CANADA

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
MINES BRANCH
OTTAWA

SEISMIC MEASUREMENTS AND BORE HOLE PHOTOGRAPHIC OBSERVATION

G. E. LAROCQUE, F. KAPELLER AND D. F. COATES

Reprinted from Canadian Mining Journal

Volume 94 Number 3 pp 44-45 March Montreal 1973

COMPARATIVE GROUND-SHOCK MEASUREMENTS FOR EVALUATING PRE-SPLITTING

G. E. LAROCQUE AND D. F. COATES

Reprinted from Western Miner Volume 45 Number 12

pp 33, 34, 36, 38 December Vancouver 1972

Reprint Series RS 123 Price 25 cents

Available by mail from Information Canada, Ottawa,
and at the following Information Canada bookshops:

HALIFAX
1687 Barrington Street

MONTREAL
640 St. Catherine Street West

OTTAWA
171 Slater Street

TORONTO
221 Yonge Street

WINNIPEG
393 Portage Avenue

VANCOUVER
800 Granville Street

or through your bookseller

Price 25 cents Catalogue No. M38-8/123

Price subject to change without notice

Information Canada
Ottawa, 1973

Seismic measurements and bore hole photographic observation*

By G. E. LAROCQUE,
F. KAPELLER and
D. F. COATES**

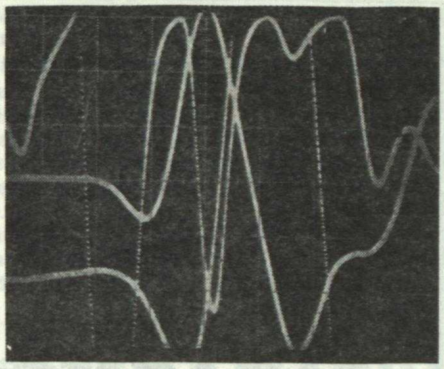


Fig. 1 Waveform of first arrivals at three seismometers (sweep 2 millisecs/cm).

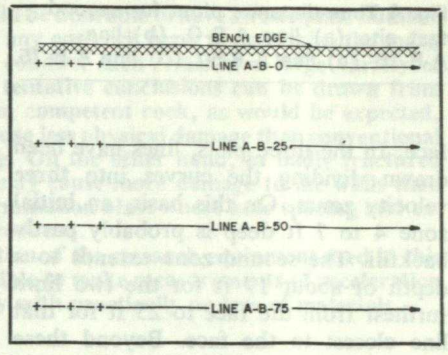


Fig. 2 Plan diagram of test site indicating position of refraction survey lines with respect to face of bench.

■A need exists to develop geophysical methods which permit a rapid and economical assessment of the structural properties of benches and walls in open-pit mines. The purpose of such measurements would be to establish the presence of faults and other features that must be allowed for in initial mine planning, and to detect subsequent structural changes caused by mining which can affect the stability of a mine.

Seismic refraction surveying is one geophysical method which has indicated some potential [1], and is being tested by the Mining Research Centre for detecting intensely fractured zones and faults. Test sites are the benches in an open-pit iron mine whose upper surfaces have been subjected to blasting of the 5 ft sub-grade from previous cuts. It was therefore expected that an intensely fractured upper section would exist in each bench, which could be indicated by photographing the holes.

The equipment

A hammer seismic survey was conducted with a conventional 12-pound hammer with attached inertia switch to produce seismic disturbance. The switch is used to trigger a Tektronic model 549 Storage Oscilloscope equipped to provide four traces in a chopped mode. Normally, 3 to 7.5 cps seismometers have been used simultaneously. Dynamic Model 2460A pre-amplifiers condition the signal developed at the seismometers. Fig. 1 is a trace resulting from some seismic array measurements.

The oscilloscope has normally been used in the storage mode. This permits the use of interludes between hammer blows to adjust the time base and gain settings, reducing to a minimum physical effort by the hammer man. After a set of acceptable traces has been produced, an oscilloscope camera provides a permanent record for later examination.

Seismic refraction measurements

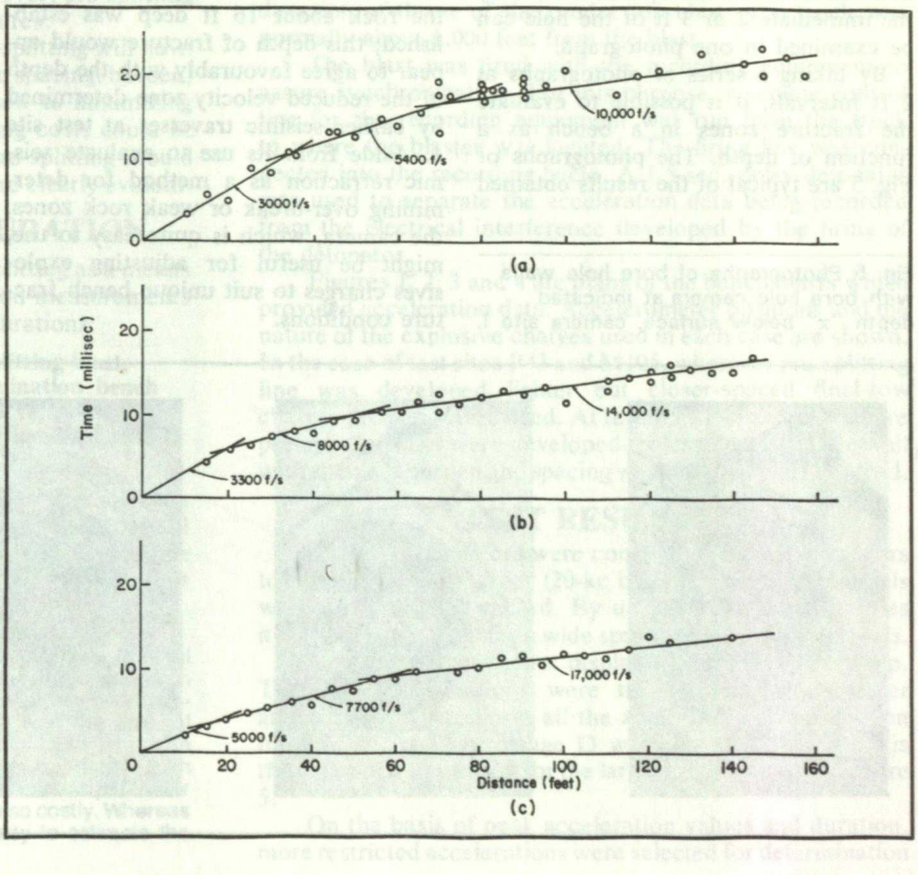
In the iron mine, benches 66 ft high are mined in two 33-ft cuts. Drill patterns vary from 18 x 18 ft to 22 x 22 ft with 4 to 5 ft of subgrade, depending on whether ore or waste is blasted. The toe load is 150 to 200 pounds of aluminized slurry explosives with a top charge of 300 pounds of AN-FO.

Referring to Fig. 2, measurements were made parallel to the face of existing benches. The line A-B-O was placed as close to the edge as physically practical and succeeding lines were 25, 50 and 75 ft behind it. The procedure was to place the three seismometers 10 ft apart at one end of these lines. Hammer distance was varied to produce refraction profiles for the different lines.

Fig. 3 shows refraction profiles for lines paralleling the bench face at the first test site. Fig. 4 shows similar profiles for the second test site.

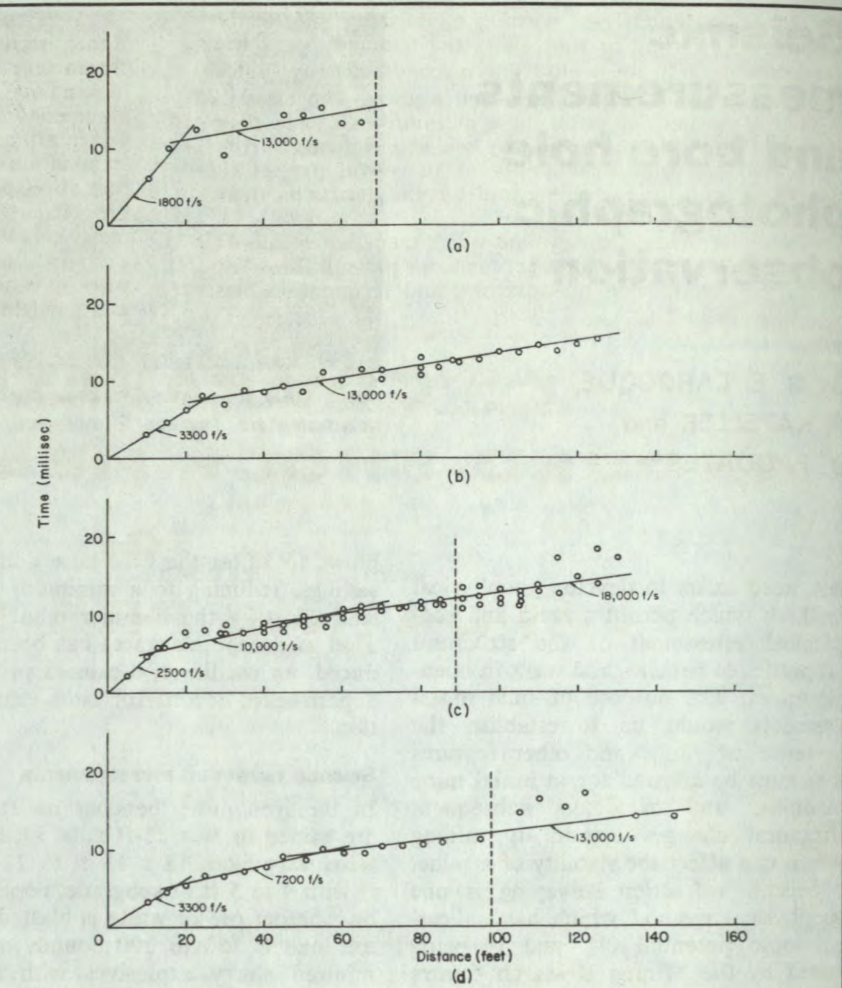
At this first test site, the refraction profiles indicated a gradual increase in seismic velocity with depth below sur-

Fig. 3 Time-distance plots for first test site (a) line A-B-O, (b) line A-B-25, (c) line A-B-50.



*IR 72/76 — EMR, Ottawa.
**Respectively research scientist, technician and head, Mining Research Centre, Mines Branch, EMR, Ottawa.

Fig. 4 Time-distance plots for second test site (a) line A-B-O, (b) line A-B-25, (c) line A-B-50, (d) line A-B-75.



face. In the three plots, lines have been drawn dividing the curves into three velocity zones. On this basis, an initial zone 4 to 7 ft deep is probably partly backfill. The second zone extends to a depth of about 17 ft for the two lines furthest from the face to 25 ft for that line closest to the face. Beyond these depths, seismic velocities indicate a relatively competent rock.

For the second site, shown in Fig. 4, there is not as clear an indication of three distinct velocity zones for all lines. After the first low velocity zone, there is only what could be called an intermediate velocity zone in the case of A-B-O and A-B-25. It is believed the high velocity zones are relatively deep on lines A-B-50 (20 ft) and A-B-75 (25 ft). Unfortunately observing actual structural conditions by borehole photography was not possible at that time.

Borehole photography

Blast holes are 7 in. in diameter. A camera unit was constructed to examine visually the extent of fracture damage. The optical axis is parallel to the borehole, and the camera photographs the entire cylindrical surface of the hole from about 9 in. away from the front of the camera facing down the hole. Because of the increasing obliqueness with distance between the borehole surface and the optical axis, only the immediate 2 or 3 ft of the hole can be examined in one photograph.

By taking a series of photographs at 2 ft intervals, it is possible to evaluate the fracture zones in a bench as a function of depth. The photographs of Fig. 5 are typical of the results obtained with this camera during preliminary trials. A continuous fracture zone in the rock about 16 ft deep was established; this depth of fracture would appear to agree favourably with the depth of the reduced velocity zone determined by earlier seismic traverses at test site 1. Aside from its use to evaluate seismic refraction as a method for determining over-break or weak rock zones, the camera, which is quite easy to use, might be useful for adjusting explosives charges to suit unique bench fracture conditions.

Conclusion

Zones of reduced seismic velocity have been found to exist in the upper portion of open-pit benches. Photographs have indicated that these are fracture zones. A program is required to determine if the reduction in seismic velocity is clearly related to the degree of fracturing. □

References

1. Lacy, W. C. Quantitizing Geological Parameters for the Prediction of Stable Slopes, AIME Trans., Sept. '63, pp 272-276.

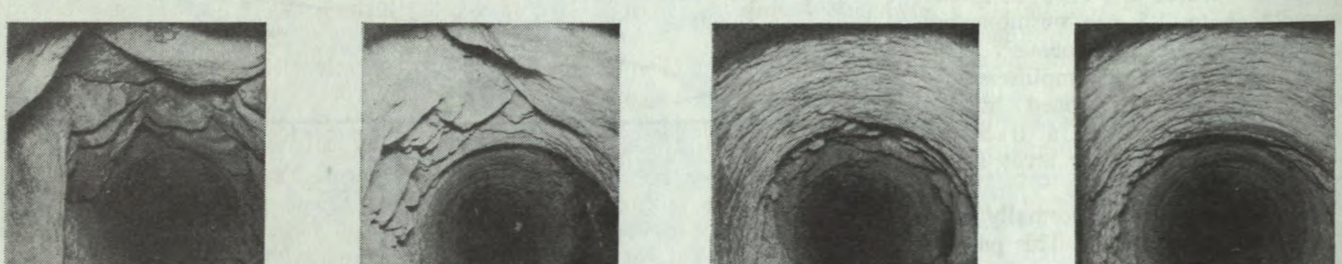


Fig. 5 Photographs of bore hole walls with bore hole camera at indicated depth "x" below surface, camera site I.

ABSTRACT

Considerable interest exists in establishing the effectiveness of pre-splitting in controlling the damage in the walls left after blasts in open pits. The mechanics of pre-splitting under idealized conditions are well known. The effects of geological discontinuities on these mechanisms can be determined, at the present time, only by field experiments. Further, the effects on mine profitability of successful pre-splitting remain difficult for each mine to determine for its particular conditions.

Measurements of the ground shock transmitted into wall rocks at three different sites were made for pre-splitting blasts, production blasts with pre-splitting, and termination blasts without pre-splitting.

Whereas it would be desirable to have an adequate number of measurements in any one rock mass to determine the mean parameters and to conduct such trials in a large variety of rock masses, some tentative conclusions can be drawn from the present work. In competent rock, as would be expected, pre-splitting may cause less physical damage than conventional termination blasting. On the other hand, in badly fractured rock, pre-splitting may cause more damage to the walls than the conventional termination blast where hole spacing and explosive charge are reduced.

With the evolution of the research equipment used in this work, it is now possible to make measurements of acceleration and particle velocity with practically no loss of materials.

COMPARATIVE GROUND-SHOCK MEASUREMENTS for EVALUATING PRE-SPLITTING

By

G. E. LAROQUE

**Research Scientist,
Mining Research Centre,
Mines Branch,
Department of Energy, Mines and Resources, Ottawa**

and

D. F. COATES

**Head,
Mining Research Centre,
Mines Branch,
Department of Energy, Mines and Resources, Ottawa**

INTRODUCTION

The processes involved in pre-splitting rock have been extensively studied. The shatter zone around lightly charged and pre-splitting holes should be more limited than the shatter zone around a production blast-hole. However, pre-splitting can have different effects on natural fractures.

The estimated cost and benefit of pre-splitting will have involved considering such variables as: hole spacing, burden, charge weight, and charge type with a view to minimizing wall damage. By using pre-splitting, drilling costs could be increased as much as by 30%. Obviously pre-splitting should be used only where its economic benefits are clearly evident.

EXPERIMENTAL CONFIGURATION

To evaluate the effectiveness of pre-splitting as a means of reducing the ground motion, acceleration measurements were made with three experimental configurations:

Type — 1, in a wall behind a pre-splitting blast,
Type — 2, in a wall behind a termination bench blast without pre-splitting, and
Type — 3, in a wall behind a production blast after pre-splitting.

It had been planned to do three experiments of each type; however, there were suitable sites in just five successful experiments — two Type-l tests, two Type-2 tests, and one Type-3 test$. The bench height is 66 feet achieved in 33-foot cuts.

This document is an interim report prepared primarily for internal departmental reference and does not represent a final expression of the opinion of the Mines Branch. The manuscript has been supplied to Western Miner for publication, along with the original figures, because of the interest in field trials attempting to determine the benefits to be obtained from pre-splitting in open-pit-bench blasts. Dr. Coates comments: "The various methods of perimeter blasting are of great interest, however, they are also costly. Whereas it is easy to establish the costs, it is not so easy to estimate the benefits".

Four accelerometers were used in each of these experiments, placed in a row approximately at the centre of the final berm parallel to the row of pre-splitting or blastholes. Test sites were selected so that the cables and instrument truck could be located either behind or to one side of the direction of throw of the production blast. The truck was normally about 1,000 feet from the blast.

The blast was fired with the recording equipment to assure synchronization.,For this purpose, a remote control line for the recording equipment was run from the truck to where the blaster was located. The firing line was connected into the recording cycle. A 1.5-sec. delay detonator was used to separate the acceleration data being recorded from the electrical interference developed by the firing of the detonator.

Figures 1, 2, 3 and 4 are plans of the bench blasts which provided acceleration data. Accelerometer positions and the nature of the explosive charges used in each case are shown. In the case of test sites P43 and M105, where no pre-splitting line was developed lighter but closer-spaced final-row charges (helpers) were used. At test sites P43 and P38 where pre-splitting lines were developed, holes adjacent to the wall with standard burden and spacing were more heavily charged.

TEST RESULTS

The accelerometers were connected through amplifiers to an F.M. tape recorder (20-kc bandwidth). Two channels were used for each record. By using different sensitivities it was hoped to allow for a wide spread in acceleration levels.

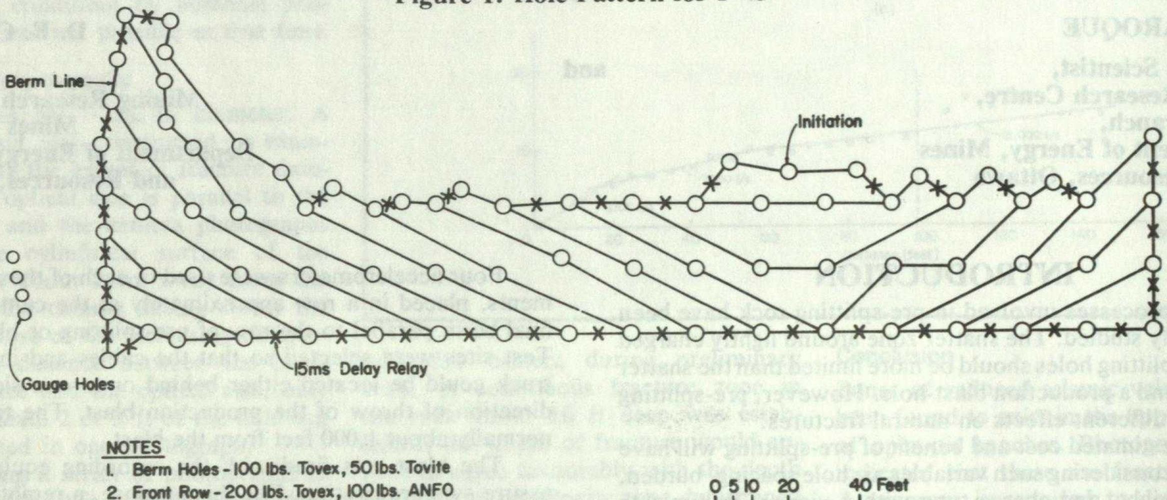
The records were first displayed using a slow sweep. The large accelerations were then selected for further analysis. Figure 5 shows all the acclerations in production blast M105 to which gauge D was subjected. Figure 6 is the expanded wave form for the largest acceleration in Figure 5.

On the basis of peak acceleration values and duration, more restricted accelerations were selected for determination

TABLE 1 — ACCELERATION AND PARTICLE VELOCITY DATA

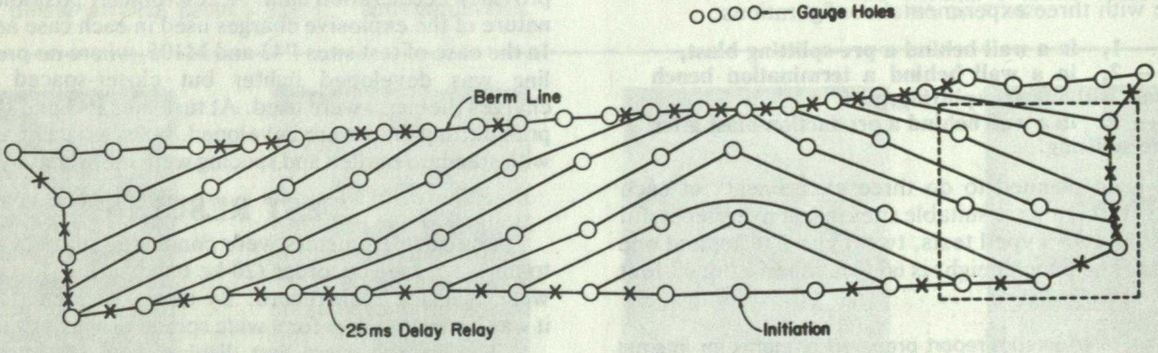
Site Number	Description	Peak Accelerations (g's) Gauge 1	Gauge 2	Gauge 3	Gauge 4	Peak Particle Velocity (cm/sec) Gauge 1	Gauge 2	Gauge 3	Gauge 4
P38S	pre-splitting blast	400	350	420	370	60	51	60	95
P48S	pre-splitting	1800	8800	saturated >8000	hole collapsed	380	880	—	—
P43	main blast, no pre-split line	440 230 370	1200 490 320 610	710 920	217 160 300 560	120 120 150	194 167 165 184	170 210	110 90 99 140
P48	main blast, pre-split line	565 1000	170 1500	360 770 1500	hole collapsed	145 125	127 274	82 164 210	— —
M105	main blast, no pre-split line	2000 430 900	480 570	855 1560 940 875	965 2600 6900 3400	99 55 88	62 100	91 170 370 91	130 240 310 140

Figure 1. Hole Pattern for P-43



NOTES
1. Berm Holes - 100 lbs. Tovex, 50 lbs. Tovite
2. Front Row - 200 lbs. Tovex, 100 lbs. ANFO
3. Other Rows - 200 lbs. Tovex, 400 lbs. ANFO
4. Prima Cord Interconnection Of Holes
5. 39 Delays Used, X, 15 ms Each Delay
6. All Holes 7" Dia, Except Where Noted

Figure 2. Hole Pattern for M-105



NOTES
1. Berm Holes - 150 lbs. Tovex, 50 lbs. Amite II
2. Boxed Holes - 175 lbs. A-2 Tovex, 175-200 lbs. ANFO
3. Other Holes - 150 lbs. Tovex, 175-200 lbs. ANFO
4. Prima Cord Interconnection Of Holes
5. 34 Delays Used, X, 25 ms Each Delay
6. All Holes 7" Dia, Except Where Noted

0 5 10 20 40 Feet

Figure 3. Hole Pattern for P-48

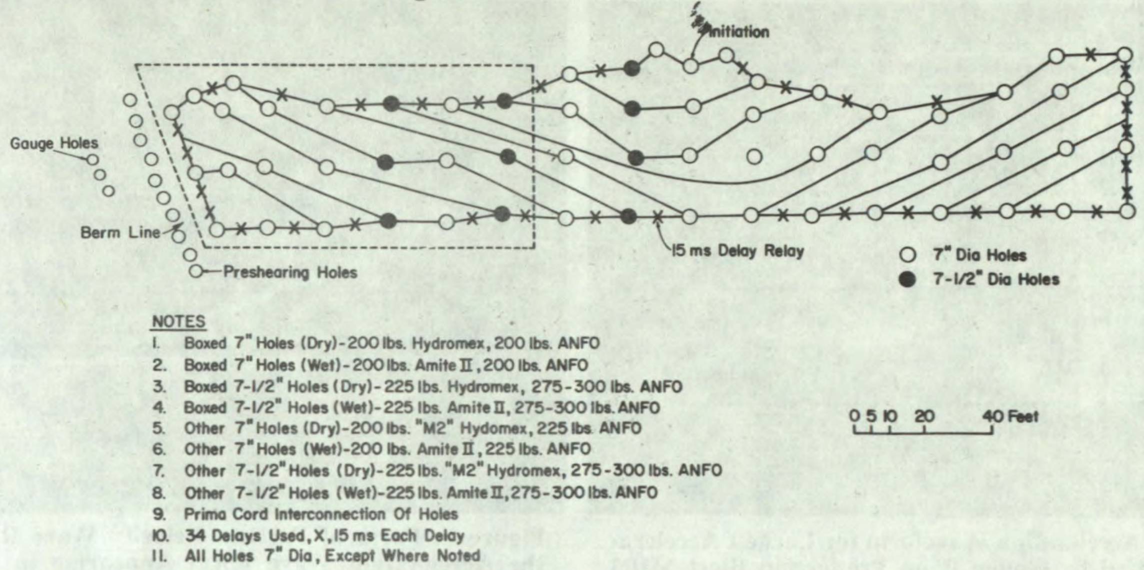
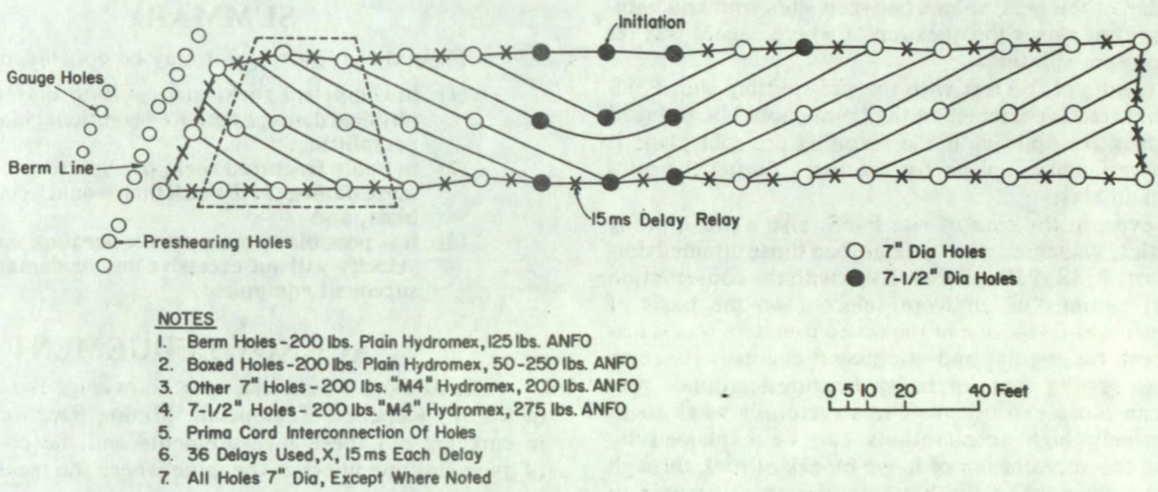


Figure 4. Hole Pattern for P-38



of particle velocity wave shape and amplitude. Figure 7 in the particle velocity wave shape for the acceleration shown in Figure 6.

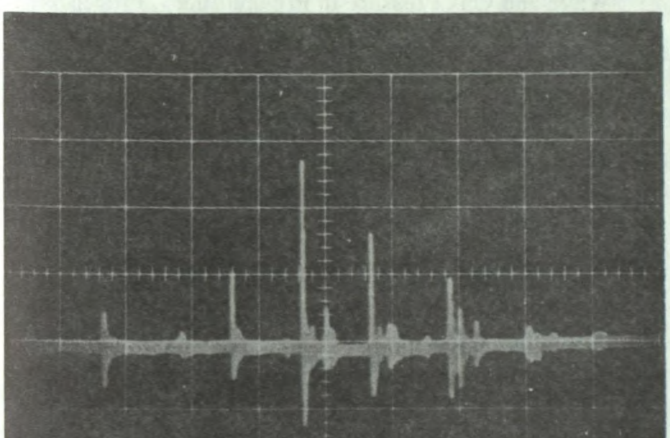


Figure 5. Complete Acceleration Record for Gauge D on Production Blast M105 (Sweep 30 millisec/div., Gain 1 volt/div.).

DISCUSSION

Sites P38 and P48 are all located in sections of the mine where it is difficult to maintain a berm. It is in this area that pre-splitting would be used if the effect were beneficial. M105 is a waste zone adjacent to the opposite wall where no difficulty is being experienced in achieving an even and intact wall.

Among sites P38, P43 and P48 drilling indicated that P48 is structurally the poorest site. For example, one of the gauge holes collapsed, and blast holes had to be drilled to replace those which collapsed before they could be loaded. In Table 1, it is evident, particularly from the peak particle velocity date for sites P43 and P48, that pre-splitting has not reduced the peak particle velocity produced in the wall during the main blast. In fact a higher peak velocity (i.e. 274 cm/sec) has been recorded in the wall with pre-splitting than without pre-splitting (i.e. 184 cm/sec). Peak particle velocity can be considered a measure of the peak radical stresses produced in the rock. (In Table 1, the suffix S attached to a site location number indicates that the associated acceleration measurements were made as part of the pre-splitting blast; without the suffix the accelerations are those of the main blast at the particular site.)

The highest particle velocity without pre-splitting occurred at site M105 (370 cm/sec); however, it was a relatively short duration. At any one test site, with or without

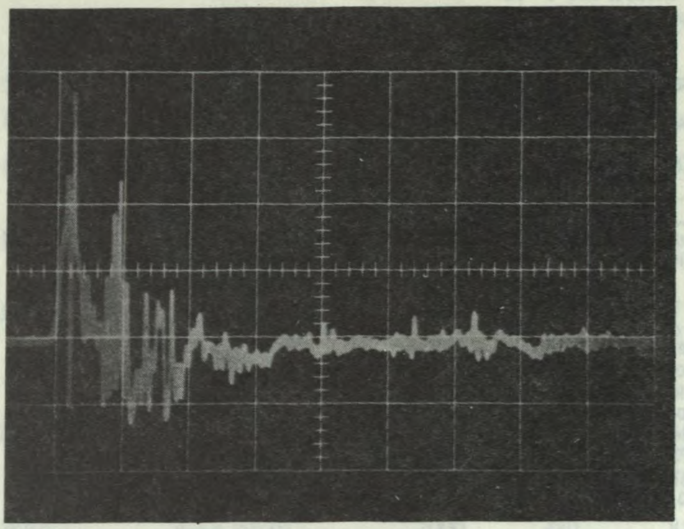


Figure 6. Acceleration Waveform for Largest Acceleration Realized by Gauge D on Production Blast M105 (Sweep 0.5 millisec/div., 0.2 volt/div.).

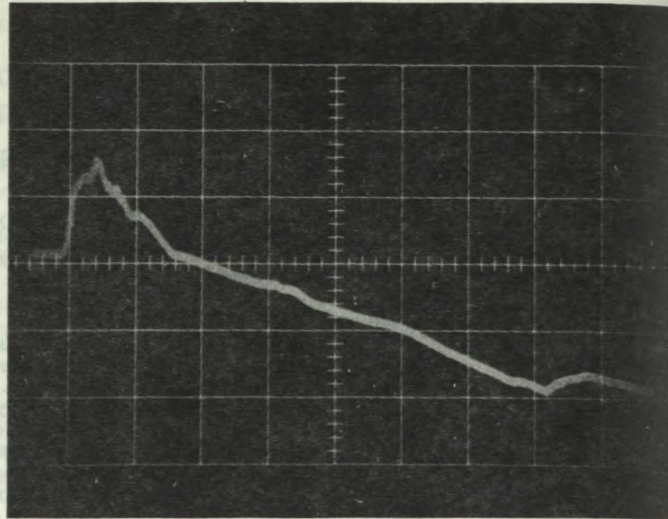


Figure 7. Form of Particle Velocity Wave Related to the Acceleration Wave Form Appearing in Figure 6 (Sweep 1 millsec/div., 0.5 volt/div.).

pre-splitting, there was considerable variation between the peak accelerations measured by the four accelerometers. The overlap of the peak values between sites with and without pre-splitting raises the question of where benefit was received from pre-splitting.

The results of the test with the pre-splitting shot P38S suggest that fracture damage in the berm should be reduced as a result of pre-splitting if the resulting pre-split plane is to be the termination plane for fractures during the subsequent main blast.

However, in the case of site P48S, also a pre-splitting blast, particle velocities were greater than those attained during test shots P38S, P38 and P48. Even with the conservation equipment settings which were selected on the basis of measurements at P38S, one of the accelerometers was saturated on both the regular and attenuated channel. It seems from these results that, in badly fractured ground, pre-splitting can cause extra damage to structurally weak rock. The extremely high accelerations can be explained by visualizing the acceleration of loose blocks of rock through the gaps or openings in the bounding joints or fissures to impact on the blocks of material containing the sensing units. Further, it is visualized that the gas pressure applies a normal force to the face of the bench for an appreciable period of time and that the resulting minor movements are not likely to benefit the structural stability of a pit wall.

The location of the gauge holes, as at site M105 (see Figure 2), provide a record of the time interval between acceleration peaks resulting from the delays being used. In these circumstances, the sensing units have a potential use as a check on the proper functioning of the delays and the explosive charges.

SUMMARY

From these few tests, it may be concluded that:

(1) in competent rock, pre-splitting may cause less physical damage than a conventional blast without presplitting;

(2) in badly fractured rock, pre-splitting might cause more damage in the wall than would a conventional blast, and

(3) it is possible to measure acceleration and particle velocity without excessive loss or damage to measurement equipment.

ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance of Mr. F. Kapeller, Technician, Mining Research Centre, in carrying out these measurements and the co-operation of mine staff members at the mine where the measurements were made.

REFERENCES

1 Kutter, H. K. and Fairhurst, C. "The Roles of Stress Wave and Gas Pressure in Pre-splitting", Proceeding of the Ninth Symposium on Rock Mechanics, Colorado School of Mines, 1967.

2 Ito, I. and Sassa, K., "Etude sur le Méchanisme de Fragmentation au Cours du Sautage Ménagé à l'Explosifs" No. 3, 1969 pp. 39-105.