The reworking of old mines — a rock mechanics challenge*

by R. C. MORE O'FERRALL†, M.Sc. (Wits.), M.S.A.I.M.M.

SYNOPSIS

The author mentions some of the problems he has encountered, together with their solutions. These include the stoping of isolated pillars, the reduction of the size of shaft pillars, the stoping of a new horizon above or below a horizon that has already been stoped out, and the mining of thick bands of reef left behind in the footwall or hangingwall.

SAMEVATTING

Die skrywer noem sommige van die probleme wat hy teëgekom het, tesame met hul oplossings. Hierdie probleme sluit in die afbouing van geïsoleerde pilare, die verkleining van skagpilare, die afbouing van 'n nuwe horison bo en onder 'n horison wat reeds uitgewerk is, en die ontginning van dik stroke rif wat in die vloer of dak agtergelaat is.

Introduction

The opening up and reworking of old gold mines can be a severe challenge to the Rock Mechanics Engineer. His ingenuity will be tested to the full, and he will require, not only all the technology placed at his disposal during the past two decades, but also a good insight into the behaviour of fractured rock and sound judgement regarding the amount of new support required. Bad judgement in this latter sphere could result either in high support costs, rendering the mining operation uneconomical, or unsafe working conditions.

His first priority lies in designing, with the production personnel, the best and safest sequence of mining for the orebody concerned. Once this has been decided, he is required to appraise the condition of current working support, and to determine what additional support is required. This can be a difficult task, involving an appraisal of the possible occurrence of seismic activity in the area and its effect on the condition of the old workings.

The ore can arise from a variety of sources, the most important being

(1) previously unpayable blocks on a continuation of a one-reef horizon,

(2) one or more reef horizons in the hangingwall and/or footwall of the original reef, and

(3) hangingwall or footwall bands of the original reef horizon.

In this paper, the techniques used in solving these problems are described, the illustrations being drawn from actual mines.

Stoping of Isolated Pillars

The stoping of isolated pillars should always be considered very carefully before mining commences. They are very highly stressed blocks of ground in which a large amount of strain energy is stored and, if disturbed, could result in a severe rock burst. In addition, they are often largely responsible for the stability of geological and mining structures in the vicinity.

Interaction of Pillars

It has often occurred in the past that the extraction of a pillar in one area has resulted in the loss of excavations in another. Frequently this situation is not appreciated at the time. An example of such an occurrence is given in Fig. 1, which is a hypothetical layout of a shaft pillar surrounded by 7 blocks of ore.

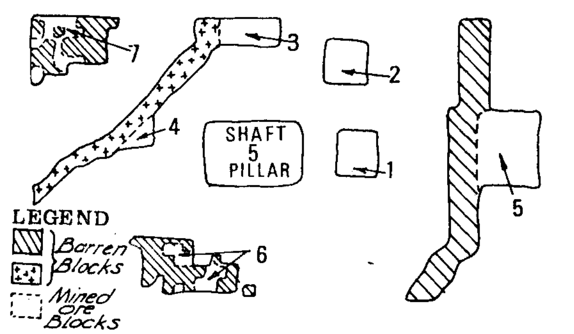

Fig. 1—Seven blocks of ore in the vicinity of a shaft pillar

Fig. 1 demonstrates the relative effect of various blocks on stress at the intersection between the shaft and the reef. The shaft is assumed to lie at a depth of 1000 m, where the primitive vertical stress is 26,5 MPa. Owing to previous mining of the reef, the stress at the shaft had risen to 49,82 MPa. If a field stress of 53,0 MPa is the maximum that can be tolerated, the mining of each block of ore will affect the shaft position as shown in Table I.

It can be seen from Table I that the mining of either Blocks 1 or 2, which are close to the shaft, accounts

TABLE I

EFFECT OF MINING ON SHAFT POSITION

Block no.	Stress kPa	Stress increment kPa
1	52,47	2,65
2	52,09	2,27
3	51,63	1,81
4	50,26	0,44
6 and 7	49,82	None

* Paper presented at the colloquium on 'The Influence of a Fluctuating Gold Price on the Potential Mining of Low-grade Areas', which was held by the South African Institute of Mining and Metallurgy in Randburg on 5th June, 1981.

† Stilfontein Gold Mining Company Limited, P.O. Box 1, Stilfontein 2550, Transvaal.

almost entirely for the total permissible stress increase, whereas Blocks 4 to 7 show very little increase. This latter effect is due to the shielding effect of barren areas in the vicinity of the blocks.

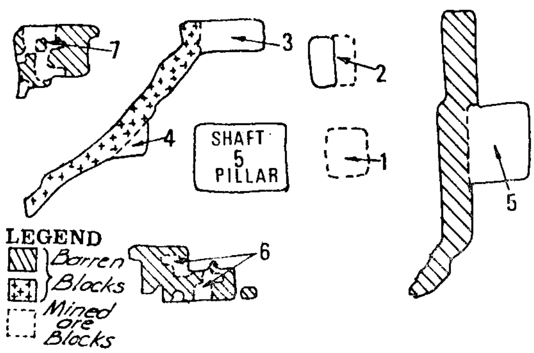

Fig. 2—Block I and a portion of Block 2 have been mined, and the stress level at the shaft is critical; 20 per cent extraction

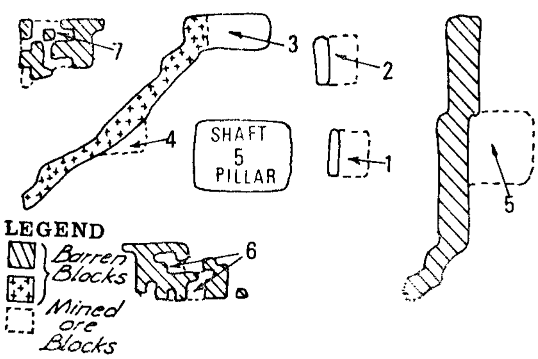

Fig. 3—Blocks 4 to 7 have been mined out, as have major portions of Block I and 2; the stress level at the shaft is critical; 76 per cent extraction

Figs. 2 and 3 are two possible mining configurations, both of which result in the maximum permissible stress level of 53 MPa. In Fig. 2, only some 20 per cent of the total available ore has been extracted because the two blocks closest to the shaft were mined first. These blocks had a maximum influence on the stress level in the shaft, and in a real situation the mining of these two blocks of ore could have seriously jeopardized the economics of the entire operation. In Fig. 3, 76 per cent of the ore had been extracted before the maximum permissible stress was reached. This was achieved by the mining of the blocks remote from the shaft and/or shielded from the shaft by large barren blocks. The results of the sensitivity test given in Table I served as a guide as to which blocks could be stoped with minimum effect.

This example shows how the injudicious extraction of ore blocks can seriously affect the economics of an entire pillar-extraction programme. In practice, such an operation should be planned carefully so that as much of the mineral content as possible can be extracted.

Effect of Isolated Pillars on Geological Features

Pillars in the vicinity of faults and dykes have a considerable bearing on the stress fields within these structures.

The effect of pillars on dykes can easily be ascertained by the use of computer techniques that are currently available.

The effect on fault planes of such pillar removal is not easily established, since the stress field in the vicinity of faults, particularly young faults, frequently differs considerably from the rest of the mining area. When pillars near faults are stoped, full remnant conditions should be observed at all times whether a mine is prone to rock bursts or not, since the movement of fault planes is known to be the cause of the larger seismic events.

Effect of Removal of Pillars on Secondary Closure

Frequently, particularly where scattered mining has been practised, isolated pillars have prevented total closure taking place. The stoping of these pillars can result in total closure occurring, thereby transmitting to the footwall stress of a magnitude similar to primitive stress. If excavations exist in the footwall fracture zone of the stope, they can suffer considerable damage because the strength properties of the rock have been reduced by the fracturing process.

If the footwall excavations are overlain by a pillar or waste wall, 'point' loading can take place with dramatic consequences.

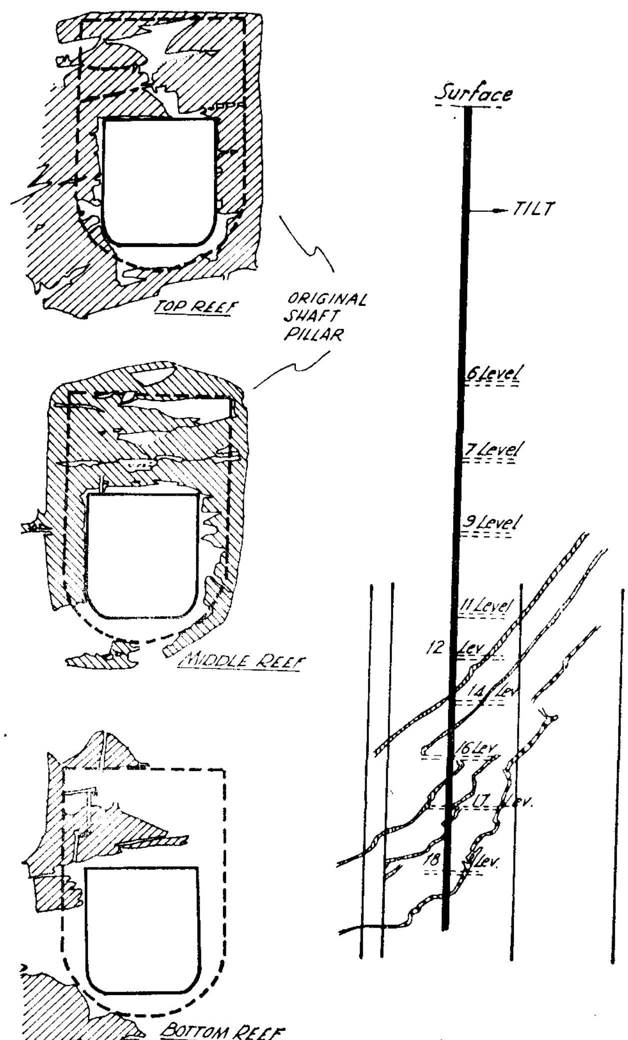

Fig. 4—Damage to a shaft resulting from a reduction in the size of the pillar.

Reduction in the Size of Shaft Pillars

It is often possible to reduce the size of shaft pillars, if it is undesirable to remove them altogether, from their original planned size, since barren blocks, dykes, and faults left unmined in the vicinity of the shaft pillar help to reduce the stress in the shaft pillar to below that originally planned. However, any reduction in size of a shaft pillar should be carefully planned after the necessary calculations have been made, and a close watch should be kept on all vulnerable excavations.

Change in stress is not the only feature that must be watched when portion of a shaft pillar is removed. The injudicious stoping of three of the four reefs on an up-dip side of the shaft pillar shown in Fig. 4, resulted in a shortening of the shaft between 6 and 7 levels, accompanied by considerable scaling of the shaft sidewalls and damage to 6 level station and crosscut. The actual shortening of the shaft was about 250 mm and was accompanied by a tilt towards the up-dip workings. The workings below 7 level showed no sign of any abnormal increase in stress.

Multi-reef Stoping

Stoping of a new reef horizon above or below a horizon that has already been stoped out can create its own peculiar problems.

Where the general hangingwall strata of the old stope consist of a good solid quartzite, not much difficulty is experienced when the upper horizon is stoped.

However, should the hangingwall strata comprise well-bedded quartzite layers with shaly partings, bed separation is likely to occur up to 20 m above the stope. Situations are on record where gaps of more than 100 mm between the strata have been encountered during raise development on upper horizons. This situation can occur in relatively shallow areas where scattered mining has taken place and the spans are limited in extent. In vast stoped-out areas, total closure will ensure that no partings exist in the hangingwall.

Stoping of Hangingwall Reefs

Where lower horizons have already been stoped, little can be done to consolidate the hangingwall strata. Where the upper-horizon stopes are 20 m or less above the lower horizon, they usually have to be heavily timbered and are often subjected to rapid convergence.

In weak ground it is obviously best for the upper horizon to be mined first in a multi-reef situation. However, owing to grade and tonnage requirements, this may not always be possible and it becomes necessary to mine the lower horizon first. In such cases, a system of pipe sticks and crush pillars has been used to advantage. The crush pillars have dimensions that are less than twice the stoping width to ensure fracture and thereby avoid high stress concentrations while providing considerable support resistance. Fig. 5 is an actual stope layout using crush pillars 15 m below the higher stoping horizon. The pillars are spaced at 20 m centres on strike.

Stoping of Footwall Reefs

In extensively stoped areas where total closure has occurred, stoping of the lower reefs can take place in much the same manner as when the upper reef was stoped. Problems can arise if waste ribs had been used as permanent support during the stoping of the upper reef horizon because high stress points will be transmitted to the lower reef if the parting is small.

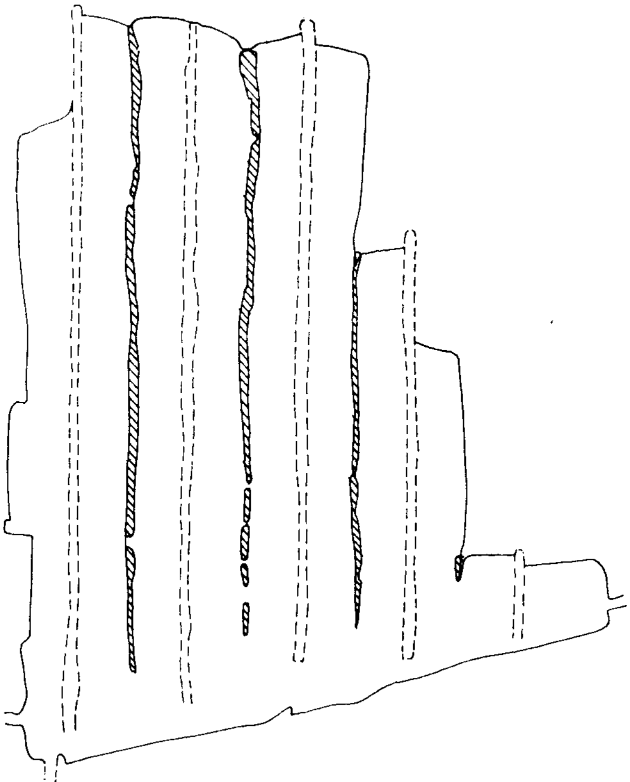

Fig. 5—Layout of crush pillars on the bottom horizon of a reef

When the stoping span has been limited and total closure has not occurred, it is often possible for the support costs to be reduced considerably by the use of solid pillars and wooden props as support. In that case,

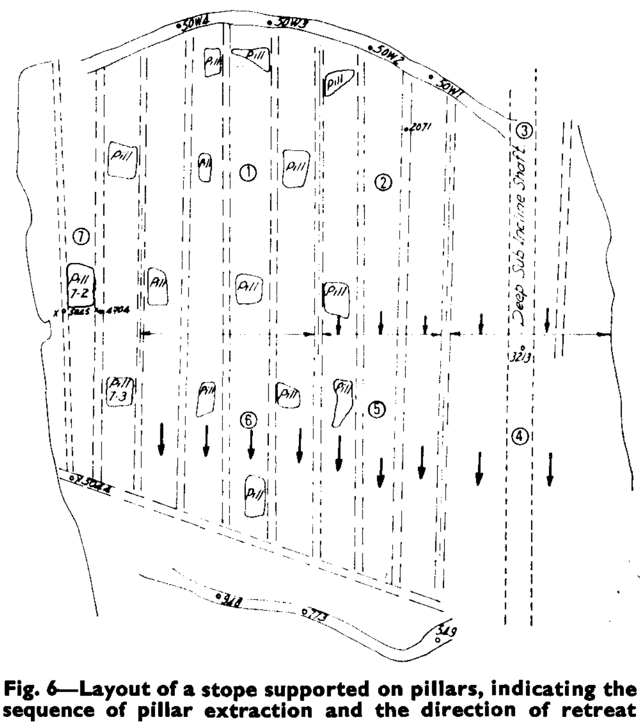

Fig. 6—Layout of a stope supported on pillars, indicating the sequence of pillar extraction and the direction of retreat

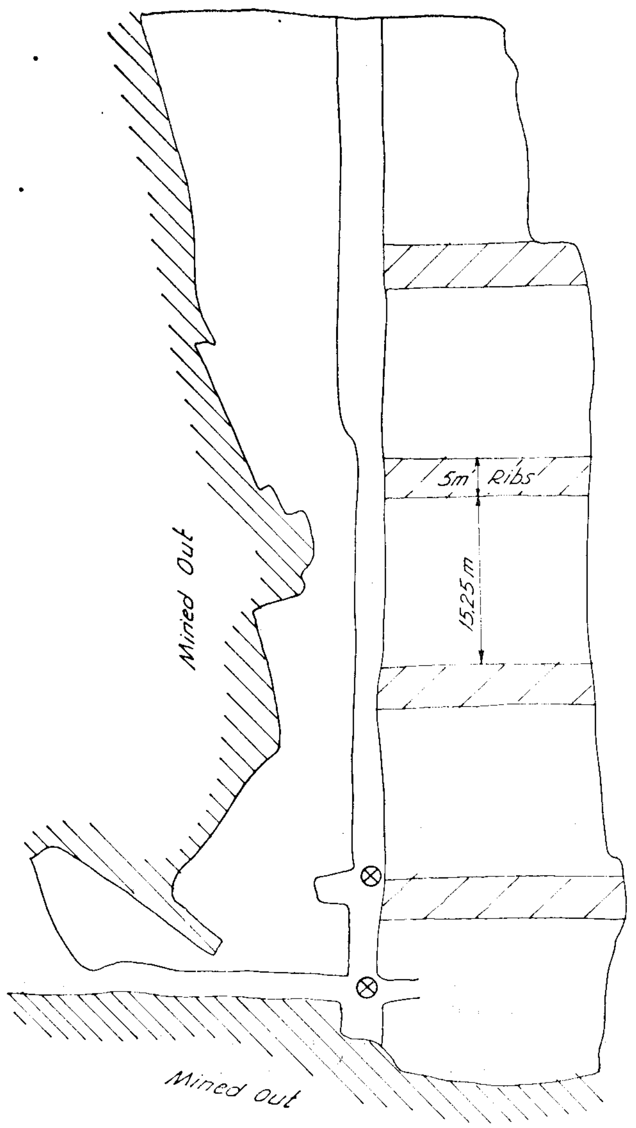

Fig. 7—Layout of typical footwall ribs to facilitate the stoping of footwall bands

the pillars should be designed to carry the weight of the parting between the reefs and the weight of the rock in the fracture zone above the top stoping horizon. Pillars should be designed in such a way as to permit systematic extraction, if so desired, at the end of the life of the lower horizon. This system of support is particularly useful if the lower reef horizon is greater than 2 m wide, which makes the use of conventional packs ineffective and costly.

Fig. 6 shows the layout of a Main Reef stope supported on pillars under the stoped out South Reef some 30 m above. The order of footwall lifting and pillar removal is shown on the plan.

Footwalling and Hangingwalling

Thick bands of reef left behind in the footwall or hangingwall of an orebody during initial stoping operations create support problems when, sometimes years later, it becomes desirable to mine them.

All the closure took place during the initial stoping, and therefore only the dead weight of the hangingwall is available to load the pack during the second phase of mining. Furthermore, as the load generated by a pack depends on its degree of compression, a high pack will generate a smaller load resistance than a low pack for the same amount of closure. A situation can therefore develop in which stoping operations continue while the high packs generate very little load until a critical span is reached, at which stage the hangingwall will rapidly settle on the packs, often resulting in the loss of the stope.

To avoid this, 5 m ribs of footwall or hangingwall are left at intervals of, say, 15 to 25 m on dip. On these ribs the original support is left intact to form zones of rigid support. If the original timber has decayed, new rigid packs or pipe sticks should be installed in these ribs. Obviously, if so desired, these ribs can be removed on the retreat and the stope allowed to collapse. Fig. 7 shows an old stope where it is planned to use this technique to solve the support problem.

Support

The timber supports installed in old workings have often decayed by the time reworking takes place, and are replaced as a matter of routine.

On the other hand, rockstuds that were installed during the original working may still appear to be in good condition. The appearance of the washers can be misleading since the stud often corrodes at some depth up the hole. If the rockstuds were grouted in during their initial installation, there is a fair chance that they will be intact.

If the rockstuds were not grouted in, they should be regarded as suspect, and the tunnels should probably be resupported since extensive collapse of the hangingwall fracture zone can occur, particularly if mining triggers a large seismic event.

Conclusion

Each of the problems that can arise during the reworking of old areas of mines requires considerable investigation and discussion before a suitable solution can be arrived at. The material for this paper was drawn from typical problems that have arisen on the mines with which the author is associated.

Acknowledgement

The author thanks the Consulting Engineer and General Managers of the mines in which the problems mentioned in the paper were encountered.