ROCK-CUTTING AND ITS POTENTIALITIES AS A NEW METHOD OF MINING

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Introductory remarks

Dr N. G. W. Cook: This paper was published in your *Journal* in May of this year and you will, therefore, have had the opportunity of reading it over the past six months. I can state that experience has shown that the paper is substantially correct, but a number of questions have to be answered.

The first question, Mr President, that I would be happy to answer, is how is it that one is able to cut hard, abrasive quartzite with a strength some six times greater than that of good concrete?

The essence of the answer is that there is a tremendous difference between abrasion, or scratching, and cutting, or chipping. For example, it is well known that a diamond will scratch or abrade almost anything. It is also relatively easy to chip, crack or crush a diamond.

As a demonstration I have here an ordinary bench grinder, and with the bench grinder I also have a piece of tool steel. The wheel on this bench grinder is a silicon carbide wheel, which is an extremely hard material, and the tool steel is much softer. In rock-cutting we use tungsten carbide for cutting the quartzite. The quartzite and the tool steel have roughly the same hardness. You can sharpen tungsten carbide with a silicon carbide wheel. In fact, this is done. It won't surprise any of you, therefore, when I show you that tool steel can be sharpened with silicon carbide.

Now, what I propose to do is to change the configuration of this experiment and use the soft tool steel to cut silicon carbide, and if I can do that, I think you will agree that I have gone some way to being able to cut quartzite, which is about as hard as tool steel, with tungsten carbide, which is harder than quartzite. Let me do this. (*Demonstrates.*) That, I think, is a very clear demonstration of how it is possible, with a metal, to cut an extremely hard and brittle material. What, essentially, is the difference that we have here?

In the first case, I held the tool with a relatively low force against the hard silicon carbide wheel. This generated a relatively low average stress, which was insufficient to fracture the carbide wheel. Nevertheless the protuberances on the silicon carbide wheel indented the tool steel and abraded it at a multiplicity of points, and quickly reduced the section of the tool steel that I held against the wheel.

By changing the configuration and clamping my tool steel in a firm post, against the silicon carbide wheel, I changed these conditions very extensively. I now had a high force. I had to exert a considerable moment on that lever. The tool was anchored so that it could sustain these high forces, and they generated high stresses, which were adquate to fracture the silicon carbide.

Now, what about wear? It so happens that, in these two experiments I have just done, the power I was using was about the same—a small fraction of a horse power.

In the first case, the wheel travelled a few thousand feet, rubbing against the tool steel. In the second case, it travelled a fraction of a foot, and the wear on the tool steel is roughly in proportion to the distance of travel, so that the amount of wear on the tool steel in cutting the wheel, was a minute fraction—a few thousandths—of that which occurred while I was sharpening the tool steel.

To come to the question of making rocks cuttable, and the essence of a machine for doing that, one has to control the depth of cut, and one has to resist the high forces which generate the stresses sufficient to fracture the hard, abrasive material.

Had I been able to force that tool against the wheel with sufficient force, without the guide of a post—if I had been strong enough—I would have run into two difficulties. The first of these is that the motor would have stalled. That we could presumably overcome by putting a motor with a virtually irresistible force on it. That is the first thing you have to do in a rockcutting machine. The second is that, had I held it there with adequate force, I would have had very little control over the depth, and two things would have happened. Some quirk would have either reduced the depth, in which case I would have reverted to a grinding situation, or else, if the wheel had had a weak point, then applying the same force, the depth would have increased, and if the motor had, indeed, not an irresistible ability to apply load, then it probably would have stalled. You have to have a high measure of control—that is the essence of rockcutting.

The second question is, how do I propose to use this to mine?

In Fig. 1 we have, in a very diagrammatic way, a plan, on the right-hand side, and three sections of a typical stope in a gold mine, at depth. The sections are blown up about two-to-one, compared with the plan. We have three panels, each of which is 10 ft long, with a 1 ft step in it, a row of props, chute, down which we are going to get our gold reef, another row of props, and there we have a whole lot of waste rock, packed at the back.

Let us study the sequence of operations by which we propose to mine. First, let me remark that the whole secret of being able to make a profit out of rock cutting is the fact that in the newer gold fields the gold-bearing reefs are thin; they are much thinner than the 40 in. at which we customarily mine. The thickest of them averages 30 in., and some of them are as low as 5 in. Even in the thick reefs, the gold is confined within the thickness of, perhaps, 10 in. of that 30 in., so in order to get all revenue out of the reef we only need to extract the small thickness—for argument's sake, let us say 10 in.—which contains the gold.

What makes rock breaking in a deep mine so difficult is the fact that, above the stope, one has between one and two miles of rock, which is rather heavy. This generates very high forces at the face, so that the rock at the face is held in, much as it would be between the jaws of a vice, with the roof and the floor being the two opposing jaws.

The first thing one has to do is not to try and work against these forces, but to try and work around them. We have a machine which is mounted on props and has two blades, and these blades cut horizontal slots, one above and one below the reef. For many practical reasons, the depth of these slots is limited to 1 ft. Their length is limited to about 10 ft, and their width is as narrow as is convenient. This is limited by closure of the slots to about $\frac{3}{4}$ in., or perhaps a little more.

As we cut these slots, one can see that one is removing the vertical stresses, because they can't go through the slots, so that you are working around these stresses. In fact, the damage which these stresses do at the base of the slot assists the cutting. Also, these stresses do tend to come back into that slab of rock between the blades. In doing so, they push it off, just as a diamond core discs when you are drilling into rock, so that as you cut in this reef slabs off.

Having completed the cuts, one takes reef and puts it down the chute—and we've only mined 10 in. of rock. Then we are left with two steps. Those steps are now much easier to break than they were before we cut, because they, too, are no longer held between the vice-like jaws of the hanging- and footwall. We can get them off with a variety of techniques.

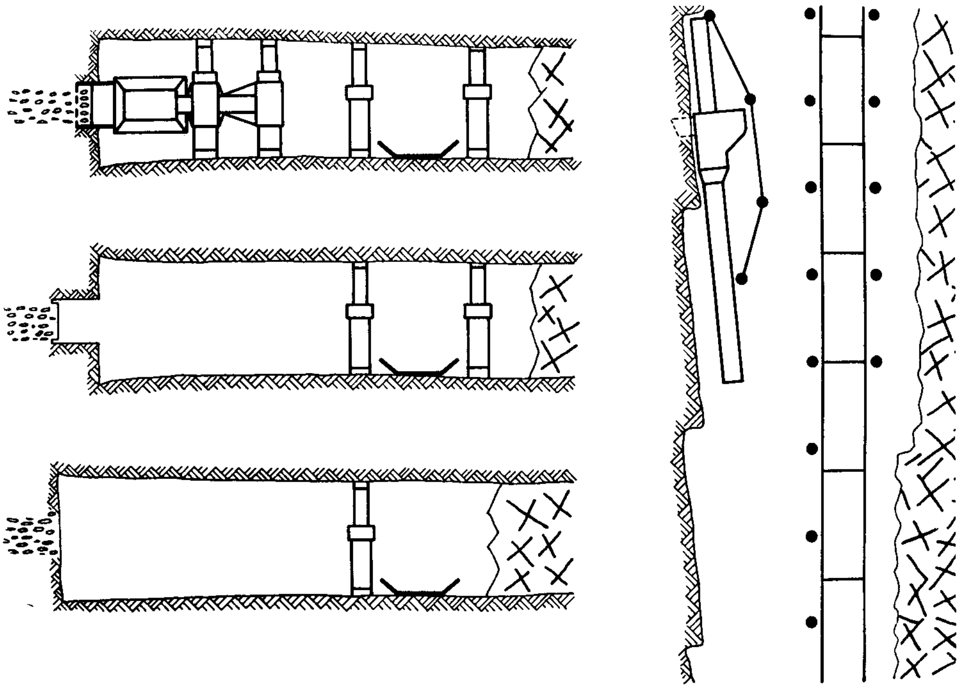

Fig. 1

Once you have mined this waste rock—it contains no gold because you have not blasted it and mixed it up with reef—all you have to do is pack it back. You notice that the waste walls move forward and the face is re-exposed for you to find the reef and proceed again with the cutting.

So that, in essence, is how we propose to mine with our new-found ability to cut hard rock, and the whole purpose of doing this is to mine the rock which contains the gold, and leave the rest of it behind.

To give you a little better idea of how the cutting machine looks, Fig. 2 is an isometric projection of the cutting machine in a stope. We have our machine frame on which slides the cutting head with two blades. The frame is mounted on four props, which anchor themselves between the roof and the floor.

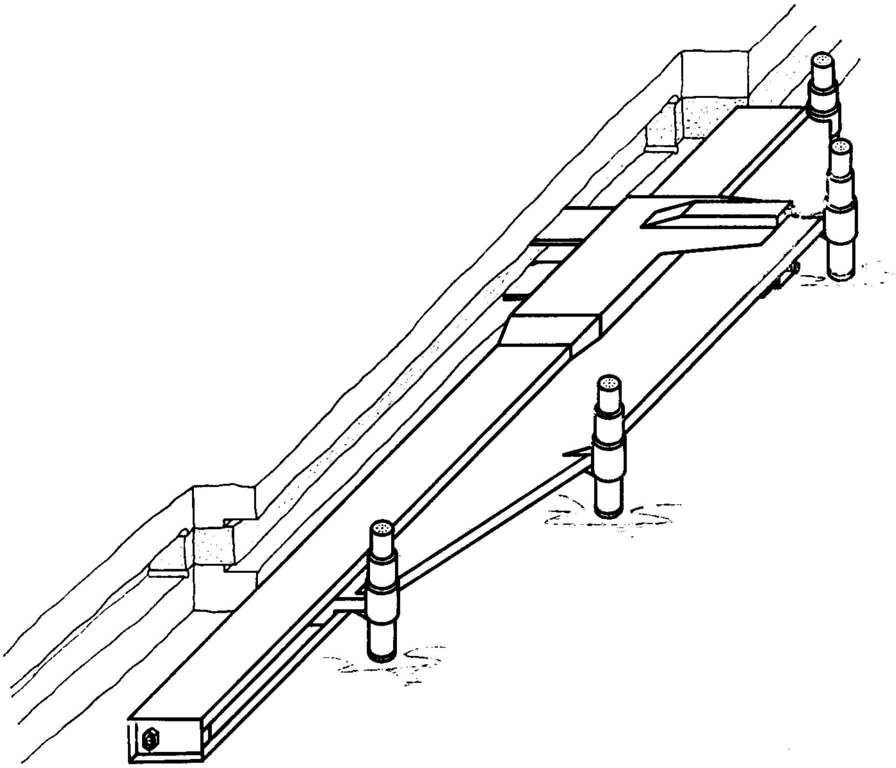

Fig. 2

The third question is, how far has rock cutting progressed in the last year, since it became topical?

A year ago it was generally held that it was not possible to cut quartzite—except, perhaps, in a laboratory. This view is still more or less widely held, but the facts prove otherwise, and to show you some of these facts, I have here a series of slides taken in a stope some 8,000 ft below surface at the Doornfontein Gold Mining Company Limited, where some 50 square fathoms of rock have been continuously mined exlusively by rockcutting.

We have been cutting since about April, and these, I must point out, are experiments in rockcutting. The first purpose of these experiments is to find out whether it is possible and feasible to cut rock on a large scale, under conditions of deep-level mining in a stope. The answer to that question is, 'Yes, it is definitely possible'. Fifty fathoms have already been cut under these conditions, and about as many fathoms have been cut by other people.

The second purpose of these experiments is to find out just what are the problems involved in doing this, and how does one go about solving them. The answer is that there are problems, that they have not been solved, but that the way to solving them is now quite clear, so let me give you a breakdown on this.

So far, these experiments, which are not aimed at production, have shown that the costs of mining in this way have proved to be about three times greater than those of conventional mining, but this is the cost of mining on an experimental basis, which is necessarily more expensive.

What are the prospects of reducing this three-times cost factor? I think they are very good. When we started off, we were cutting something like a sixth of a fathom per machine shift, and we were using something like three tools per fathom. Right now the machines are cutting somewhat better than this. They are cutting something like half a fathom per machine shift—that's three times as good—and the tool life has gone up to something like half a fathom per tool, which is somewhat better.

On many occasions three-quarters of a fathom have been cut per machine shift and several tools have cut a few fathoms, so that the way seems clear to a very significant—certainly a three-fold—improvement in the cutting, based on the present machine configuration. There are means by which we can accomplish considerable improvements within this configuration. As the machine is now, it takes an hour to do the cutting, and it takes an hour to do the moving.

The cutting time cannot be much reduced, because of the limitations in cutting speed, which are inherent in this system, so let's say that the cutting time can be reduced to 40 minutes per bench of one-quarter fathom.

The other thing is that it's a very cumbersome device to move, because each of those props weighs about 120 lb, and there are four of them which have to be taken off and put on every time the machine is moved. That is just one of the difficulties, so that there is every prospect, with no real research involved at all—just straight engineering design—to improve the moving time and reduce it to 20 minutes. We can then see that the utilization of the machine can also be increased by a factor of about two over the best present, and something like three times over our average performance as of to date. Work is already in hand on these developments.

We can see quite clearly, then, that there is every prospect right now, of building a machine which could be used to mine at the same cost as conventional mining. You might well ask, 'What benefit, then, is there in rock cutting, if we are going to mine at the same cost as conventional mining?'

Firstly, let me give you the least good reason for doing this, and that is that rockcutting is in its infancy. If, in its infancy, it is as good as conventional mining, which dates from Nobel's invention of dynamite and the detonator just over 100 years ago, and from the introduction of pneumatic rock drills in about 1925, then it's doing pretty well, and there is every prospect that it can do a lot better as soon as we approach as much know-how as we have with the conventional system. That's the least reason for rockcutting.

The real reason for rockcutting is that one is mining gold, not rock, and there is every prospect, with the new thin reefs that we have available to us, of reducing the tonnage of rock mined, to produce a given revenue, by between two times and three times. This means that a mine, which has to mine at present at 40 in. stoping widths 200,000 tons per month to produce its revenue, could derive the same revenue from mining a tonnage of 100,000 or perhaps even 70,000 tons per month. It does not have to work in terms of these figures. I am merely trying to demonstrate the fact that you are selecting that part of the rock which contains gold and mining that, and leaving the rest of it in the mine.

Where do the benefits of this come in? The direct benefits are obvious. The reticulation system of a mine is very expensive. This is, perhaps, best illustrated by the fact that old mines, which have paid off their capital costs, can mine at something like four dwt per ton and make a profit, whereas to open a new mine you need ten dwt per ton.

Anything one can do to get better utilization of the capital facilities is a major step forward in mining technology, and this is what rockcutting seeks to achieve, because by reducing the tonnage you mine, or if you want to look at it another way by upgrading the reefs that one mines, one gets a much better utilization of one's capital facilities, and this is where the major asset of rockcutting lies. I cannot dwell on this because time does not permit, but the whole thing has been thoroughly and very conservatively analyzed by my colleagues Mr Immelman and Mr Mrost and myself, and the results are to be presented at the Ninth Commonwealth Mining Congress in London in May next year. This shows, quite conclusively, that there are dramatic benefits to be gained from increasing the capital utailization of those expensive facilities such as shafts, development work, hoisting and ventilation equipment that a deep-level mine requires.

Those are the direct, obvious and unarguable benefits. There are others which are equally unarguable and just as important. These are involved with the problems of strata control and thermal control. I won't dwell on these either, because my colleagues, Dr Whillier and Mr Hodgson, are going to enlarge upon this in the discussion. The essence of these problems really depends on the extent to which you disturb the equilibrium of the earth by mining, and the more tons you take out, and the greater the depths from which you take them, the bigger is the disturbance to equilibrium and the more it costs you. It's as simple as that. You can work out the argument in detail.

One of the consequences of this is that, with our present system of mining at 40 in., it would be very difficult to mine safely, from a strata control point of view, and it would be very costly from a thermal control point of view to mine much below 12,000 ft. However, there are ways in which one might be able to do this. For example, one might be able to fill the stopes either completely or partially, or leave pillars behind —and these are possibilities which have been considered—but by far the best solution is to leave all the rock behind which does not contain any significant quantities of gold. This is what selective mining, by reducing the thickness of the stope, accomplishes. If we reduce the stoping widths from some 40 in. to some 12 in., then with our current knowledge of strata control and thermal control, there is no reason why we should not mine down to 18,000 ft below surface.

I have sketched out how we can cut rock, how we propose to mine by cutting rock, the progress that rockcutting has made, and finally, I would like to make one point, and that is that I have spent some time describing to you an early rockcutter, I have shown you about 16 slides in which early rock cutters appear. All of you are familiar with the appearance of a modern crawler tractor. May I, finally, show you a slide of what an early crawler tractor looked like. The principle is the same.