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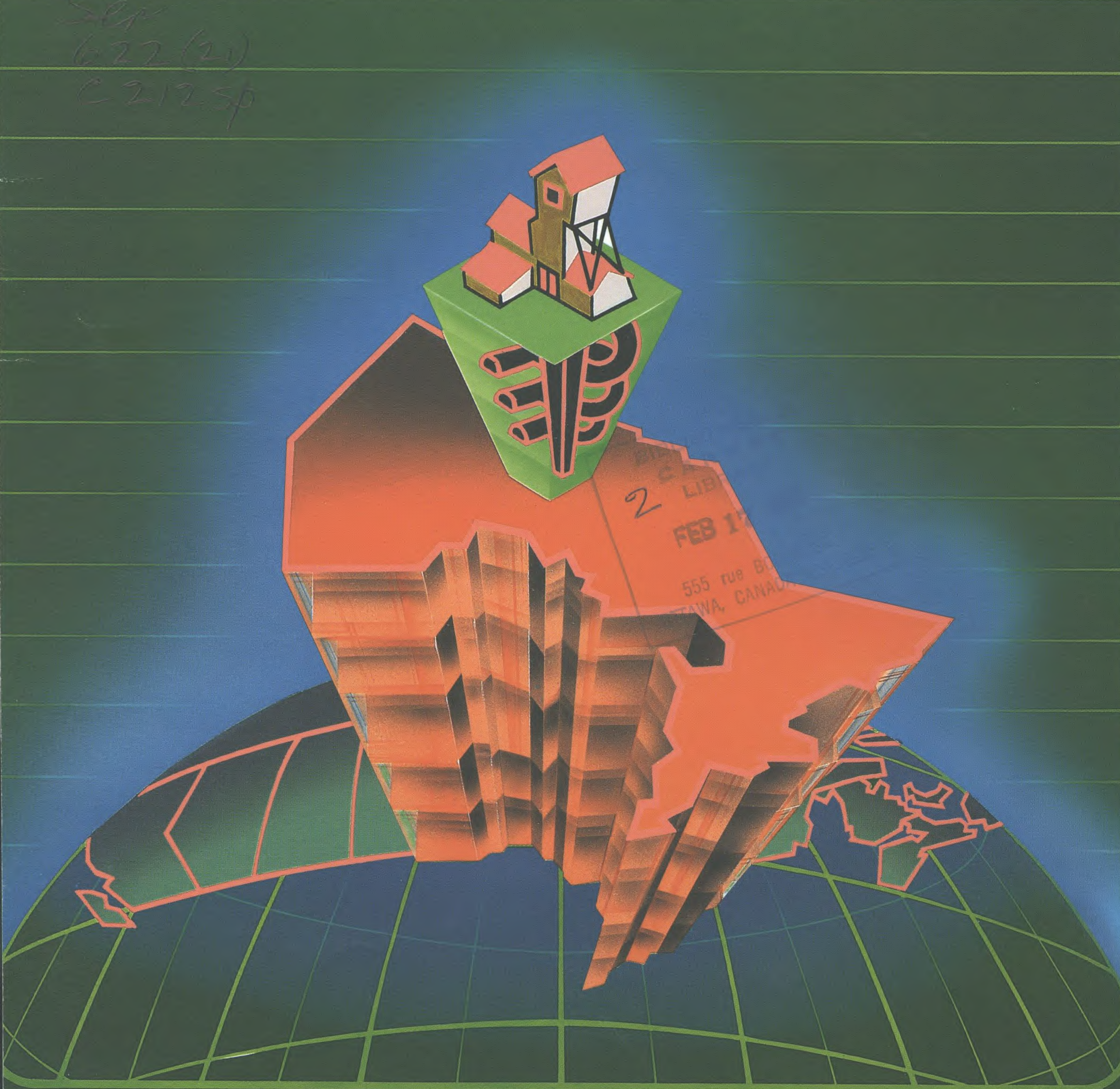
1986 - 1987 ANNUAL REPORT OF THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

SP87-7E



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C.H. Brehaut
Chairman
Management Committee

D.G.F. Hedley
Chairman
Technical Committee

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1986-1987 ANNUAL REPORT OF THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

Foreword

The second annual report of the Canada-Ontario-Industry Rockburst Project documents the excellent progress which has been made to date towards the development of systems and techniques which would be utilized in conjunction with in situ measurements and computer models to evaluate both strategic and tactical methods of alleviating rockbursts. The individual research programs have been well conceived and implemented under the direction of D.G.F. Hedley of CANMET and his Rockburst Project Technical Committee. The results to date and future plans as described in this report illustrate the effectiveness of cooperative action which is a credit to all participants.

C.H. Brehaut
Chairperson
Management Committee

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INTRODUCTION

The Canada-Ontario-Industry rockburst project was initiated in September 1985 after increased rockburst activity in Northern Ontario hard rock mines. 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, 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, in order to improve safety and the economics of underground hard rock mining.

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 industry, 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 Campbell Red Lake Mines Ltd. as Chairman. A Technical Committee, with Dr. D.G.F. Hedley of CANMET as Chairman, reviews and approves the research plans. During 1986/1987 quarterly meetings of the Technical Committee were held at Red Lake, Kirkland Lake, Elliot Lake and Falconbridge. Present membership on both committees is listed in the Appendix.

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. These are listed below, by mining district.

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
Totals	106	127	92

RESEARCH ACTIVITIES

The research being done by CANMET and the mining companies is reviewed in the following sections as well as in the research plans for 1987/88.

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 the 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 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.

Rio Algom Mines

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 and 300 m on dip. The subsequent pattern of rockburst activity spread progressive 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 and 600 m on dip.

During 1985, a change in pattern was observed, with some rockbursts again 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 had progressed to surface. With this fracturing of the hanging wall, rockburst incidents decreased dramatically.

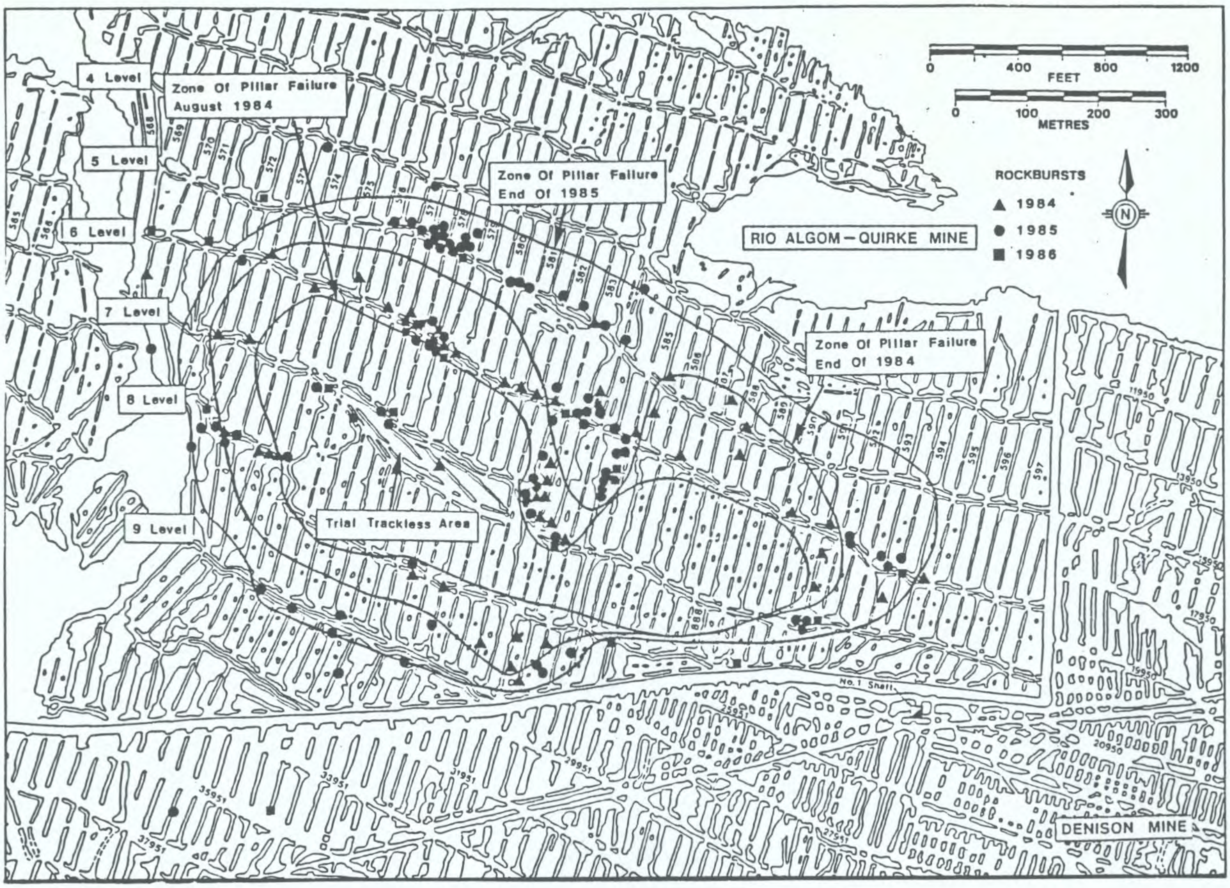
As part of the Rockburst Project, it was decided to diamond drill from surface to establish whether the hanging wall was also caving. An old surface exploration borehole was utilized, which, in retrospect, was a mistake. Numerous problems were encountered with this old borehole including spalling, lateral 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 of the 15 channels 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.

Denison Mines

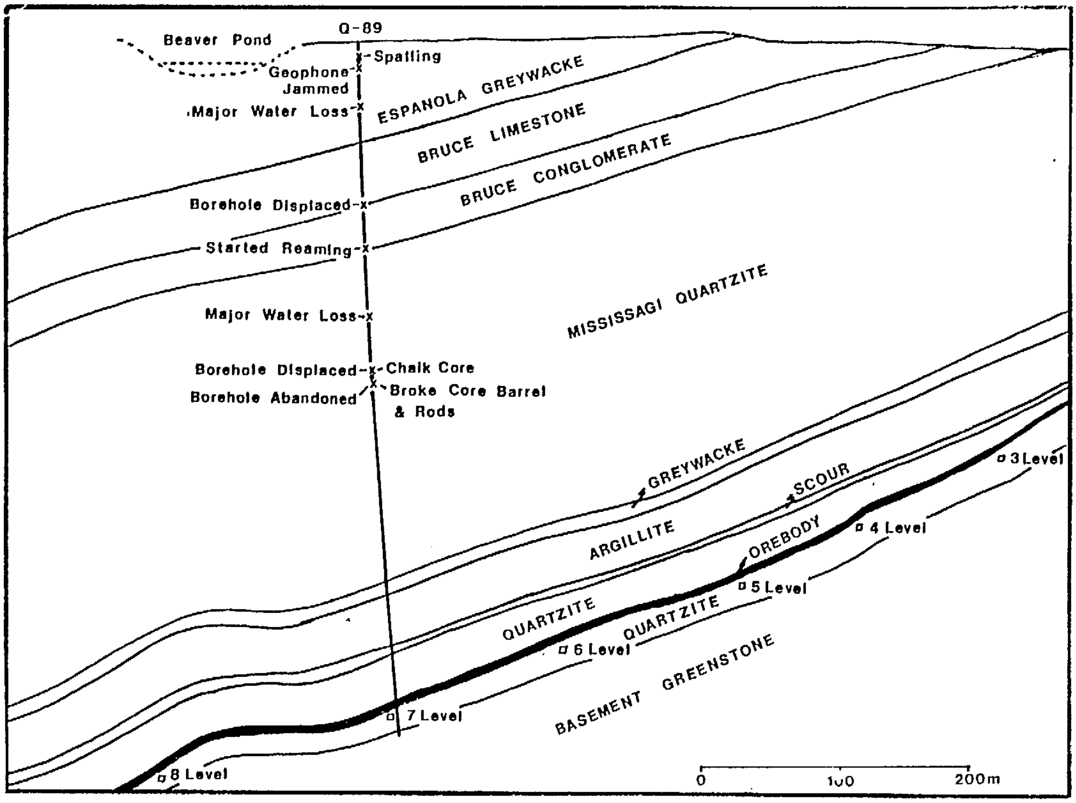
Since 1983, backfill has been used at Denison Mine to stabilize pillars directly down-dip from the rockburst area at Quirke Mine. In other areas of Denison backfill has been used in pillar recovery operations. The backfill is deslimed mill tailings with cementitious slag added in a ratio of 30:1. Uncemented classified 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 curves or peak strengths of the specimens, but, after failure, the residual strengths were 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 the Quirke Mine. All of these events were located in pillars where the stopes had not been backfilled, whereas there was no seismic activity in the adjacent backfilled areas.



Partial plan of Quirke and Denison mines showing locations of rockbursts and spread of the zone of pillar failure. Most of the rockbursts were located in the sill pillars rather than in the rib pillars in the stope.

Beaver pond above the south-west part of the rockburst area at Quirke Mine which disappeared in mid-1985.



Cross-section through the rockburst area at Quirke Mine showing depths at which problems were encountered during drilling in an old exploration borehole.

Location of seismic events during May 1986 at Denison Mine. It is of interest, that no seismic activity was recorded in the surrounding backfilled area.

Research Plans 1987/88

a) To drill a new diamond drill hole, next to the old exploration borehole at Quirke Mine. Again, the objective is to establish if the hanging wall is caving and at what depth above the rockburst area. It is anticipated that significant grouting will be required to ensure water circulation. Also, if feasible, a seismic reflection survey will be done over the rockburst area.

b) To continue to monitor seismic activity using the surface macroseismic system at Quirke Mine. Using waveform analytical techniques, to evaluate source location, mechanism and attenuation characteristics of these events.

c) Under the Canada/Ontario Mineral Development Agreement, Denison Mine is backfilling an area where pillar failure has occurred. A microseismic network has been installed around this area as well as convergence and stress measuring equipment. Under a sub-contract the Mining Department of Queen's University is investigating ultrasonic emissions as a method of determining stress levels in pillars and their rockburst potential.

SUDBURY MINES

The objective of research at Sudbury is to determine the causes and mechanisms of rockbursts using waveform analysis 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 this data for research purposes. Ports are also available for CANMET, INCO Ltd. and Falconbridge Ltd. to have access to this data.

Falconbridge Mines

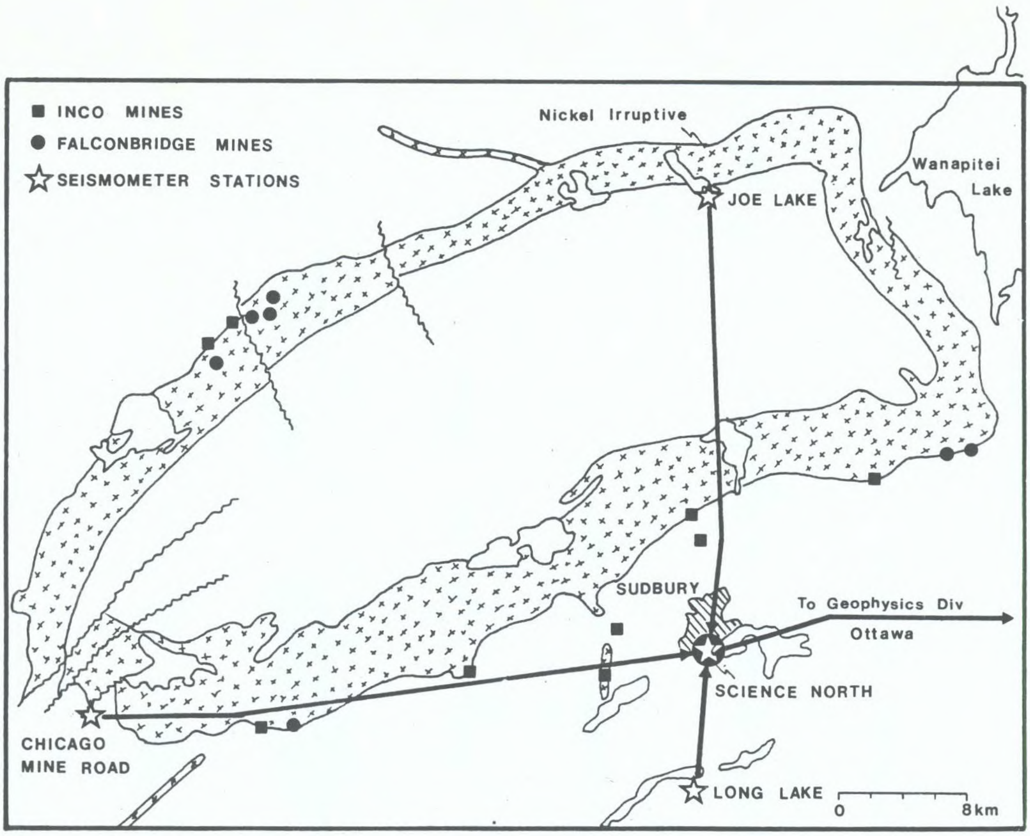
Rockbursts at Falconbridge's No. 5 Shaft in June 1984 resulted in closure of the mine. Visual evidence indicated a fault-slip mechanism. Microseismic aftershock patterns in a one minute period following two major rockbursts, of magnitudes 3.4 M_N and 3.5 M_N, were analyzed. All of these microseismic 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.

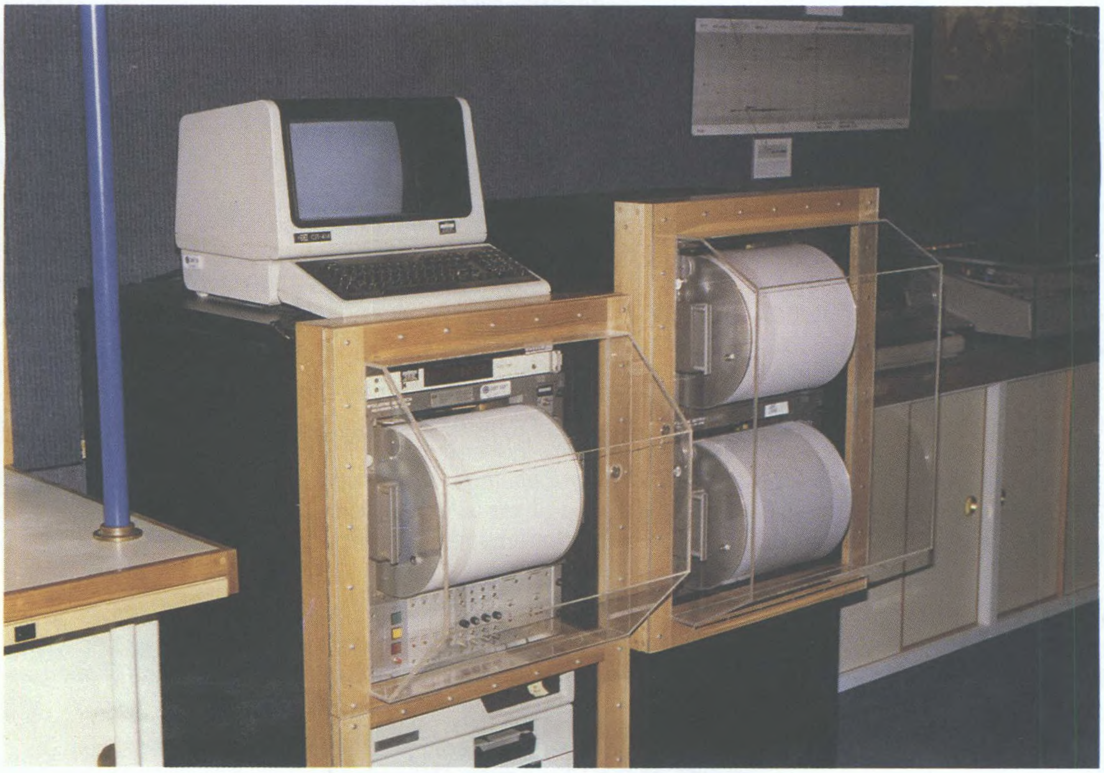
A new macroseismic system for Falconbridge's Strathcona Mine has been designed and ordered. The system consists of five strong-motion accelerometers from Teledyne-Geotech, which will be installed underground and on surface. Analog signals from the sensors will be transmitted over cables to a processing unit being built by Instantel Inc. The processing unit will be responsible for event recognition and analog to digital conversion. Data 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. Blasting in the adjacent stopes would initiate a series of microseismic events along the dyke and off-set features indicating a fault-slipping mechanism.

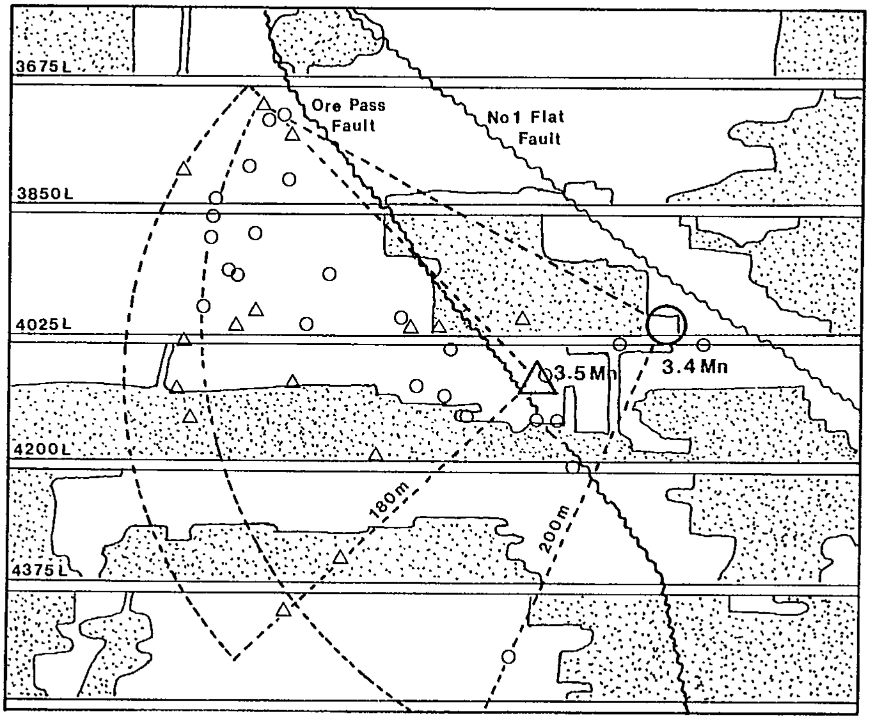
Falconbridge Ltd., in conjunction with the Department of Geological Sciences at Queen's University, are conducting trials of tomographic imaging at the Strathcona Mine. A pilot tomographic survey has been done on a mine pillar. This demonstrated that areas of the pillar with anomalous seismic velocities can be readily identified.



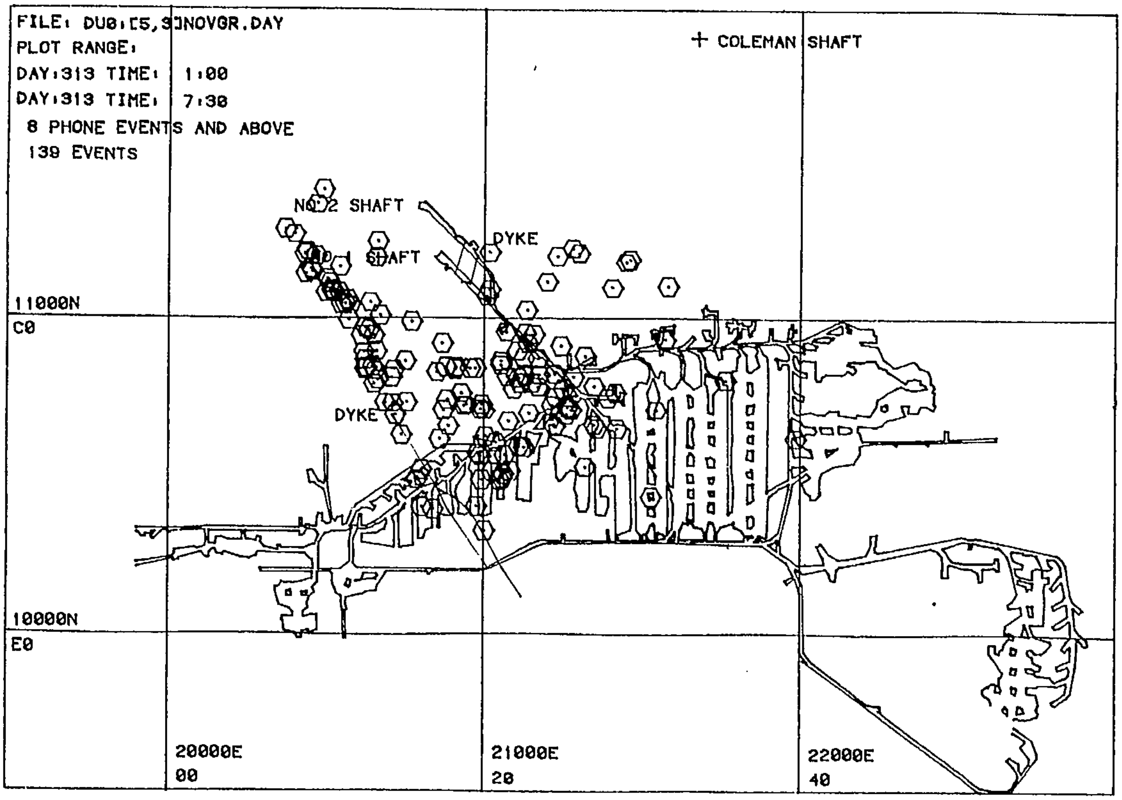
Map of the Sudbury Basin showing the locations of the three seismograph stations. Seismic data is continuously transmitted through Science North to the Geophysics Division of Energy, Mines and Resources Canada in Ottawa.



Drum recorders and computer set-up at Science North, which is on public display.



Longitudinal section of Falconbridge Mine showing the location of aftershocks following two major rockbursts. All of these microseismic events occurred in the footwall in a well defined quadrant distribution.



Plan of 2350 level at Strathcona Mine showing the location of microseismic events following a production blast. There is a tight cluster of events along a dyke.

Also at the 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 Mines

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. A fibre optics shaft cable, to transmit the microseismic signals to surface, has been installed.

During 1986 INCO Ltd. also installed two additional Electrolab microseismic systems at the 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.

Research Plans 1987/88

a) Connection of the third seismograph station, in the Sudbury Basin at Joe Lake to Science North and the dataline to the Geophysics Division of Energy, Mines and Resources in Ottawa. CANMET intends to hire a person to look after the Sudbury seismograph network, as well as the rockburst records in the other mining camps in Ontario. This person will be located at the Geophysics Division in Ottawa.

b) Installation of the macroseismic system around the Strathcona Mine and a telephone connection to Elliot Lake. Being a new system it will require de-bugging and calibration.

c) Rehabilitation of the microseismic system at the Falconbridge No. 5 Shaft, by expanding the system to 16 geophones and replacing defective wiring. Once this is done the Gould unit can be connected to record waveforms of the seismic events.

d) Design, ordering and installation of a macroseismic system at the Creighton Mine.

e) Installation of a microseismic system around the destress slots in the crown pillars of the 6800 and 7000 level stopes at the Creighton Mine. The geophone array will be in a tight cluster to accurately locate the microseismic activity to determine if there is any pattern recognition prior to major seismic events. This research will be carried out by INCO Ltd.

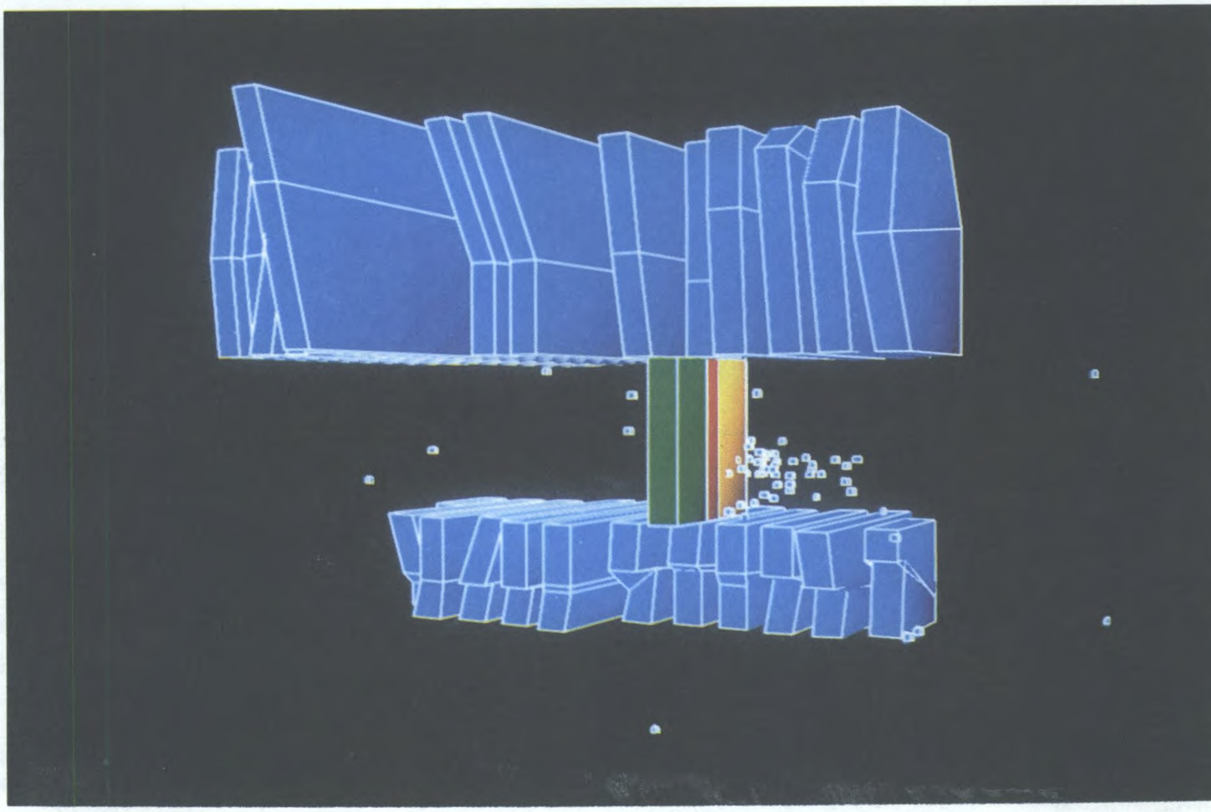
RED LAKE MINES

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 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 in 1983, 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.

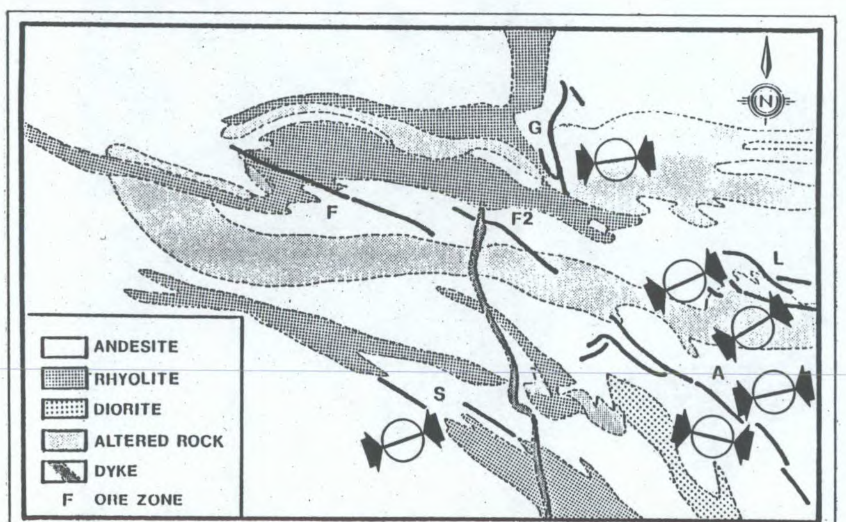
To determine the stress regime around the multiple ore zones, CANMET in conjunction with the Campbell Mine, undertook a program of field stress measurements. Sites were chosen at various depths and next to different ore zones. In general, the measurements indicated that the principal stress direction is sub-

Lacing installation at Strathcona Mine. Subsequently, a rockburst of 3.0 M_N occurred 40 m away without damaging the laced section, although an adjacent conventionally supported area collapsed.

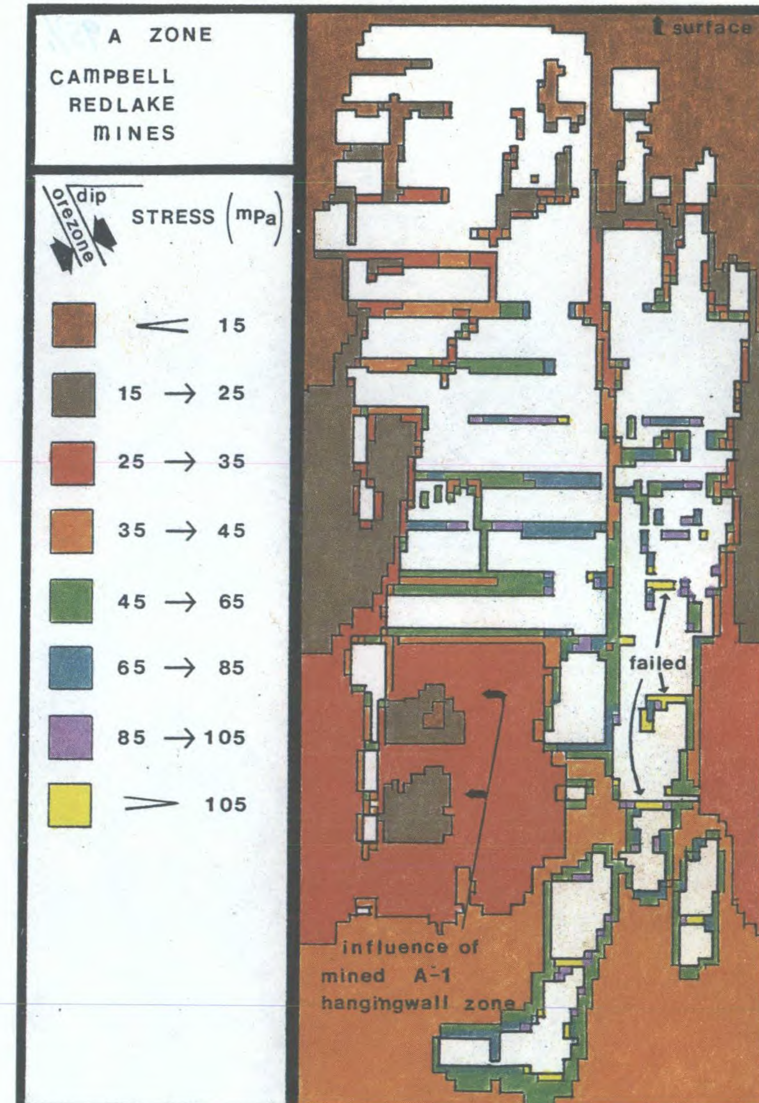


Three-dimensional display of the 6600 and 6800 stopes at Creighton Mine showing the microseismic activity associated with mining of a destress slot in the sill pillar.

Rockbursts in crown pillar in F ore zone, Campbell Mine. Track has heaved at least 1 m.



Principal stress directions in relation to ore zones at Campbell Mine.



NFOLD computer model of the A ore zone at Campbell and the adjacent Dickenson mines showing perpendicular stress distribution and areas where failure is expected.

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. 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.

Research Plans 1987/88

a) To evaluate a number of surface sites near Balmertown for a suitable location of a permanent seismograph station. Installation of the seismometer with a dedicated phone line to the recording unit at the Campbell Mine.

b) Installation of five triaxial geophones at the Campbell Mine connected to a Gould waveform recorder and computer. This system is designed to record complete waveforms of the larger seismic events. It will also be part of the mine's microseismic system.

c) To continue installing fill pressure cells and convergence meters to measure the in situ properties and performance of cemented backfills.

d) If scheduled, monitor destress blasts in crown pillars and with computer modelling evaluate the effectiveness of these blasts.

KIRKLAND LAKE MINES

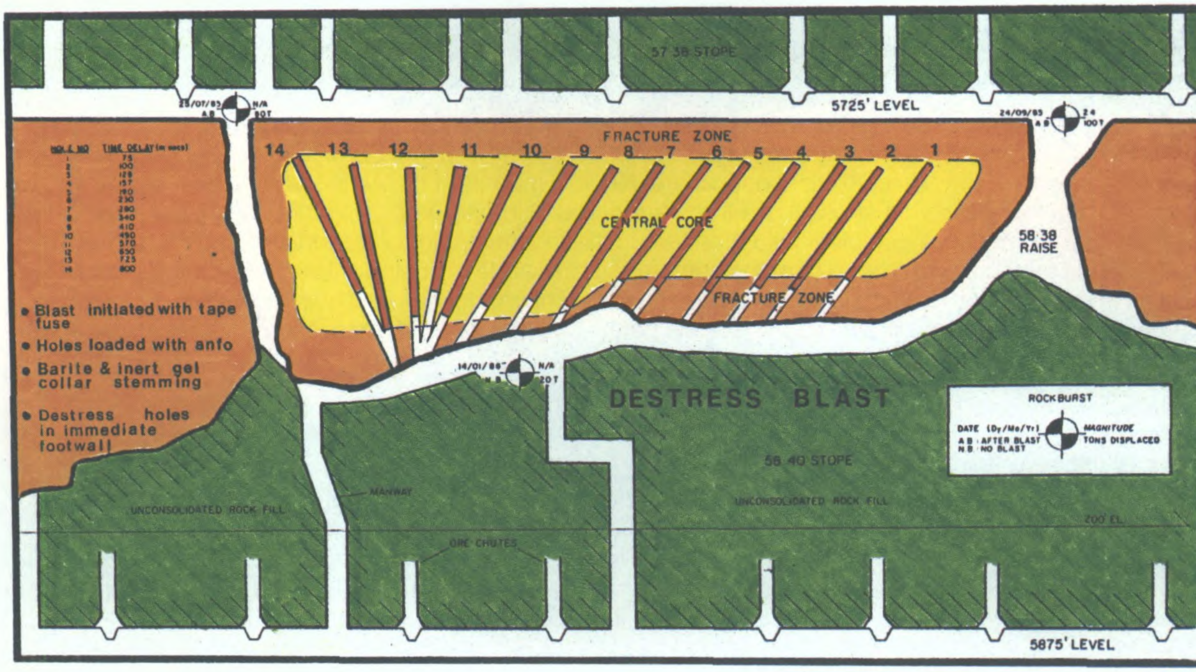
The objective of the research at Kirkland Lake is to develop techniques that allow safe and efficient recovery of crown pillars in narrow, steeply-dipping orebodies using cut-and-fill methods with waste rock backfill and cemented rockfill. As such, it complements the research at the Red Lake mines with the backfill material being different and the mine workings being at a much greater depths (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. This was responsible for the closure of the mine. Lac Minerals' Macassa Mine is now the only remaining mine in production in the area. Isolated rockbursts have occurred at this mine, usually when the crown pillars of cut-and-fill stopes reach a critical size.

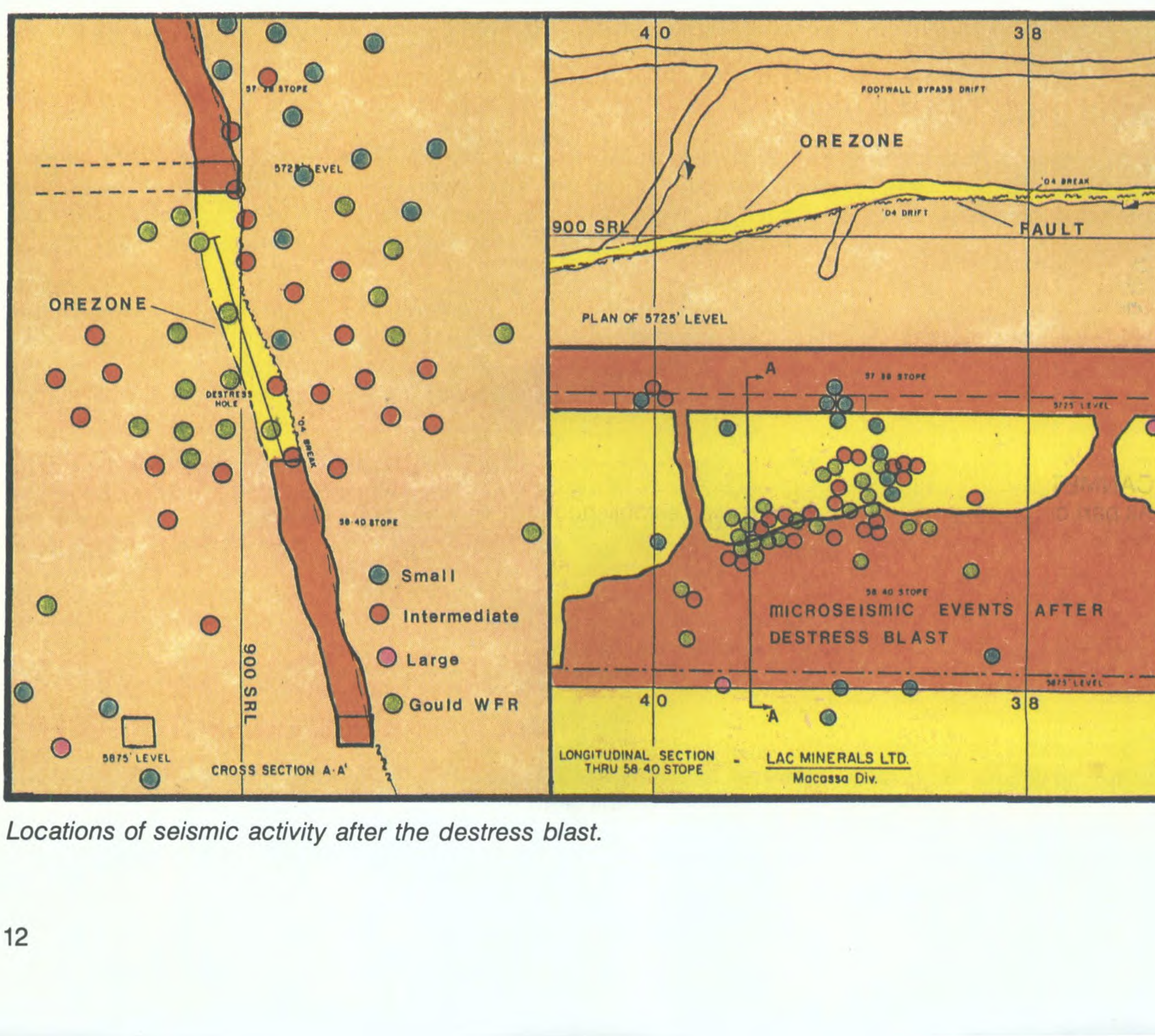
CANMET, in conjunction with Lac Minerals Ltd., monitored a destress blast of a crown pillar below the 5725 level at Macassa Mine on June 28, 1986. Prior to the blast three rockbursts occurred in this pillar, two in the raises at each end of the pillar, and one in the stope back. The blast was designed 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. 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 borehole (6 mm).



Layout of destress blast in 58-40 crown pillar at Macassa Mine. Locations of rockbursts prior to destressing are also shown.



Locations of seismic activity after the destress blast.

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 blasts 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 rock bolts 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 activity 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.

Research Plans 1987/88

a) Installation of a seismograph station at Kirkland Lake, with a dedicated phone line to the recording unit at Macassa Mine.

b) Installation of five triaxial geophones at Macassa Mine connected to a Gould waveform recorder and computer. This system is designed to record complete waveforms of the larger seismic events. It will also be part of the mine's microseismic unit.

c) To install fill pressure cells and convergence meters to measure the in situ properties and performance of the waste rock backfill.

d) If scheduled, to monitor destress blasts in crown pillars and with computer modelling evaluate the effectiveness of these blasts.

BASIC STUDIES

The purpose of these studies is to provide an overview of rockburst activity in Ontario mines, to be aware of rockburst research in other organization and other countries, and to conduct fundamental research on methods of source location, measurement of seismic energy, and mechanisms of rockbursts.

The review of rockburst activity in Ontario mines during 1985 was completed. In all, 127 rockbursts were recorded, ranging up to 3.1 M_N in magnitude. Pillar bursting in thin tabular orebodies (i.e., at Quirke, Denison, Campbell, Dickenson and Macassa mines) is still the most common rockburst mechanism, representing 70% of the events. Fault-slip rockbursts are thought to have occurred at Strathcona Mine and in the hanging wall above Quirke Mine, and represent about 15% of the total. Preliminary data has been obtained on the 1986 rockbursts. The number of rockbursts had declined to 92 and the Sudbury mines have overtaken the Elliot Lake mines in number of occurrences.

In 1986, a "Memorandum of Understanding" was signed between the United States Bureau of Mines, CANMET and the Ontario Ministry of Labour covering cooperation in rock mechanics and ground control. As part of this Agreement a committee was established on rockbursts and outbursts. This committee held its first meeting in conjunction with the quarterly meeting of the Technical Committee for the Rockburst Project at Falconbridge in March 1987. The research activities of all participating organizations were reviewed and it was agreed to exchange information and relevant technical reports on rockbursts and outbursts.

A study has been completed on the accuracy of source location techniques which utilize P-wave arrival times. Four methods were evaluated; least squares, USBM-Mt. Isa, block, and simplex. The first two methods use linear equations and employ direct solutions, whereas the latter two methods use non-linear equations and involve iterative solutions. All methods give reasonable accuracy for events which occur within a geophone array. For events outside the array the block and simplex methods provide a more accurate solution.

Reviews have been written on rockburst mechanics and a catalogue of rockburst literature. The former evaluates the causes and mechanisms of rockbursts using an energy balance approach. The source of the liberated seismic energy is identified for strain, pillar and fault-slip types of bursts. The concept of loading and pillar or fault stiffness is used to define violent or non-violent failure. In the latter chapter over 200 papers on rockbursts in the English language press are listed and categorized.

A preliminary evaluation has been done relating peak particle velocity to rockburst magnitude and distance from source. Data from Quirke and Creighton mines indicate a relationship between peak particle velocity and a scaled distance/magnitude factor. These results, however, are not consistent with those obtained in a South African gold mine.

Research Plans 1987/88

a) A review of rockburst activity in Ontario mines during 1986, and collect data for 1987.

b) Evaluating source location techniques using P and S wave arrival times.

c) A review of destress blasting practices used in Ontario mines.

d) To produce a draft chapter on a Historical Review of Rockbursts in Canadian mines.

SUMMARY OF ACHIEVEMENTS

Since the project started in 1985, a number of advances have been made in our knowledge and understanding of rockbursts and methods of alleviation. Highlights of these achievements are summarized below.

Rockburst Magnitudes

Since 1984 rockbursts in Ontario mines have been classified by their magnitude. This has assisted in defining the extent of the problem, stability can be assessed over given time periods, and a comparison can be made between mines not only in Ontario but throughout the world. These magnitude values are obtained from the Eastern Canada Seismic Network, operated by Energy, Mines and Resources. At present, any rockburst of magnitude greater than 2.0 in Ontario mines is usually detected by this network. Installation of additional seismograph stations at Sudbury, Elliot Lake, Red Lake and Kirkland Lake will lower the threshold limit of the recorded rockbursts.

Microseismic Systems

After several years experience with microseismic monitoring systems, the Ontario mines have realized numerous benefits. Problem areas of a mine can be identified immediately from surface, and during an emergency the systems are invaluable. The pattern of microseismic activity frequently indicates the mechanisms of a rockburst. For instance, the fault-slip seismicity at Falconbridge, Strathcona and Garson mines was only realized after the microseismic systems indicated a concentration of microseismic events along geological structural planes.

The mining companies have made enormous progress in the graphical output from their microseismic systems. At many Ontario mines, company officials now have immediate access to plans and sections showing recent seismic activity in the areas they supervise.

Rockburst Causes and Mechanisms

Before developing methods to alleviate rockbursts, it is necessary to establish their causes and mechanisms. Three types have been identified: strain, pillar and fault-slip. All of these types have been observed in Ontario mines. The explosive energy liberated during a rockburst comes from the surrounding rock mass, rather than the structure that fails (e.g., a pillar). The violence of the failure is controlled by the stiffness of the loading system (i.e., wall rocks). During rock failure the proportion of the released energy which is liberated seismically (i.e., seismic efficiency) varies with the different types of rockbursts. It is very low for fault-slip rockbursts and very high for pillar bursts.

Destress Blasting

Destress blasting is successfully used in Ontario mines to alleviate the rockburst problem or to control the time of its occurrence. In crown/sill pillars, in steeply-dipping orebodies, the purpose of the destress blast is to reduce the potential energy of the surrounding rock mass. This is achieved by fracturing the pillar and allowing the hanging wall and footwall to converge. One of the main criteria for a successful destress blast is that significant convergence occurs.

The use of microseismic systems to monitor seismic activity following a destress blast (or major production blast) has proved to be a very useful tool to determine the immediate stability of the area. It is possible to listen to seismic activity on surface prior to the labour force going underground.

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APPENDICES

APPENDIX A

Rockburst Project Management Committee

C.H. Brehaut — Campbell Red Lake Mines Ltd., Chairperson
C. Barsotti — INCO Ltd.
M. Musson — Falconbridge Ltd.
V. Pakalnis — Ontario Ministry of Labour
G. Weatherson — Ontario Ministry of Northern Development and Mines
K. Whitham — Energy, Mines and Resources Canada
J.E. Udd — Energy, Mines and Resources Canada.

APPENDIX B

Rockburst Project Technical Committee

D.G.F. Hedley — Energy, Mines and Resources Canada, Chairperson
C.G. Graham — Ontario Mining Association Secretary
D. Ames — Ontario Ministry of Labour
W.J. Logan — Ontario Ministry of Northern Development and Mines
P. MacDonald — INCO Ltd.
A. Makuch — Campbell Red Lake Mines Ltd.
D.M. Morrison — Falconbridge Ltd.
S.N. Muppalaneni — Rio Algom Ltd.
W.J.K. Quesnel — Lac Minerals Ltd.
A. Sheikh — Denison Mines Ltd.

APPENDIX C

Energy, Mines and Resources Personnel Involved in Project

*__Dr. J.E. Udd__, Director, Mining Research Laboratories, CANMET
Dr. D.G.F. Hedley, Research Scientist, MRL, CANMET
*__Dr. B. Arjang__, Research Scientist, MRL, CANMET
Dr. J. Niewiadomski, Post-doctorate Fellow, MRL, CANMET
Mr. P. Rochon, Ground Control Engineer, MRL, CANMET
Mr. D.S.G. Hanson, Ground Control Engineer, MRL, CANMET
Mr. A. Makuch+, Ground Control Engineer, MRL, CANMET
Mr. T. Semadeni, Ground Control Engineer, MRL, CANMET
Mr. W. Ropchan, Electronics Technologist, MRL, CANMET
Mr. T. Jewiss, Mining Technologist, MRL, CANMET
*__Mr. G. Vaillancourt__, Mining Technologist, MRL, CANMET
*__Mr. M.D. Andrew__, Engineer, Geophysics Div., Geological Survey of Canada
*__Mrs. M. Cajka__, Research Technologist, Atomic Energy of Canada Ltd.
(attached to Geophysics Div., Geological Survey of Canada).

*Part time.
+Now with Campbell Red Lake Mines Ltd.

APPENDIX D

Equipment and Services Budget in 1986/87

Diamond drilling at Quirke Mine, carry over	$5,759
Fill pressure cells and convergence meters	$8,671
Seismograph stations at Sudbury, Elliot Lake, Red Lake and Kirkland Lake	$58,902
Macroseismic system for Strathcona Mine	$63,483
Waveform recorders for Campbell and Macassa Mines	$64,251
Miscellaneous electronic equipment	$4,944
Electric cable	$3,403
Shipment of equipment	$694
	$210,107

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