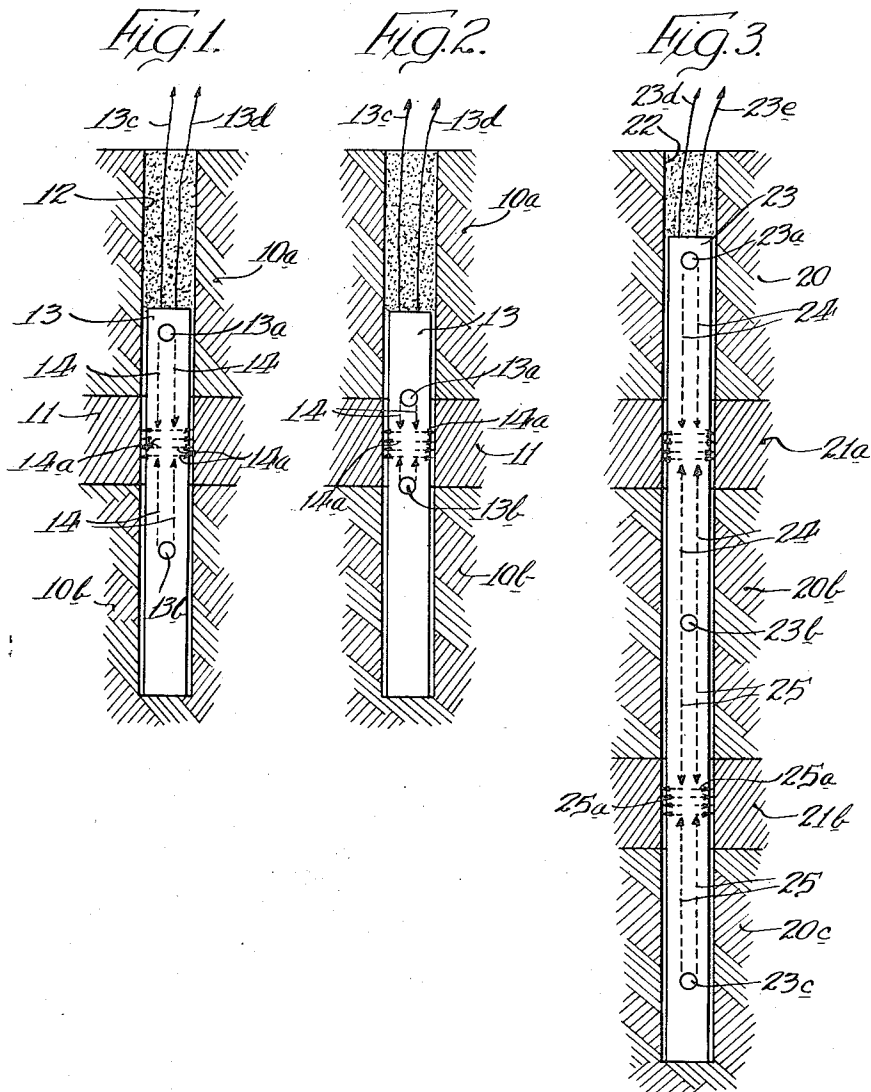


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METHOD FOR BLASTING
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METHOD FOR BLASTING

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This invention relates generally to a method of and apparatus for blasting within a bore hole and more particularly to a method of and apparatus for enhancing laterally directed explosive forces at any desired point or points along a columnar or elongated explosive charge by varying the positions of a plurality of spaced points of detonation.

In many commercial blasting operations in the earth's crust such, for example, as quarries, construction projects, open pits, deep mines, and the like, the material comprising that portion of the crust which is to be fragmented by explosive action is not homogeneous. In other words, strata of various hardness and toughness are successively encountered by bore holes which are customarily drilled in the material to be blasted for the purpose of containing the explosive charges. When such material is blasted by employing holes loaded uniformly with explosives which are initiated in the usual way by blasting caps or by a detonating fuse, the resulting breakage is non-uniform due to the fact that the harder or tougher strata are not broken finely enough to permit removal by known methods. Thus it becomes necessary to resort to expensive secondary blasting and other costly procedures in order to break up, remove, and handle the fragmented material.

Prior efforts to minimize the breakage of material into relatively large blocks have generally been limited to loading explosives of a higher strength and detonating velocity at that part of the bore hole which traverses the difficult to break strata or by placing an initiating blast cap adjacent such strata. These efforts have met with only indifferent results since regardless of the loading of the explosives the detonating forces developed at the high resistance points tend to escape in both directions up and down the bore hole and to expend their fragmenting powers in the softer, less resistant materials immediately adjacent the tough layer. Therefore, the proper fragmenting of such tough strata or rock bands remains one of the principal problems in commercial explosives engineering.

It is an object of the present invention, therefore, to provide a simple and inexpensive method of and simple and inexpensive apparatus for fragmenting rock bands or hard strata located in the earth's crust.

Another object of the invention is to provide a method of and apparatus for distributing explosive forces produced within a bore hole in order to concentrate the maximum effect of the explosive blast on the tough strata to be fragmented.

A further object of the invention is to provide a method of and apparatus for controlling the collision point of opposed detonating waves so that the explosive forces created within the bore hole are concentrated and laterally directed at the location of the material which is most difficult to fragment.

In accordance with the present invention, the troublesome problem of fragmenting hard subsurface strata is solved by a novel method of and apparatus for distributing explosive forces developed in the bore hole which utilizes the principle that the explosive forces are concentrated whenever opposing detonating waves meet in collision. These detonating waves, which may be initiated substantially simultaneously at separate spaced points within the same explosive charge, collide at a point approximately mid-way between the points of location of the originating sources to produce a resultant laterally directed explosive force of greater magnitude than that produced at the origin of either of the waves. The points of collision of such detonating waves may be controlled by properly positioning initiating detonating caps within a bore hole in order to concentrate the explosive forces and direct them at an optimum point within the tough strata or rock band to be fragmented.

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The invention both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in conjunction with the accompanying drawing in which:

Fig. 1 is a cross-sectional view illustrating a broken away portion of the earth's crust containing at least one tough stratum which is to be fragmented by distributing explosives within a bore hole in accordance with one embodiment of the present invention;

Fig. 2 is a cross-sectional view of a broken away portion of the earth's crust identical to that shown in Fig. 1 but illustrating an alternative distribution of the explosives within the bore hole also embodying the present invention; and

Fig. 3 is a cross-sectional view illustrating a broken away portion of the earth's crust differing from that shown in Fig. 1 in that it includes a plurality of hard layers or rock bands which are to be fragmented in accordance with the present invention.

Referring now to the drawing and more particularly to Fig. 1 thereof, there is shown a section of the earth's crust including a plurality of relatively soft layers designated by the reference characters 10a and 10b and at least one rock band or high resistance stratum 11. The rock band 11 may be several feet thick and, of course, is extremely difficult to fragment. The soft layers 10a and 10b and the resistant stratum 11 are penetrated by a bore hole 12 which is drilled therein for the purpose of containing an explosive charge 13. The depths of the soft layers 10a and 10b as well as the depth and thickness of the hard stratum 11 may be determined by core samples taken as the bore hole 12 is drilled or by any suitable means known in the art.

The explosive charge 13 may be a single elongated cartridge or, alternatively, may be of the type including a long column or string of individual charges positioned in end to end relationship. In the event that a sectioned columnar explosive charge is employed, the individual charges may be fastened together by various means referred to in the art by such descriptive terms as "stringing," "lathing," "taping," and "pegging" or, as is even more common, the individual charges may be dropped one at a time into a bore hole where they fall into aligned end to end positions.

The explosive charge 13 is detonated by suitable means positioned at a pair of spaced detonating points 13a and 13b which points may be located at opposite ends of the charge or, as will become evident as the description proceeds, may be located at points intermediate the ends of the charge. The detonating means may comprise the customary blasting caps or detonating fuses both of which are capable of being initiated from a conventional electrical firing mechanism, not shown, but located at the surface equipment and connected through the detonating circuit conductors 13c and 13d to each of the detonating means.

In accordance with the present invention, the detonating points are located at such positions within the bore

hole 12 that the detonating waves simultaneously produced at each of these points collide approximately at the center of the rock band 11. If the composition of the explosive charge 13 is uniform so that the detonating waves produced at each of the points 13a and 13b travel through the explosive charge 13 at the same rate, it is apparent that the detonating points are positioned equidistant from the center of the resistant stratum 11. By positioning the detonating points in this manner, the detonating waves represented by the dotted lines 14 in Fig. 1 travel toward each other in the direction indicated by the arrows and collide at approximately the middle of the rock band. When the explosive forces meet they combine and produce a concentrated blast directed laterally through the tough resistant stratum 11 as indicated by the dotted line arrows 14a.

The concentration of the effect of the explosive blast at the center of the rock band greatly enhances the destructive capacity of the explosive charge 13 at this particular point while the strength of the explosive blast at the detonating points and along the explosive column is sufficient to fragment the relatively soft layers 10a and 10b.

If the explosive charge 13 is non-uniform due, for example, to the use of more than one type of explosive in the charge, the detonating points 13a and 13b must be so positioned as to compensate for the difference in the rate of travel of the detonating waves through the different types of explosives. In any case, the points 13a and 13b are so located that the detonating waves will meet in collision approximately at the center of the high resistance stratum. Since in a large majority of practical applications the composition of the explosive charge 13 will be uniform, this condition will be assumed in the ensuing description and it will be understood that in the event that non-uniform charges are employed the above indicated corrections can be made.

As previously indicated, the location of the rock band with respect to the earth's surface and its thickness are determined by known means thereby facilitating the location of the detonating points at their proper positions. Thus if the center of the resistant stratum 11 is known to be at a given depth below the earth's surface it is relatively simple to lower the explosive charge 13 into the bore hole 12 until the point midway between the detonating points 13a and 13b coincides with the center of the resistant stratum 11. When the detonating means are simultaneously energized from the surface equipment the explosive blast is then concentrated at the center of the material which is most difficult to fragment.

Although the detonating points 13a and 13b shown in Fig. 1 are respectively located above and below the bounding surfaces of the resistant stratum 11 at a position in the bore hole 12 adjacent to the relatively soft layers, it should be understood that the detonating points may be positioned in that portion of the bore hole which is adjacent to the resistant stratum 11 if desired. Thus in Fig. 2 a portion of the earth's crust similar to that shown in Fig. 1 is illustrated having a rock band or resistant stratum 11 interposed between a plurality of relatively soft layers 10a and 10b. The explosive charge 13 shown in Fig. 2 includes detonating means located at spaced points 13a and 13b intermediate the ends of the explosive charge and positioned in the area of the bore hole 12 adjacent to the rock band 11. When the spaced detonating means are simultaneously initiated by energizing current supplied through the circuit conductors 13c and 13d, the resulting detonating waves collide at a point located adjacent the approximate center of the rock band 11 since the detonating points are located approximately equidistant from this center point. At the point of collision, the destructive capacity of the explosive blast is increased as indicated by the concentration of the arrow pointed dotted lines 14a directed laterally into the resistant stratum 11 while at the same time the strength

of the blast in other portions of the bore hole is not affected. It thus becomes apparent that the maximum effect of the explosive blast from the charge 13 occurs at the point in the resistant stratum 11 where a blast of high magnitude will be most effective.

The method described above may be successfully employed in blasting a portion of the earth's crust containing more than one rock band or tough strata merely by properly positioning one additional detonating means for each additional rock band to be broken. Thus in Fig. 3 there is shown a cross section of a portion of the earth's crust to be fragmented including a plurality of relatively soft layers designated by the reference characters 20a, 20b, and 20c and a plurality of rock bands or tough strata 21a and 21b interposed therebetween. A bore hole 22 is drilled into the earth's crust to penetrate all of these layers for the purpose of housing an explosive charge 23. As previously indicated, the explosive charge 23 may be a single elongated cartridge or may comprise a plurality of individual cartridges stacked in end to end relationship, but in either case this charge includes detonating means positioned at a plurality of spaced detonating points 23a, 23b, and 23c. The detonating means may be simultaneously initiated by actuation of an electrical firing mechanism located at the surface and connected to the detonating means through current carrying conductors 23d and 23e.

Assuming that the explosive charge 23 is of uniform composition, the detonating point 23b is located in the bore hole 22 approximately midway between the centers of the two resistant strata 21a and 21b. The detonating point 23a is located above the center of the upper stratum 21a and is spaced therefrom a distance approximately equal to the spacing between the center of the upper stratum 21a and the detonating point 23b. Similarly, the detonating point 23c is located below the center of the lower stratum 21b a distance corresponding to the spacing between the detonating point 23b and the center of the resistant stratum 21b. As previously indicated, the relative disposition and depth of the soft layers 21a, 21b, and 21c of the resistant strata 21a and 21b may be determined by known means, thereby facilitating the location of the detonating points 23a, 23b, 23c at the desired positions within the bore hole 22.

Simultaneous actuation of the detonating means at the spaced detonating points through actuation of the firing mechanism produces within the explosive charge 23 a plurality of detonating waves represented by the various dotted lines shown in Fig. 3 having arrows affixed thereto in order to indicate the direction of propagation of the detonating waves. Specifically, detonating waves represented by the dotted lines 24 and having their origin at the spaced detonating points 23a and 23b travel toward each other through the charge 23 and collide at a point approximately coincident with the center of the upper stratum 21a. These colliding waves combine to produce a concentrated explosive blast laterally directed at the center of the upper stratum thereby increasing the destructive capacity of the explosive charge 23 at this particular point. Simultaneously therewith, detonating waves represented by the dotted lines 25 and originating at the spaced detonating points 23b and 23c travel toward each other through the explosive charge 23 and collide at a point approximately coincident with the center of the lower stratum 21b. The colliding waves combine to produce an explosive blast of increased magnitude which, as indicated by the dotted lines 25a, is directed laterally into the center of the resistant stratum 21b, thereby concentrating the effect of the blast at the point of location of the material which is most difficult to fragment. From the foregoing explanation it will be apparent that the force of the blast created by the explosive charge 23 is concentrated at the two points within the spaced resistant strata where the greatest destructive capacity is required. In similar manner, any number of rock bands or resist-

ant strata may be broken merely by positioning additional detonating means within the bore hole at the proper locations.

While particular embodiments of the invention have been shown, it will be understood that the invention is not limited thereto since many modifications may be made, and it is therefore contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A method of blasting in a portion of the earth's crust which contains at least one stratum having greater resistance to fragmentation than the remaining portion to be blasted, comprising the steps of drilling a hole in said crust which penetrates the portion of the earth to be blasted, positioning explosives in said hole, and detonating said explosives above and below the center of said stratum, so that the effect of the explosive blast is laterally directed at approximately the center of said stratum.

2. A method of blasting in a portion of the earth's crust which contains at least one stratum having greater resistance to fragmentation than the remaining portion to be blasted, comprising the steps of drilling a hole in said crust which penetrates the portion of the earth to be blasted, positioning explosives in said hole, and detonating said explosives at equal distances above and below the center of said stratum so that the effect of the explosive blast is laterally directed at approximately the center of said stratum.

3. A method of blasting in a portion of the earth's crust which includes layers of relatively soft material separated by a stratum of material having greater resistance to fragmentation, comprising the steps of forming a hole in said crust which penetrates the portion of the earth's crust to be blasted, positioning explosives in said hole, and simultaneously detonating said explosives at points located adjacent said relatively soft layers approximately equal distances above and below the center of said stratum so that the effect of the blast is concentrated and laterally directed at approximately the center of said stratum.

4. A method of blasting in a portion of the earth's crust which includes layers of relatively soft material and at least two separated strata of material having greater resistance to fragmentation, comprising the steps of forming a hole in said crust which penetrate the portion of the earth to be blasted, disposing a column of explosive material in said hole, positioning a first detonator in said column at a point located approximately midway between the centers of the two strata, positioning a second detonator in said column at a point located below the center of the lower of said strata a distance approxi-

mately equal to the distance between said first detonator and the center of said lower stratum, positioning a third detonator in said column at a point located above the center of the upper of said strata at a distance approximately equal to the distance between said first detonator and the center of said upper stratum, and simultaneously energizing all of said detonators so that the effects of the blast are concentrated and laterally directed at approximately the centers of said strata.

5. A method of blasting in a portion of the earth's crust which includes layers of relatively soft material and at least one stratum of material having greater resistance to fragmentation, comprising the steps of forming a hole in said crust which penetrates the portion of the earth's crust to be blasted, positioning explosives in said hole at points located adjacent said relatively soft layers above and below said stratum, and simultaneously detonating said explosives so that the effect of the blast is directed laterally of the hole into said stratum.

6. A method of blasting in a portion of the earth's crust which includes layers of relatively soft material and at least two separated strata of material having greater resistance to fragmentation, comprising the steps of forming a hole in said crust which penetrates the portion of the earth to be blasted and passing through said two strata, positioning a column of explosive material in said hole, and detonating said column at a point located between the centers of said two strata and at points located respectively above the center of the upper stratum and below the center of the lower stratum so that the effects of the blast are concentrated and directed laterally of the hole into both of said two strata.

7. A method of blasting in the earth's crust in which it is desirable to concentrate the blast at any predetermined depth comprising the steps of forming a hole in said crust which penetrates the predetermined depth, positioning explosives in said hole, and detonating said explosives above and below said predetermined depth, so that the effect of the explosive blast is directed laterally of said hole at said predetermined depth.

8. The method defined by claim 5 wherein the explosives are so positioned within the formed hole that the blast is concentrated at the center of said stratum.

9. The method defined by claim 6 wherein the explosives are so positioned within the formed hole that blasts are concentrated at the center of each of said strata.

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