Recent Developments in Rockburst Research at Lake Shore Mines

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A serious hazard which must be faced in some mines, though quite absent in others, is that of rockbursts. Bursts cannot be wholly avoided in such mines, but the hazard would largely disappear if they could be predicted. The problem of prediction resolves itself into that of measuring pressure in the mine and determining when that pressure nears a critical value. The geophysical approach to the problem lies in discovering some physical property of the rock, which varies with pressure, which can be measured for rock in place, and for which the indication of critical conditions is sufficiently definite and open scale.

A physical property, suggested first in connection with earthquake prediction, is that of subaudible snapping. It was argued that, as the pressure grows, the rock probably yields microscopically and that minute snapping occurs which is so faint as to be inaudible to the unaided ear. Experience has proved this to be the case.

Following other earlier work begun early in 1939, experiments with this method were initiated at Lake Shore Mines in 1941, and equipment was slowly being developed in practice when, fortunately, it was found possible to by-pass this tedious development program. Experiments with subaudible snapping in mine rocks had been carried out by Dr. L. A. Obert of the U.S. Bureau of Mines and his associates over a period of about four years. An amplifier and a recorder were developed, each reasonably satisfactory in practice. Lake Shore Mines offers a tempting field for rockburst research. Dr. Obert was invited to test his equipment in this and other mines in Ontario and did so. As a result, he and the administrative personnel of the Bureau became interested in the Lake Shore experiments to the extent of most generously arranging for the manufacture of sets of their own designed equipment for use in this program.

The first three sets of recorders were ordered at once and were delivered in May, 1942. A second group of three sets, incorporating various improvements indicated by experience both in the United States and in Canada, reached Kirkland Lake in April, 1943. The pick-up devices, known as geophones, were

made in the electronics laboratory at Lake Shore by Mr. Gibbs, who has had charge of all the instrument development in this research.

A brief, and hence necessarily incomplete, description of the equipment may be given. The geophone housing is a steel tube about 1 1/4" in diameter and 8" long. In this tube is rigidly mounted, spring-board fashion, a two-layered, Rochelle salt crystal, about 1 1/2" x 1/2" x 1/4". This double crystal is closely wrapped in silver foil, connected to one electric terminal inside the geophone. A separate strip of silver foil, connected to a second electric terminal, lies between the two layers of the crystal. When the geophone, set deep in a diamond drill hole in the mine, is subjected to the impulse of one of the small subaudible snaps previously mentioned, the inertia of the crystal causes it to suffer a slight flexure, which results in the generation of a momentary voltage difference at the two terminals. These are connected, through a small transformer mounted in the geophone tube, and a shielded, two-wire cable, to an amplifier-recorder mounted in a conveniently situated, underground instrument room, serviced by the 110-volt lighting supply.

The slight currents generated are amplified to the order, in practice, of about half a million times, and caused to pass through a coil of fine wire, mounted on a pivoted stylus and lying in the field of a powerful permanent magnet. The slight mechanical energy of the subaudible snap is thus translated into an amplified throw of the stylus, transverse to a strip of special paper 2" wide, moving at the rate of 1 1/2" per minute. Recording is done by means of a small current carried by the stylus to and through this record strip to a stationary metal platen. The record requires no processing and permits the clear recording of snaps at intervals as close as 1/2 sec, for the paper speed indicated. Higher speeds and hence greater resolving power can be obtained through the use of alternate gear ratios.

A separate registering stylus permits the identification of time. The gain of the amplifier is selected by means of an attenuator. A further limitation is introduced by a unit which ensures that the record shall vary logarithmically with the strength of the input signal. Thus, even should a heavy audible snap occur, it cannot damage the recording mechanism.

Experiments in the mine showed that, when a pressure zone develops, many small snaps occur and that these cannot

be picked up by a geophone at distances much greater than 50 to 75'. This short travel distance is a definite advantage as it permits the close delimitation of high pressure zones.

After some months spent in gaining experience with the method under the conditions in Lake Shore, and in determining the best locale for further study, a regular observing program was begun on January 2, 1943, in a section of the so-called, west pillar. Three recorders and seven geophones were then available. Time switches permitted the running of two geophones for alternate half hours on the same recorder. Six geophones were placed in the recording service and one geophone was used for a special listening post, using a separate amplifier. There was one geophone in a drill hole on each of the levels, 3825, 3950, 4075, 4200, and 4325, with two others on the 4200' level. All geophones were set in 30' holes (except one on the 4200 which was in a hole 100' deep). All the holes were drilled in the hanging wall, which experience had showed to be much more active than the foot wall.

The program continued through to 2-12 a.m., January 29, when a major crush burst occurred which affected every level of the west pillar on which the geophones were installed. Every geophone was lost, together with one recorder. One geophone was later recovered and others were made as quickly as possible. A new hole was drilled on each of the levels 3825 and 4200 and a program run through the latter part of February and all of March. On March 31 a second heavy burst occurred which affected the levels 3200 to 3950 in the same pillar. The geophone on 3825 was lost and the recorder badly shaken up but not seriously damaged. The set on 4200 was not affected. However, the drifts were so badly blocked that it is necessary, for the time being at any rate, to abandon further study in the west pillar. Another locale must be determined by a reconnaissance program now being undertaken.

The experiments from July to December, inclusive, 1942, yielded conclusions of considerable value in shaping the program for January. The results of the January records are decidedly interesting and informative, since they were taken for a full four weeks from geophones distributed as evenly as possible over what proved to be exactly the site of a major burst. After the burst, no recording was done until the new geophones were available on February 15. Records were then taken on 3825 and 4200 until the burst of March 31; but, as the geophone nearest the burst was at a distance of,

at least, 500', the records yielded no information of value.

As a result of the studies to date, it has been found that;

(1) Test holes should be deep (30' was finally adopted as standard), should be drilled in the foot wall, and should be washed out before being used.

(2) Light disturbances (small snaps, tapping on the wall with a hammer, etc.) do not carry well across a discontinuity (fault, vein, etc.).

(3) Effective listening can be done only in the off-shift periods and recording for more than off-shift time, though yielding some extra coverage, uses up a great deal of paper.

(4) Records of small snaps by two geophones separated by various distances show that disturbances of this type die out in 50 to 75'.

(5) Larger simultaneous snaps occur at geophones separated as much as 700', and in some cases the gradation in intensity shows clearly the position of the origin of the snap.

(6) To permit any definite conclusion to be drawn from the recorded data, the entire instrumental track of every record must be calibrated to a definite common standard and the calibration tests must be run regularly as a matter of routine.

(7) Small pre-bursts or "salvos" occur in badly strained ground and seem to indicate an approach to bursting conditions. They do not register on the surface seismograph and, in most cases, could not be heard with the unaided ear even by persons in the locations affected. They record to different degrees of intensity on geophones separated by 125' (the distance between levels) and often even less.

(8) The progress of mining greatly affects the number of snaps per minute and must be taken into account when making any deductions from the summarized data.

(9) The ground seems to be in a critical state of pressure when the total number of snaps per minute (large, medium, and small) approaches 100. Even higher counts have been passed without bursting but evidently conditions are unsafe with a count so high. The small snaps much more closely follow the local pressure trends than do the large and medium ones.

(10) The large and medium snaps affect more country and a study of the coincidences of such snaps on various geophones tends to indicate the extent of the region taking pressure.

(11) Critical pressures shift from one position to another within a few hours and peaks of critical pressure are not maintained for more than a few hours at any given spot.

(12) To determine what parts of a pillar are related seismically, it is necessary to make continued observations for a long term over the entire pillar. The pressure shifts indicate the interdependent regions. Then, as any one of these approaches a critical pressure, precautions must be taken in all the others since a burst in the section immediately under pressure will quite possibly shift the last intolerable addition on a related section, resulting in a second burst within a few minutes, as is evident from the cases illustrated in Figs. 1-2.

(13) Geophones must be placed within, at most, 100' of each other over the entire exposed development and stope areas in a pillar under observation.

Finally, it may be stated that the subaudible method, properly applied, definitely indicates the location of pressure zones and permits a study of their shift from one point to another. So far as experience shows to date, ground is unsafe when the average total count per minute is nearly 100. It may not burst, but the risk is great and men should be removed from the area. If it does not burst, the count will soon fall and mining can be resumed until further warning signs appear.

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