ROCK BURST RESEARCH AT LAKE SHORE MINES KIRKLAND LAKE, ONTARIO

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The conditions under which a miner works are hazardous at best. Most of the hazards (gas, rock falls, explosions, etc.) can be anticipated so that steps may be taken to minimize, or even eliminate, them. Where mines are carried to depths of 2,000 feet and more, a hazard appears which, so far, has not been found to give invariably definite evidence of its magnitude or even of its presence. This is the rock burst.

Whatever other pressures may be present at depth, one is certain - the pressure due to superincumbent rock. Until the mine workings make excavations at depth, the rock at deep levels is held in place by pressure from all sides, which, at depths of half a mile or so, tend to become pseudo-hydrostatic in nature. When this pressure is relieved by mine workings on one or more sides of a section of rock, its strength can no longer sustain the load. Pieces spall or fly from the face of workings, some so small that they do no serious damage even if they do happen to strike a man. Casualties are confined to an occasional cut from a sharp fragment. At other times, pieces weighing several pounds will be thrown off from the surface (floor, walls, or roof of an excavation) as one might pinch a melon seed between thumb and finger. A burst of this type can cause serious injury and even death. Such failures, large or small, are called strain bursts. In some cases the walls will snap in such a burst without any rock spalling from the surface.

If a volume of rock under pressure is exposed on two or more sides, it is referred to as a pillar. The progress of mining operations may tend to diminish the size of a pillar and/or to throw extra weight upon it, until finally the pressure per square inch becomes more than the rock can sustain. The whole pillar may burst, sometimes throwing down tons of rock and perhaps overloading adjacent pillars so that they too burst, practically simultaneously or perhaps after the lapse of an interval which may be minutes or even days. A failure of this type is designated a crush burst.

The energy released in a crush burst may approach that of a small earthquake. Eight of these, occurring at Lake Shore Mines, are known to have been the cause of records on the short-period Benioff at Ottawa (Δ = 280 mi.). Gutenberg and Richter state that the energy released in the smallest recorded earthquakes is of the order of 10^8 ergs. Computations show that sufficient energy could be stored in the rock, due to the burden of superincumbent rock alone, to account for that evidenced by these records. While other pressures may exist, it is not necessary to postulate them in order to explain the source of energy evidenced.

The factors which determine the time and place of a rock burst are many. Most of them cannot be measured. Even the fact of the existence of some of them in any particular case is often uncertain. The depth of the workings, the shape and size of the openings and their distribution as a whole throughout the mine, the strength or brittleness of the rock, the geology of the region in general and of the workings in particular, the mining methods employed, the rate of mining -- these are only a few of the many conditions which determine if, when, and how a pillar will burst. The discussion of these factors is beyond the scope of this brief paper but they must be studied in the mine itself by those responsible for applying geophysical means for their evaluation, if progress is to be made in this type of research.

Rock bursts cannot be prevented. They can be controlled to some extent by proper choice of mining methods. These are designed to work hand-in-hand with the rock bursts, so to speak. Heretofore, the mining industry has depended solely on the good common sense and painfully acquired experience of its best miners. This, thoughtfully applied, has helped very greatly to reduce the damage and casualties arising from rock bursts. The mining industry now asks whether geophysical means can be found to supply data for the guidance of their men as they excavate to greater depths. The general principle followed is to so arrange the methods and speed of mining that the rock may be induced to burst under conditions which will not cause great reservoirs of strain to build up without release. The geophysicist is asked to devise for their guidance some means for determining where and to what extent the strains are developing.

The rock burst study at Lake Shore Mines began when, in January, 1939, this company asked the Dominion Observatory to arrange the installation of a surface seismograph to record the occurrence of rock bursts and their relative intensities. The installation was completed and began operation on December 19, 1939. The equipment consists of a Heiland geophone such as is used in seismic prospecting which registers by means of a galvanometer on a recording drum giving 30 mm/min. line speed. The geophone and recording pier were placed on solid rock in a specially constructed basement room of a dormitory.

The recorder was designed and built by the Heiland Research Corporation, Denver, Colo., and has since been somewhat modified in the light of experience. It now records all the larger blasts as small displacements from the record line in addition, of course, to the larger strain bursts and all the crush bursts. While the Heiland recorder was being modified from time to time, one of another type was used in its stead so that the operation of the seismograph has been practically continuous since December 19, 1939.

One of the main reasons, from the point of view of the Observatory, for devoting the time to installing and maintaining this seismograph has been for the purpose of timing the bursts so that the travel-time to distant seismographs could be determined. To this end, the installation includes a HRO radio receiver, a Dent chronometer and all accessories for timing the minute signals and obtaining the correction automatically by radio.

During 1939, while the equipment was being designed and built, seven crush bursts occurred at Lake Shore Mines of sufficient intensity to register at Ottawa. Since the surface seismograph was installed, no burst has occurred of that intensity. So, thus far, no measure of the travel-time has been obtained, although more than a hundred bursts of noteworthy intensity have registered at Kirkland Lake. However, the service is operating continuously; and, should a major burst occur, valuable travel-time data will be obtained.

In January, 1940, Lake Shore Mines invited the Dominion Observatory to organize rock burst research in the mine. A mine seismograph was designed and assembled at Ottawa using a Heiland geophone and a Brush crystal detector as alternative pick-ups and an ink recorder designed and assembled by V. E. Hollinsworth of the Observatory staff. On the recommendation of the Observatory, the mine engaged Mr. Zack E. Gibbs to assist for a month in tentative experiments at the mine. Mr. Gibbs has had wide experience in the application of electronics to seismic exploration. The tentative experiments were carried out in March, 1940.

It was found that underground conditions were such that recording bursts for a statistical study is out of the question without special precautions being taken. Blasts and other mine noises kept the mine seismograph in a constant state of unrest. However, on the basis of the experience gained, recommendations were made for a program of instrument development which was to take at least a year. As a preliminary, a well-equipped electronics laboratory and workshop was considered a necessity.

Several possible lines of investigation were suggested in addition to the development of a mine seismograph which would respond to bursts alone. These included: Measurements of variations of velocity of sound through pillars presumably undergoing increasing strain, development of strain meters, metric studies of active faults, attempts to measure temperature variations due to variations in pressure, and attempts to detect and register supersonic vibrations, if, as suspected, these occur in a pillar subjected to increasing strain or pressure.

The program was accepted. Mr. Gibbs was engaged for the work and the laboratory was built and equipped with the recommended instruments and tools. This was done with remarkably little delay considering the disruption to business due to war conditions. At the time of writing, a full year of this work has been completed and arrangements have been made to continue it indefinitely.

Based on the experience gained in the March experiments a new mine seismograph was designed and built by Gibbs, using a commercial Esterline-Angus ink recorder and the pickups already tried, together with other crystal detectors sensitive to still higher frequencies. It was suspected that vibrations in the rock caused by blasting might have a frequency which differs from that caused by bursting. Several attempts to measure these frequencies failed, so a regular seismograph prospecting outfit was leased from L. Don Leet of Harvard University. This was used in Lake Shore Mines and also in the Frood mine at Sudbury which shared the expense of obtaining the equipment.

It was found that blasts induce a frequency of from forty to sixty cycles per second, while that due to bursts ranges from a little over 200 to more than 400 cycles. Other mine noises, hoists, tramming, ore chutes, crushers, etc. induce frequencies less than 100 cycles. It then appears possible to devise a filter which will enable the mine seismograph to register only bursts.

It was early recognized that if the frequencies differ it was to be expected, a priori, that burst frequencies would accompany some of the blasts for these undoubtedly release strain in the rock. Experiment confirmed the deduction. Some blasts show high burst frequencies, superposed on their own low frequencies. Some blasts do not. The records, where good fortune enabled the experimenters to catch a strain burst when no blasting occurred, showed no low frequency.

It was difficult to obtain a suitable filter, owing to the pressure of war work. Finally, computations were furnished by one company and the filter built by another. After some experimenting by Gibbs the characteristics of the equipment as measured in the laboratory were found to suppress the registration of frequencies under 200 and to give good amplification for those above. This equipment has had only a few days use in the mine and some experimenting will be necessary to find a location where the blasting will be far enough distant that it will not force its way through the network but that bursts can still record. It is believed that this is only a matter of time and experiment and that compilation of burst data can soon be undertaken as routine.

A strain gauge of hydraulic type was designed and built and has been in continuous operation in a particularly bad part of the mine since August 26, 1940. Since then two heavy and other smaller bursts have occurred in the vicinity. It appears that there is a sort of hypothetical straight line graph, the inclination of which shows the average rate of closing-in of the stope. For some weeks prior to each of the two large bursts, the graph fell below this line and, at the time of bursting, abruptly rose to meet it. Further experience is necessary but the results to date have been very encouraging.

An electric gauge was designed by Mr. V. E. Hollinsworth of the Observatory staff for rapid checking of master gauges.

The device is very sensitive, showing a deflection of about a quarter of an inch on the meter for a movement of 10^{-5} inches at the gauge. It was believed that such a gauge could yield valuable information if designed to be placed deep in a diamond drill hole run into a pillar.

The gauge, redesigned with this object in view, was tried out at the mine by Hollinsworth and Gibbs in late March of this year. Experiments in the laboratory showed that a drill hole 1.5 inches in diameter in a piece of rock about the size of a football could be deformed sufficiently by pressure with the hand alone to show deflections by means of the microgauge installed in the hole. No difficulty was experienced in installing the gauge at any desired depth in drill holes in the mine. But, difficulties were found in obtaining sufficiently constant voltage for successful continued operation.

Pending the delivery of equipment ordered for further experiments in the mine, two sets of the gauge and its accessories are being arranged for - one at the mine and one at Ottawa. At the mine, Gibbs will experiment with the view to obtaining the necessary constant power supply and in ironing out other difficulties connected with continued registration. At Ottawa, Hollinsworth will use the gauge to obtain the pressure-strain curve for large samples of rock, bored at the mine, and supplied for these experiments. The pressures, applied by a hydraulic press, will be carried up to the point of failure of the specimens.

As soon as the equipment is ready for further experiments underground, the work will be resumed at Lake Shore Mines. It is believed that this method promises interesting data of a very local character. It is evidently most desirable to be able to measure strictly local conditions. The details of the gauge and the results of the experiments will be reported later.

Steps have been taken toward developing equipment for detecting and recording supersonic vibrations in pillars. Delays in obtaining parts are responsible for no progress in experiments having been made to date. This method is considered most promising. It should, if successful, yield data which will also be of a local character. No work has so far been attempted with thermometric devices; and, except for a few tentative shots with Leet's equipment, no measures of sound velocity have been made. Regular seismic equipment would have to be greatly modified for such work and for the moment it is not planned to attempt this method.

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Ernest A. Hodgson.