragmented rock enough at least to equal the combined volume of said opening plus the volume occupied by such rock prior to its fragmentation, and delivering the fragmented rock into the opening by the force of the fragmenting explosion, so that it exerts force against and supports the unbroken geologic formation surrounding the opening without withdrawing support from the unbroken geologic formation surrounding the space whence the fragmented rock was derived.

Since in general explosive fragmentation of solid rock increases its volume to about one and one-half times the original volume, it is the general practice in accordance with this invention to fragment by explosive means a volume of solid rock that is about twice as great as the volume of the underground opening to be filled. When the fragmented rock is suitably confined, its compressive strength approaches that of the solid. Its effectiveness in providing support to surrounding geologic structures is therefore substantially equal to that of solid rock.

It is not essential, in accordance with the invention, that a large underground opening be completely filled at one time, in order to provide effective support to the surrounding structures. Instead, a portion only of the opening may be filled at one time. Packing of the fragmented rock back of its exposed face in the opening provides effective support for the structures against which such packing takes place; even though the exposed face of the fragmented material is not itself confined, the mass of the fragmented material just back of such face serves to confine the broken rock still farther back, and so enables it to provide effective support to the structures with which it is in contact, at least for a considerable period of time. Eventually a further part of the opening adjacent the exposed face of fragmented rock may be filled with additional fragmented material, and so confine the previously exposed face.

The new geofragmental support method may be applied in a variety of ways. Large underground rooms may be filled and the overlying geologic structures may be supported by blasting rock from the roof, the ribs, or from the floor into the room, the amount of rock blasted being sufficient to expand, due to fragmentation, enough to fill tightly both the room itself and the space occupied by the blasted rock prior to fragmentation. Stopes and drifts may be filled by blasting in the same manner. If waste fill is readily available, the opening may be partly or substantially wholly filled with such waste by conventional methods, and then a relatively small volume of

rock bordering on the opening may be fragmented by blasting to fill the remainder of the opening and pack tightly against the fill. Or alternatively, the fill itself may, if coarse, be further fragmented by blasting, in order to expand it tightly against the walls of the opening.

The foregoing and other features of the invention, and advantageous embodiments of the invention in improved mining methods, are described below with particular reference to the accompanying drawings, in which

Fig. 1 is a plan view of a mining operation utilizing a modified room and pillar mining method to extract mineral from a substantially horizontal bed or seam;

Fig. 2 is a cross section, on an exaggerated scale, taken substantially along the line *a*—*a* of Fig. 1; and

Fig. 3 is a vertical section through a deep mining operation showing an adaptation of the new geofragmental support method to the control of rock bursts.

In Fig. 1 several main entries **1**, supporting pillars **2** and crosscuts with stopings **3** are constructed in numbers required by the law of the locality. Cross entries **4**, with their pillars, crosscuts and stopings, serve to delineate a working panel, or section, and the length of a working face **5**. There is nothing fixed about the number of main and cross entries to be used. As shown, they are arranged in a pattern well known to the coal mining industry.

The working face **5** is established adjacent to an entry protection pillar **8**, and is to advance away from the pillar **8** normal to the cross entries **4**. Several advances **6**, and advance crosscuts with stopings **7**, are established to provide for the free movement of air and materials along the working face **5**. In Fig. 1 the flow of air is shown by arrows as traveling generally from right to left; it passes from a main entry **1** through the inby cross entry **4** on the right, then through crosscuts and along the working face **5** to the outby cross entry **4** on the left, and then through an overcast **9** into the return main entry.

In the actual mining operations, an undercut may or may not be made along working face **5**. The use of an undercut depends upon the nature of the material being mined, the state law, and the demands of the inspection service. No undercut is shown in the drawings. The ore or coal in the working face **5** may be drilled for blasting by placing long holes **10** parallel to the face, or short holes **11** perpendicular to the face (see Fig. 2). Long hole drilling and blasting will result in the complete length of the working face **5** being blasted for the full advance. Short hole drilling and blasting permits blasting of sections along the face of any desired length. The length of working face **5** should be geared to the capacity of the equipment. For example, utilization of a loading machine with a 1500 ton capacity per working shift, will require a face length—depending on the height of the ore and the depth of the cut—sufficient to provide 1500 tons per shift.

After the blasting the loading machine comes in and loads the material on a conveyer unit **13** (i. e. a belt or cars). It is assumed here that the loading machine travels along the face **5** from right to left (as viewed in Fig. 1), and that ore flow on the conveying unit is from left to right.

As shown in Figs. 1 and 2, support for the roof **15** is provided by props or roof bolts at positions indicated by numerals **12**. Preferably roof bolts are used, as shown in the drawings, and preferably they are removable so that when they have served their purpose they may be removed and the bolt holes **14** may be used as roof blast holes. The roof support work follows close in to the work of the loading machine along working face **5**, to minimize the length of time that a roof portion is unsupported.

As new support is placed near the working face **5**, the roof bolts are withdrawn from their holes at the rear part **15** of the working area. These holes are now loaded with explosives and the roof is blasted. Sufficient rock bordering on the roof is fragmented by this blasting operation so that it expands to fill the combined volume of the rear portion of the working area opening and the space it occupied prior to fragmentation, and to be packed tightly therein by the force of the fragmenting blast. The fragmented material, indicated at **16**, bears against and provides excellent support for the overlying and adjacent geologic structures.

Complementary work, such as the moving of conveyers or track, the erection of stopings, the driving of advances, and the advancing of power lines, takes place at convenient times. The cycle of work is continually repeated until the mineral vein is exhausted. The work is shown in Figs. 1 and 2 as being carried out on the advance. On the retreat, all the supporting pillars **2**, including those in the cross entries **4**, may be removed. When this is done using the geofragmental support method of the invention to provide the support lost upon removal of the pillars, the net result is to effect substantially complete extraction of the mineral in the bed or seam being mined, without allowing any surface subsidence to occur. Also, the mining of each section proceeds without any ground movement which would increase the difficulty of mining adjacent sections, for the geofragmental support operations follow close enough on the ore or coal extraction operations so that the overlying and adjacent geological structures are well-supported at all times.

The application of the geofragmental support method described above with reference to Figs. 1 and 2 assumes a barodynamic structure where the roof immediately over the working area consists of a series of thin beds A, B, C and D requiring considerable support by roof bolts anchored in a strong formation E to provide a sufficient span **17** (Fig. 2) between the working face **5** and the supporting fragmented material **16** for the free movement of men and equipment. However, with a barodynamic structure consisting of thick, strong, overlying beds, which will allow for a sufficient working span **17** without artificial roof support, roof bolts or equivalent temporary support may not be necessary, and it may be more desirable to drill holes into and blast the bottom rock to secure the necessary volume of fragmented material for the desired degree of support. It is, of course, immaterial to the geofragmental support method of this invention whether the rock which is fragmented comes from the roof, the floor, or the ribs of the opening. Equally good support is provided in any case. For maximum economy, however, the specific fragmentation procedure best suited to any particular set of circumstances, and the amount of material fragmented, should be determined on the basis of a barodynamic study of the surrounding geologic structures and upon experiments to determine the physical characteristics of the rock to be fragmented.

Fig. 3 shows deep mine openings **23** and **24** in a geologic structure which is subject to rock bursts, especially in the supporting pillars **25**, **26**, **27**, **28** and **29**, since the depth of the working below the surface is great and the overlying beds A′ and B′ are of considerable strength and thickness. Such beds will support themselves over large spans with minimum deformation, thus transmitting large compressive loads to the supporting pillars. If L is the distance between pillar centers and *Ps* is the weight per unit column of material up to the surface, then the load on the pillar will equal $Ps \times L$. If this load is sufficient, the pillar will be subject to rock bursts.

By drilling and blasting holes indicated at **30** into the floor between pillars **25** and **26** for, generally speaking, a vertical distance greater than twice the height of the pillars, the rock thus fragmented will increase in volume to such an extent as to fill the opening between the pillars and exert a strong force indicated by the arrows **31** on the

overlying geologic structure, thus relieving the pillars of much of their load and of their tendency to burst.

Where the orebody is thick and fill is available, the amount of drilling and fragmentation necessary to provide upward forces may be reduced by the preliminary use of fill as illustrated in Fig. 3 between pillars **26** and **27**. Here fill **32** is first placed so as to partially fill the mined out cavity, after which holes **33** are drilled and blasted to fragment the roof in a sufficient amount to provide an upward pressure **31** on the geologic structure between the pillars **26** and **27**. The fill **32**, no matter how completely it fills the space between the pillars **26** and **27**, by itself is not effective in preventing rock bursts in either flat or dipping deposits, where the hanging or wall beds are thick and deform only a small amount over large areas, thus transmitting large pillar loads, since all unconsolidated fill becomes deformed to some extent by pressure exerted upon it. But when hanging or foot wall rock is fragmented by blasting and is packed by the force of the fragmenting blast into the mine opening, which may or may not have been partially filled with conventional waste fill, pillar loads are relieved by the pressure which the fragmented material exerts upon the surrounding geologic structure as a result of having been delivered forcibly by the fragmenting blast into the mine opening.

For a deep mine in the condition illustrated in Fig. 3, where the space between pillars **26** and **27** has been provided with geofragmental support, and where the pillar **28** is between the two open workings **23** and **24**, the pillar **26** which is in position to benefit from the geofragmental support will be safe from rock bursts whereas the pillar **28** is not benefited by any geofragmental support will tend to burst into the openings **23** and **24**. Thus by following up deep mining operations with geofragmental support, it is possible to make deep underground mines relatively safe from rock bursts without sacrifice in the amount of ore that can be extracted.

The method of the invention may be also applied to inclined beds of mineral. This may be illustrated by tilting Fig. 3 at an angle to the horizontal. As the angle becomes steep, the stress component exerting pressure on the pillars approaches the horizontal and is normally referred to as "side pressure." Fragmentation-expansion of the hanging wall or foot wall to produce counter-pressures, with or without the aid of fill as above described, will effectively decrease the effective side pressure on the pillars, and hence will decrease their tendency to burst. Even in steeply dipping or vertical stopes, conventional fill normally cannot be expected to exert effective counter-pressures to the side pressure of the walls, because the supporting effect of such unconsolidated fill does not become effective until the walls move a considerable distance. With thick or massive beds as part of the hanging or foot wall, small movement would not be transferred to the yielding fill, but to the pillars which would burst. Geofragmentation of the hanging or foot walls in accordance with the invention, however, produces pressure on both of them, and with or without the aid of fill will effectively decrease the tendency to burst.

"Bottom heave," or the tendency of the bottom to rise in mine workings, is often caused by high unit pillar loads on the mine bottom rock. These loads exert lateral forces which cause the bottom rock to flow and rise in openings. The cost of maintaining mine openings under such conditions is high. A tendency toward "bottom heave" may be relieved by use of the geofragmental support method of this invention to decrease the unit load on the pillars and thereby reduce the lateral forces on the bottom rock.

In the foregoing description, and also in the appended claims, particular reference is made to effecting expansion of the rock used to provide support by explosive fragmentation. This is indeed much the most generally useful manner for effecting such expansion, and is the method most generally adaptable to a wide variety of geologic formations. It is apparent, however, that the process of explosive fragmentation is used simply as a means to effect a permanent increase in the volume of the rock delivered into the opening, and to pack such rock into the opening with sufficient force so that effective support of the surrounding geological structures is provided. In particular circumstances this same result can be achieved by quite different but nonetheless equivalent means. There are, for example, rocks compounded of minerals which expand substantially when heated. If enough rock of such composition, either bordering on or delivered into the opening, is heated to the temperature at which expansion occurs, it can thus be expanded and can be packed into the opening with sufficient force to provide the desired support. Again, there are rocks compounded of minerals which can be caused to expand by chemical treatment, for example, by hydration. In special cases, therefore, this type of expanding process may be used to develop the supporting force, by substituting it for the explosive fragmentation process, particularly described above. All references herein, and in the claims, to explosive fragmentation are therefore to be construed as contemplating and including equivalent procedures for developing the supporting force.

It is evident from the foregoing that the new geofragmental support method provides for economically using the material of the earth's crust to increase the depths at which mining may be carried on, by relieving mine pillars of load and stress. Also, the method of the invention makes possible a greatly increased percentage of ore extraction, by reducing the size and number of ore pillars required. Indeed, in some operations such as that exemplified in Figs. 1 and 2, ultimate substantially complete extraction of the ore, with none left permanently in pillars, is possible. The new method minimizes deformation of and stress upon the surrounding geological structures, thus conserving mineral deposits therein for future use; and it can be used to prevent or control surface subsidence, thereby conserving surface lands for agricultural, residential, and industrial uses and making available minerals under areas of considerable population density. Furthermore, the new method facilitates the extraction of mineral deposits situated under lakes, rivers, or streams, or underlying solution-bearing beds, by controlling the deformation of the overlying geologic structure so as not to endanger present or future mine workings.

The new method enables a high tonnage output to be constantly maintained from a concentrated mine area by an orderly factory-type system and sequence of work which is adaptable to use in conjunction with all types of continuous mining and conveying equipment.

By use of the new geofragmental method, shaft areas may be supported and realigned, as may subsided surface areas, by creating sideward or upward pressures through geofragmental-expansion of rock portions adjacent to such shafts or underneath such subsided surface areas.

The dependability of the new method, and the fact that the supporting forces developed by its use are virtually incapable of collapsing, makes for greatly increasing the safety of mining operations in connection with which it is employed.

The flexibility and adaptability of the new method is evident from the fact that fragmentation of solid rock adjacent an underground opening may be employed in conjunction with conventionally added fill to produce the desired support or realignment pressures, or fragmented material already in place within an underground opening may be further fragmented by additional blasting so as to increase the uniformity of fragment size and thus increase the pressure exerted by the fragmented mass on surrounding geologic structures. The new

method may be employed in conjunction with mining operations to provide support during the course of ore extraction, or it may be used after ore extraction is complete to provide permanent support for the ground over abandoned mine workings.

It is thus apparent that the method of the invention provides a safer, less expensive, more dependable method of mine support than any heretofore known to the mining industry for general use.

I claim:

1. The method of providing support to geologic structures overlying or adjacent to an underground mine opening which comprises drilling bolt holes into the rock bordering on the roof of said opening, anchoring rock bolts in said holes, thereby to provide support for the roof while mining operations are carried out in said opening, subsequently removing said rock bolts, then loading said bolt holes with explosive and blasting the rock bordering on the roof of said opening into said opening, the amount of said rock blasted being sufficient to expand when fragmented by the blasting to fill both the volume of said opening and the volume occupied by said rock prior to fragmentation and to place the fragmented rock under sufficient compressive stress to exert the force required to support the overlying and adjacent geologic structures without allowing any substantial subsidence of said structures, whereby the surrounding unbroken geologic formations are supported by the broken rock.

2. The method of mining minerals from an underground deposit which comprises forming a mine opening having a working face in said deposit, excavating

from said deposit minerals bordering on said working face, whereby said working face is advanced into the deposit, drilling holes into the roof of said opening adjacent the working face thereof and anchoring roof bolts in said holes, thereby to support the roof of said opening adjacent its working face, removing the roof bolts from said holes at the rear of said opening when the working face of said opening has been advanced substantially into said deposit, loading explosives in the holes following the removal of the roof bolts therefrom and detonating said explosive, whereby rock bordering on the roof at the rear of said opening is explosively fragmented and blasted into the rearward portion of said opening, the volume of the fragmented rock being sufficient to fill both the rearward portion of said opening and the space occupied by said rock prior to fragmentation thereof and to place the fragmented rock under sufficient compressive stress to exert the force required to support the adjacent unbroken geologic formations without any substantial subsidence thereof.

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