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THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

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THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

by

D.G.F. Hedley* and J.E. Udd**

SUMMARY

This project was started in 1985, after a particularly extensive period of rockburst activity in several Ontario mines. Three parties participate in the project: the Government of Canada, through CANMET, the Ontario Ministries of Labour and Northern Development and Mines, and the Ontario Mining Association.

The first two years of the project have been mainly devoted to the design and installation of new seismic monitoring systems. It is intended to install three different types of monitoring systems at the four mining camps experiencing rockbursts (Red Lake, Elliot Lake, Sudbury, and Kirkland Lake). Seismograph units will be installed at each mining camp to obtain permanent records of the larger seismic events and their magnitude. Macroseismic systems are being installed around five mines (Campbell, Quirke, Strathcona, Creighton and Macassa). These systems consist of triaxial, strong-motion geophones with processing units for event detection and data digitization. Complete waveforms are captured to study first motion, peak particle velocity, seismic energy and spectral frequency. At present, 13 mines in Ontario operate their own microseismic systems which are used exclusively for real time source location of seismic events.

The instrumentation already installed and the present research activities at the mines are described in the paper.

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INTRODUCTION

This rockburst project was initiated in September 1985 in response to a growing problem in Northern Ontario hard rock mines, which had resulted in fatalities, mine closures, lay-offs and abandonment of ore reserves. The estimated cost of these losses to the industry is in excess of $200 million.

Management and funding of the project, over a five-year period, is on a tripartite footing. The Government of Canada, through the Canada Centre for Mineral and Energy Technology (CANMET), provides staff to operate the project. The Government of Ontario, through the Ministry of Northern Development and Mines, and the Ministry of Labour, provides funds for equipment and services. The Ontario Mining Association, through Campbell Red Lake Mines, Ltd., Denison Mines Ltd., Falconbridge Ltd., INCO Ltd., Lac Minerals Ltd., and Rio Algom Ltd., contribute their existing microseismic monitoring systems, assist in the installation and operation of new equipment and provide data on rockbursts at their mines.

The project is overseen by a Management Committee consisting of representatives of the three sponsoring organizations with Mr. C.H. Brehaut, President of the Ontario Mining Association as Chairman. A Technical Committee, with Dr. D.G.F. Hedley of CANMET as Chairman, reviews and approves the research plans.

The rationale and objectives of the rockburst project are first to develop new seismic monitoring systems capable of capturing complete waveforms, then, using improved source location techniques, first motion studies, peak particle velocity, liberated seismic energy and spectral frequency analysis, to investigate the causes and mechanisms of rockbursts. These techniques will then be utilized in conjunction with field trials, in situ measurements and computer models to evaluate methods of alleviating rockbursts.

Research is being carried out at mines in the four mining areas experiencing rockbursts (Red Lake, Elliot Lake, Sudbury and Kirkland Lake). The types of orebodies range from steeply dipping narrow vein deposits at Red Lake and Kirkland Lake, gently dipping reefs at Elliot Lake, to massive sulphide deposits in Sudbury. Mining methods in use include shrinkage, cut-and-fill, room-and-pillar and blasthole. During the past three years about 325 rockbursts have been recorded on the Eastern Canada Seismic Network operated by the Geophysics Division of the Geological Survey of Canada, as listed in Table 1.

Table 1 - Rockbursts in Ontario Mines 1984-1986

Mining District	1984	1985	1986
Red Lake	26	5	10
Elliot Lake	59	88	22
Sudbury	16	31	56
Kirkland Lake	5	3	4
Total	106	127	92

ELLIOT LAKE MINES

The objective of the research at Elliot Lake is to establish whether the hanging wall is caving above the rockburst area at Quirke Mine and to monitor the spread of seismic activity at both Quirke and Denison Mines. Also of interest is the contract research being done by Denison Mines Ltd. on the use of backfill to control violent pillar failure.

Two seismograph stations have been installed on surface and connected to CANMET's Elliot Lake Laboratory. One station has a higher sensitivity than the other to record the smaller seismic events. The larger seismic events are correlated with those recorded by the Eastern Canada Seismic Network and a magnitude is assigned. In 1986, of the 1500 events recorded on the Quirke Mine microseismic system, 33% were also recorded on the local seismograph network and 1.5% on the national network.

Rockbursts started in an old mined-out area of Rio Algom's Quirke Mine in 1982. Since that time they have continued with varying levels of intensity. September 1984 to April 1985 was a very active period with over 140 rockbursts of magnitudes 1.5 to 3.0 being recorded. Prior to the start of this activity the zone of pillar failure extended about 870 m on strike by 300 m on dip. The subsequent pattern of rockburst activity was a progressive spreading outwards, as pillars at the edge of the affected area failed. By the end of 1985, the zone of pillar failure had expanded to 1100 m on strike by 600 m on dip, as shown in Figure 1.

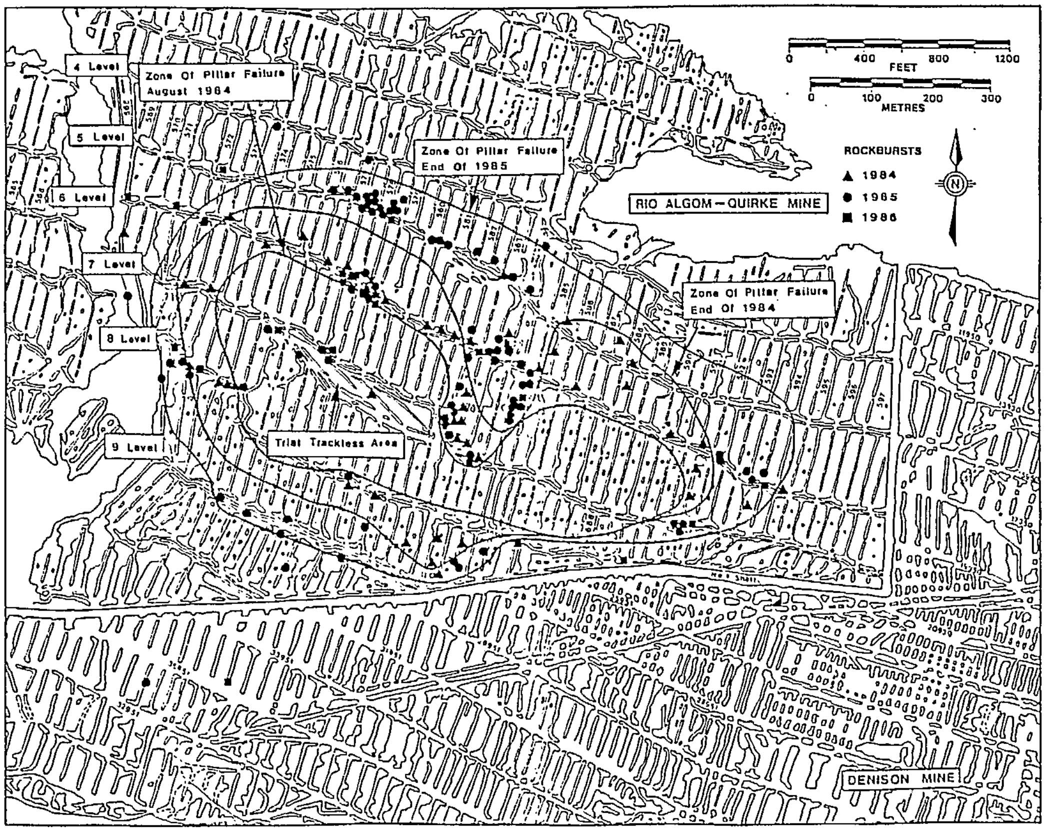

Fig. 1 - Partial plan of Quirke and Denison mines showing locations of rockbursts, and spread of the zone of pillar failure.

During 1985, a change in pattern was observed, with some rockbursts being located in the centre of the failure zone. It was suspected that these events were occurring in the hanging wall. This was reinforced by a sudden increase in the waterflow into the rockburst area and the disappearance of a beaver pond directly above. This established that fracturing has progressed to surface. With this fracturing of the hanging wall, rockburst incidents decreased dramatically.

As part of the Rockburst Project, it was decided to diamond drill from surface to establish whether the hanging wall was also caving. An old surface exploration borehole was utilized, which in retrospect was a mistake. Numerous problems were encountered in this old borehole including spalling, lateral displacement at bedding contacts and major water losses at a number of horizons. Eventually, the borehole was abandoned at a depth of 265 m. The diamond drilling did confirm, however, that the hanging wall was fractured to surface, and that the beds were subsiding with lateral slippage along the bedding contacts.

To improve the source locations and mechanisms of seismic events occurring in the hanging wall a new macroseismic system, developed under contract by Noranda Research Centre, was installed on surface in March 1987. This system employs five triaxial sensors with a fibre optics transmission system. A processing unit determines if a seismic event has occurred and digitizes the waveforms from each channel (i.e., 15) which are then stored in a computer. The data can then be viewed on a monitor and analyzed to determine source location, peak particle velocity, first motion, seismic energy and seismic moment.

Since 1983, backfill has been used at Denison Mine to stabilize pillars directly down-dip of the rockburst area at Quirke Mine. In other areas of

Fig. 2 - Locations of seismic events at Denison Mine during May, 1986.

Denison backfill has been used in pillar recovery operations. The backfill is deslimed mill tailings with cementitious slag added in a ratio of 30:1. Uncemented tailings have also been poured in places.

Preliminary laboratory tests by CANMET had indicated that rock specimens surrounded by backfill failed non-violently. The backfill had no effect on the loading curve or peak strength of the specimens, but after failure the residual strength was significantly increased. Indirect confirmation of this stabilizing effect was obtained at Denison Mine in May 1986. About 60 seismic events, recorded on the seismograph at Elliot Lake, occurred in the 33 and 35 panels next to the boundary pillar with Quirke Mine as shown in Figure 2. All these events were located in pillars where the stopes had not been backfilled, whereas there was no seismic activity in the adjacent backfilled areas.

SUDBURY MINES

The objective of research at Sudbury is to determine the causes and mechanisms of rockbursts using waveform analytical techniques, and to evaluate methods of alleviating and/or limiting their damaging effects.

Two of the three seismograph stations have been installed on the south and west rim of the Sudbury Basin. Dedicated phone lines from these stations are connected to Science North, where the drum recorders are on public display. The waveforms of seismic events are also digitized and stored on a computer at Science North. This is accessed by the Geophysics Division of Energy, Mines and Resources in Ottawa for magnitude evaluation and analysis. The Geological Department of Laurentian University also has access to these data for research purposes.

Rockbursts at Falconbridge's No. 5 Shaft in June 1984 resulted in closure of the mine. Visual evidence indicated a fault-slip mechanism. Microseismic after-shock patterns, in a one minute period following two major rockbursts of magnitude 3.4 M_N and 3.5 M_N were analysed. As shown in Figure 3, all of these microseismic events occurred in the footwall in a quadrant configuration of radius 180 to 200 m, centered on the locations of the major rockbursts. Previously a circular fault model had been used to evaluate the mechanics of fault-slip (i.e., stress drop, average slippage and radius). Re-evaluating using a quadrant model gave much closer agreement with the radius of damage and the amount of slippage.

Falconbridge Ltd. has also undertaken a research project to re-evaluate these fault-slip rockbursts at No. 5 Shaft. A detailed geological examination is being done on the affected levels to detect any movement along faults or prominent joint sets as well as documenting any damage. On the 3850 level movement has been found on a number of structures. The track in the sill drift is noticeably kinked where a prominent fault passes through. It is suspected that this movement took place after the mine closed down.

A new macroseismic system for Falconbridge's Strathcona Mine has been designed and ordered. The system consists of five strong-motion accelerometers from Teledyne-Geotech. which will be installed underground and on surface. Analog signals from the sensors will be transmitted over cables to a processing unit being built by Instantel Inc. The processing unit will be responsible for event recognition and analog to digital conversion. Data

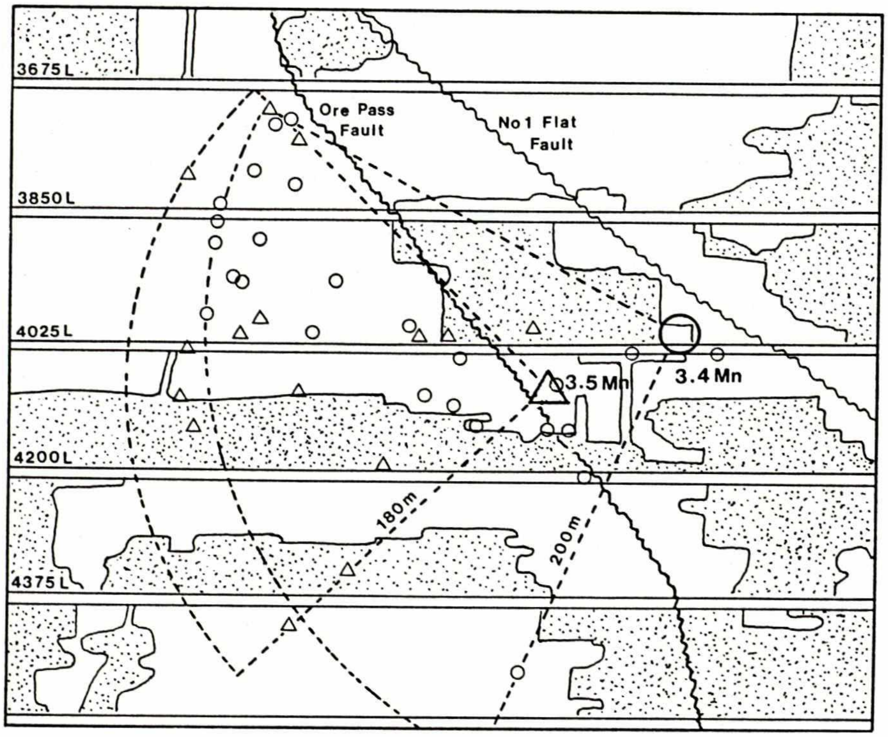

Fig. 3 - Longitudinal section of the Falconbridge Mine showing the locations of the aftershocks, following two major rockbursts.

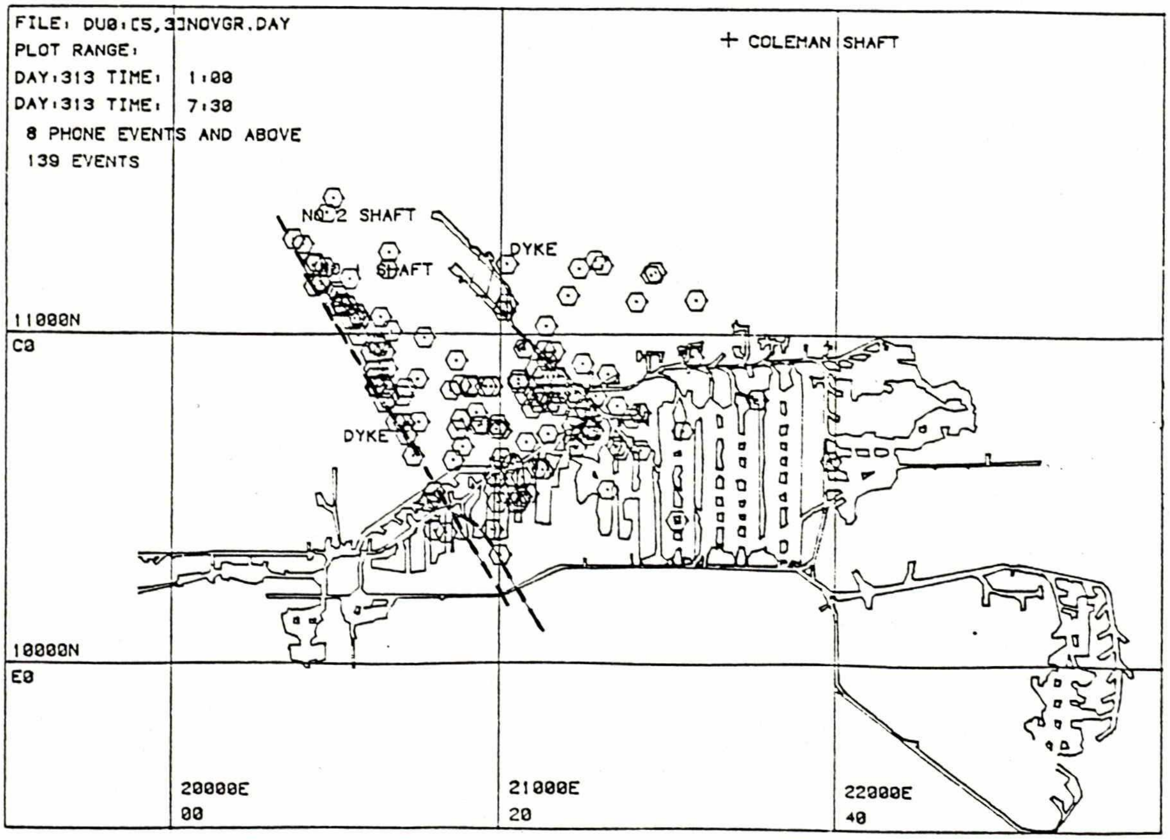

Fig. 4 - Plan of the 2350 level at the Strathcona Mine showing the locations of microseismic events following a production blast.

will be stored on an IBM-AT microcomputer at the mine site. These data can then be transferred using asynchronous modems to the computers at the Elliot Lake Laboratory where the waveform analysis will be performed.

Falconbridge's Strathcona Mine has experienced significant rockburst activity in the past two years. The mine's microseismic system indicated that seismic activity was concentrated along a dyke and associated structures in the west end of the mine as illustrated in Figure 4. Blasting in the adjacent stopes would initiate a series of microseismic events along the dyke and off-set features indicating a fault-slippage mechanism.

Also at Strathcona Mine, a lacing support trial was undertaken. Lacing is a support technique developed in South African gold mines for rockburst-prone openings. It consists of mild steel eyebolts, chain link screen and flexible steel cable threaded through the eyebolts in a diamond pattern. It is designed to yield when subjected to impact loading. At the Strathcona Mine the footwall development drift and accesses to the overcut and undercut of a blasthole stope were laced. Subsequently, a rockburst of magnitude 3.0 M_N occurred in the area. This blast severely damaged the conventionally supported overcut (grouted rebar and wire mesh) which was about 25 m away. The nearest lacing was about 40 m from the burst. This area suffered no damage, although some bagging of the screen and loading of the flexible cables was observed.

INCO's Creighton Mine has a history of rockbursts dating back to the mid-1930's. During 1986, twelve rockbursts at the mine were recorded on the Eastern Canada Seismic Network. The mine's microseismic system located most of these events in the crown pillars of mechanized cut-and-fill stopes between the 5400 and 6800 levels. In a major departure from previous mining practice a destress slot is being mined in the centre of the crown pillar of the 6800 level stopes. The seismic activity associated with this destress slot is being closely monitored to evaluate zones of fracture around the slot. The fibre optics shaft cable, to transmit the microseismic signals to surface, has been installed.

During 1986, INCO Ltd. also installed two additional Electrolab micro-seismic systems at Garson and Copper Cliff North mines. At Garson Mine seismic activity appears to be associated with dykes and auxiliary shear structures in the footwall. This is similar to the seismic activity in the adjacent Falconbridge Mine. Copper Cliff North Mine has experienced rockbursts in 1986, especially after large pillar blasts. Seismic activity is significant (up to 2000 events in a weekend) after these blasts and is fairly widespread.

RED LAKE MINES

The objective of the research at Red Lake is to develop techniques that allow safe and efficient recovery of crown pillars in narrow, steeply dipping orebodies using cut-and-fill methods with cemented tailings.

The Campbell Mine at Balmertown has had a history of rockbursts since the early 1960's. These usually occurred during recovery of the crown pillars of shrinkage or cut-and-fill stopes. There are a number of separate orebodies at the mine with various orientations. To date, bursting has been mainly confined to the narrow F, F-2 and A ore zones which are en-echelon, striking

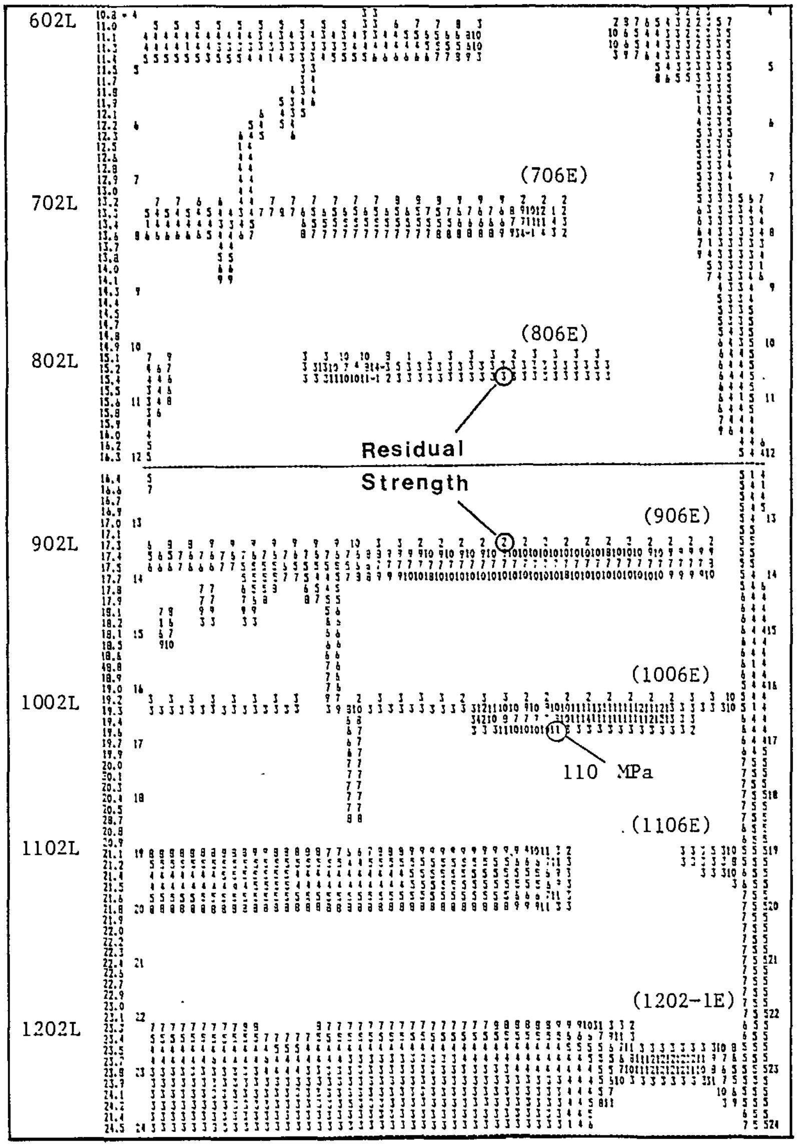

Fig. 5 - Longitudinal section of the 'A' ore zone at the Campbell Mine. The estimated stress levels from an NFOLD model.

north-west to south-east. In recent times the most significant rockburst sequence occurred in the F zone, where shrinkage techniques were used. Over a two day period 22 rockbursts, up to a magnitude of 3.3 M_N, occurred in the crown pillars between the 7th and 13th levels completely closing off these levels. No mining has taken place in this orebody since that time.

To determine the stress regime around the multiple ore zones, CANMET in conjunction with Campbell Mine, undertook a program of field stress measurements. Sites were chosen at various depths and next to different ore zones. In general, the measurements indicated that the principal stress direction is sub-horizontal in a north-east to south-west direction, which is almost perpendicular to the main ore zones. However, there are local variations around specific orebodies. Stress measurements in boxhole pillars of shrinkage stopes indicated that some of these had yielded, especially those near the centre of a mining zone.

CANMET has run an NFOLD computer model on the A ore zone and sub-parallel A-1 zone. The model also incorporates part of the adjacent Dickenson Mine. An example printout of the pillar stresses is shown in Figure 5. NFOLD models simulate the post-failure characteristics of the rock, thereby allowing stress to be transferred and failure to progress until equilibrium is achieved. The results indicated a similar pillar failure pattern to that observed underground in the upper levels mined by shrinkage methods. Also, this part of the orebody was in a state of unstable equilibrium, in that only minor increases in stress could initiate additional pillar failures. The model has now been calibrated to reasonably represent conditions underground and can now be used to evaluate alternative mining sequences for the remaining ore in the 'A' zone.

Since 1982, four destress blasts have been done in crown and boxhole pillars at the Campbell Mine. The Company has documented the reasons for destressing, the design of the blast, the instrumentation used to show its effectiveness and post-blast observations and microseismic activity. A paper on these destress blasts was presented at the CIM Underground Operators Conference, in Elliot Lake, in February, 1987.

KIRKLAND LAKE MINES

The objective of the research at Kirkland Lake is to develop techniques that allow safe and efficient recovery of crown pillars in narrow, steeply dipping orebodies using cut-and-fill methods with waste rock backfill. As such, it complements the research at the Red Lake mines with the backfill material being different and the mine workings being at a much greater depth (down to 2200 m).

Mines at Kirkland Lake have had a history of rockbursts since the early 1930's. Much of the original rockburst research was carried out at the Lake Shore Mine in the 1940's. The largest rockburst (of estimated magnitude 5.0) recorded in Canada occurred in the Wright-Hargreaves Mine in 1964, which closed the mine. Lac Minerals' Macassa Mine is now the only remaining mine in production. Isolated rockbursts have occurred at this mine, usually when the crown pillars of cut-and-fill stopes reach a critical size.

CANMET, in conjunction with Lac Minerals Ltd., monitored a destress blast of a crown pillar below the 5725 level at Macassa Mine on 28 June, 1986. Prior to the blast three rockbursts occurred in this pillar: two in the raises at each end of the pillar, and one in the stope back. The blast was designed with 14 holes in the orebody spaced at about 3 m intervals. The first and last holes could not be loaded properly because of squeezing ground.

A temporary microseismic monitoring system with 12 geophones was installed around the area and 8 of the channels were also connected to a Gould waveform recorder. Convergence stations were installed in the last cut in the stope and the overlying drift. Diamond drilling was done in the crown pillar to establish fractured zones around the edges.

Considerable microseismic activity followed the destress blast being mainly clustered around the crown pillar and the adjacent stopes as shown in Figure 6. However, some parts of the pillar were free of seismic activity, especially next to the first borehole which was not fully loaded. Significant convergence (about 25 mm) also occurred in the stope except next to the first

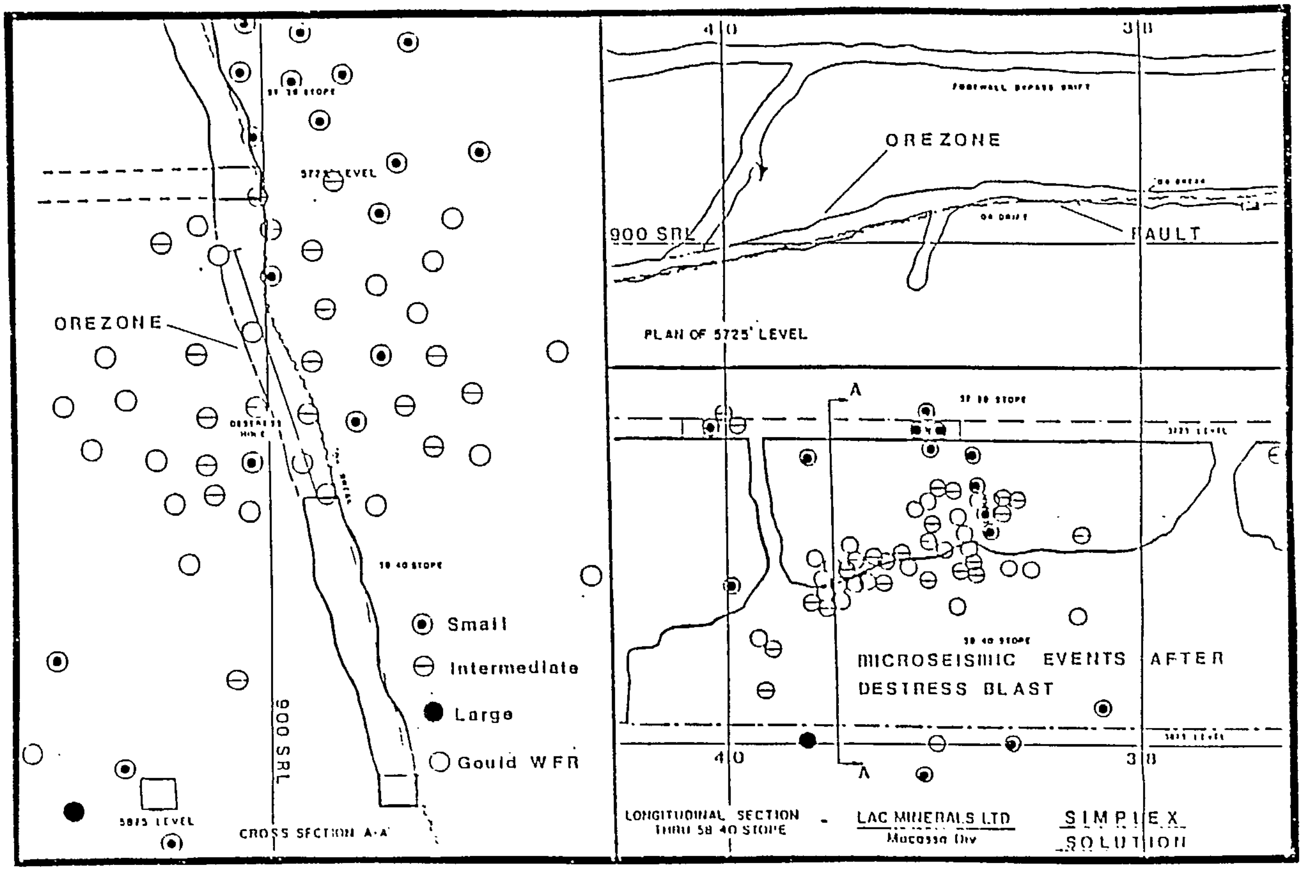

Fig. 6 - Seismic activity following a pillar destress blast at the Macassa Mine.

borehole (6 mm).

The first production blast in the pillar took place about one month after the destress blast. Microseismic activity also occurred after this blast but was more widespread with no clustering around the crown pillar. The second production blast was near the first borehole which had not been fully loaded in destressing. A small rockburst followed this second blast causing some damage to the timber stulls and rockbolts in the stope. The convergence in this area also increased by about 33 mm. It was concluded that the lack of initial convergence and microseismic ativity was indicative of only partial destressing of the pillar.

An NFOLD computer model was also run to simulate the destress blast. By assigning various elastic and post-failure properties to different sections of the orebody a reasonable fit was obtained with observed areas of failure underground. To obtain a reasonable fit to the convergence in the stope the modulus in post-failure had to be reduced by about 67%. This model can now be used to evaluate any additional destress blasts planned for the area.

Lac Minerals, in conjunction with Golder Associates, investigated the seismic activity associated with sinking a new rectangular shaft down to a depth of 2200 m. A paper describing the rock reinforcement and destressing techniques, as well as the cause and mechanism of the bursts is to be presented at the CIM Annual Meeting, in Toronto, in May, 1987.

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