

[54] RECOVERY OF ORES AND MINERALS
WHILE USING ICE AS MEANS OF
SUPPORT IN MINED ROOMS

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[22] Filed: May 3, 1972

[21] Appl. No.: 250,052

[30] Foreign Application Priority Data

June 11, 1971 Norway..... 2209/71
Dec. 17, 1971 Sweden..... 16199/71

[52] U.S. Cl..... 299/11, 61/36 A

[51] Int. Cl..... E21c 41/00

[58] Field of Search..... 299/11; 61/36 A

[56] References Cited

UNITED STATES PATENTS

1,207,569	12/1916	Langerfeld.....	299/11
1,004,418	9/1911	Griffith.....	299/11
1,233,301	7/1917	Bartlett.....	299/11

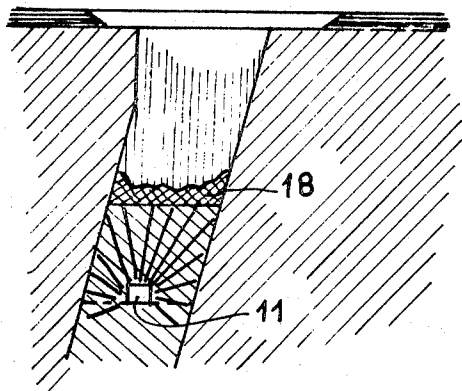
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[57] ABSTRACT

For supporting lateral or hanging rock walls in mines it is proposed to make ice flow into the mine rooms freshly worked, according as the mining proceeds to constantly lower levels, so as to protect miners without having to leave pillars requiring second mining.

9 Claims, 8 Drawing Figures



RECOVERY OF ORES AND MINERALS WHILE USING ICE AS MEANS OF SUPPORT IN MINED ROOMS

BACKGROUND OF THE INVENTION

When recovering ores and minerals from solid rock problems are encountered in supporting the remaining rock. Without separate measures being taken it is only possible to recover a certain quantity of ore and expose a corresponding area of rock without danger to people and equipment being caused by falling blocks or rock slides.

For supporting side or hanging walls of mining rooms several methods are used, of which the oldest is to leave pillars of the ore itself of sufficient dimensions and placed close enough to each other. This method entails loss of ore that might otherwise have been recovered. In other methods pillars or props of timber, masonry, steel etc. are used, which permit complete recovery of the ore, but entail large costs. It has also been practiced to fill the mine spaces with rock, gravel, morainic deposits or tailings or wastes from the concentration process to which most ores must be subjected before they can be sold, but this involves technical complications and additional costs even though the method permits full recovery of the ore deposit.

Further, methods have been developed which permit the rock side wall to cave in continuously concurrent with the mining of the ore. When such methods are operated in the prescribed manner, there will never be open spaces that can entail safety risks. These methods have several advantages, but will by necessity result in a mixture of ore and side rock, which decreases the quality of the ore recovered and at the same time causes a loss of ore in the caving rock — both in the order of for example 15 to 20 percent.

For the recovery of pitcoal there is often used a long wall working, making use of the fact that the ceiling consists of tenacious kinds of rock that will sag down and close the mine room at a certain distance from the working front. The method is specific and can only under exceptional circumstances be used in recovering ores, and, if so, only for flat deposits.

The present invention relates to a method of supporting sidewalls or hanging rock in mine cavities while using ice as a supporting material. This has already previously been suggested. Thus, it is known from Norwegian Pat. No. 92.249 at first to mine part of the deposit by the room and pillar method and thereafter to fill the rooms with ice, whereafter the remaining pillars are mined out. In this known form the method is troublesome and even in the case of artificial cooling of the ice masses filled in, it can only be carried out to relatively small depths if the ice walls shall be capable of resisting the pressures occurring during the mining of the pillars.

Further, from the U.S. Pat. No. 1,207,569 it is known to fill mines by passing ice into them by glacier flow in order to support especially the roofs of more or less horizontally extending mines and hence to prevent overlying strata from sinking into the mine and/or to permit recovery of the ore in the pillars by a second mining. Even with this method it is rather laborious to effect a substantially complete recovery of the ore, since a second mining must be resorted to.

SUMMARY OF THE INVENTION

An object of the present invention is to make use of the physical properties of ice for effecting a safe and economical recovery of ores and minerals without leaving pillars in the mines and hence to permit substantially complete recovery to be carried out without second mining.

A further object is to permit mining to be effected to relatively great depths in highly productive workings and large mine rooms while using equipment, the use of which has hitherto been restricted to work in open pits.

The main characteristic feature of the invention consists in that the filling of the mines with plastic flowing ice is effected progressively and continuously during the primary mining operation in the same speed and sequence as ore in front of or under the ice is mined and removed.

Thus, in this case, the capability of the ice to flow plastically under a static head is made use of for forming a constantly after-flowing protective roof under which it is possible to work safely during the mining of the ore. According to calculations effected it will thereby be possible to carry out the mining process at a cost of about 60 to 75 percent of the usual costs for the recovery of ore in mines and also in deep open pits, because the removal of waste rock may be dispensed with.

The method can most easily be carried out by mining the ore level by level in a downward succession from an open pit floor or possibly under an existing glacier, whereby the weight of the ice itself can be made use of for affording the necessary supporting effect and desired speed of flow, and in that connection it is possible to adapt flowing speed and working rhythm mutually, so that the after-flowing will correspond to the mine working rhythm. If desired, the pressure may be modified by weighting or mixing the ice with masses of higher specific cavity or by placing hollow bodies in it, for example empty drums reducing the average specific gravity. It will also be possible, when required, to modify the flowability of the ice locally by forced cooling.

With respect to the calculation of the necessary thickness to give wanted rate of flow of the ice, it is known as far as the physical characteristics are concerned that ice is plastic when the pressure is higher than corresponding to an ice thickness of about 22 meters. At lower ice pressures an overstressing of the ice will result in brittle ruptures of the kind occurring in solid substances, whereas at higher ice pressures the load will cause plastic deformations and flow depending both on the size of the load and the time during which it is exerted.

Known formulae for the deformation of plastic materials are valid for ice only to limited extent, and in addition a calculation of the strength of the ice depends on temperature, age of the ice, crystalline structure, recrystallization and load variations, variations in melting point by pressure changes, great melting heat, low heat conductivity etc.

However, based on glacier studies it is possible to calculate figures that can be used for carrying out the present method. Thus, the professor L.W. Glen has elaborated a formula that has been published in several periodicals, and to our knowledge for the first time in

Journal of Glaciology, vol. 2, 1952, page 111, and gives the following expression for the flowing speed of ice: $s' = B e^{-Q/RT} p^n$, in which

s' = flowing speed in meters per year

B = constant = $7 \cdot 10^{24}$

e = basis for natural logarithms

Q = melting heat of ice = 32 kcal/gmol

T = temperature in °K

p = pressure in Bar

n = constant = 3,2

R = Gas constant = $8,314 \cdot 10^7$ erg/gmol

By inserting the constants and assuming a temperature of 0°C, i.e., the temperature measured in ice when the average temperature during the year is higher than 0°C, the formula is simplified into:

$$s' = 1/5,8 \cdot p^{3,2}.$$

Though it is hardly permissible to expect entirely analogous conditions in relatively small ice quantities or ice in limited rooms in mines or caves where the surroundings may play a greater part than in glaciers of much greater dimensions, since for example projecting rocks may be supposed to have a retarding effect, while, on the other hand, a positive temperature gradient from the rock may also contribute in local melting of the ice, Glen's formula will anyhow constitute a sufficiently reliable starting point so that there will only remain minor corrections that may be effected based on the experiences in the individual cases by controlling pressure, flowability etc. by expedients as indicated above.

It is believed that the method may most easily be used directly in the breaking of ores in cases where open pit mining, sublevel stoping, sublevel caving, shrinkage stoping or backfilling are regarded as technically correct and economic methods today. Thus, this applies directly to steep orebodies of a thickness greater than 3 to 4 meters and preferably with outcrop at the surface.

DESCRIPTION OF THE PREFERRED EMBODIMENT

How the method may be carried out in this case, is illustrated in the accompanying drawings and will now be described in detail.

FIG. 1a illustrates an initial phase of an ore recovering process in accordance with the invention, showing a vertical cross-section of the upper part of an area from which an ore deposit is to be mined out, taken at right angles to the main extension of the deposit, and *b* showing a section taken along the line B—B in FIG. 1a in a plane oriented along the main extension of the deposit and projected onto a vertical plane.

FIG. 2a, FIG. 2b, FIG. 3a, FIG. 3b, FIG. 4a, and FIG. 4b illustrate in a corresponding manner successive later stages of the ore mining process.

In the drawings 1 designates the deposit with boundary faces 2, 3 and 4 towards surrounding rock 5, and 6 the overburden layer on top.

In a first phase, the overburden layer 6, i.e., loose masses covering the outcrop of the ore, is removed both directly above the ore and on both sides to a distance of 5 to 10 meters. The remaining loose masses are evened out to a slope of about 30° in order to reduce washing out of sand into the future mine opening.

A second phase comprises recovery of as much ore as can be worked without removal of more than small amounts of side rock, mostly overhanging rock as indicated at 7 in FIG. 1a, where the ore does not extend vertically. The recovery is preferably carried out so that the bottom of the open pit will be horizontal as indicated at 8 in FIG. 1a.

Already while the working in the open pit proceeds, filling of ice 9 into the open pit may be started, as indicated in FIG. 2a. For economic reasons the production of the necessary quantities of ice ought to be carried out on the surface. If the temperature is below the freezing point, this may be done by spraying water in at a suitable rate. If desired, water may be mixed with snow and ice from occurrences in the environment, but not more than that the snow is all the time completely soaked so that inhomogeneity in the ice mass is avoided. The freezing of ice can take place in horizontal layers largely as on a skating rink, but it may also be contemplated to spray the walls of the open pit so that the water will flow down as a film until it freezes. Possible surplus water will flow to the floor of the open pit in such small amounts that it freezes completely to the bottom. In this manner the production of ice may start and proceed rather far before the production in the open pit is terminated. If spraying of water in thin layers is not sufficient because the winter is too short or too mild or the water supply too scarce, it may also be contemplated to use screens conveniently placed for collecting snow in the pit. If necessary, artificial freezing in ice machine or other suitable technical equipment may be resorted to.

As a third phase a charging, drilling and loading tunnel is driven at an economic depth below the floor of the open pit. An "economic depth" will depend on the thickness of the ore, on the strength of the ore and of the side rock and on the equipment used for the tunnel driving phase and for the subsequent operations. In Scandinavia the economic depth will at the present time be 25 to 30 meters. This distance is also used as a vertical distance when providing new levels by proceeding downwards in the deposit. In the drawings such a first tunnel has been indicated at 10 in FIGS. 2a 3a and 3b, and a second one at 11 in FIGS. 3a, 3b, 4a and 4b. Since, as it will be mentioned later, it is intended to drill holes in a fanlike pattern for blasting the ore, conveniently with a diameter of 50 to 64 mm and a length up to 30 meters or more, such a tunnel will therefore cover ore widths of 50 to 60 meters and ore cross-sections of up to about 1,500 m². Ore widths more than 50 to 60 meters will require the driving of two or possibly more tunnels.

As a fourth phase an opening is worked from the tunnel up to the floor 8 of the open pit, and the opening is enlarged into a slot 12, FIG. 2b, into which the first fan of the ore is blasted.

In the fifth phase fans of drill holes 13 are, as illustrated in FIG. 3a, drilled systematically from the drilling tunnel 10 to the floor 8 of the open pit, to the boundaries 2 and 3 of the ore towards the side rock or possibly to the areas of other drilling tunnels. The fan ought to extend throughout at least 180° above horizontal, and economic considerations may even make it advisable to drill some holes below the horizontal so as to reduce the length of holes to be drilled from the level below. The drilling of fans is continued systematically with equal spacing.

In the sixth phase one or more fans are charged and blasted towards the slot 12 or to the mine cavity thus formed, alternating with loading and transport of the blasted ore 14 out through a tunnel 10 and further to the surface. As this work proceeds, the ice 9 filled into the open pit will gradually flow down behind the working front 15, and during flow its bottom face 16 will form a largely S-shaped curve while leaving an open space 17 behind the front. It will normally be safe to let both people and equipment advance into the space 17 so that practically all the blasted ore can be removed. It is then convenient to have mining rate and ice flowing rate geared to each other in such a manner that the space will constantly have suitable dimensions as a working room. However, it is also possible, if desired for safety reasons, to restrict the loading to the ore avalanching into the tunnel by itself, corresponding to sub-level caving or cross-cut loading, so that at no time it will be required that people or equipment stay behind the front. In any case, the ore — 18, FIGS. 4a and 4b — blasted so far out in the room that it cannot be reached from the tunnel, will not get lost, since it will in its entirety be included in the ore blasted from the next lower level from the tunnel 11.

Then, when the sixth phase has been terminated and the ice 9 has flowed after so as to form a continuous supporting roof over the next lower level, the process is repeated in this level, starting from a slot 19 at the extremity of the tunnel 11 as illustrated in FIG. 4a and 4b. During this working, ore 18 that may remain from the preceding level will be included. In that connection it is of interest that the low temperatures, down to 0°C, and the slight exchange of air in a closed room under the ice roof will have the effect that the broken ore that has been left will not have undergone noticeable changes by ageing or oxidation, so that this ore will be mostly of the same quality as the freshly blasted ore.

During the further work it is necessary to maintain an ice layer at least 30 meters thick, in order to afford a safe support and protection against rock falls, and also to prevent local pressure reductions during the flow of the ice behind the mining front.

Pressure reductions may cause falling of ice blocks into the broken ore, which might be inconvenient for the later handling of the ore. The demand for supplementing ice, that arises because of melting at the top, from the side rock and also from ventilating air in tunnels and working rooms etc., can easily be detected by measuring the height of the ice layer.

However, as a rule it will be preferable not only to maintain an ice layer of constant height, but also to increase the height of it successively, when proceeding towards greater depth, partly to resist higher pressure from the side rock and partly, in the first place, to re-

strict and protect against rock caving in on top of the ice layer.

Loose blocks falling onto and being entrained by the ice, will not cause any safety risk, since experiences derived from glacier studies it is known that such blocks will follow the ice during the flow, so if they should extend so much from the ice that they can fall down, this will take place along the sides of the mine rooms, and they will be visible long time before they can fall down.

What I claim is:

1. A method for the substantially complete recovery of ores or minerals from steeply extending formations while using ice as means of support for side and hanging rock walls, comprising causing a mass of ice to flow under a static head into rooms being worked out for filling the latter, the filling with flowing ice being effected progressively during the primary mining successively to and at the same rate as ore in front of and below said ice is blasted and removed.

2. A method as claimed in claim 1, characterized in that the pressure of the ice is adapted to provide a flowing rate corresponding to the mining rate.

3. A method as claimed in claim 1, said flowing rate and said mining rate being adapted to each other so that a resulting space formed between ice flowing into new mine spaces and the constantly retiring working front forms a working room during operations forming part of the recovering process.

4. A method as claimed in claim 1, characterized in that for providing the pressure required for support and flow there is maintained a mass of ice suitable for this purpose.

5. A method as claimed in claim 4, characterized in that the pressure is modified by masses of higher specific weight than ice, which are charged onto it or mixed into it, or by hollow bodies placed in it for reducing the average specific gravity.

6. A method as claimed in claim 1, characterized in that the flowability of the ice is modified locally by forced cooling.

7. A method as claimed in claim 1, characterized in that ice melted off is subsequently replaced by fresh ice produced in situ.

8. A method as claimed in claim 1, characterized in that the mining is started from an outcrop and ice is filled in gradually so as to provide support and flow for ore removal.

9. A method as claimed in claim 1, characterized in that the mining is effected at successively lower levels and at each level proceeds in the main horizontal direction of the ore deposit and immediately under the bottom face of the ice mass.

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