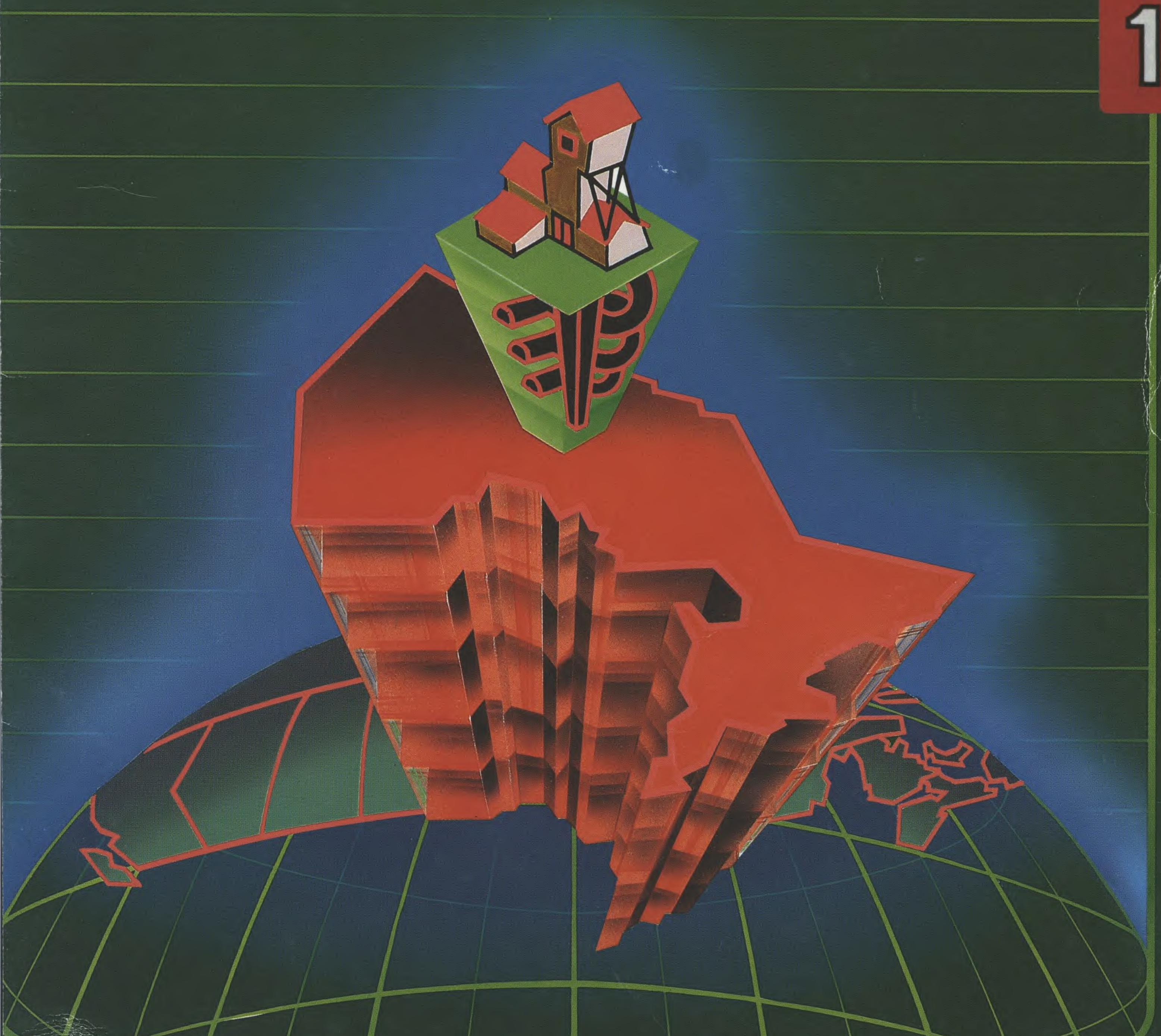
Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

1985-1986 ANNUAL REPORT OF THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

SP86-3E



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1985-1986
ANNUAL REPORT OF THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

C.H. Brehaut

Chairperson
Management Committee

D.G.F. Hedley

Chairperson
Technical Committee

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1985-1986 ANNUAL REPORT OF THE CANADA-ONTARIO-INDUSTRY ROCKBURST PROJECT

Foreword

It is well recognized that effective research can best be carried out when the expertise and resources of the interested parties can be brought together in a cooperative manner. In June, 1985, the Government of Canada and the Government of Ontario, together with members of the mining industry in Ontario, agreed to cooperate in the conduct of a major rockburst research project costing $4.2 million over a five-year period. The Canada-Ontario-Industry Rockburst Project is being directed by a Management Committee with members drawn from the senior ranks of each group, supported by a Technical Advisory Committee consisting of six industrial representatives and one member each from the federal and provincial governments.

The Technical Advisory Committee has been active in formulating and guiding the research program of the Rockburst Project, and the results of their work are well illustrated in the company's annual report for the 1985-1986 fiscal year. The Management Committee believes that the objectives, work plan, and the results of the individual programs should be communicated to all interested parties on a regular basis, with the expectation that the dissemination of such information will serve to further advance the understanding of rockbursts.

C.H. Brehaut
Chairperson
Management Committee

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BACKGROUND

The inclusion of mining research projects as part of a Canada-Ontario Mineral Development Agreement was first raised in early 1984. A meeting to discuss mining research priorities was organized by CANMET in Sudbury on May 9, 1984, and was attended by 14 technical representatives from the northern Ontario mining industry, plus representatives from the Ontario Ministries of Labour and Natural Resources. At this meeting, CANMET identified three priority research areas: rockbursts, in situ mining trials involving backfill, and computer modelling.

Rockburst research would be concerned with installing special seismic-monitoring systems to locate rockbursts accurately, with measuring the seismic energy liberated, with evaluating changes in energy due to mining using computer models, and with in situ monitoring of stress and displacement. In situ mining trials would involve measurements of pillar stress and deformation, closure of stope walls, pressure buildup on backfill, and load-on support systems. Two trials were envisaged using either longitudinal or transverse cut-and-fill and blasthole, with either tailings or rock backfill. Computer-modelling work would be concerned with giving the small and isolated mines wider access to the geomechanical computer programs currently being run on mini- and mainframe computers. These three projects were estimated to cost $2.5 million over five years, with most of the research being contracted out.

The representatives at the Sudbury meeting endorsed the high priority of these projects and also suggested other research projects if additional funding were available. These included:

- blast fragmentation and vibration monitoring;
- borehole orientation and position instrumentation;
- development of rock mechanics instrumentation;
- methods to determine the effectiveness of rock-bolting systems;
- studies on structurally controlled rock falls.

In the following weeks, CANMET personnel visited most of the hardrock mines in Ontario to follow up on this initiative. This process was interrupted by the occurrence of multiple rockbursts at three mines in Ontario.

On June 20, 1984, a series of rockbursts occurred at Falconbridge's No. 5 shaft that resulted in four fatalities and the subsequent closure of the mine. Three weeks later, a series of rockbursts occurred at Inco's Creighton Mine during the summer shutdown. The first rockburst had a magnitude of 4.0 and was felt throughout the Sudbury area. Starting in September, 1984, significant rockburst activity was experienced at Rio Algom's Quirke Mine at Elliot Lake. Over an eight-month period, 120 rockbursts of magnitudes up to 3.5 were recorded by the Eastern Canada Seismic Network.

This level of rockburst activity, in a short time-span and at three separate mines, attracted considerable attention from the public, media, mining industry, unions, and government agencies. International technical review committees were organized by the mining companies to evaluate the mechanisms and causes of rockbursts, as well as to advise on future mining operations in the affected areas at both Falconbridge and Creighton Mines. The Ontario Ministry of Labour appointed an inquiry into ground control and emergency preparedness in Ontario mines. This provincial inquiry held public and private meetings at mining camps throughout Ontario.

In light of these developments, CANMET reorganized its research priorities and wrote a proposal solely on rockburst research*. The emphasis of this research was to improve seismic-monitoring equipment for more accurate source location of events and elimination of spurious events. Wave-form analysis would be used to try to differentiate between rockburst mechanisms, from which the cause of bursting could be established. Much of the initial research would be concentrated in the Sudbury mines, with up-grading of the microseismic systems already installed at the Falconbridge and Creighton Mines. However, research would also be initiated at other mining camps to investigate a common problem of rockburst activity during mining of crown pillars in narrow, steeply-dipping deposits. The estimated cost of this rockburst project was $4.2 million over five years. A major difference from the May 1984 proposal was that the research would be carried out by CANMET personnel rather than being contracted out.

**Udd, J.E. "A proposal for a major research project on rockbursts"; Division Report MRP/MRL 84-84(TR); CANMET, Energy, Mines and Resources Canada; 1984.*

This rockburst research proposal formed the basis for further discussions with the Ontario Ministries of Natural Resources and Labour, initially within the Mineral Development Agreement, but then as a separate identity to facilitate early implementation. Its place in the Agreement was eventually allocated to mining research involving backfill and, as such, incorporated many of the items of in situ mining trials and geomechanics computer modelling put forward in the May 1984 proposal.

The rockburst project was organized with tripartite funding from the Federal Government, the Ontario Government, and the Ontario mining industry. The Federal Government's contribution through CANMET would be to provide staff to operate the project, training, and maintenance of equipment. The Ontario Government would provide funds for equipment and services, while the mining industry would contribute its existing microseismic-monitoring systems as well as assisting with the installation of new equipment at its mines.

Agreement on the rockburst project was announced in June, 1985, by the Minister of State (Mines), (Hon. R.E.J. Layton), representing Canada, and the Minister of Natural Resources, (Hon. M. Harris), representing Ontario. A Management Committee, appointed to oversee the project, consisted of six members and a chairperson. Two members represented Energy, Mines and Resources Canada, two members represented Ontario, and two members represented the Ontario mining industry; Mr. C.H. Brehaut, President of the Ontario Mining Association, was appointed Chairperson of this Committee.

The main functions of the Management Committee are to:

- review and approve the annual project plans developed by CANMET;
- submit for approval, or ensure the submission for approval, of the annual project plans to the mining companies on whose properties the actual projects will be carried out.

The Management Committee, in turn, appointed a Technical Advisory Committee consisting of six members representing the mining companies where the research will be done (Campbell, Denison, Falconbridge, Inco, Lac Minerals, and Rio Algom), plus a representative from the Ontario Ministry of Labour. Dr. D.G.F. Hedley of CANMET was appointed Chairperson of this Committee.

The main functions of the Technical Committee are to:

- report to the Management Committee, through the Chairperson, on the plans and progress of the research;
- screen technical proposals and recommend their acceptance and application;
- review and recommend on purchases of equipment.

The present membership of both the Management and Technical Committees is listed in the Appendix.

A "Memorandum of Understanding" between Energy, Mines and Resources Canada, the Ontario Ministry of Labour, and the Ontario Ministry of Northern Development and Mines, was signed on September 20, 1985, at which point the research project was initiated. Several months had elapsed since the writing of the first research proposal in December, 1984, so an updated work plan* was prepared by CANMET for the immediate research plans of the project. This document formed the basis of initial discussion of the Technical Committee at its meetings in Elliot Lake on November 15, 1985, and in Copper Cliff on February 25, 1986.

**Hedley, D.G.F. and Udd, J.E. "The CANMET/MRL rockburst research project – an updated work plan"; Division Report MRP/MRL 85-106(TR); CANMET, Energy, Mines and Resources Canada; September 1985.*

RATIONALE AND OBJECTIVES

Although mining has been carried out for at least a couple of millenia, rockbursts have occurred only over the last century. They are a direct result of improved mining technology, especially in the areas of pumping, hoisting, and ventilation, that allowed the mines to go deeper into an ever-increasing stress environment.

The magnitude of the forces involved and the complexity of rockbursts have made them a very difficult problem to solve. In the early years some practical guidelines were developed, notably by government-appointed committees in South Africa in 1908, 1915, and 1924, as well as by the Ontario Mining Association (Morrison Inquiry) in 1940. These guidelines mainly relied on the traditional engineering approach of observation, experience, reasoning, and trial-and-error methods. Recommendations included avoidance of remnant pillars, systematic sequencing of extraction, and procedures for mining around dykes and faults.

A theoretical understanding of rockbursts was only developed during the 1960's, notably by Cook and Salamon in South Africa. Since rockbursts are a violent release of energy, an energy-balance approach was used. All the energy sources entering the mining system were balanced against how the energy was used or dissipated. Surplus energy would be released seismically as a rockburst. In addition, it was realized that the violent failure of rock was dependent on the stiffness of the loading system. For instance, the violent failure of a brittle rock specimen, in the laboratory, was a result of the stiffness property of the testing machine and not that of the rock.

During the same time, seismic-monitoring systems were being installed in South African and American mines. These systems gave a much better insight into rockburst problems, since to understand the mechanisms involved in a rockburst, it is essential to know the source location accurately.

In Canadian mines, seismic- or microseismic-monitoring systems were first introduced during the early 1980's; at present, 10 such systems are operating in Ontario mines. These systems give source locations of seismic events based on first-wave arrival times and on a relative measure of the seismic energy liberated. As such, they have been extremely useful in establishing trends in seismic activity and from source locations, relative to the mine openings, a mechanism can usually be inferred.

Three types of rockbursts have been identified based on the mechanism involved and the source of the liberated energy. These are as follows:

1. Strain-energy bursts are caused by high stress concentrations at the edge of an opening. The energy liberated is the stored strain energy within the rock.
2. Pillar bursts occur when a pillar suddenly fails, accompanied by rapid closure of the hanging wall and footwall. The energy liberated is part of the change in potential energy of the wall rocks.
3. Fault-slip bursts occur when the shear stress along a fault exceeds the clamping stress. Again, the major source of liberated energy is the change in potential energy. This type of rockburst can occur within the orebody or remote.

Of the 217 recorded rockbursts in Ontario mines during 1984-85 of magnitude 1.5 to 4.0, 5% are classified as strain-energy bursts, 81% as pillar bursts, and 14% as fault-slip bursts.

The present microseismic systems are specifically designed to measure first-wave arrival times using extremely sensitive geophones. Other information, such as direction of first motion and peak particle velocity, is sensed, but not recorded. In addition, the geophones are so sensitive that they saturate at very low magnitudes of seismic events, and the energy values recorded are discrepant.

First motion studies should indicate the mechanism involved in the rockburst. In a fault-slip burst, opposite sides of the fault move in opposite directions, movement that should be picked up by strategically located geophones around the fault. Pillar bursts are an implosion and the first motion is inwards, whereas a blast is an explosion and the first motion is outwards.

Peak particle velocity is a measure of the damage caused by a rockburst similar to that in blasting. It is used to design support systems so that they can withstand certain levels of rockbursting. In South African gold mines, an empirical relationship has been developed between rockburst magnitude, peak particle velocity, and distance. A similar relationship is required for Canadian mines.

A reliable value for the seismic energy liberated in a rockburst is required since it is fundamental in understanding the energy balance. It is also required to check the energy components calculated in computer programs.

Consequently, the first priority in the Rockburst Research Project is to design a seismic-monitoring system that will capture the complete wave-forms and provide information on first motion, peak particle velocity, and seismic energy. Because of the massive amount of seismic data generated, initial research will be concentrated on the larger seismic events of magnitude greater than 1.0, which are the most important. Even here, it is likely that the seismic-monitoring system will saturate for the large rockbursts of magnitude 3.0 and greater. In these cases, it is necessary to rely on the National Seismograph Network. This network is being enlarged by installation of additional seismographs in the Sudbury Basin and at Elliot Lake.

There are two approaches to the alleviation of rockbursts, which can be termed 'strategic' and 'tactical'. The strategic approach is to diminish the possibility of encountering rockburst-prone ground or to diminish the severity of the rockbursts. Techniques include sequencing of extraction to minimize large energy releases; layout of permanent or semi-permanent pillars to reduce volumetric closure and change of potential energy; and the use of backfill to both limit closure and to absorb energy otherwise liberated as seismic energy. The benefits of these techniques are only realized in the long-term.

The tactical approach is to accept that some rockbursting is inevitable, but to seek to limit the extent of the damage. Techniques include design of support systems that yield with the vibrations rather than snap; and destress blasting to soften the rock and control the timing of the change in potential energy. The benefits of these techniques are realized in the short-term.

Prediction of rockbursts is always a long-term objective of rockburst research. However, there are two components to prediction: location and time. At many mines, the present microseismic systems indicate a buildup in seismic activity prior to a major rockburst. Consistent prediction of time has been much more elusive. Some fault-slip rockbursts have occurred without warning of location or time. It is thought that these were caused by a reduction in the clamping stress, and hence a buildup in seismic activity would not be expected.

In summary, the rationale and objectives of the rockburst project are first to develop a new seismic-monitoring system capable of capturing the complete wave-forms for the larger rockbursts. Then using improved source location techniques, first motion studies, peak particle velocities and liberated seismic energy, the causes and mechanisms of rockbursts would be investigated. Finally, these techniques would be utilized in conjunction with in situ measurements and computer models to evaluate both strategic and tactical methods of alleviating rockbursts.

WORK PLANS 1985-1987

The detailed work plans cover the first two years of the project and are split into five elements. The first four elements cover the proposed research in the four mining camps experiencing rockbursts (Sudbury, Elliot Lake, Red Lake, and Kirkland Lake), while the fifth element covers basic studies. In each element, besides the work plan, the expected contributions from CANMET, Ontario, and the mining industry are listed.

Element 1: Sudbury Mines

Objective:

To determine the causes and mechanisms of rockbursts at both Inco and Falconbridge Mines using wave-form analytical techniques, and to evaluate methods of alleviating rockbursts and/or limiting their damaging effects.

Work Plan: (covers the first two years to 1987)

1. Up-grade the microseismic network at Creighton Mine by replacing geophones with accelerometers (Mar./86).
2. Conduct wave-form analysis studies at Falconbridge Mine using a Gould recorder over a three-month period (Dec./86).
3. Enlarge the regional seismic network in the Sudbury Basin from one to three stations (connected to Science North and via telephone to EMR's Seismology Division in Ottawa), to increase the range for recorded rockbursts and to improve the source location of previously unlocated rockbursts (Oct./86).
4. Install two new seismic networks consisting of five units with three-dimensional sensors around Inco's Creighton Mine and Falconbridge's Strathcona Mine. These units will be installed both underground and on surface, about 1 km from active rockburst areas, and will be designed to record rockbursts above a magnitude of 1.0. Complete wave-forms of these larger seismic events will be stored on processing units at the mine sites and transferred over phone lines to CANMET's Elliot Lake Laboratory. Analysis of P-S wave arrivals for source locations, for first motion studies, for seismic energy, and for peak particle velocity will be done on the computers at Elliot Lake (first installation Oct./86, second installation 1987).
5. Calibrate new seismic networks, probably using isolated production blasts (Oct./86,1987).
6. Continue monitoring activity at Strathcona and Creighton Mines, using both the existing mine microseismic systems and the new seismic systems.
7. Evaluate the monitoring capabilities of the regional seismograph network covering the Sudbury Basin, the new seismic networks at the two mines, and the mine microseismic systems (1987).

Reports:

1. Design of a new intermediate seismic network (June/1986);
2. Layout and calibration of the new seismic networks at Strathcona and Creighton Mines (Dec./86,~1987);
3. Wave-form studies at the Falconbridge Mine (Mar./87);
4. Evaluation of regional and intermediate seismic systems and mine microseismic system (~1987);
5. Preliminary evaluation of wave-form studies at Strathcona or Creighton Mines (~1987).

Contributions From CANMET:

1. 3 full-time positions for five years;
2. $15 000/year data transmission costs to Ottawa and Elliot Lake;
3. Writing of technical reports.

Contributions From Ontario:

1. Upgrading of Creighton microseismic systems, (estimate $37 000), actual $44 000 (1985/86);
2. Wave-form equipment at Falconbridge Mine, (estimate $47 000), actual $42 000 (1985/86);
3. Enlarged regional seismic network, Sudbury Basin, (estimate $79 000), actual $55 000 (1985/86);
4. First new seismic network at a Sudbury mine, $140 000 estimate (1986/87);
5. Second new seismic network at a Sudbury mine, $140 000 estimate (1987/88).

Contributions From Industry:

1. Existing microseismic networks at Falconbridge, Strathcona, and Creighton Mines;
2. Day-to-day operation of these networks and provision of seismic data to CANMET;
3. Installation (drilling boreholes, installing sensors, laying cable) for the Gould system at Falconbridge Mine and the new seismic networks at Strathcona and Creighton Mines.

Element 2: Elliot Lake Mines

Objective:

To establish whether the hanging wall is caving above the rockburst area at Quirke Mine, to monitor the spread of seismic activity at both Quirke and Denison mines, and to establish a relationship between energy values from the mine microseismic system and a seismograph at CANMET's Elliot Lake Laboratory.

Work Plan: (covers the first two years to 1987)

1. Install a seismograph unit at CANMET's Elliot Lake Laboratory (Nov./85).
2. Re-drill existing surface exploration holes above the rockburst area at Quirke Mine to determine if the hanging wall is caving and at what depth (Mar./86).
3. Install geophones in these surface boreholes about 150 m above the orebody to improve vertical resolution of seismic events (May/86).
4. Calibrate the complete microseismic system using small blasts (May/86).
5. Continue monitoring seismic activity at Quirke and Denison mines.
6. Evaluate energy values from microseismic and seismograph units (Mar./87).

Reports:

1. Evaluation of hanging wall conditions and calibration of microseismic network (July/86);
2. Microseismic/seismograph energy relationship (Mar./87).

Contributions From CANMET:

1. Manpower covered by existing personnel;
2. Writing of technical reports.

Contributions From Ontario:

1. Diamond drilling of surface boreholes, (estimate $20 000), actual $22 000 (1985/86);
2. Back-up power and radio for seismograph, (estimate $3 000), actual $2 000 (1985/86);
3. Second seismograph unit, $6 000 (1986/87).

Contributions From Industry:

1. Seismograph unit (donated by Denison);
2. Existing microseismic network covering Quirke and Denison Mines;
3. Day-to-day operation of this network and provision of seismic data to CANMET;
4. Installation of geophones in surface boreholes (Rio Algom);
5. Calibration blasts (Rio Algom and Denison).

Element 3: Red Lake Mines

Objective:

To develop techniques that alleviate the rockburst problem and allow safe and efficient recovery of crown pillars in narrow, steeply dipping orebodies mined using cemented tailings.

Work Plan: (covers the first two years to 1987)

1. Installation of fill pressure cells and closure meters in backfilled stopes in both narrow (2 m) and wide (15 m) orebodies with varying tailing/cement ratio, to determine in situ fill stiffness, support pressure, and energy absorbed in the fill (starting Jan./86 and continuing with each fill pour).
2. Monitoring of seismic activity with complete wave-form analysis (Gould system), change in stress, wall closure, and backfill pressures in association with a crown pillar destressing blast (Jan./86), as well as other large blasts.
3. Measurements of stress in boxhole and sill pillars (1986 and 1987).
4. Computer modelling, with post-failure rock properties, of existing mining layouts for calibration purposes and then of alternative mining layouts, including destressing blasts (1986 and 1987).

Reports:

1. Results of destressing blast (June/86);
2. Pillar stresses (Dec./86);
3. Calibration of computer models (Dec./86);
4. Preliminary report on measurements of fill stiffness, support pressures, and energy absorbed (Mar./87).

Contributions From CANMET:

1. 1 full-time position for five years;
2. Stress measurements in pillars;
3. Writing of technical reports.

Contributions From Ontario:

1. Fill pressure cells and closure meters, (estimate $8 000), actual $8 000 (1985/86);
2. Portable computers (for use at all mine sites), (estimate $5 000), actual $13 000 (1985/86);
3. Fill pressure cells, stressmeter cells, and closure meters, $15 000 (1986/87);
4. Computer modelling on outside computers, $20 000 (1986/87).

Contributions From Industry:

1. Existing microseismic network at Campbell Mine;
2. Day-to-day operation of this network and provision of seismic data to CANMET;
3. Installation of instrumentation;
4. Diamond drilling for stress measurements.

Element 4: Kirkland Lake Mines

Objective:

To develop techniques that alleviate the rockburst problem and allow safe and efficient recovery of crown pillars in narrow, steeply dipping orebodies mined using rock fill.

Work Plan: (covers the first two years to 1987)

1. Installation of a combined conventional/research microseismic network at Macassa Mine. The conventional system would consist of a 16-channel accelerometer network with processing unit similar to the other systems installed in Ontario mines. The research system would consist of three-dimensional sensors with the ability to capture complete wave-forms that would also feed into the same processing unit (1987).
2. Monitoring of destress blast and the resultant seismic activity using the portable wave-form recorder (June/86), as well as other large blasts.
3. Review of previous rockburst activity at the Macassa Mine, with particular reference to rock types and structure (Sept./86).

Reports:

1. Review of rockburst activity at the Macassa Mine (Sept./86);
2. Results of destress blast (Oct./86).

Contributions From CANMET:

1. 1/2 full-time position for four years;
2. Design of sensor layout for microseismic system;
3. Writing of technical reports.

Contributions From Ontario:

1. Research part of microseismic system, $60 000 est. (1986/87/88).

Contributions From Industry:

1. Conventional part of microseismic system (Lac Minerals);
2. Installation of microseismic system (drilling, installing sensors, laying cable) (Lac Minerals);
3. Day-to-day operation of this network and provision of seismic data to CANMET;
4. Installation of instrumentation and 'master' NFOLD model for additional computer runs.

Element 5: Basic Studies

Objective:

To provide an overview of rockburst activity in Ontario mines; to be aware of rockburst research in other organizations and other countries; and to conduct fundamental research on methods of source location, measurement of seismic energy, and mechanisms of rockbursts.

Work Plan:

1. Annual review of rockburst incidents in Ontario mines (July each year).
2. Comparison of source location techniques using blast calibration data, and standardization on one completely automated technique (Dec./86).
3. Acquisition/development of software for wave-form analysis covering first motion studies, seismic energy liberated, and peak particle velocity (Dec./86).
4. Review of the factors affecting the energy values on the present microseismic system and definition of specifications for an improved energy measurement (Mar./87).

Reports:

1. Rockbursts in Ontario Mines in 1984 (Dec./85);
2. Rockbursts in Ontario Mines in 1985-86 (July/86, 1987);
3. Standardized source location method (Dec./86);
4. Review of energy factors and specifications (Mar./87).

Contributions From CANMET:

1. Manpower covered by existing personnel;
2. Writing of technical reports.

Contributions From Ontario:

None required.

Contributions From Industry:

1. Information on rockbursts for annual review;
2. Blast calibration data.

PROGRESS TO DATE

The rockburst project started on September 20, 1985, and this review covers to March 31, 1986, which is the end of the first fiscal year.

As part of CANMET's contribution, four additional persons were hired to operate the project. Also, a seismologist on a post-doctorate fellowship joined the Elliot Lake Laboratory. Visits were made to the Seismology Division of Energy, Mines and Resources Canada, the University of Saskatchewan, the Coeur d'Alene area of Idaho, the United States Bureau of Mines in Denver, and the Sandia Laboratories in Albuquerque, New Mexico, as well as visits to Ontario mines to establish the present state of the art in microseismic/seismic technology.

Ontario contributed $186 000 for capital equipment and services in 1985/86. These funds were used for diamond drilling at Elliot Lake; seismograph stations in Sudbury and Elliot Lake; semi-portable wave-form analysis equipment; accelerometers to up-grade the Creighton microseismic system; convergence meters and pressure cells for backfill studies at Campbell; and computer and electronic equipment for the Elliot Lake Laboratory.

The Technical Advisory Committee met on two occasions: in November 1985 at Elliot Lake, and in February, 1986, at Copper Cliff. In addition, visits and discussions were held with individual mines. All mining companies provided information on rockburst activity at their mines in 1985 for the annual review.

The diamond drilling at Quirke Mine was to establish whether the hanging wall was caving above the rockburst area. Even before drilling started it was known that the water pumped from the mine had increased by about 50% in 1985, and the level of a beaver pond on the surface had dropped by about 4 m. Hence, there is a connection between surface and underground, although it is not known whether this is by general fracturing or along prominent structures. Significant problems were encountered in re-drilling an existing surface exploration borehole. Complete water-loss occurred at a number of horizons. At a depth of 125 m, the original borehole had an offset of 50 mm at the contact of the limestone-conglomerate beds. An offset of 25 mm was also encountered at a depth of 145 m in the middle of the quartzite beds. At a depth of 165 m, the drill rods snapped twice due to fractured ground and the hole was abandoned, some 230 m above the orebody. Although the height of caving could not be established, general fracturing of the rock mass was encountered. Dye is being placed in both the borehole and the beaver pond in an attempt to find out on which level the water enters the mine. A report is in preparation.

A seismograph station was installed at the Elliot Lake Laboratory in November, 1985. This unit has recorded seismic activity in the local mines (Quirke, Denison, and Stanleigh) as well as rockbursts with a magnitude greater than 2.0 in the Sudbury mines (Strathcona, Creighton, and Copper Cliff North) and magnitudes over 3.0 at Kerr Addison Mine. The amplitude of the signals on the seismograph will be compared to the energy values from the microseismic unit at Quirke Mine to see if there is any correlation.

The seismograph stations and associated equipment for the Sudbury Basin are being assembled; they are due for installation and hookup to Science North in October, 1986.

A destress blast was monitored at Campbell Red Lake Mine in January, 1986. Instrumentation included the Electrolab microseismic system, wave-form recorder (Gould unit), blast vibration monitors (Instantel units), convergence meters, and stressmeters (IRAD gauges). Both finite element and NFOLD computer models were run to estimate the change in stress and displacement as a result of the destress blast. Initial results indicate the change in stress and displacement is small (70 kPa and 2 mm) due to the blast. Wave-form analysis gave consistent values for P and S wave velocities, which were slightly higher than those recorded by the Electrolab microseismic system. The geophones in the system were saturated by the destress blast (300 kg instantaneous) over a distance of at least 500 m. A report is in preparation.

The wave-form recorder was attached to the existing microseismic network at Falconbridge's No. 5 shaft in late March, 1986. Although the mine is closed (due to the rockbursts in June 1984), minor seismic activity continues. This provides the opportunity to capture wave-forms from fault-slip mechanisms.

Design of the new intermediate seismic system is almost complete. Strong-motion, three-dimensional sensors will be installed about 500 to 1000 m from active mining areas. Seismic signals will be transmitted to a central computer at the mine. A modem link will allow transfer of this data to the Elliot Lake Laboratory on a daily basis. Analysis of the wave-forms will be done at Elliot Lake.

REPORTS

Only one report was scheduled for this period, as follows:
Hedley, D.G.F. and Wetmiller, R.J.; "Rockbursts in Ontario mines during 1984"; *Special Report* SP85-5; Energy, Mines and Resources Canada; July 1985.

Abstract

During 1984, more than 100 rockbursts occurred in seven mines in Ontario, a significant increase over previous years. An unusual feature was the multiple rockburst sequence that occurred in four mines over periods ranging from a few hours to months.

These rockbursts were recorded on the regional seismograph networks and, in most cases, on the microseismic systems installed in the mines. It was possible to match magnitude values from the regional network to accurate source location from the mine networks, which greatly assisted in evaluating mechanisms, causes, and spread of rockburst activity.

Most rockburst activity occurred in pillars in thin tabular orebodies, either gently dipping as at Elliot Lake, or steeply dipping as at Red Lake and Kirkland Lake. Some rockbursts in the Sudbury mines have been attributed to a fault-slip mechanism.

Other Relevant Reports

Dampier, W.T. & Associates Limited. *Improving Ground Stability and Mine Rescue; Report of the Provincial Inquiry into Ground Control and Emergency Preparedness in Ontario Mines*, ISBN: 0-7729-1064-2; 1986.

Hedley, D.G.F. and Udd, J.E. "The CANMET/MRL rockburst research project – an updated work plan"; *Division Report* MRP/MRL 85-106(TR); CANMET, Energy, Mines and Resources Canada; September 1985.

Udd, J.E. "A proposal for a major research project on rockbursts"; *Division Report* MRP/MRL 84-84(TR); CANMET, Energy, Mines and Resources Canada; 1984.

APPENDIX

Rockburst Project Management Committee

C.H. Brehaut – Dome Mines Ltd., Chairperson
C. Barsotti – Inco Ltd.
M. Musson – Falconbridge Ltd.
B. Goodman – Ontario Ministry of Labour
V. Milne – Ontario Ministry of Northern Development and Mines
K. Whitham – Energy, Mines and Resources Canada
J.E. Udd – Energy, Mines and Resources Canada

Rockburst Project Technical Committee

D.G.F. Hedley – Energy, Mines and Resources Canada, Chairperson
D. Ames – Ontario Ministry of Labour
P. MacDonald – Inco Ltd.
D. Morrison – Falconbridge Ltd.
S.N. Muppalaneni – Rio Algom Ltd.
M. Neumann – Campbell Red Lake Mines Ltd.
W. Quesnel – Lac Minerals Ltd.
A. Sheikh – Denison Mines Ltd.

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