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MINING OF WIDE, FLATLY DIPPING REEFS AT KAMATIVI TIN MINES LTD., RHODESIA

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SUMMARY

A description is given here of the development of ideas and activities that have led to the introduction of a new method of mining deep, thick, flatly dipping pegmatite reefs at Kamativi, Rhodesia.

INTRODUCTION

Up and until 1965 approximately 75% of the run-of-mine ore was supplied by cheap open-cast mining of low grade wide reefs of over 20 feet in width (approximately 35,000 tons per month); the rest from two small underground sections producing 10,000 to 15,000 tons of ore per month from high grade narrow reefs, occurring at shallow depth. The standard practice for the mining of the underground reefs has been centre gully, barrow stoping, and extraction method suitable for reefs varying in width from 1 foot to 18 feet. The method is described by Bellasis (1960).

Before the underground and open cast ore deposits became exhausted new reserves at a greater depth were found by an extensive diamond drilling programme. The character of these reserves differs considerably from that of the shallow reefs. The most important feature is that they are much wider, generally in excess of 18 feet. This, together with the fact that the total future productions would have to come from deeper mining operations, demanded a new mining approach. The ultimate result was a combination of previous experience and new ideas, tested by practical mining operations.

Shaftsinking started in 1962 to give access to the new reserves. Thereafter they were progressively brought into full production. Since early 1968 these newly exploited reserves have supplied the total mined tonnage.

REEF CONDITIONS

A description of the geology of the Kamativi area has been given by Fick (1960). Only the main particular features concerning the reef conditions will be given here.

The tin-bearing pegmatites being mined at the present time belong, to what is locally called, the "Deep Wide Lode", indicating its greater depth of over 600 ft. and greater reefwidth as compared with the depleted underground reserves. The reefs are moderately dipping, from between 10° and 25°, and vary in width from 6 to over 30 feet. They cut across micaceous schists that have almost vertical, schistose planes. These schists show better roof conditions at this greater depth than is the case at the narrow reefs close to the surface. The properties of the reefs are also different. This wider reef is brittle and splintery as a result of the presence of large flakes and slabs of feldspar. This, was an important factor in the development of the design of the mining method.

The narrow reefs on the contrary were more solid and compact. This characteristic property was exploited to strengthen the less secure areas of the

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hanging wall by leaving a thin layer of reef; subsequently to be reclaimed at the closing down of the mine section.

GENERAL LAY-OUT OF THE MINE

Outside the indicated ore reserve an exploration shaft, 18 ft. diameter, was sunk vertically to a depth of 750 feet. This shaft contributes only a small percentage of the total tonnage: its main use being to supply the mines ventilation, power and communication services, and for the access of men and material. An inclined production shaft follows, more or less, the dip of the reefs – approximately 14.5° to the horizontal – to a vertical depth of 750 ft. and has a total length of 3000 ft. These two shafts are approximately 2,400 feet apart and are interconnected by two main haulage ways: that is levels No. 2 and No. 3. The inclined shaft is equipped with two bottom discharging skips, of 7.5 ton capacity. Balanced hoisting is effected by using a double drum hoist of 250 R.M.S. H.P., manufactured by Hunslet and Taylor. These skips travel on 60 lbs/yd welded rails, resting on longitudinal concrete sills, which run the whole length of the shaft. The underground skip receiving ore-pass system and measuring bins are pneumatically operated. The filling of the skips is a matter of a few seconds and, as the raising of the loaded skip takes little more than 4 minutes, the capacity of this shaft is approximately 100 tons per hour. The underground ore is tipped directly into a 1800 ton-capacity ore-bin on the surface adjacent to the mill.

As little information was available concerning reef and hanging wall conditions, the development and initial stoping was based on previous practice. Where possible all development was carried out in ore along the footwall of the reef. The vertical distance between the levels was made 100 ft. resulting in a raise length of from 350 to 400 ft. between levels. The raises – 7 ft. x 8 ft. – are 400 ft. apart producing a block area of 400 x 400 ft. Initially 60 H.P. scrapers were installed in the drives opposite the boxhole of the stopes, but later a special arrangement was developed to avoid interference with the scraping operations by traffic in the drives. The ore is scraped into 4 ton Granby mine cars, hauled to the incline shaft by diesel locomotives and tipped into the ore-pass system.

INITIAL STOPING METHODS

Experimental stoping was based on the following principles that there should be:

1. High daily production from a stope in order to have a minimum number of stopes in operation.
2. A minimum of stope preparation and waste cutting.
3. The minimum number of labourers.
4. Safe working conditions.
5. Safe and easy access to the working places for men and material.
6. A possibility for selective mining.
7. High extraction ratios, i.e. percentage of the ore reserve block mined.

A description will be given of the two methods from which the fully operational one was developed. (fig. 1 to 5)

A. The bottom-ledge method.
B. The top-ledge method.

These two methods have many common features. (The numbers in parenthesis refer to the numbers as indicated in figures 1 to 4.)

1. Slot cutting is carried out over the whole length of the raise, 8 ft. wide and up to the hanging wall (fig. 5).
2. Parallel along the slot a ledge of 15 ft. wide and 9 ft. high is formed in reef either on the footwall (11), or against the hanging wall (1).
3. Benching from the ledges can start by overhand or underhand stoping.
4. The ore is removed by scraping along the length of the face parallel with the original raise.
5. Along the haulage levels (7 & 8), a drive pillar (4) of 20 ft. wide is left.
6. Above the bottom drive pillar a bottom stope drive (3) is driven ahead; to prepare loading boxes (5) in the drive pillar 40 to 60 ft. apart. Boxhole sites (6) have to be blasted in the drive for the installation of the Joy-Sullivan scraper winches.
7. Access drives (2 & 12) for men and material have to be established before the actual mining starts. They are driven parallel with the main haulage levels either, on the footwall (12), or against the hanging wall (2), between two raises, thereby dividing the blocks into three parts.
8. After mining an area of 80 ft. wide a rib pillar (10 & 13). 20 ft. wide, is left and a new raise started.

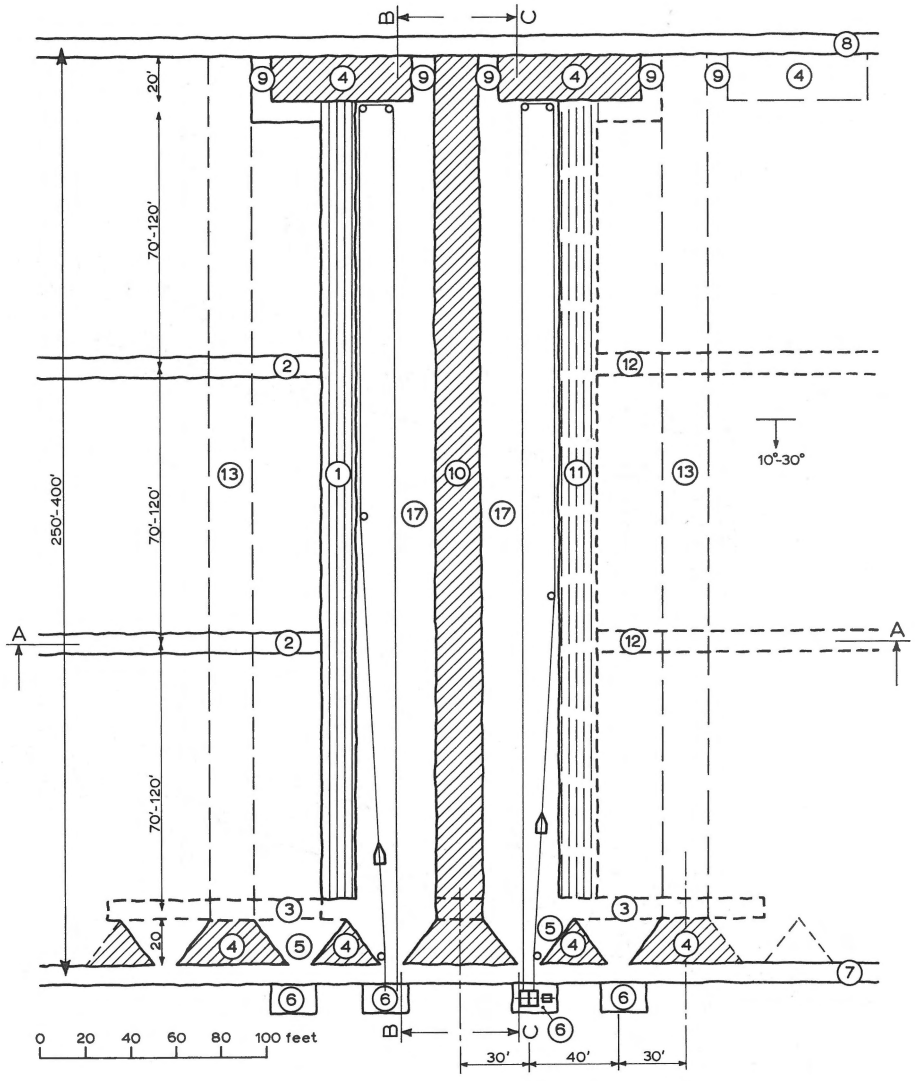


Fig. 1
Principle of top- and bottomledge stoping method. Stope plan parallel with reef.

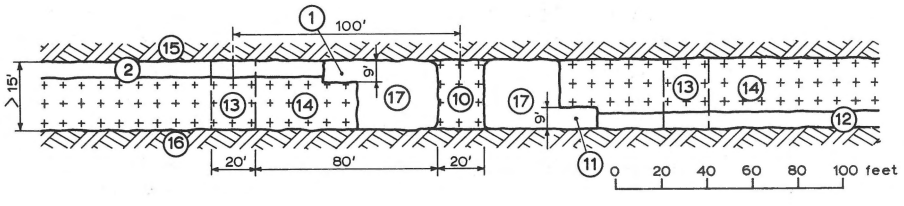


Fig. 2
Section A-A.

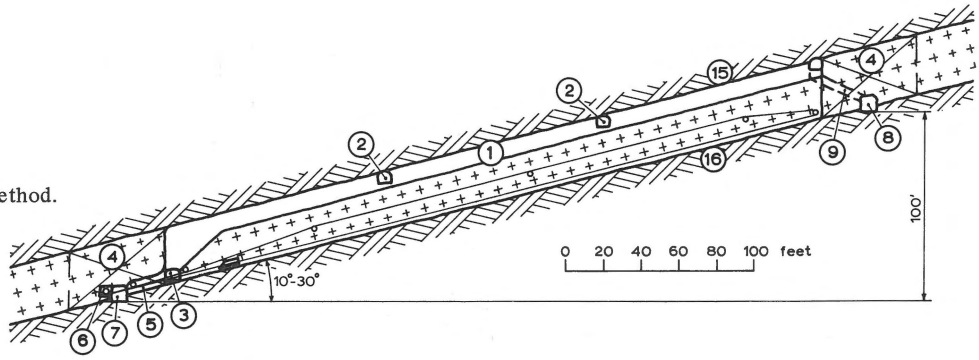


Fig. 3
Section B-B. Topledge method.

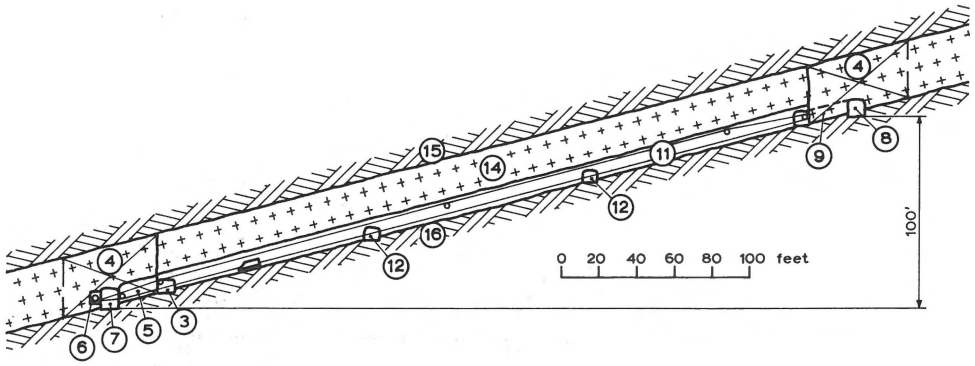


Fig. 4
Section C-C. Bottomledge method.

explanation of figures 1-4

1	topledge	9	manways
2	hanging wall access drives	10	rib pillar
3	bottom stope drive	11	bottom ledge
4	drive pillar	12	footwall access drives
5	boxhole	13	planned rib pillar
6	scraper chamber	14	reef
7	main haulage lower level	15	hanging wall
8	main haulage upper level	16	footwall
		17	mined-out area

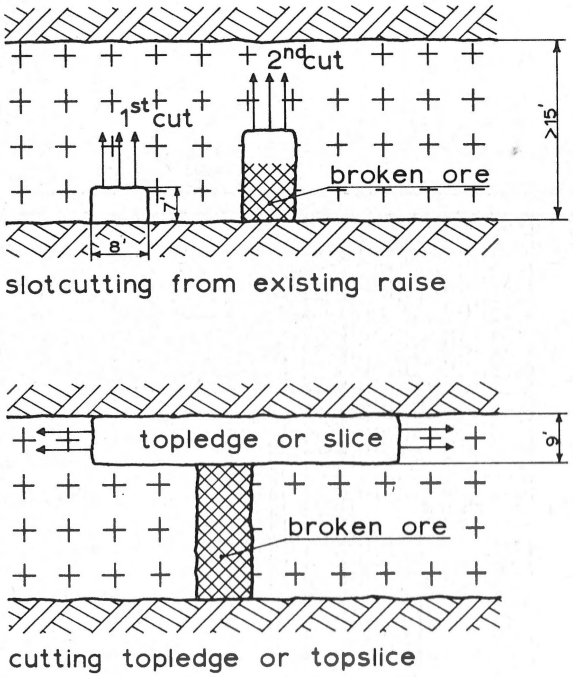


Fig. 5
Stages in slotcutting and cutting of topledge or topslice.

Although the bottom-ledge method was considered the most suitable and safest, it soon appeared that a switch-over to the top-ledge method was desirable due to the fractured character of the ore. The safety of men working under the roof of ore was endangered by the scaling-off of large tabular slabs of ore, caused by the combination of fractures running to the hanging wall and zoning of the reef parallel with the dip of the ore body. The top-ledge method showed an unexpectedly safe roof of schists.

These facts were contrary to what was originally asssumed and could not be predicted from boreholes and development works; as they only became obvious once wide, unsupported areas were excavated.

The preparation of the access drives required a considerable amount of development work. A high daily production was not obtained due to the long scraping distance of over 300 ft. The accumulation of a few thousand tons of broken ore at the top of the stopes was a permanent obstacle to maintaining a straight working face since the ore was, by preference, scraped from the bottom end firstly, to extract the required tonnage quickly. Trials with two scraperhoes, approximately 150 ft. apart and on the same rope, were not successful.

The number of labourers employed was large, but unavoidable for the necessary cleaning of the ledges: required before drilling of the benches could start. This problem could have been solved by the use of more stopes and a more mobile labour force. However, in the event, this solution was not a practical proposition as the mine was still in its early period of development and it would have necessitated the deployment of additional resources.

Blasting of the scraper chambers (6), in the main drive (7), delayed the hauling of mine cars unless this was done during the development and before the ore reserves were blocked out.

The driving of a new raise past the rib pillar would cause a serious hold-up in the continuation of stoping activities. This operation is accelerated by implementing the practice as will be described in the next chapter.

The extraction ratios are approximately 70%, but may be raised to between 80 & 85% by reclamation of rib and drive pillars.

PRESENT STOPING METHOD
(figures 5-10)

The preceding methods provided a good deal of information concerning rock-characteristics, working-conditions and efficiency. Based on these experiences the following aspects were reconsidered in order to seek improvement.

1. The increase of daily tonnage per stope by the use of more scrapers in one stope. This was obtained (a); by scraping along the ledge which is converted into a topslice (1), extended as an independent unit, and (b); by cleaning from short benches (21 & 22) which are blasted in a direction that is parallel to the main level drive (7).
2. Reduction of unproductive stope preparation work by omitting the cutting of two extra access drives.
3. Improvement of safety conditions by reducing the necessity for work in the open stopes; and better roof control over the topslice (1).

From these considerations resulted the following working procedure.

From the existing raises a slot (fig. 5) is cut up to the hanging wall and at the same time a bottom stope

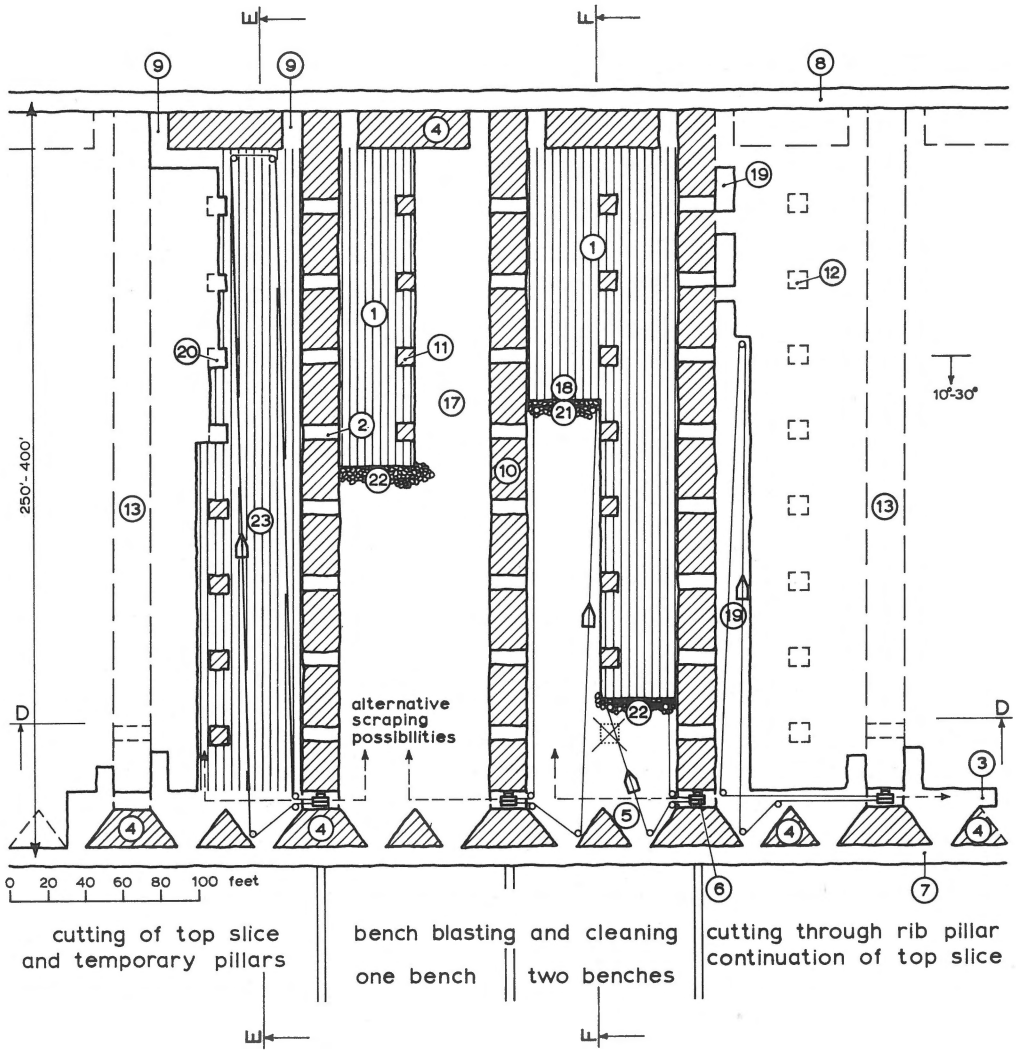


Fig. 6

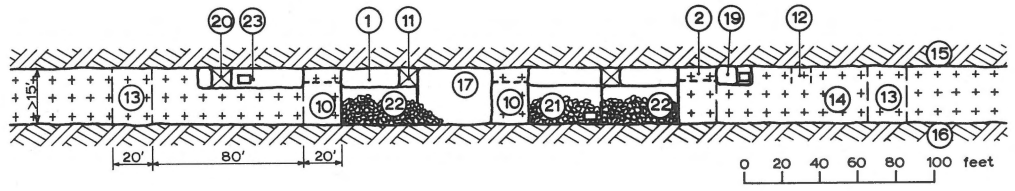


Fig. 7
Section D-D.

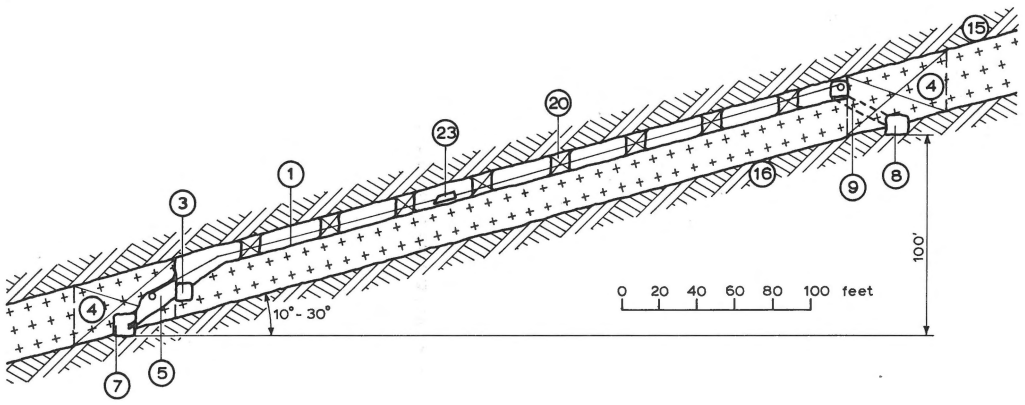


Fig. 8
Section E-E. Cutting of topslice and scraping.

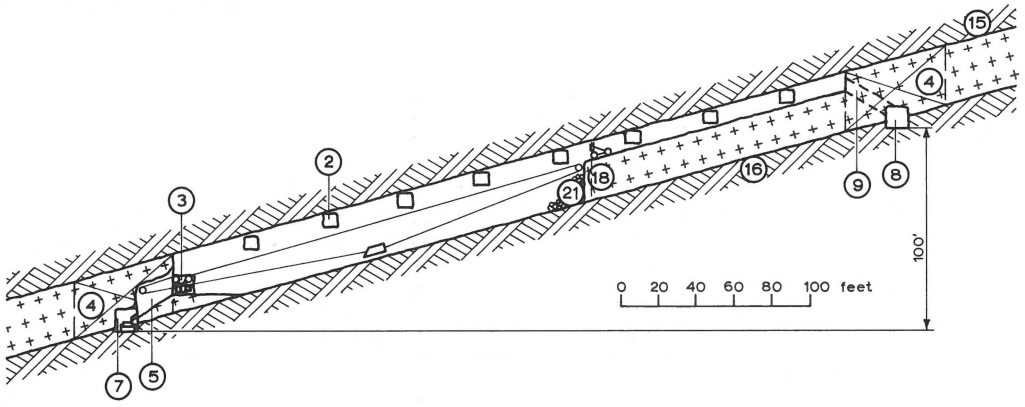


Fig. 9
Section F-F. Bench drilling and scraping.

explanation of figures 6-9

1	topslice	12	planned temporary pillar
2	connection of topslice through rib pillar (10)	13	planned rib pillar
3	bottom stope drive	14	reef
4	drive pillar	15	hanging wall
5	boxhole	16	footwall
6	scraper position	17	mined-out area
7	main haulage lower level	18	bench
8	main haulage upper level	19	continuation of topslice past rib pillar
9	manways	20	cutting of temporary pillar
10	rib pillar	21	scraping from bench nr. 1
11	temporary pillar	22	scraping from bench nr. 2
		23	scraping from topslice

drive (3) starts parallel with the main level (7), at a distance of 20 feet up-dip. This bottom drive holes-down through the so formed drive pillar (4) into the main drive at intervals of 40 and 60 ft., giving access to the stope and forming the future boxholes (5). Scraper winches are installed at suitable points in the bottom drive (6). From the slot (fig. 5), a topslice (1) 9 ft. high is mined against the hanging wall and connected to the bottom drive (3) (fig. 8 & 10). The upper level (8) provides access to the stope by manways (9) through a drive pillar, 20 ft. wide (4). When the advance of the slice is 80 ft. along the strike a rib pillar (10 & 13), 20 ft. wide, is left. The hanging wall of the topslice is temporarily supported by timber props and an off-set row of 9′ x 9′ pillars (11 & 12) 40 ft. apart and parallel with the rib pillar. This off-set row of pillars is provided in order to maintain safe roof conditions throughout the first benching stage. The rib pillar is holed by narrow crosscuts (2), at 40 ft. intervals. These crosscuts are connected-up again (19) past the rib pillar and the mining of the topslice then continues over a distance of 80 ft. along the strike towards the next rib pillar (13). As soon as 40 ft. of the topslice has been mined, benching (18) can start. This first benching area (21) is free of the temporary pillars and the timber props are removed as this bench, 40 ft. wide, advances up-dip.

Mining of the second bench of 40 ft. (22) will be possible when the topslice has advanced past the rib pillar through the narrow crosscuts (2). Not only the timber props have to be removed, but also the 9′ x 9′ pillars (11), as the bench face moves upwards. Access to the stope is always possible through the boxholes (5), the topledge (1) and the rib pillar (2).

CONCLUSION AND COMMENT

The described method has these several advantages:

As more faces and scrapers can be employed in one stope it is possible to draw ore from more than one boxhole, thereby increasing the production rate. Moreover, stoping can be made more flexible and systematic by planning for a spare face, which gives time to deal with mechanical breakdowns, occurrence of large boulders, misfires etc; without loss of production.

Scrapers do not have to be allocated to one specific face, but are able to switch over from, for example, topledge to bench No. 1 or No. 2; or to a bench on the other side of the rib pillar by a simple re-arrangement of snatchblock pulleys. The scraping from the benches is concentrated and such difficulties as there may be are confined to a small area near the bench. This gives the advantage that they are more easily solved than along benches of over 300 ft. of the previous methods. At the same time, cleaning down to the footwall is under closer supervision.

Although the cleaning of the topslice has still to be done over a distance of 300 to 400 ft., it can be said that this operation too gives less problems, as the occurrence of large boulders, though rare, can be dealt with safely.

Stope preparation is greatly reduced. The preparation of the bottom stope drive, the boxholes and manways, required as routine mining tasks in any event, form an integral part of the stoping operation; and as such, do not reduce the tonnage that would be expected from normal stoping. The continuation of the topslice through the rib pillar gives a reduced tonnage for a limited period. This is partly overcome by the simultaneous cutting of the cross-cuts. By comparison, the cutting of an entirely new raise takes at least four times as long with an adversely low tonnage, as it would be produced by one machine only. In addition, all new raises for primary development are driven along the hanging wall of the reef, so that slotcutting is avoided and topslicing can start immediately.

From a safety aspect complete roof-control is possible during the topslicing operation. The topslice is temporarily supported by a row of pillars with extra timber props adding further to the safety of this work. Less secure sections of the roof will be already revealed by the topslicing operation. However, as the cleaning of the benches is concentrated at a small area, any possible risk is diminished by close supervision; and special precautions, including dressing-down loose rock and roofbolting, will reduce the hazards from rockfall.

The number in the lashing gang can be kept small, as handlashing is kept to a minimum by the fullest application of face-scraping. This method of cleaning is not possible with the ledge methods, where scraping hampers the drilling of the benches.

Valuation of the ore reserve block is made in part by chip-sampling of the visible faces of the drives, the raises and from diamond drilling. During stoping operations the face of the topslice is regularly sampled by chip-sampling. That the benching area can

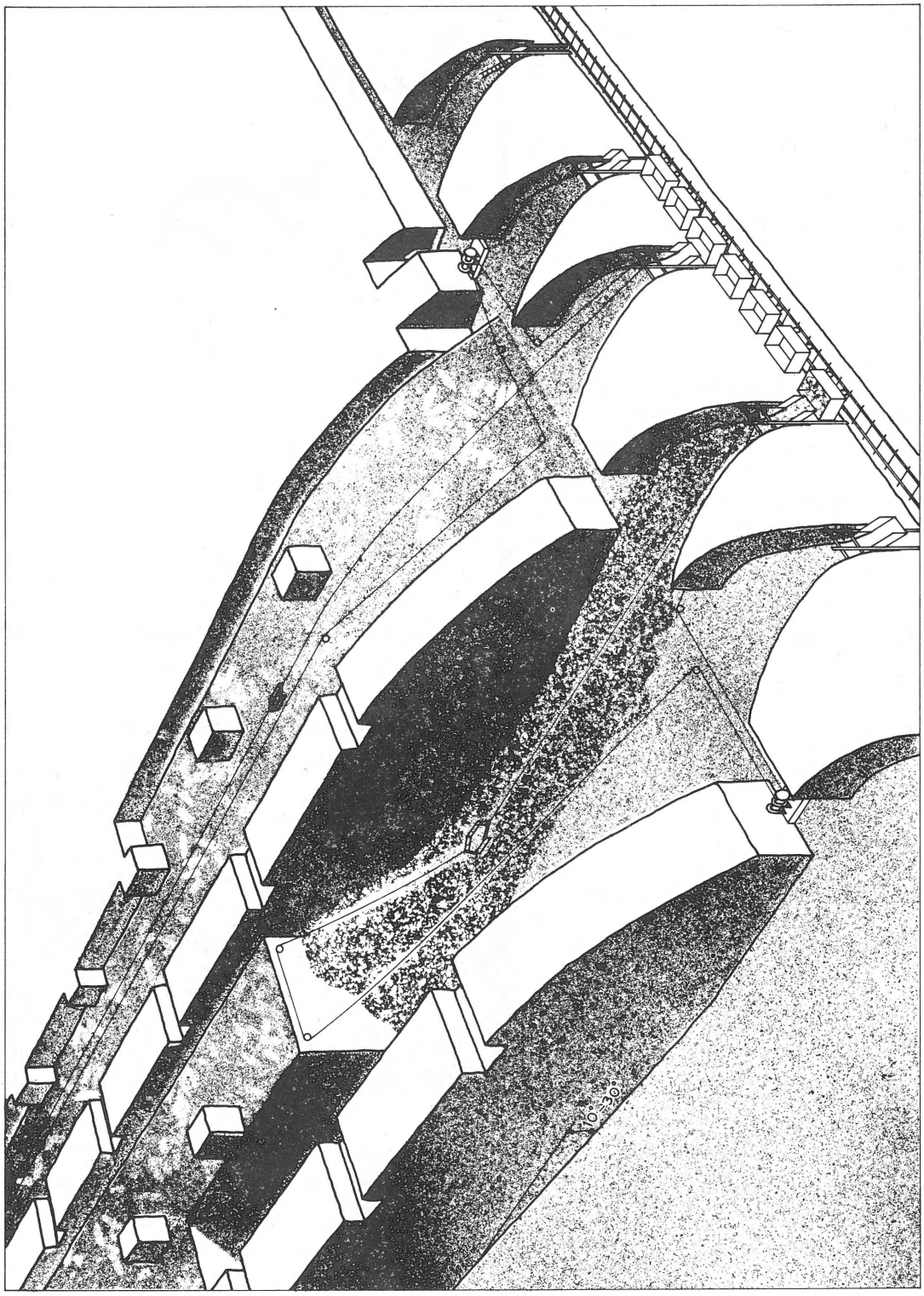


Fig. 10
3-Dimensial impression of the adopted mining method, hanging wall formations and timbersupport are left out.

be pre-sampled by diamond drillholes is an important additional advantage. By these means the grade of the benches is known and any possible low yield areas can be anticipated, and compensated for, by the adjustment of production schedules.

This method is now the routine mode of mining operations. Its introduction has been amply justified in the light of the readily maintained 50,000 tons per month ore-output; and, furthermore, without any material increase in the labour force.

ACKNOWLEDGMENTS

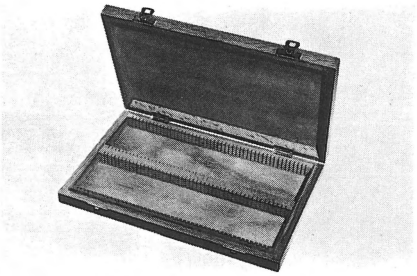
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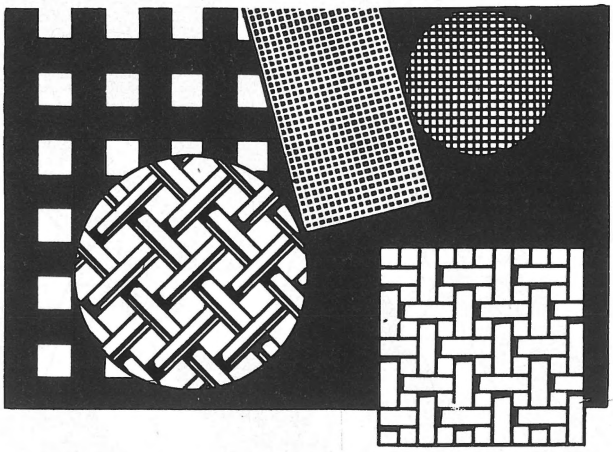
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