

WIDE-SPACE BLASTING
FIELD EXPERIENCE FROM PRODUCTION
BLASTS USING WIDE-SPACED BOREHOLES
P.A. Persson and A. Ladegaard-Pedersen
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Summary

A reduced frequency of boulders and better fragmentation resulting in considerably decreased overall costs can be achieved by modifying the drilling pattern. The modification consists in a considerable increase in hole spacing and a corresponding decrease in burden compared to present-day practice.

This paper gives an account of comparative field tests comprising half a million m³ of limestone and granite and also production results from three years of continuous operation of a granite quarry with a total production of over one million tons of rock.

The wide-space blasting method can be recommended as a safe, practical and useful method. A reduction in boulder frequency by 50 percent and a decrease in handling and crushing costs resulting in a reduction of total cost by 10 to 15% may be expected.

1. Background

The development in the field of modern open cast blasting is rapidly progressing towards larger borehole diameters and larger benches. The ultimate goal consists in fewer and larger machines, providing the advantages of less people involved and also a more flexible organization more easily administered. In return, an ever increasing part of the costs will consist in capital costs for the large loaders, trucks, and crushers, which become indispensable because of the coarser fragmentation. It then becomes more and more important to avoid breakdowns and capacity losses. Therefore, attempts are made in various ways to reduce boulder frequency as well as the size of the fragments. One way is to increase the specific charge as well as the specific drilling. This way, however, is comparatively expensive, and its advantages are limited.

2. In 1963, at a meeting of the Swedish Rock Blasting Committee, Ulf Langefors and Tommy Sjölin gave an account of model tests carried out in plexiglass (Langefors 1959, Langefors and Sjölin 1963). The tests indicated a possibility to affect the fragmentation in the way desired, by modifying the spacing. In so doing, smaller maximum boulders as well as a more uniform size distribution of the fragments were achieved. The investigation concerned the 2-dimensional case, which is comparable to slab blasting. To check in rock the results of these experiments, the present authors carried out a series of field tests with blasting in homogeneous granite at Misterhult, near Västervik, in 1967. In these tests the holes were drilled down to a substantially horizontal fissure extending beneath the whole rock (slab blasting). The test blastings in granite showed the same tendency as did the model tests in plexiglass, that is, a modification in the drilling pattern resulted in reduced size and frequency of boulders in the column part of the bench. The results were presented at a meeting of the Swedish Rock Blasting Committee in 1968 (Kihlström, Ladegaard-Pedersen and Persson 1968). Additional model tests were made in order to compare the fragmentation in slab blasting with that in bench blasting with a fixed bottom (Ladegaard-Pedersen 1969). In spite of the bottom being fixed so that the loosening of fragments in those parts has to take place in a direction perpendicular to the holes, these

model bench blasting tests were in good agreement with the results from the previous slab blasting tests.

3. Charge calculation

The principle of wide space blasting is simple. The number of holes is kept constant, the amount of explosive per bolehole is the same, but the burden V is decreased, while the spacing E is increased in the same proportion, so that the product $E \cdot V$ will maintain its constant value. Instead of the conventional values of the ratio E/V around 1.25, values from 4 to 8 are used. (See fig. 1).

Example: In a blasting round of conventional type, the burden V is 2 m and the spacing E , 3 m. Thus $E \cdot V = 6 \text{ m}^2$. If we choose the ratio $E/V = 6$, the burden will be 1 m and the spacing 6 m. In case the ratio $E/V = 8$ is chosen, we get $V = 0.85 \text{ m}$ and $E = 7 \text{ m}$.

The constant number of holes and the unaltered charge both imply that drilling below the bottom level, bottom charge, and column charge keep the same values as they should have in a conventional round.

These quantities will have the following recommended values:

$$\text{Drilling depth below bottom level} \quad 0.3 \sqrt{\frac{EV}{1.25}}$$

$$\text{Length of bottom charge} \quad 1.3 \sqrt{\frac{EV}{1.25}}$$

$$\text{Length of uncharged hole} \quad \sqrt{\frac{EV}{1.25}} \quad \text{or} \quad \sqrt[4]{\frac{EV}{1.25}}$$

The strength of the column charge is the same as normally, that is, 40-60% of the bottom charge strength, in both cases calculated per meter of drilled length.

In wide space blasting certain savings in the consumption of explosives, too, might be brought about if a shorter bottom charge than that recommended above can be used. This, however, has not yet been tested, and modifications in this direction have to be carried out with the utmost precaution.

To avoid throwing, the larger conventional burden is maintained in front of the first row of holes (in this example 2 m). The bulk from the first row will then act as a barrier, and the immediately following ejection of stones from the next hole will become captured. The last two rows in the rear give a certain zigzag outline to the rear bench edge; this outline disturbs the eye since the first row of the subsequent round will

not be "in phase" with the outline. There does not seem to exist any real disadvantages in this, but in some rounds a last row has been used with conventional spacing and burden.

4. Ignition pattern

The ignition pattern employs the same interval numbers as in a conventional round, only one cut is shot in the centre. It is important that the two adjacent holes in the previous row are shot in an earlier interval before shooting a hole in the subsequent row. It is still possible to start in the centre, so that the round will be concentrated forwards in the same way as in earlier methods. The most convenient way is to draw desired lines of breakage for each interval number, which makes it possible to control that subsequent holes have a free breakage in the moment of detonation of their charge. In fig. 2 are shown examples of ignition patterns employed in the test series.

5. Full scale comparative tests

During the last two years, the wide-space method of blasting has been tested in large benches in practical operation scale to such an extent as to let us state safely that the method can be employed in practice. Since the detailed follow-up requires a relatively long time, complete results where a direct comparison with conventional blasting can be made are available from only two of the experimental sites, namely the limestone quarry at Stora Vika, and a granite quarry near Umeå.

5.1 Results of the test at Stora Vika in 1969

Fig. 3a shows a bench at Stora Vika after blasting, $E/V = 6$, fig. 3b shows the round during loading, and fig. 3c shows drilling pattern of the round.

Table I shows a detailed comparison of a number of conventional rounds and wide spacing rounds in limestone (Stora Vika). All the rounds were shot under accurate control and within a limited area of the quarry. External factors were kept constant as far as possible. The comparison shows that the number of boulders, that is, blocks for a maximum dimension above 1 m, was only half as large in wide space blasting as in the conventional method, though specific drilling and charge had both been reduced by about 10%. In these tests, the loading (mucking) capacity was not measured. The subjective impression on the site, however, was that the wide spacing rounds seemed to be more easily

* particularly not when the ratio of E/V is large say > 4 .

loaded than the conventional ones.

5.2 Results of the tests at Umeå in 1969

Fig. 4 shows a comparison between conventional round and wide spacing round in granite.

Table 2 provides an equivalent comparison of a number of conventional rounds and wide spacing rounds in granite (Nils P. Lundh, Umeå). During these rounds, a more detailed investigation of the costs was made. In addition to this, the daily quantity of loaded rock was investigated separately in order to provide a measure of fragmentation.

In this series of wide spacing rounds, the specific charge as well as the specific drilling increased as compared to the conventional rounds. This was a result of the rear row being drilled with a spacing less than that of the other rows without counterbalancing this with an equivalent increase in the burden. Since this excess charge only has reference to a limited part of the round, its influence on the total fragmentation and the number of boulders should be negligible.

In this series, too, the number of boulders decreased considerably, from an average of 170 boulders per 1000 tons of rock to below 100, that is, a 43% reduction.

The comparison of the loading capacities shows that the improvement does not consist in a reduced number of boulders only. The 30% increase in loading capacity indicates that the fragmentation is improved within a larger range of dimensions. This improvement is of exceedingly vital importance. Normally, the costs for loading and transport in a larger quarry may be of the same order as the total cost of drilling and charging. A 30% reduction of so significant a cost seems to us a very great step forward.

In the special test series at Umeå, the economical importance of this result is somewhat obscured by the unnecessary increase in drilling and charging costs, but, as we can see from fig. 5, in spite of this, the total cost was reduced by 15%.

On the basis of these results, the Umeå quarry in 1969 transferred to using wide-space blasting as a production method and has continued with this method since then. Results of the three years operation are given in the following chapter.

6. Practical experience from wide-space blasting at the Västerbotten Grusförbättring AB quarry, during the years 1969 - 1972

The plant is situated at Brännadal, about 10 km from Umeå. According to approved plans, there is about 2 mill. tons of solid rock to be worked. The rock products crushed are used for highways, various contract work, and concrete. The rock is granite. The plant has an average capacity of about 2000 tons per shift, and in the year 1970, the amount of loosened solid rock was approximately 400.000 tons. The units employed for drilling are the Gardener Denver 3600 with the machine PR 123, and the Atlas Copco Roc 601. The Atlas machine has a device for absorbing dust as well as a silencer. The drill rod diameter is 1 1/2", length 3 m. The bench height is 25-30 m, which means that 8 or 9 rods are joined by sleeves. The borehole diameter is 3", burden 1.25 m, and spacing 5 m. Since there is rather much water in the rock, the loading work becomes difficult. The explosives used are Nabit ϕ 55 mm and Dynamex ϕ 65 mm, packed in plastic bags, both manufactured by Nitro Nobel Co Ltd. When loading, a detonating fuse is first inserted into the Dynamex bag at the bottom by means of a copper needle. After that, a VA-MS detonator is applied to the upper end of the fuse. The use of detonating fuse in this case is motivated by the presence of water in the boreholes, and also to obtain safety against unintentional initiation by thunderstorms during loading.

The mucking is performed by one excavator Nordvest 6, and a wheel rolling loader Yale 300, the bucket volume being 1.4 and 3 m³ respectively. The rock material is loaded on trucks, Kockum-Lansverk KL 120, and is then transported 100-200 m up to the feeding pocket of the preliminary crushing unit. The preliminary crusher is a Svedala Arbro RH 120100-210; its crushing jaw measures 120 cm. From this first stage crusher, the rock material flows to an excenter screen, where the size fraction 0-35 mm is separated from the rest. After the preliminary crushing and screening, the material will consist of stones measuring less than 20 cm. After passing through an Allis-Chalmers cone crusher, the largest stone diameter will have been reduced to about 6 cm. Since the material is passed through various screens and conveyors, several fractions can be obtained. If the material is intended for concrete, however, it will have to pass through one more unit, the "Alpine" percussion crusher, to obtain cubic shape.

6.1 The influence of fragmentation on crushing capacity and wear of crushing plates

The durability of the crushing plates is largely determined by the hardness and the fragmentation of the rock material. Accompanying the introduction of the wide-space blasting method at the Umeå quarry, according to data from the years 1969-1972, the durability of the plates has increased from 65.000 tons up to 130.000 tons. Since the crushed rock has been taken from this quarry all the time, and tests have proved the rock hardness to have been the same, it appears likely that the improved rock fragmentation resulting from the wide-space blasting has contributed.

According to our observations, a constant level of rock material in the crushing jaw seems to improve the crusher plate durability. Great variations will cause uneven wear. A condition for an even flow of material into the crushing jaw is a sufficient fragmentation of the rock. In this case, though the slit opening of the crushing jaw varies by 5 cm only, and its average is 17 cm, very large differences can be noticed as for the material leaving the crusher. If the feeding of the material into the crushing jaw is uneven, large, sliced blocks will often be able to pass. Thus, if the level of rock material in the crusher is kept low and uneven, the rock material reaching the following unit will be of large size and more difficult to crush. Therefore, the significance of fragmentation can not be determined from the first stage of crushing only. Through observations of the material flow into a cone crusher (in this case an Allis-Chalmers 1351), the situation was found to be largely the same - the durability of the crusher jackets has increased twice within the corresponding period of time.

From what is stated above, it becomes evident that the crushing capacity will increase through the entire plant, at the same time as wear will be reduced.

6.2 Evaluation of fragmentation

One method for evaluating the fragmentation has been suggested by the Swedish State Power Board. The Boliden Company, among others, has also employed this method. It is based on estimates of fragment size as related to the intake opening of the loader bucket. In order to obtain a handy measure of the fragmentation, a so called "fragmentation coefficient" has been defined, being the mesh width relative to

the bucket opening, where 50% of the material is able to pass through.

At the Umeå quarry the fragmentation was evaluated by means of the more time-consuming method of screening. The tests were carried out when a good half of the round had been removed. The partial samples were taken by letting the loader pick up a bucket of material from the rock masses. The test spot in the round was chosen after estimating several spot check samples taken by the loader bucket. The aim was to pick out the partial samples as close to the centre of gravity of the round as possible, see fig. 6.

The material was sorted by hand. In order to avoid misleading results for boulders (blocks larger than 1200 mm), the weight proportion of boulders was calculated from the total number of boulders and the total volume of the round. The average boulder volume was estimated to be 1.4 m^3 . An example of a typical screen analysis after wide-space blasting is given in Table 3. Table 4 shows the practical results (1 million tons) for 3 years. The values from the year 1969 are average values of conventional and wide-space rounds. We also refer to Table 2.

7. Underground mining

The Boliden Company operates 20 mines throughout Sweden. The wide-spacing technique is used in normal production in six of these mines, where horizontal cut and fill with backfilling is the mining method. After introduction of this new technique in the mines, according to reports by Lindgren and Travis 1971, the number of holes has been reduced by about 30 per cent with sufficiently good fragmentation.*/
Fig. 9 and 10.

8. Large hole-diameter, open pit mining

Boliden Company's largest mine, Aitik, is situated 30 miles north the Arctic Circle near the town of Gällivare. The average grade of the ore body at the Aitik open pit mine is 0.5 percent copper. The ore body rocks are gneisses, schists, and leptites. Apart from the mineral content the ore body does not differ much from the surrounding rocks. A Bucyrus Erie 45 R drilling machine drills all production blast holes. The hole diameter is 9 7/8 inches, and the vertical

*/ The authors of the present paper do not believe that such a large reduction in the number of holes can be made possible by the introduction of wide-space blasting alone. Reductions in the number of holes is normally not recommended.

holes are drilled three meters below the toe of the 15 meter benches. The burden and spacing are 8 meter and 10 meter respectively and this bore-hole pattern is used as a standard. During several years of experimentation 80 m² per hole was found to give the best results. The fragmentation is good and the frequency of boulders is about 1:1000 tons. - In the year 1971 when the wide-space blasting technique was brought to the attention of the mining industry two full scale tests were carried out in the Aitik mine. A bold calculation indicated that the holes could be drilled with a burden of 5 metres and a spacing of 20 metres which means 100 m² per hole.

It seemed to be a good solution because of reduced drilling and the same amount of explosive per hole as in earlier tests. Unfortunately the theory ~~was not~~ was not useful in practice. Directly after the blasting the fragmentation was found to be satisfactory at the surface of the rock pile. The frequency of boulders was higher. During loading, difficulties began because of stumps and incomplete tearing at the bottom of the bench, which obstructed the loading, caused complementary drilling, break downs etc. After the two rounds it was decided that the surface per hole had been made too large. Instead, one returned to the earlier drilling pattern 8 x 10 m, and arranged to have wide-spacing with respect to the direction of throw by means of a modified ignition pattern. Earlier the rock was thrown at an angle of 80-90 degrees to the rows of boreholes, but with the modified ignition pattern the rock was thrown at an angle of 25-30 degrees to the row of hole, fig 8. With this arrangement the ratio between burden and spacing was changed from 1.25 to 3.2. This method was only possible because of vertical drilling and blasting against two free surfaces.

The result, with unchanged specific charge and drilling, was very good. Frequency of boulders was less than 1 per 1000 ton. The rock masses were easy to load. The change in ignition pattern may not be the only cause of this fine result. The changed pattern combined with the stratification of the rock may also have had an influence. The observations and viewpoints from Aitik again stress the importance of good fragmentation, which greatly influences both the productivity and the maintenance costs of shovel, truck and crusher. The blasting technique must not be isolated and considered as a separate operation in the mine.

The technique of wide-space blasting should be regarded as a means of improving fragmentation with no increase in drilling and blasting costs, rather than as a means to decrease drilling and blasting costs only.

9. Acknowledgement

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277-284, 1969.

Table 1. Comparison of wide spacing blasting and conventional blasting in limestone rock. (Stora Vika).

	Conventional spacing								Mv	Wide spacing			Mv	Change, %
	3	6	10	12	14	15	17	19		A	B	C		
Round	3	6	10	12	14	15	17	19	Mv				Mv	
E/V	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		4.3	6	8		
E·V	6	6	6	6	6	6	6	6		8.4	6	6		
Diameter of borehole, mm	76	76	76	76	76	76	76	76		76	76	76		
Spec. charge q kg/m ³	0.54	0.53	0.59	0.60	0.54	0.45	0.5	0.48	0.53	0.44	0.51	0.49	0.48	- 9
Spec. drilling, drill m/m ³	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.12	0.17	0.16	0.15	- 12
Number of holes	69	50	61	39	49	63	50	51		67	66	45		
Burden	2	2	2	2	2	2	2	2		1.40	1	0.85		
Spacing	3	3	3	3	3	3	3	3		6	6	7		
Total volume, m ³	8280	6000	7320	4680	5880	7560	6000	6120	6480	11070	7920	5800	8263	
Boulders/1000 m ³	112	164	112	164	112	107	109	86	121	57	47	86	63	- 48

Table 2. Comparison of conventional blasting and wide spacing blasting in granite. (Umeå).

	Conventional spacing						Wide spacing						MV	Change. %
	A	B	C	D	2	4	1	3	4	6	7	8		
Round														
E/V	1.25	1.25	1.25	1.25	1.3	1.25	5.2	4	4	4	4	4		
E·V	6.9	6.9	5	5	8.1	5	8.1	6.25	6.25	6.25	6.25	6.25		
Diameter of borehole, mm	76	76	76	76	76	64	76	76	76	76	76	76		
Spec. charge g kg/m ³	0.62	0.34	0.42	0.50	0.50	0.55	0.49	0.62	0.62	0.73	0.63	0.75	0.63	+ 29
Spec. drilling drill m/m ³	0.14	0.14	0.15	0.16	0.15	0.23	0.16	0.17	0.19	0.20	0.17	0.21	0.18	+ 13
Number of holes	10	25	43	44	44	59	24	66	67	67	68	41		
Burden V, m	2.3	2.3	2	2	2.5	2	1.25	1.25	1.25	1.25	1.25	1.25		
Spacing E, m	3	3	2.5	2.5	3.25	2.5	6.50	5	5	5	5	5		
Total volume, m ³	1280	3345	5740	5885	5600	5220	2870	8150	7440	7000	8122	4000	6264	
Boulders/1000 m ³	219	190	171	185	124	126	107	90	112	85	102	88	97	- 43
Loading capacity	883	1200	1580	1545	1189	1729	1584	1819	1861	1591	1837	1684		
Loading ton/day	1006	1346	1773	1733	1462	2040	2091	2146	1861	1814	2094	1920	1983	+ 28
Costs \$w.cr./m ³														
Drilling	0.95	0.95	1.02	1.02	1.02	1.56	1.09	1.16	1.29	1.36	1.16	1.55	1.27	+ 17
Explosives	1.87	1.00	1.19	1.29	1.24	1.40	1.33	1.09	1.56	1.69	1.61	1.92	1.62	+ 22
Boulders	2.00	1.73	1.56	1.69	1.14	1.15	1.55	0.98	0.83	1.02	0.78	0.80	0.89	- 43

x) Corrected value because of change of machines.

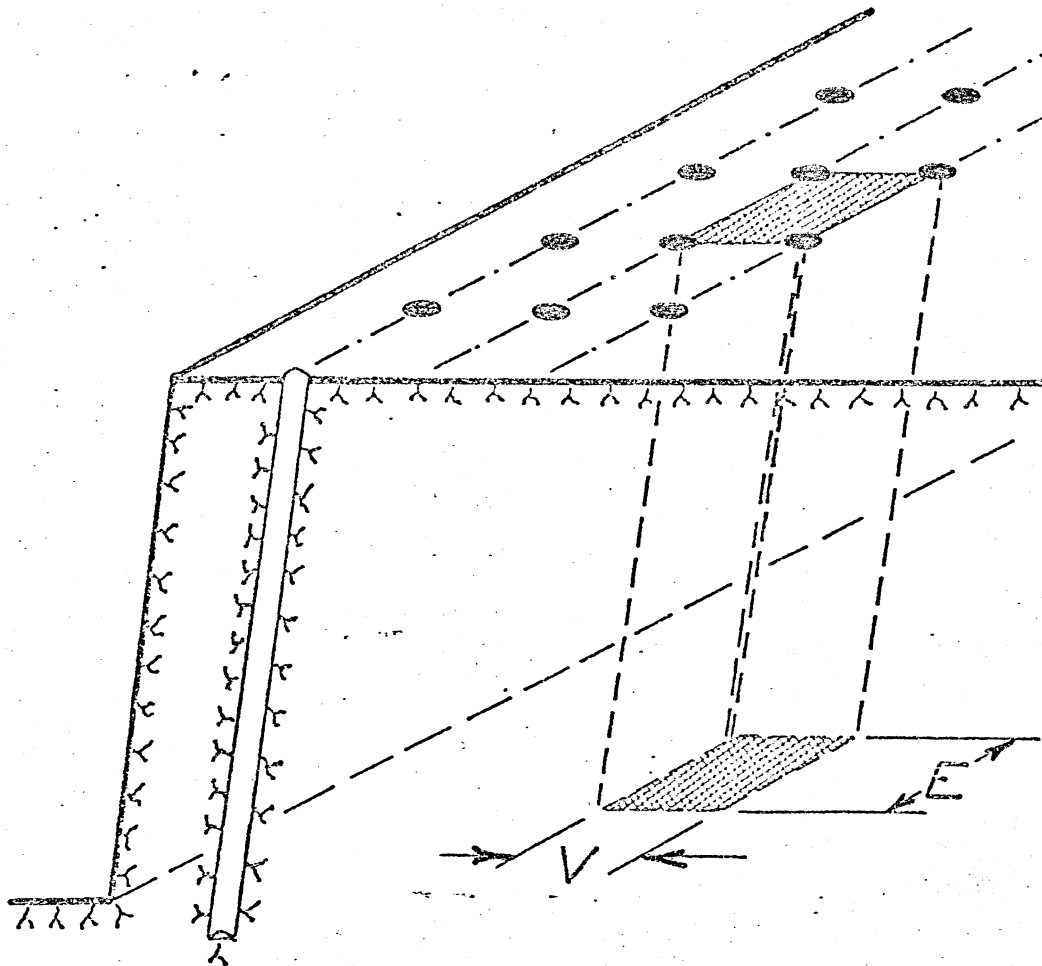
Table 3

Grading of a rock pile produced by wide spaced blasting.

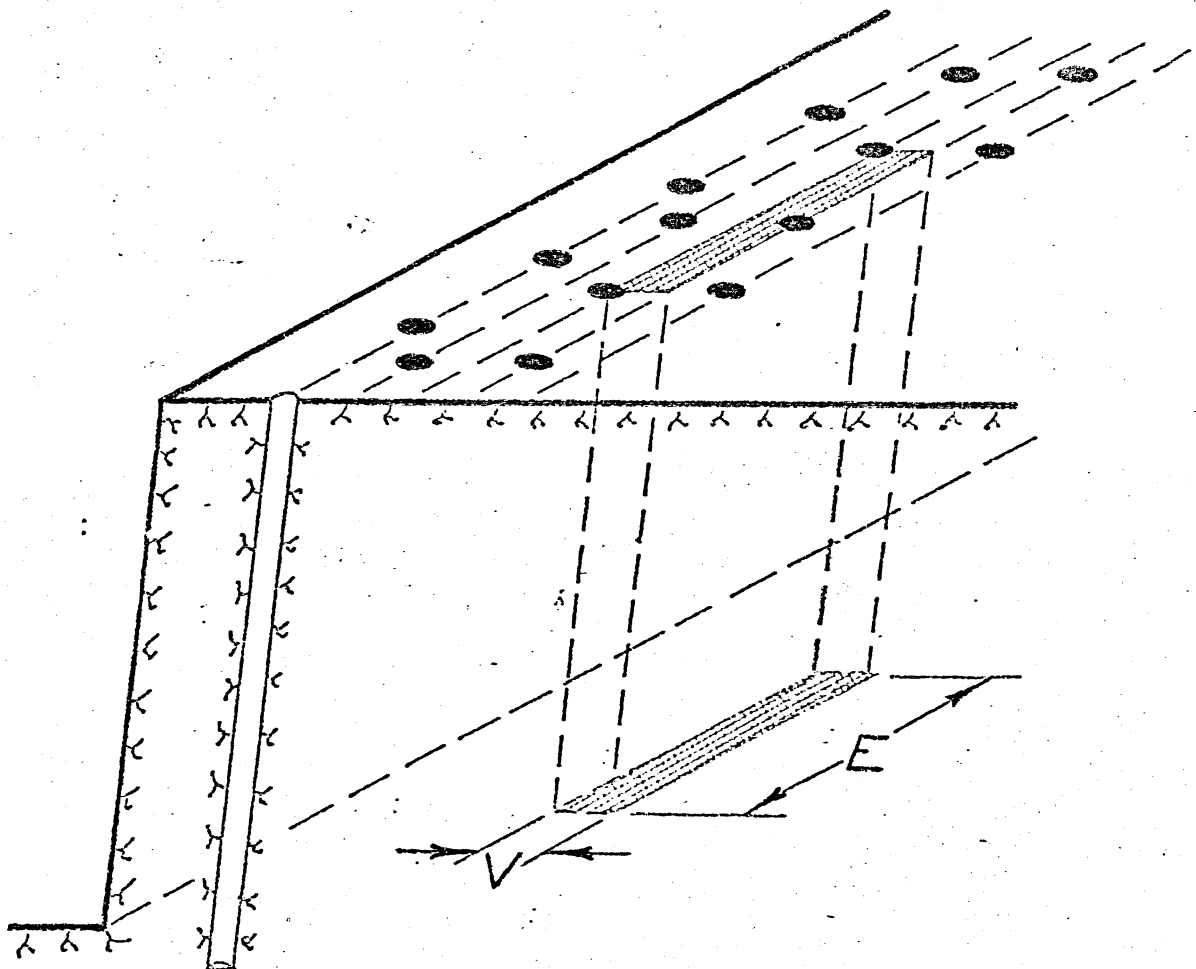
Particle sizes mm	Proportion % by weight
0 - 9	11,4
9 - 24	8,3
24 - 52	9,0
52 - 128	6,1
128 - 256	25,3
256 - 512	25,3
512 - 1200	10,3
1200 -	

Table 4

	<u>1969</u>	<u>1970</u>	<u>1971</u>
Drilled meters per solid m ³	0,172	0,202	0,191
Consumption of explosives per solid m ³	0,56	0,74	0,69
Frequency of boulder, numbers per 1000 m ³	124	97,6	65
Crushing capacity, metric ton per hour	184,4	200,1	240,3



Conventional round



Wide spacing round

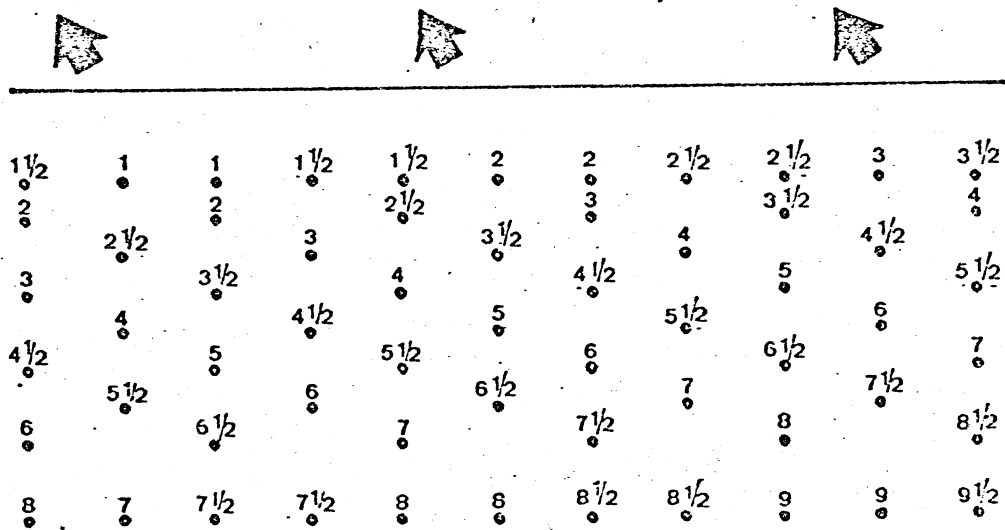
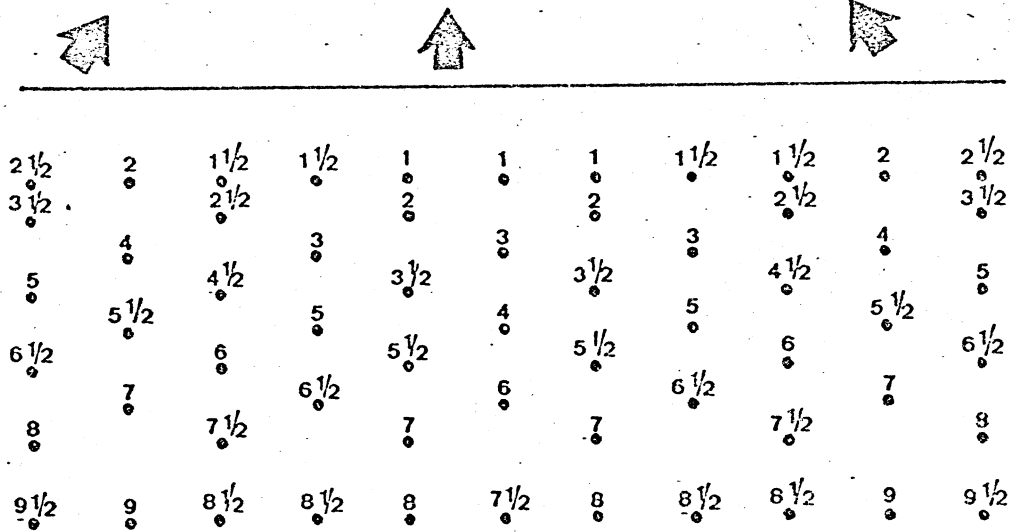
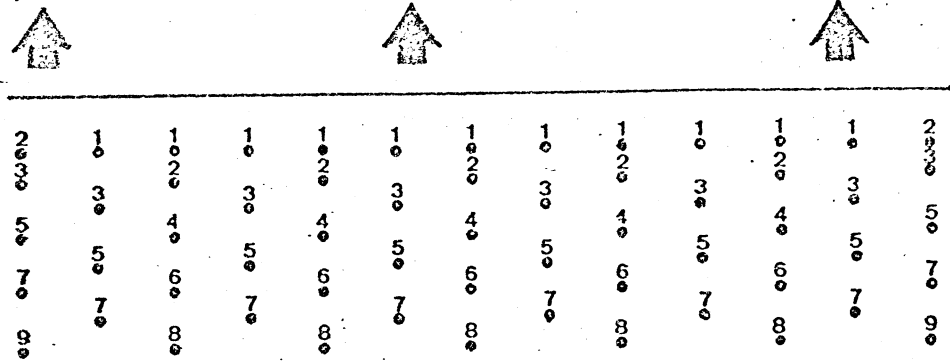
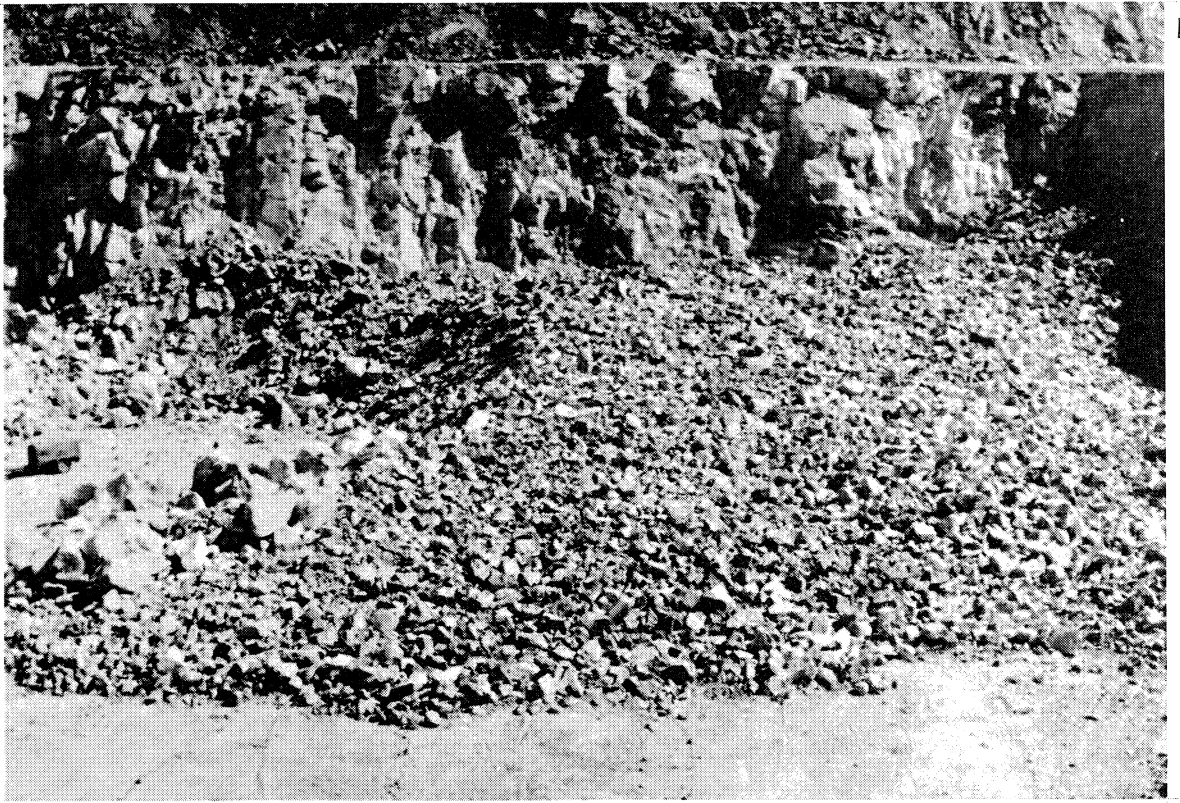
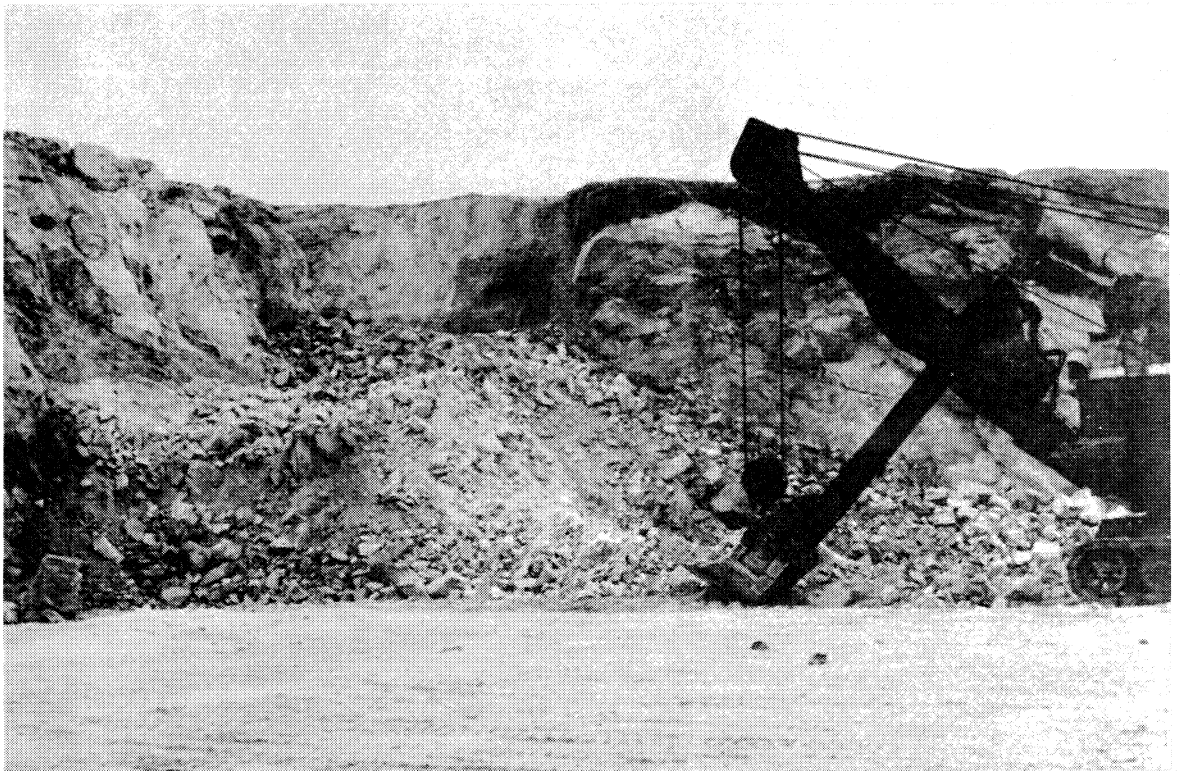


fig. 2



Burden 1 m. Spacing 6 m. Bench height 20 m.
Stora Vika, limestone



The loading has started to the left.

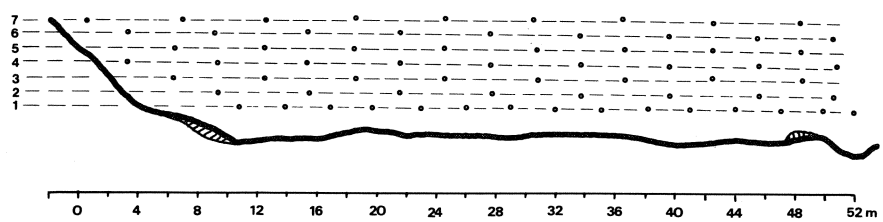


fig.3



Burden 1.25 m

Spacing 5 m

Bench height 20 m

Nils P. Lundh, Umeå

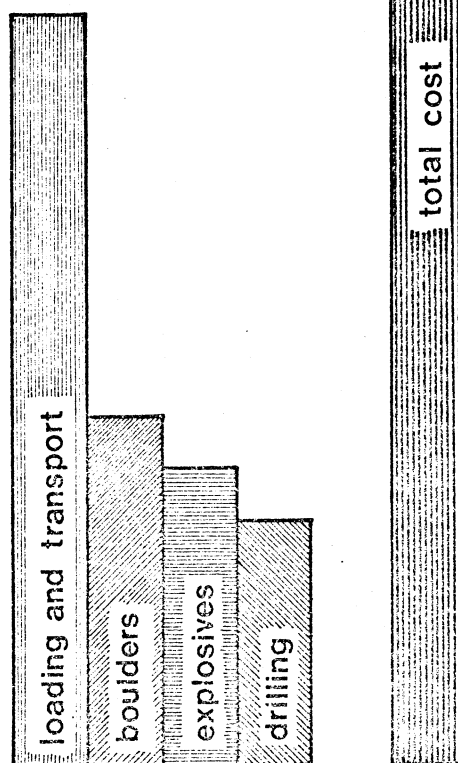
Granite



Burden 2 m. Spacing 2.5 m. Bench height 20 m

fig.4

CONVENTIONAL SPACING



WIDE SPACING BLASTING

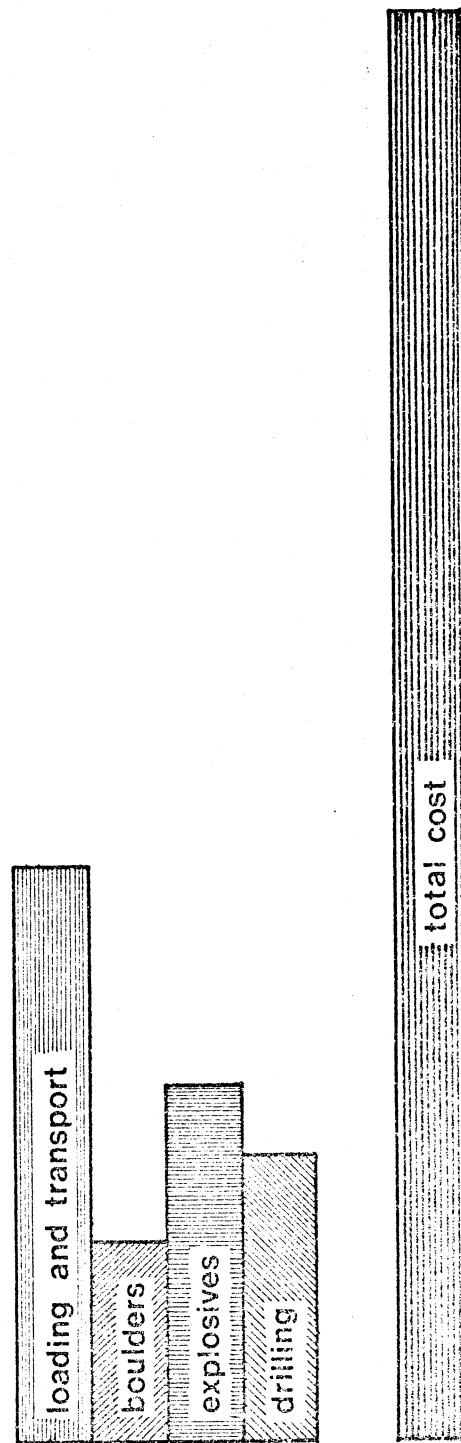


fig. 5

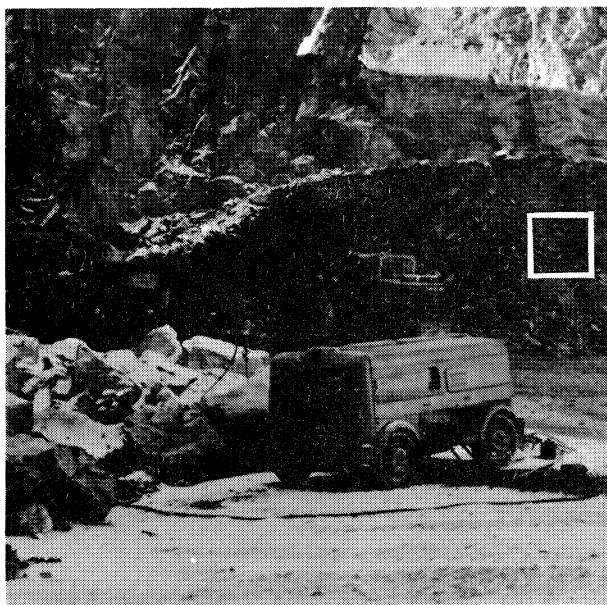


Fig. 6. The marking indicates the spot in the round from which the sample has been taken.

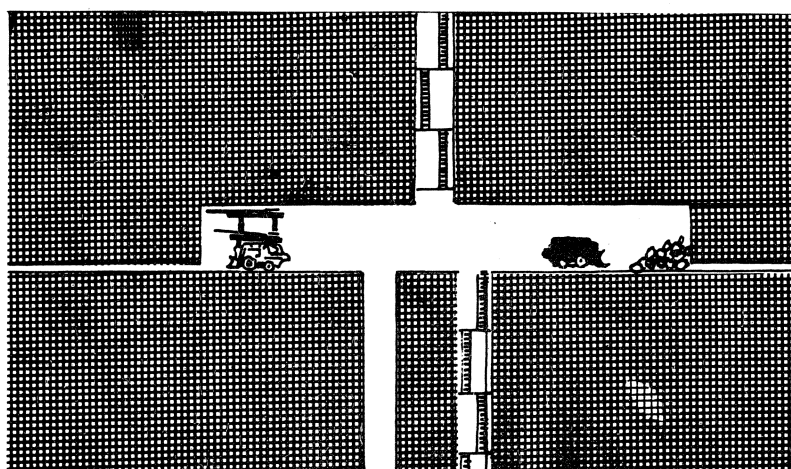


Fig. 7. Horizontal cut and fill. A slab 3-4 m high is mined out, drilling horizontally. A slot 3 m high is blasted down at the communication raise. Equipment is hung there during drilling, and the next slice is started from this slot.

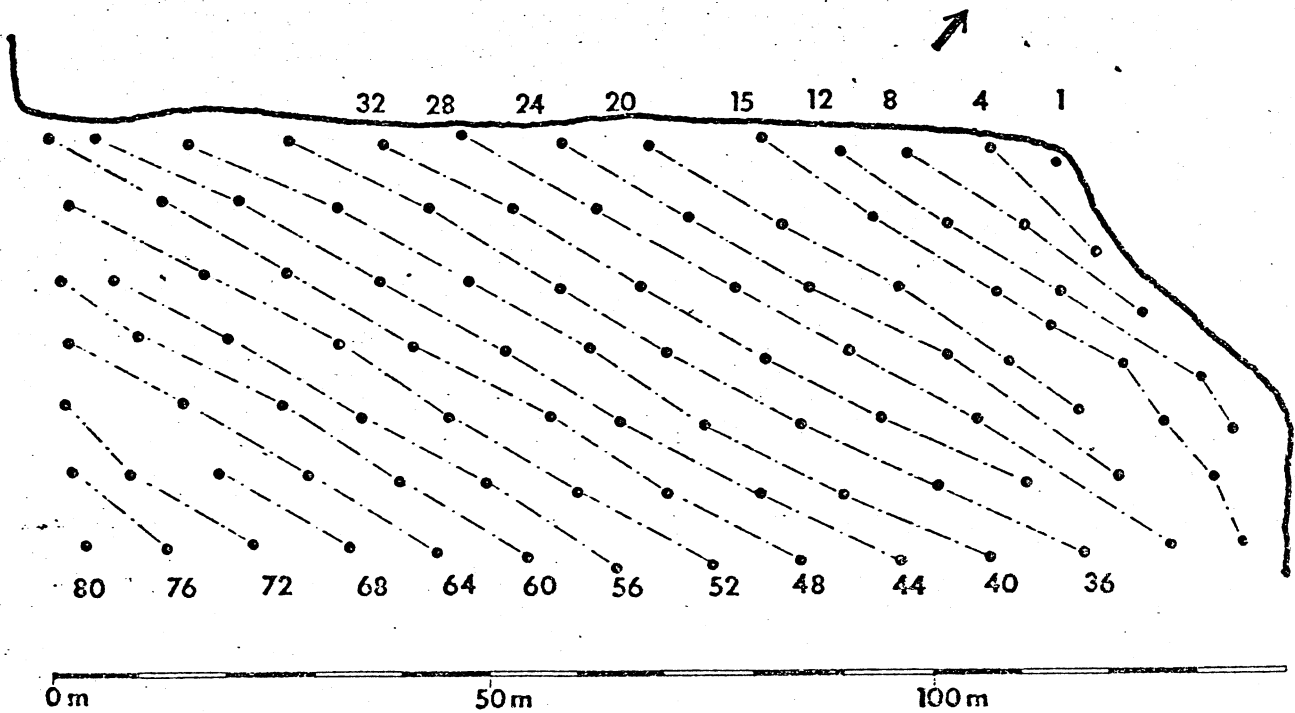


Fig. 8. Drilling and ignition pattern of Aitik open pit mine. Numbers indicate the cap number used in each row of holes connected by a dot dash line. Time interval between rows is 100 msec. 116 tons of explosive was used to break up 300,000 tons of ore.

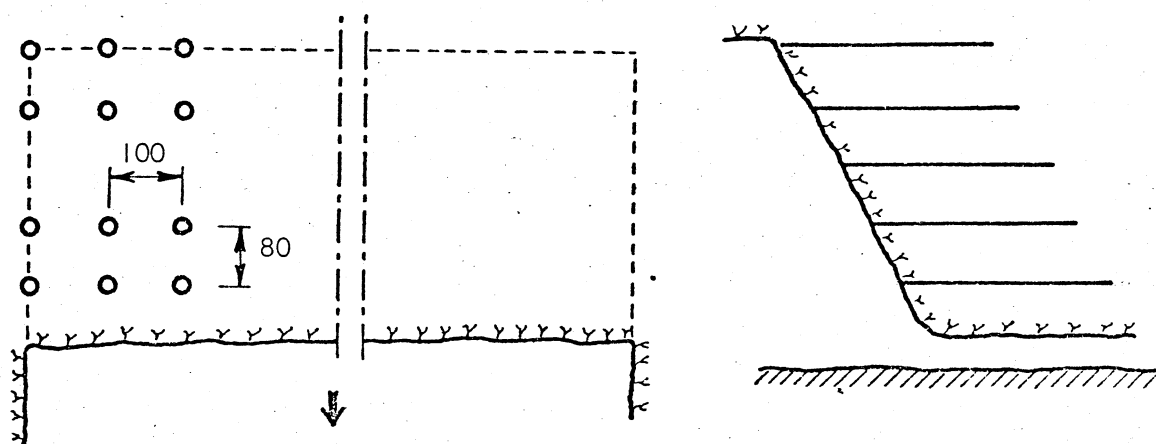


Fig. 9. Previous drilling pattern.

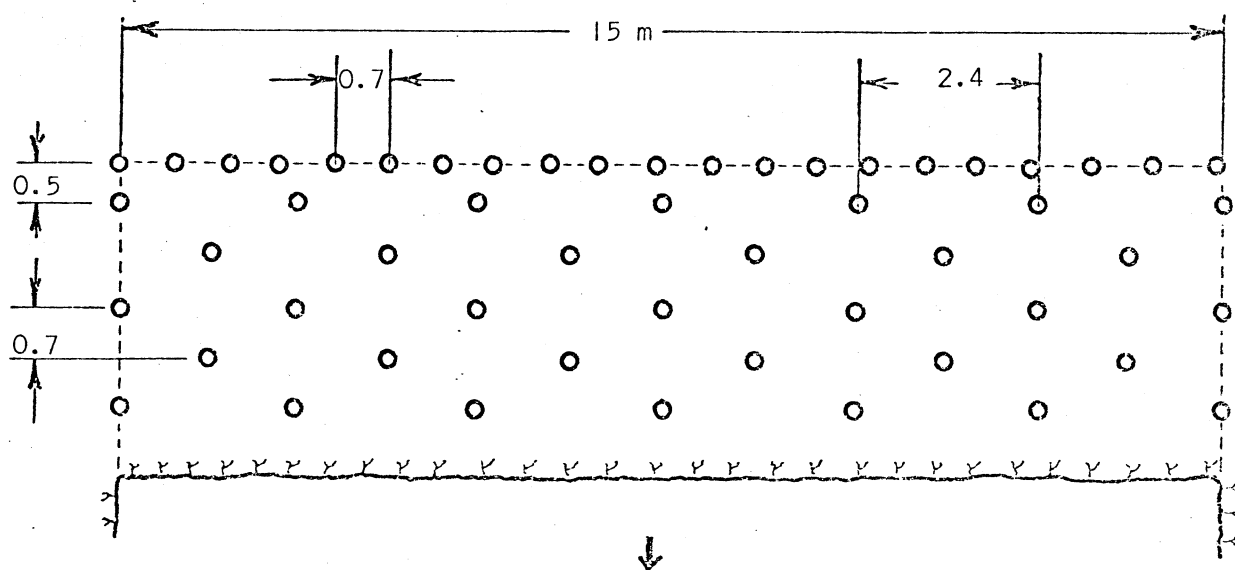


Fig. 10. Present drilling pattern.