Trackless mining at Thabazimbi Mine

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SYNOPSIS

Certain aspects of the methods used in the exploitation, by sub-level caving, of a wide, tabular, steeply dipping orebody are described, reference being made to the use of modern mechanized equipment. Statistics relating to production and labour, as well as some geological details, are given.

SAMEVATTING

Sekere aspekte van die metodes wat gebruik word by die ontginning van 'n breë, tafelvormige en steil hellende ertsliggaam deur subvlakinstorting word beskryf met verwysing na die gebruik van moderne gemeganiseerde uitrusting. Daar word statistiek oor produksie en arbeid, asook sekere geologiese besonderhede verstrek.

INTRODUCTION

Towering above the Crocodile Valley in the Bushveld of the North Western Transvaal is the 'Mountain of Iron', known by its Bantu name—Thabazimbi. Here mining operations started in 1931, and for twenty years this centre supplied virtually all Iscor's iron ore requirements. It is still practically the sole source of supply to the Pretoria steelworks.

At Thabazimbi the orebodies lie in the heart of the majestic mountain, making it a unique mine in the sense that miners, instead of going down, have the novel experience of going up by incline haulage to their working places. Since the commencement of mining operations until the end of 1972, well over 53 million tons of high-grade ore have been despatched from Thabazimbi.

There are about 300 white and 1300 non-white employees living in the village at the foot of the mountain. Iscor provides three-bedroomed houses at a nominal rental, and all the usual amenities are available. It is also possible to hire air conditioners to alleviate the worst of the summer heat.

GEOLOGY

The orebodies stretch almost without a break over a strike length of about 3000 m and continue in a westerly direction on to Donkerpoort, the adjoining farm, which Iscor is now developing as an additional source of iron ore. Including Donkerpoort, the total known strike length is about 4500 m.

The iron ore occurs as big, irregular tabular bodies, usually in direct contact with the footwall shale, but in places separated from it by banded ironstone of varying thickness. The width of the ore averages roughly 25 to 30 m, and there is generally a layer of banded ironstone, about 50 m in depth, between the ore and the hanging wall diabase (Fig. 1).

The ore encloses many irregular 'horses' of banded ironstone, while the footwall and hangingwall are undulating both on dip and on strike. The dip near the outcrop averages 40 to 50°, gradually increasing to 50° on the lower levels and, owing to its undulating nature, reaching inclinations of up to 70°. The large orebodies sometimes peter out rather abruptly laterally, but recur after development has passed through a barren stretch of banded ironstone. In a vertical direction the orebodies are separated from one another by elongated constrictions of banded ironstone.

The typical hematite ore of the outcrops and upper levels is a hard, compact, massive, blue hematite, containing up to 68 per cent iron, but with increasing depth the ore becomes specularitic and limonitic, tending to become friable and reddish in colour and yielding a large proportion of fines. The core of high-grade hematite is fringed by an enriched zone of semi-ferruginized banded ironstone, which is a good-quality, intermediate-grade ore. With increasing depth, calcitic ore makes its appearance and, below this, talcose ore (Fig. 2).

MINING

Two mining methods are employed at Thabazimbi, viz, open pit and underground sub-level caving, the latter yielding almost 44 per cent of the total iron ore produced by the mine. On each of the two main levels, Delfos and Mostert, which are 106m apart vertically, a wide haulage was driven eastwards on strike in the footwall dolomites and is called a 'Voortrekker'. This haulage is used to transport the ore from both open pit and underground through a system of ore passes to the primary gyratory crusher, from where the minus 140 mm crushed ore is carried by conveyor belts to the beneficiation plant, which is situated at the foot of the mountain.

The sub-level caving method has been used in Sweden since the beginning of this century, but it was not until the large iron ore mine in Kiruna fully implemented this method during the fifties that a systematic research programme was organized to obtain a better understanding of what happens in the cave area.

Near-vertical orebodies lend themselves best to this method of mining, which involves the minimum of waste development. No pillars are needed because a total 'block' is mined out on retreat. The ideal orebody would have a width of more than 30 m. However, it is also possible to apply this method to narrow orebodies, in which case the production drifts are developed on strike.

The sub-level technique has been scientifically studied in laboratory tests, with the object of solving the greatest problem in this type of mining, namely, waste contamina-

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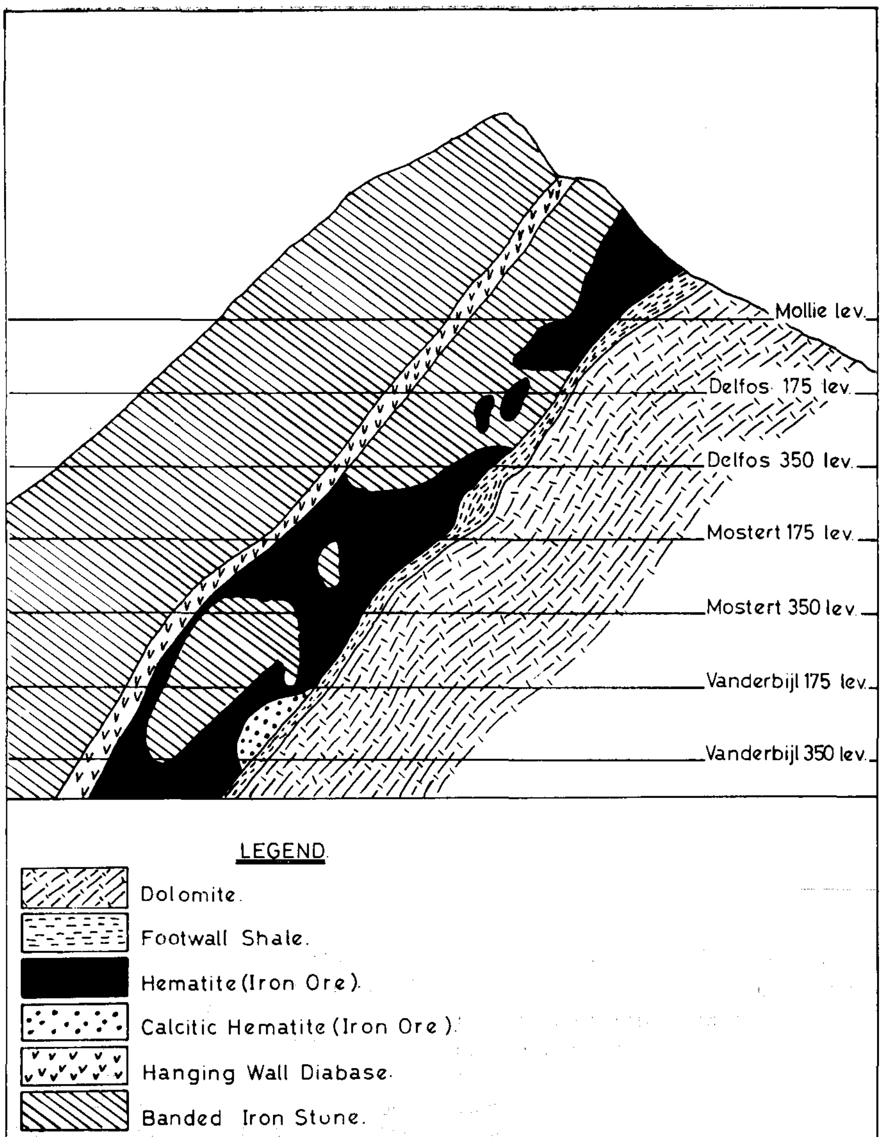


SECTION SHOWING MINERALISATION.

Fig. 1

tion and ore losses. The different parameters and their influence on the result of the layout are very easy to study in a short time at a relatively low cost, and the results of laboratory tests can be verified by full-scale tests.

The critical point in sub-level caving is the gravity flow. The different mining parameters should be chosen so that each blasted slice of ore coincides as nearly as possible with the gravity-flow pattern. The blasted slice is defined principally by the burden of charged-up rows of holes, the height between sub-levels, and the width of the pillars between the drifts. These three are very important parameters, the values of which must be carefully considered.

Theoretical studies and model tests show that the gravity flow describes ellipsoidal surfaces that are influenced by the following.

Width of the Drifts

A wide drift means a wide 'draw-point' and a better lateral distribution of the flow, provided the possibility of drawing equally over the total width of the drift is utilized. If loading is concentrated only in the centre of the drift, a narrow portion in the middle will come down faster. The top part of the blasted slice will not come down prematurely, but will rather, unless it is extremely well fragmented, be locked by the slower-moving sides.

Shape of the Drifts

The ideal roof is flat. The more rounded the roof, the more the ore will flow down the middle of the drift, resulting in a narrow flow pattern. The shape is subject to practical limits as stability generally requires slightly rounded roofs.

Fragmentation

The coarser the fragmentation, the wider the gravity flow pattern. However, in this case it is not a question of an ellipsoidal flow pattern, but rather an increase in width from the drift upwards. A widening flow means a greater risk of intrusion of waste from those drifts situated obliquely above, which have been mined out and filled with waste.

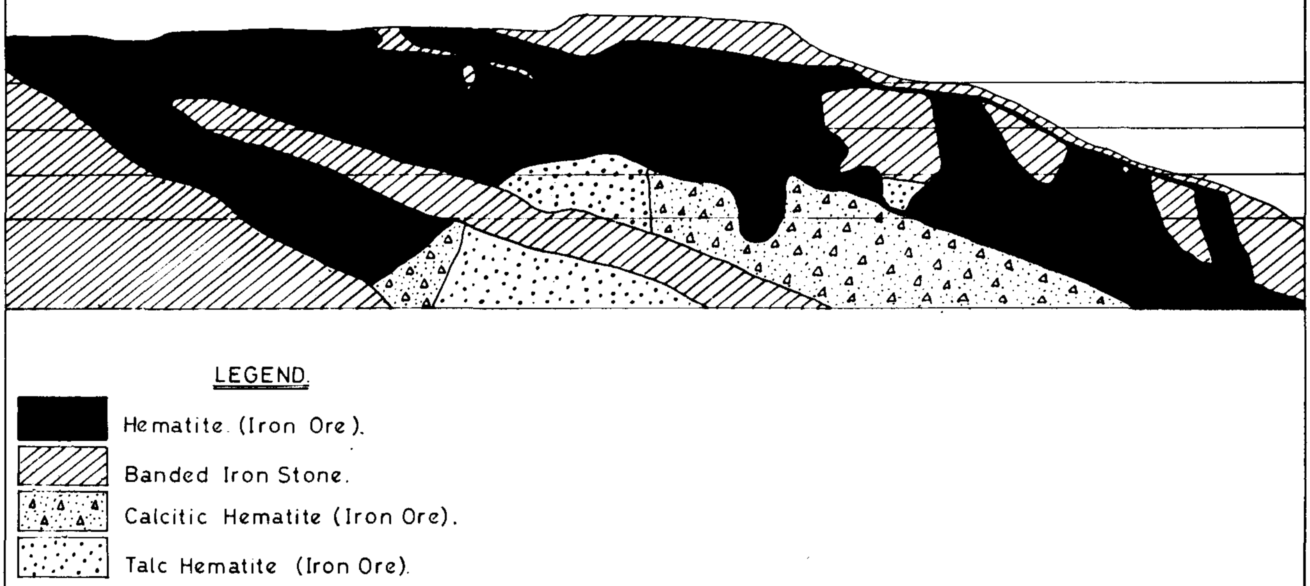
One point of interest is the difference in fragmentation between the blasted ore and the caved-in waste. This relation is matched by the inclination of the front. If the waste is much finer than the ore, the front should be inclined towards the caved-in waste and *vice versa*. Equally fragmented ore and waste would require a vertical front, but here again the actual situation may call for an inclined front towards the waste.

DEVELOPMENT

All access ways, including a ramp system to a new caving area, are developed 4,6 m wide and 3,5 m high. In the orebody, the drift sizes are 4,5 m by 3,5 m, except the slot drifts, which are 3,5 m by 3 m.

Drilling equipment per development end consists of three Seco S23 jackhammers, which have a piston diameter of 73,8 mm and a mass of 27 kg, with Seco RAL-type retractable airlegs, stroke 1295 mm. The air pressure at the face is 540 kPa.

A 42-hole burn cut is drilled with integral drillsteel, of which the following lengths are used: 1,4; 2,0; 2,6; 3,0; and 3,8 m. The diameters are 42, 40, 38, 36, and 34 mm respectively. A bottom primer is used (Dynagel 25 by 200 mm), and



VERTICAL PROJECTION SHOWING MINERALISATION

Fig. 2.

the remainder of the hole is charged with Anfex. On account of water, the lifter holes are charged only with Dynagel. Capped fuse and slow igniter cord—burning rate 13 to 26 s/m—are used.

Mucking is done on the following shift by a low-profile load-haul-dump machine. The same machine is used for production loading.

The master drift is developed along the hangingwall contact, though it is often necessary to determine the contact by the drilling of holes from the upper level. From the master, cross-cuts perpendicular to the general orebody strike are developed to the footwall, where a slot drift is developed all along the footwall contact. In future the master drift will be developed in the hangingwall to eliminate the ore losses at the master cross-cut turn-offs.

At present the sub-level interval is 10,7 m (35 ft) and the cross-cut spacing 15,2 m (50 ft). The cross-cut spacing does not conform to the gravity flow pattern, and future layouts will be at 10 m spacing.

ROOF SUPPORT

While rock pressure creates no serious problems, a combination of roofbolting and wire netting, supported by 150 mm-square steel washers, is extensively used. Normally, from three to seven roofbolts are installed to a general pattern at 1,37 m horizontal spacing (Fig. 3). The number of roofbolts and the use of wire netting are left to the discretion of the mine overseer. Three different lengths of 19 mm-diameter corrugated roofbolts of high tensile steel are used, viz, 1,8; 2,4; and 3 m.

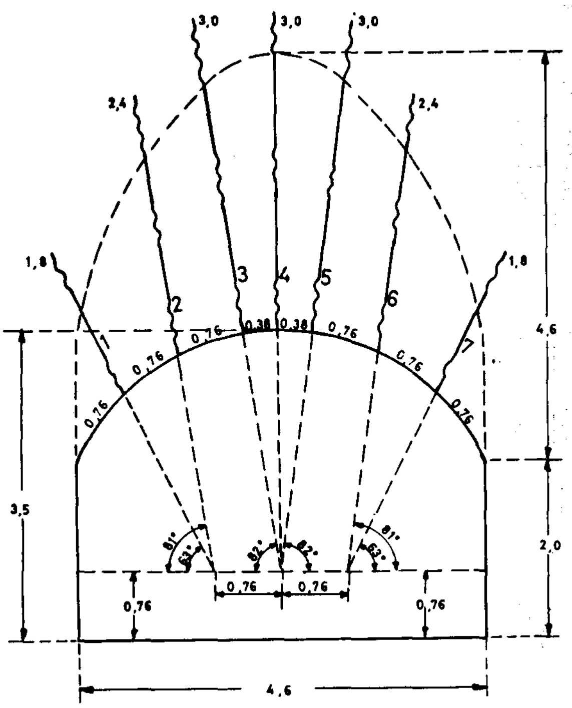
Old roofbolts are reclaimed at the drawpoints and straightened, and, in cases of damage to the thread, the threaded portion is renewed. The miner on development drills the holes for the roofbolts, and a special team later installs the roofbolts and wire netting. The bolts are grouted with a mixture of cement, water, and very fine sand in the ratio 1:1:1, pumped to the bottom of the hole (Fig. 4).

PRE-DRILLING

Two Atlas Copco machines, type Simba BUK 22, are in operation on a two-shift basis, drilling to a specified fan pattern. Drill steel is 1 m by 25 mm hexagon rod and 31 mm series 23 thread. The hole diameter is 50 mm and the burden 1,5 m, with a fan inclination of 70° towards the cage. The crew on the two machines per shift consists of one miner and 10 non-whites. The daily average penetration is 1000 m.

Fan drilling is done well in advance so that it does not interfere with production equipment; that is to say, drilling operations are always at least one level below the production level. Twenty holes are drilled per ring, starting from 40° to vertical on both sides with a maximum toe spacing of 1,25 m. A total of 183 m is drilled per ring (Fig. 5).

Pending the purchase of new drilling equipment, the future drilling pattern will be four parallel holes and two holes at 80° (Fig. 6). This pattern will conform to the gravity-flow pattern and will also eliminate the tendency for a higher explosive density towards the roof

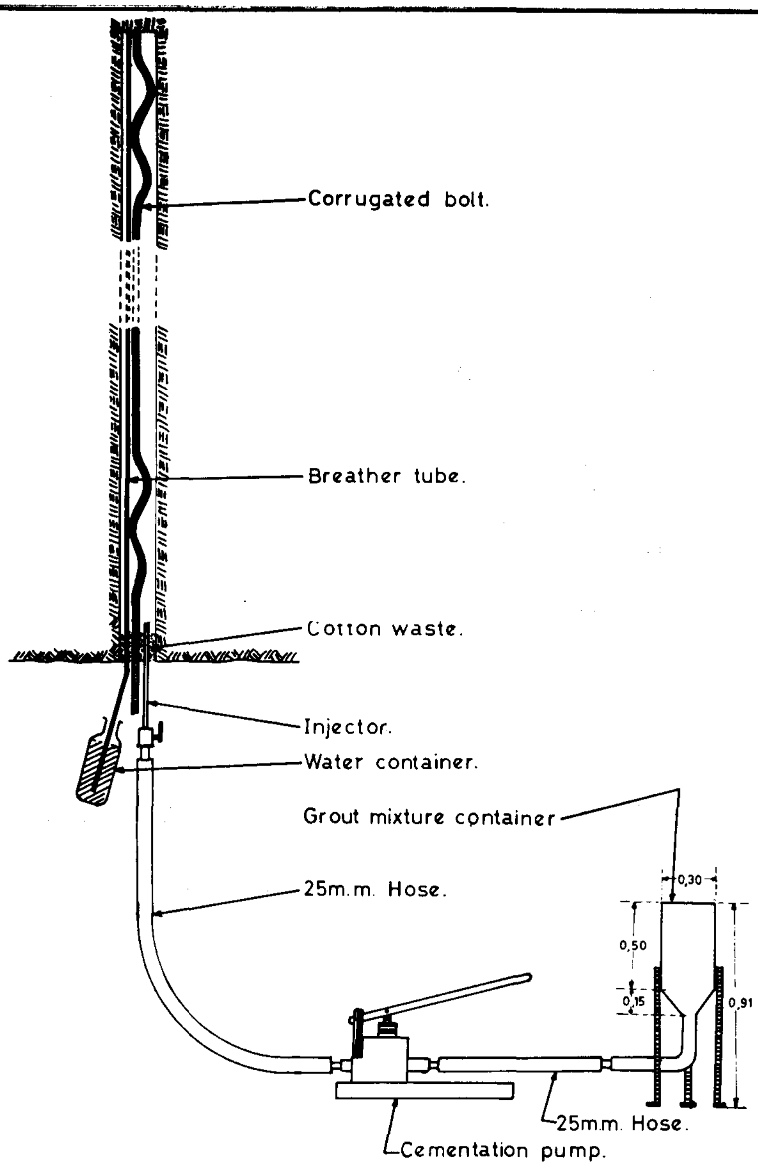


Roof bolt pattern for 4,6 x 3,5 m. drives in weak rock formation.

1. Horizontal spacing 1,37 m.
2. Additional bolts can be installed at discretion of officials.

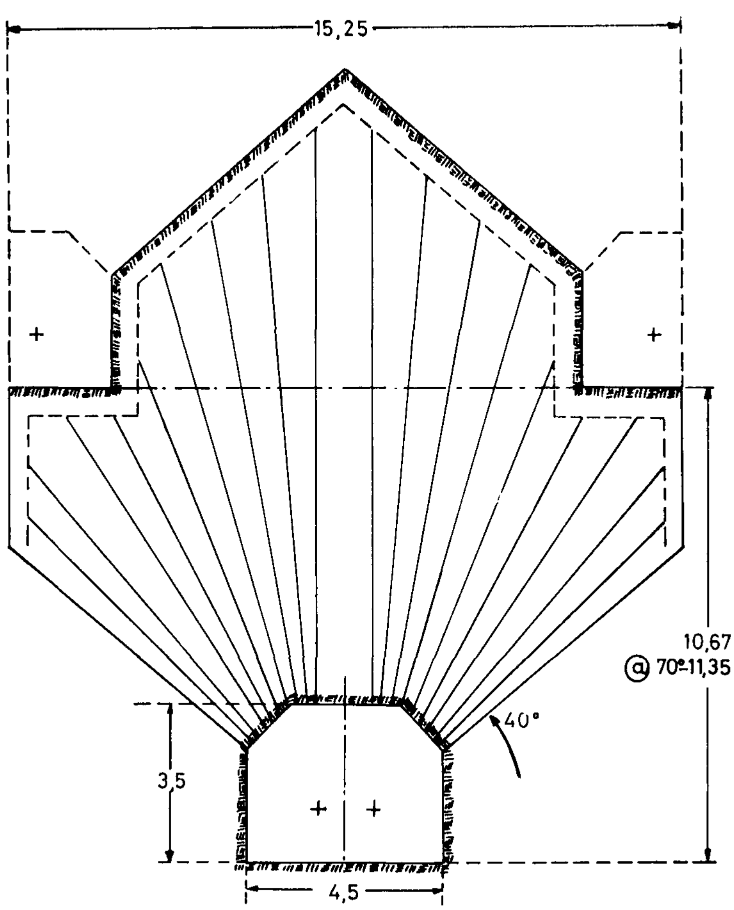
ROOF BOLT PATTERN.

Fig. 3.



ROOF BOLTING EQUIPMENT.

Fig. 4.



FAN DRILL PATTERN.

Fig. 5

of the drift. Toe spacing will then be 0,9 m.

The position of the ring to be drilled is marked off on the side wall by the surveyor, but the actual positioning of the drill rig is the responsibility of the miner.

CAVING

Production on a sub-level is started by the development of a 2 m-by-2 m slot raise to the first level above. The first ring of four holes is then blasted into the raise, and progressively more rings are blasted and loaded along the footwall drift. As soon as this process has passed a cross-drift, two or more rings from the cross-drift are blasted simultaneously, and caving then proceeds along the cross-drift.

One length of Ammon dynamite, 38 by 560 mm, is used as a primer in the bottom of the hole, and another length every 5 m. The rest of the hole is charged with Anfex. Cordtex is used, and all the holes are blasted simultaneously. Secondary blasting is normally performed in one specific drift. Large rocks, which the loaders cannot transport, are blasted at the drawpoint.

The loaders used are four Schopf L110b load-haul-dump machines, powered by eight-cylinder Deutz engines. These machines load from the drawpoint and then haul the ore an average distance of 120 m to the ore-pass tip. Drawpoint loading is stopped when the miner or shiftboss estimates that the percentage of waste and silica has risen above the beneficiation limit of the plant. Samples are taken on both main levels where the ore is drawn from the ore passes, and the results of these samples are available within 24 hours.

VENTILATION

Caving

The highly mechanized method of underground mining as practised at Thabazimbi calls for a system of ventilation that must cater for the following:

(1) high concentrations of dust at the loading faces and ore passes,

(2) fumes and dust from primary and secondary blasting during the working shift, and

(3) diesel-fuel exhaust fumes from the equipment.

Each caving section is served by a 2,45m-diameter, axial-flow, variable-pitch blade fan with a duty of 95 m^3s at 100 mm water gauge. This fan pressurizes the sub-vertical shaft and subsequently the two or three working levels. Allowing about 7 m^3s per drift, ten or twelve production drifts can be catered for and still allow ample ventilation per pre-pass tip.

In this system the worked out area consists of caved ground through to surface, and this serves as a return air passage.

At the working faces, the air moves from the loader towards the cave, thus allowing all dust and blasting fumes to virtually disappear into the rubble.

Approximately 50 to 75 mm water gauge pressure is required to overcome the cave resistance to surface, which is now approximately 160 m above the working level.

With the orebody dipping at 45°, the rubble in the caved area is coarse on the hangingwall side and allows the passage of air to surface.

Ore passes are holed through into the caved area above, and the tips are then under negative pressure, which upcasts all dust created by tipping operations.

Development

The conventional force/exhaust system is used. An 11 kW fan, using ducting of 570 mm diameter takes the return air to the nearest ore pass and via the cave to surface. Fans of 6,5 kW having ducting of 400 mm diameter are used as boosters.

Tramming Level

The ore boxes are connected to a common return airway, where a 60 kW fan exhausts to surface.

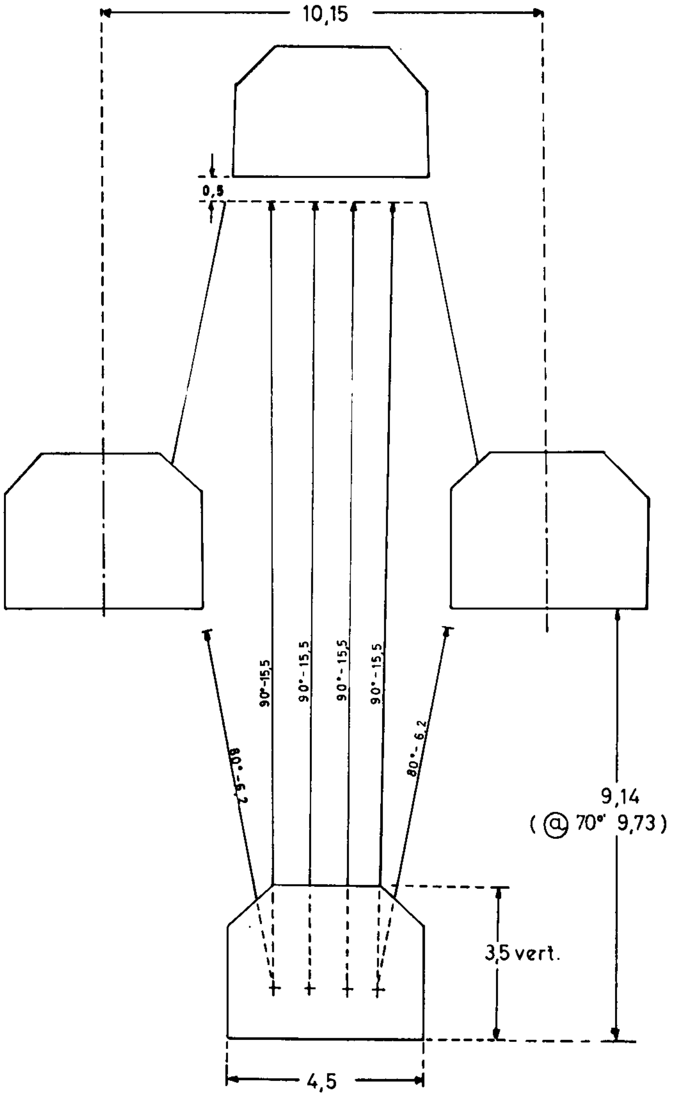
TRANSPORT

Underground Ore

Ore is transported on the various sub-levels from the drawpoint to the ore pass by Schopf machines. From the ore pass, the ore is loaded onto railroad side-dump trucks, each with a capacity of 20 tons. Ten of these trucks are then hauled by electric loco to the western section of the mine, where another ore pass is utilized to feed the primary gyratory crusher situated below it. The ore is crushed to minus 125 mm and is then transported to the plant by a series of belt conveyors.

Material

All material is transported by road along the mountain slope to the various main levels. From the main levels, the material is transported either by manually pushed railcars or by Unimog-type trucks to the working places.



FUTURE DRILL PATTERN.

Fig. 6.