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Canada

MINING RESEARCH PROJECTS IN PROGRESS AT THE MINING RESEARCH LABORATORIES OF CANMET THROUGH FEDERAL/PROVINCIAL (AND TERRITORIAL) MINERAL DEVELOPMENT AGREEMENTS

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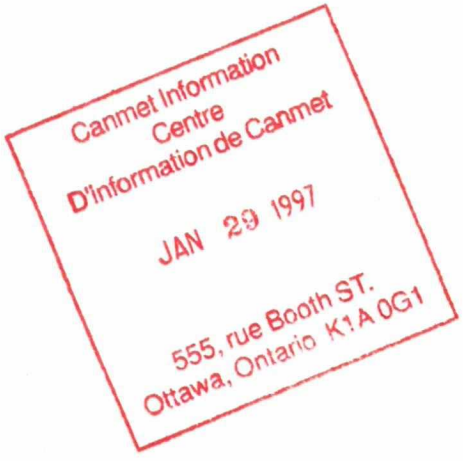

MINING RESEARCH PROJECTS IN PROGRESS AT THE MINING RESEARCH LABORATORIES OF CANMET THROUGH FEDERAL/PROVINCIAL (AND TERRITORIAL) MINERAL DEVELOPMENT AGREEMENTS

by

John E. Udd*

ABSTRACT

During the past three years, applied mining research projects have been initiated in several provinces, principally through Federal/Provincial Mineral Development Agreements. Work is now in progress in Manitoba, Ontario, New Brunswick, the Northwest Territories, and Saskatchewan. Other projects are being developed for possible implementation in the Yukon and Northwest Territories and several of the provinces.

All of the projects have been started after consultations with industry and/or provincial mining associations and address stated industry needs. The results will, therefore, be directly relevant to the industry. Additional benefits to CANMET/MRL are that a much greater proportion of research is being done externally and that communications with the industry have improved.

In this paper, the author reviews the projects that have been commenced thus far.

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Keywords

Atlantic Provinces, backfill, blast design, ground control, Manitoba, microseismic monitoring, mine communications, Mineral Development Agreements, mining research, New Brunswick, Northwest Territories, numerical models, Ontario, research, rock mechanics, rockbursts, Saskatchewan, software, Yukon Territory

PROJETS DE RECHERCHE APPLIQUÉE - PROJETS EN COURS AU LABORATOIRES DE RECHERCHES MINIERES DU CANMET

by

J.E. Udd*

RÉSUMÉ

Au cours des trois dernieres années, la recherche minière appliquée fût initiée dans plusieurs provinces, principalement par les ententes Féderale-Provinciales. Des Travaux sont présentement en cours au Manitoba, en Ontario, aux Territoires du nord-ouest, au Nouveau-Brunswick et en Saskatchewan. D'autres projets sont en développement pour implémentation possible dans le Yukon et les Territoires du nord-ouest et d'autres provinces.

Tous les projets ont étés entamés après consultations avec l'industrie et/ou les associations minières provinciales et spécification des besoins. Les résultata seront donc directement bénifiques à l'industrie.

De résultats additionnels pour CANMET/LRM sont une plus grande proportion de la recherche faite à l'extérieur et de meilleures communications avec l'industrie.

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Mots-Clés

les provinces atlantiques, communications dans les mines, conception de trou de mine, contrôle des terrains, écoute de microséismique, Ententes sur l'exploitation minérale, logiciel, Manitoba, mécanique des roches, modèles numériques, Nouveau-Brunswick, Ontario, recherche, recherche minière, Saskatchewan, terre de remblayage, Territoires de nord-ouest, Yukon

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INTRODUCTION

As a result of the recession and depressed metals prices of the early 1980's, the Canadian mining industry was forced to aggressively seek ways to improve its cost effectiveness and competitive position. While the costs of labour, goods, and services continued to rise, until only last year the prices realized for the end products remained at near historic lows. In this climate, the survival of an enterprise lies in improved productivity and efficiency.

Even now, when the prices of metals have risen greatly on international commodity exchanges, the pressures to maintain a competitive edge will continue (if not increase). Improved prices will inevitably result in increased global production. Maintenance of market share will continue to be a problem.

In recent years, the industry has increasingly converted to large-scale low-cost methods of bulk mining. Because of the exhaustion of near-surface reserves of ore, ore bodies at greater depths and under more adverse geological conditions are now exploited. Methods of mine design have been forced to become much more sophisticated and more solidly based on rock mechanics principles. There is now a much greater awareness of the needs for, and benefits resulting from, mining research. The mining process is probably the only part of the production cycle from which significant improvements in cost-effectiveness can be realized.

Concurrently with the recession in the metals industry, and commencing about 1984, a new delivery vehicle for mining research came into being through Mineral Development Agreements (MDAs) which were concluded between the federal government and many of the provinces. Under the umbrellas of Economic Regional Development Agreements (ERDAs), the MDAs define projects to be implemented in the minerals sectors and the delivery mechanisms for the work.

In some of these agreements, depending on local requirements which had been defined, provision was made for the inclusion of projects relating to the development of technology to enhance the productivity and competitive position of the minerals industry. Many of these projects are defined as "mining research". Others are in the areas of exploration extractive metallurgy, and minerals-related technology.

On another front, mining research was also being expanded through jointly-funded projects with other governments and industry. The best-known of these is the tri-partite project for a major thrust into rockburst research. Jointly funded by the federal and Ontario Governments, and the hard-rock mining industry of that province, the project is aimed at bringing Canadian technology up to world-class standards within five years. Progress to date has been excellent and the project is now in its fourth year. Discussions are now being held to evaluate the options for its future.

Before describing the mining projects and reporting on the progress to date, however, it is worthwhile to explain the processes by which the projects were conceived. Research, under the MDAs, is not yet in progress in all of the Canadian provinces in which there is mining activity.

When asked the reasons as to why a specific project is being executed in a particular place it is important that one should be aware of the negotiating processes and the timing of the agreements. This, together with a federal role of national coordination and avoidance of duplication, provides the answers.

When discussing local needs and potential projects for each of the provinces and territories, the work that has been done and is being done in the other jurisdictions is always an important initial item of consideration. CANMET, because of its national mandate and involvement, must be aware of the total research picture. With the amount of interest that is now being generated in mining research, such a national co-ordination of activity is essential.

The most important reason, then, in explaining the pattern which has developed is that all of the projects have been designed to address expressed local needs. This has usually been done through consultative mechanisms involving the governments concerned, and possibly either representatives of provincial mining associations, or of the industry, or all parties.

As the process of defining research needs has matured, the communications paths have become much better defined. These have been enhanced by the development of formal mechanisms through which discussions can be formally channelled. The Mining Technology Council of Canada (MITEC), the Mining Research Directorate of the Ontario Mining Association (OMA), and the Research Committees of both the Quebec Mining Association (QMA), and the Saskatchewan Potash Producer's Association (SPPA) are excellent examples of communication channels which have opened in the recent past. As a result, both nationally and in three provinces, mechanisms are now in place which will facilitate continuing discussions with industry on mining research needs. Similar consultative mechanisms will probably develop elsewhere. CANMET's intent is to direct work in such a way that the greatest possible benefits accrue to the industry.

In the jurisdictions not mentioned specifically, the communications paths for formal discussions with the industry are still evolving. To date, these have been less formal in approach than followed elsewhere and have been conducted with representatives of the industry on

an "as required" basis. After projects have been defined, initiated, and have started to mature, however, the "ad hoc" format of initial talks have developed into a regular reporting structure. In Manitoba, and Ontario, for example, there are now semi-annual meetings with contractors and representatives of the industry to review progress. This same pattern will probably also emerge elsewhere as progress is made on research projects.

In provinces other than those named specifically in this paper, the Mineral Development Agreements do not contain a provision for the delivery of mining research. The most important reason for this would probably be that other regional needs were selected as being of higher-priority in the early discussions. A key point is that the industry must make its needs known to those who negotiate such agreements. It is impossible to proceed without the discussion and dialogue required.

The industry is broad and diverse and it is very difficult to obtain consensus; especially regarding needed research. The Communications paths, however, are becoming better defined. It is to be hoped that, in the future, the entire process of determining research needs will be undertaken with a much better awareness of opportunities for funding. In order to address future possibilities for funding, the industry (either provincial or national) would be well-advised to have a "shopping list" of high priority projects, arranged in order of priority for sponsorship and funding, available at "a moment's notice".

The following is a review of the mining research projects presently under way through the federal/provincial MDAs with Manitoba, New Brunswick, the Northwest Territories, Ontario, and Saskatchewan. Many of these are in the areas of rock mechanics and ground control.

The reason for this is that the implementation of rock mechanics and ground control principles and practices is now recognized by the industry as having extremely high potential for return on investment. Of all of the parts of the mining production cycle, from exploration to production of metallic end products, it is the process of mining which has received the least attention to date from the research point of view. It may well be, in fact, the only part of the production cycle, in which significant reductions in costs and improvements in profitability can be made. In a threatened industry, the focus of attention on mining methods is logical.

Going one step further, improvements in mining methodology necessitate close examinations of the stability implications. Rock mechanics is an essential part of the planning process.

Most of the first MDA's were negotiated in the shadow of the recession which began in 1982. Given the focus on the mining process as a potential "cost-reduction centre" it is hardly surprising that, when asked, nearly all mine operators and provincial associations stated that their immediate needs were for practical rock mechanics and ground control.

Recently, however, because many of the highest priority needs for rock mechanics and ground control research are already being addressed, it has been possible to expand the scope of MDA work to include such topics as mining environments, ventilation, and hoisting technology. With discussions for a second round of Mineral Development Agreements now in progress it is possible that both the range of mining research projects and the geographical coverage may be expanded very considerably. It is likely that Newfoundland, Nova Scotia, and the Yukon Territory will be added to the list of jurisdictions in which work is in progress. Further, successor projects are being discussed in all of the provinces in which work was addressed in the first round.

CANADA/MANITOBA MDA - PROJECTS ON ROCK MECHANICS, GROUND CONTROL, AND MINE COMMUNICATIONS

The first of the Mineral Development Agreements involving a mining research component was that which was signed between the federal and Manitoba governments. Nearly all of the mining in that province takes place under hard rock conditions. Thus, the initial Manitoba projects will produce results which will be potentially applicable to many mines located elsewhere in Canada. The importance of the projects is already recognized on a national level.

There is a distinct Manitoba flavour to the work, however, insofar as many of the projects are being undertaken in small to medium-sized multi-lensed sulphide orebodies, of which there are several in northern Manitoba. Small mines throughout Canada will probably derive the greatest benefits from this research.

Before describing the federally-delivered projects in Manitoba, it must be mentioned that there are also other, provincially-delivered, projects in progress under the supervision of the Department of Minerals and Energy.

The following descriptions refer only to those projects which are being supervised by the Mining Research Laboratories of CANMET.

Project B.2.1.1: "Design Guidelines for the VBM Method for a Steeply-Dipping Deposit in Manitoba". (Also: "Procedures for blasting down hang-ups in ore passes and chutes")

The Vertical Block Mining (VBM) method is thought to be a viable alternative to cut-and-fill mining. There are at present, however, no design guidelines which can be used as a means of selection. The objectives of the project are to consider all of the design parameters, to monitor in-situ conditions, and to

develop a design manual which can provide a rational basis for mine design. Other objectives include the development of guidelines for the conversion of mining from other methods to VBM and guidelines for VBM blast design in order to optimize fragmentation while minimizing overbreak, scaling and dilution. The work is being undertaken by INCO Ltd. at its Thompson operations. The total value of the contract is $362,500.

In the INCO study an assessment is being made of the sizes of production stopes and pillars, the spans, the possible sequences of extraction, the blasting procedures, requirements for ground support, and use of backfill. The intent is that the guidelines should encompass all of the key parameters which are important in the selection of a mining method. An important element of this project is that the work is being done in, and makes special reference to, the particular conditions associated with steeply-dipping orebodies. Up to the present, stability analyses have been made of a number of stopes and several interim reports issued.

As will be appreciated, there are no unique solutions to the problems of design and prediction of stability in a mining environment. Mining, by its very nature, severely disturbs the surrounding rock mass - especially if full extraction is accomplished. A manual of design guidelines for VBM mining, if readily identifiable with economics and safety, will bring more confidence to design engineers and production staff.

Also included in the project is a sub-project which has major implications concerning the health and safety of underground miners. This work is in connection with the development of procedures for blasting down hang-ups in ore passes and chutes. Every miner recognizes that this is one of the most hazardous of all of the tasks in underground mining. The development of better procedures will have a major impact on safety.

This project is behind its original schedule because of the impact of very high metal prices upon priorities.

Two annual progress reports (1987 and 1988), one for VBM Design Guidelines and the other for Scaling and Hangup Removal, have been submitted. The progress on the development of a light-weight scaling tool and hangup removal has progressed reasonably well. However, the development of VBM design guidelines is rather slow. The design guidelines will be divided into six chapters, namely: Cut-and-Fill Mining, Data Collection Systems, VBM Stope Design, VBM Stoping Procedures, Drilling and Blasting, and Support Requirements.

Project B.2.1.2: "Development of a Geomechanical Data-base for Ground Control in Deep Mines"

Increasingly, mining engineers are making use of numerical modelling methods to design underground mine openings and sequences of extraction. To be truly effective such models should, among other features, be able to simulate non-linear and post-failure behaviour of both rock and backfill materials and should be calibrated and verified by reference to actual case history studies.

One of the great benefits of the MDA projects is that their scale, and execution by the industry, makes such practical verifications possible.

In this project, which is the subject of a contract in the amount of $255,500 to INCO Ltd., a numerical model will be produced for the purpose of predicting the ground stresses and deformations induced by mining. In addition to the features mentioned previously, the model will also contain provision for major discontinuities in the rock mass and dynamic effects (such as induced by blasting vibrations). In order to do this a geomechanical model will be developed in order to facilitate data collection and retrieval.

Among the outputs of the project will be software packages accompanied by user's manuals. As with the other MDA projects the intent is to transfer the technology developed to the entire industry as quickly as possible.

This project is also behind schedule for the same reason mentioned for the previous project. Again, the delivery date has been extended to September 1989.

Two annual progress reports, one on geomechanical modelling and the other on numerical modelling were submitted in 1987 and 1988. The first, "Geomechanical Modelling" (in two volumes) is still in draft form for review and comments. The numerical modelling aspect has been broken down into the development of four programs, namely: BEAP, BEAP-DD, BEAP-M, and QUAD. Both BEAP and BEAP-DD are almost completed except for the pre- and post-processors and user documentation.

BEAP has been installed at INCO, Thompson, and transferred to CANMET for further testing and verification. Currently, it is functional on both mini and micro-computers. The BEAP-M program is still under development. QUAD is a two-dimensional finite element analysis for plain strain analysis of linear or non-linear non-homogeneous rock mass. The use of QUAD is intended to be complementary to the use of the BEAP programs.

Project B.2.1.3: "Evaluation of Methods for Delayed Backfill Consolidation"

The use of cemented and consolidated fills in mined out stopes, while now common, has been a feature of Canadian mining practice for only a generation. Previously, unconsolidated alluvial sands, gravels, waste rocks, slags, and many combinations of these, were used. In many areas, depending upon the availability of mill tailings and other considerations, such is still the case.

Thus, it is not uncommon presently for a mining engineer to have to contend with the problem of mining pillars between stopes filled with unconsolidated fill. The alternatives which are available to stabilize such loose fills include pressure grouting and the percolation, by gravity, of cementing mixtures. Stabilization by such methods is necessary for, without it, the dilution by loose fill would soon render further extraction of pillar ores uneconomical.

In this project, which was the subject of a contract in the amount of $100,000 to the Hudson Bay Mining and Smelting Company Ltd., a review was to be made of the cost effectiveness of the methods which are available for delayed consolidation of backfills. This was to be followed by field trials using preferred methods and the establishment of predictability criteria. There would also have been the development of theoretical models and the correlation of field results with these. An objective is to develop practical techniques for the in-situ consolidations of fills.

At an advanced stage of the work, however, the Hudson Bay Mining and Smelting company was unable to proceed further with the field experimentation component of the project because of the lack of a suitable experimental stope in the Flin Flon area.

The following two contract reports have been produced on those portions of the project which were completed:

(a) "Stabilization of Soils and Backfill - A Review of Mining and Civil Applications".

(b) "Laboratory Investigations of HBMS Smelter Slag, Progress Report No. 1."

The results of the study, when ultimately complete, should permit the recovery of pillars surrounded by unconsolidated fills to be accomplished with greater stability and safety. Additionally, it might be possible to develop a methodology by which the consolidation of backfills could be deferred to a later stage in the mining process, thereby improving cash flows. This would be a very great benefit to smaller operations. Finally, the technology could improve shrinkage stoping methods in which broken waste is placed on top of the ore being drawn down (through lessening dilution).

Project B.2.1.4: "Ground Stability Evaluation with Particular Reference to En-Echelon Lensed Orebodies"

As mentioned, mining engineers are now making increased use of numerical modelling methods in the design of underground openings. Additionally, rock mass structural classification systems are also being used to quantify the properties of rock masses - both for predictive purposes and to provide input data for the models. There is a great need to evaluate the rock mass classification systems which are presently available and to compare the actual stability performances of openings versus predictions as mining progresses. The results would permit a calibration and an enhancement of the predictive tools which are available.

In this project, which is the subject of a $352,000 contract, originally with Sherritt-Gordon Mines Limited, but now with the Hudson Bay Mining and Smelting Company as a result of the latter's purchase of the Ruttan mine, current rock mass classification techniques will be used to forecast ground conditions in the mine. The conditions forecast will then be compared with actual conditions during mining. From those comparisons the most important criteria will be identified; and, thus, better predictive methodology will result.

Much has been accomplished to date. A review of current rock mass classification systems has been completed. As a result, both the RMR and the Q Systems have been identified as being especially relevant to the particular needs of underground hard rock mines. The testing of local mine rocks and backfill has been completed, as have: in-situ determination of stresses, assessments of groundwater conditions and numerical modelling. All of the rock mechanics instrumentation programs have been implemented. Stope design guidelines have also been established.

Micro-computer software has also been developed for use in mine planning and operations, with respect to mine design and ground control avilable are: a boundary element program, PCBEM; a stereonet program, PC-DISCODAT; and a pre-processor program for MINTAB.

Work is now in progress on the following elements of the project: a state-of-the-art review of underground cable bolting; the effectiveness of bolting in the control of dilution in large blast hole stopes, and a dynamite finite element analysis.

Project B.2.1.5: "Optimization of Blast Design for Blasthole Mining Operations"

Current blasting practices in underground mines are largely based on experience and on trial and error. This approach can be costly and can involve risks. With the trend to large-scale methods of mining, the economic consequences of overbreak, dilution, and badly-fractured rock can be very great. Clearly, there is a need for a rational process of design by which such key parameters as rock mass characteristics, stope geometry, properties of the explosives, timing, methods of initiation, and induced vibrations, can be incorporated as parameters.

In this project, which is being performed by INCO Ltd. under a $260,000 contract with the federal government, a study is being made at a number of test stopes. The field work involves: in-situ testing to determine the dynamic properties of a rockmass; evaluations of rockmass characteristics; trials of test stopes; monitoring of ground motion resulting from blasting; analysis of fragmentation achieved; and the development of theoretical and semi-empirical predictive models.

The objectives are to develop a rational blast design process, which incorporates: the important properties of the rock to be blasted, the stability of the resultant opening, the properties of the explosive used, and the blasting methods employed. The design procedures will be prepared in the form of "user-friendly" software packages and manuals suitable for use with IBM PC micro-computers. Interactive graphics will be a feature of the approach.

To date, INCO has completed an extensive search for software which can be used to evaluate blasting, blasting-induced vibrations, damage criteria, and fragmentation. The applicability of some of this software to underground mining has been evaluated and trials are under way to test the "breakage module" in practice. In the mine in which the studies are being performed, two stopes have been dedicated to the research and the data collected from these are being used to calibrate the model. The project is now approximately 75% complete.

Project B.2.2.1: "Communication Systems for Isolated Areas in Mines, Especially in Ore-bodies Composed of Multi-lenses"

There is perhaps no other MDA mining research project that has generated more interest from the industry than the current research on underground communications systems. There is a very strong consensus that improved and integrated voice and data

communications systems are needed urgently if progress is to be made towards effective mine information and monitoring systems. The present technology is seen as being a bottleneck to further development. Beyond any question, new approaches are needed.

The implications for both worker health and safety and efficiency are simply enormous. An improved voice communications system would permit instantaneous conversations with crews or workers working in isolated areas. It would also permit rapid identification of problems with conditions or equipment and permit speedy solutions to be implemented. No mine supervisor needs to be told of the costs of large production resulting from delays in obtaining urgently-needed repairs to equipment.

Likewise, a highly efficient data communications system would accelerate the development of large-scale mine information and monitoring systems.

Against this background, the interest in the awarding of a $429,400 contract to Sherritt Gordon Mines Ltd. (with Falconbridge Ltd. as a sub-contractor) can be appreciated. In the project, the contractor was required to review the state-of-the-art in available underground mine communications systems, and to select the most suitable and cost-effective of those for an extended field trial in a Manitoba mine. After a period of evaluation, recommendations were to be made for any research and development that might be needed to improve the technology.

The report of the first phase of the work, by Falconbridge Ltd. for Sherritt Gordon, was concluded at the end of 1985. The interest in it was so great that the supply of two hundred copies printed for distribution was soon exhausted!

In the conclusions for Phase 1, it was stated that a medium frequency frequency-modulated system (FM-MF) was the best choice for mine-wide communications. It was also stated that the benefits of installing such a system would be so great that a payback period of less than two years could be anticipated.

Subsequently, in the second phase of the work, systems were purchased for voice, hoist, data, and rock mechanics monitoring communications.

The Montan-Forschung radio system was tested in a pilot area on the 320 LW level and, after having been found to be satisfactory, was expanded to full-scale installations on the 660 and 860 levels. It has been found to be capable of providing good communications but maintenance - particularly of the antenna - is especially important.

On another front, the FEMCO Trolley phone/cage phone system was purchased and is now in the first stages of installation and commissioning. A Montan-Forschung data system has also been purchased and remains to be installed on mobile equipment and evaluated.

Finally, a radio-transmitter manufactured by IMS Electronics Inc., and intended for monitoring of rock mechanics instrumentation, has been purchased and installed. Operating in conjunction with the Montan-Forschung system, it has been tested successfully. It is, however, dependent on the radio system and a successful installation of the latter is critical to its success.

Even at present, and while not yet complete, the research has had a tremendous impact on the industry. Systems of the type recommended have already been installed by both Falconbridge and INCO, in the Sudbury basin, and by Kiena. Other operators are reported to be considering installations. Seminars on the topic of mining communications have been organized by the Mines Accident Prevention Association of Ontario (MAPAO), the Algoma Branch of the CIM, and the Ontario Ministry of Labour.

From a technology transfer point of view the successes to date has been outstanding. More remains to be done, however, in convincing workers of the positive effects that monitoring will have on both health and safety and productivity. Some resistance to the technology has been encountered. This must be overcome if the new technology is to be used successfully.

CANADA/ONTARIO MDA - PROJECTS ON MINE BACKFILL AND ANALYTICAL MODELS

In modern large-scale methods, mining panels are extracted in a pre-determined sequence which permits the controlled adjustment of the pre-mining state of stress. Completed panels are usually filled with backfill in order to provide support. Often, cement is added to the backfill as a means of increasing strength.

Mill tailings, as materials for backfill, have been used in the mines of the Sudbury basin for over 30 years. It was in these same mines that much of the original development work was done with cemented backfills. Originally, the intent was to provide a hardened floor in cut-and-fill stopes on which broken ore could be scraped with minimal resulting dilution.

With the advent of large-scale blasthole methods in the past two decades, however, cement has been added to entire pours of tailings in order to improve the free-standing heights of unsupported fill walls. With the fill unsupported during the mining of contiguous panels, the height at which it will stand undisturbed is of vital importance to mine design. Greater heights permit increased level intervals and, consequently, less development and lower unit costs.

The amount of cement required to provide the strengths desired is a key question. Cement is expensive and the amount consumed in large-scale backfilling operations can be enormous. Any optimization in filling technology can have far-reaching benefits for the industry.

It was for this reason that the focus of mining research under the Canada/Ontario Mineral Development Agreement, COMDA, was placed on mine fill. The industry had identified this as one of the most urgent areas for practical research. CANMET responded by recommending a total of $3.55 Million for commitment mostly to field-scale experiments to be performed by the industry. Work is now in progress on projects addressing: the comparative properties of various fills; the development of predictive models; and mining strategies. The contracts were initiated in 1986.

At the same time, provision was made to establish a small laboratory dedicated to studying the engineering and physical properties of fills. Such a highly specialized laboratory, dedicated to the mining industry as a source of technical support, did not yet exist. The laboratory, a unit within CANMET's Mining Research Laboratories Division, is now operational on the Laurentian University campus, in Sudbury.

All of the projects are now at advanced stages. These are as follows:

Projects C.1.0(a) and (b): "In-Situ Determination of Dewatered Tailing Fill Properties"

Mill tailings are emplaced as backfill in the form of a slurry. As a result, the water which is used to transport the solid particles to the stopes being backfilled must be pumped from the mine as the fill consolidates and ages. Cement, added to increase the strength of the fill, is leached away as the water percolates downwards.

The successful use of higher-density paste-type fills would offer a number of improvements to mine operators. First, with much less water being used, there would be significant reductions in pumping costs and cement losses. Second, because of the increased retention of cement and higher density, the fill would attain higher strengths more rapidly. Third, this, in turn, would

simplify the methods which are used to design the structures used to contain the fills (i.e., bulkheads and fill fences). Fourth, there would be an improvement in the handling of slimes and in costs of clean-up underground.

Two projects, involving alternative technologies are now nearing completion:

(a) At INCO Ltd., in the Sudbury basin, work has been in progress for some time at the Levack Mine to design a system which will permit the delivery of high-density fills directly through pipelines. A CANMET contract, in the amount of $112,000, is in place to accelerate this work.

At INCO a surface mixing plant and a gravitational system is used to deliver the paste fill to a test stope. The initial results, at depths at less than 1,200 feet, have been very successful. Monitoring instrumentation has been installed and the trial stope filled. Mining is in progress.

Based on the early successes, and even before completion of the project, consideration was given to extending the technology to openings at greater depths.

The Project is now nearing completion. A draft final report has been received from INCO Limited, and is being reviewed by CANMET staff.

Some of the significant findings from the report are as follows:

(i) The strengths of paste fill samples were about double those of samples of hydraulic backfill with similar cement contents.

(ii) The uniaxial compressive strengths of paste-fill samples recovered in-situ were about 80% higher than those of laboratory-prepared samples.

(b) At Dome Mines Ltd. an alternative approach to the delivery of paste fill is being investigated. Through a CANMET contract, in the amount of $152,580, the company is evaluating the potential use of a device known as the "tailspinner". Operating much like a centrifuge, the tailspinner receives liquid backfills at normal pulp densities (about 60% solids by weight). On delivery, the water is spun from the fill and removed. An extruded paste is emplaced.

At Dome, in-situ monitoring of fill behaviour is now in progress. Laboratory studies of the behaviour of paste fill are complete and a report has been received from McGill University, the sub-contractor on the project. A debriefing seminar on this aspect of the work will be held when the final report becomes available for general distribution.

A draft final report for the whole project is now being prepared by Dome Mines Ltd. A series of accidents at the mine during the past year, however, prevented access to the experimental stope for several months. As would be expected, these have delayed the completion of this project, as well as another entitled "Liquefaction Potential of Dense Backfill". The final report from Dome is expected by December 31, 1988.

Falconbridge Limited, another sub-contractor on this project, has also submitted a draft final report on a survey of World Paste Fill Practices. The Falconbridge research group is currently assessing the feasibility of using paste fill for some of their backfill operations.

Project C.2.0: "In-Situ Monitoring and Computer Modelling of a cemented sill mat and confines during tertiary pillar recovery"

In cut-and-fill mining, the intervening pillars between previously-mined stopes are recovered during secondary extraction. Sill pillars, between the mining blocks and the levels, are recovered during a final, or tertiary, stage. The entire process of extracting all of the ore between levels may involve several years.

During this process, however, mining practices and economic conditions are constantly changing. The results can be great departures from original plans and large variations between the properties of fills in contiguous openings.

In order to provide increased confidence in both design methodology and extractive practices, a project, involving both in-situ monitoring of ground conditions during the extraction of sill pillars and computer modelling for predictive and back-analytical purposes, was initiated with Falconbridge Ltd. The contract, under the Canada/Ontario MDA is valued at $154,720.

At the time of writing, the project has been completed and a draft final report is being reviewed.

Some of the significant findings of the research are:

(i) The results of computer simulations indicated a close correlation between the behaviour of in-situ fill and that predicted by the computer model.

(ii) The computer model has now been used to evaluate sill mats, other than the trial area, at Falconbridge's Strathcona Mine.

A debriefing session will be held as soon as the final report becomes available for release.

Project C.3.0: "Use of Cemented Fills for Controlling Violent Failure in Pillars"

In the room-and-pillar mines in the near-horizontal tabular uranium deposits of Elliot Lake, backfill has not been used. Until recently, this has not been considered to be necessary, since the vast mined out areas have remained quite stable. Commencing about three years ago, however, there was much increased rockbursting and failures of the rib pillars in the area near the boundary pillar between the Denison and the Rio Algom mining operations. The area affected was more-or-less in the centre of the previously mined part of the ore-bearing conglomerate reef.

Experience has shown that the area affected by rockbursting in a room and pillar mining operation can grow rapidly and become extensive. The only practical remedial action may be to pour backfill around the pillars. This seems to be a method of increasing the post-yield strengths of pillars and, consequently, of limiting the growth of the failure zones.

To study the use of tailings backfill as a means of stabilizing an area which is in the process of fracturing, a project, with a contract value of $610,000, was initiated with Denison Mines Ltd. In this research, the stabilities of pillars are being monitored as a selected area is backfilled. Monitoring involves both stress measurement and microseismic techniques. A microseismic system, belonging to CANMET, has been installed in the designated area of the mine for the purpose of the study.

The research is now well-advanced, with the previously-mined stopes of the test panel area having been filled with about 120,000 tons of deslimed tailings consolidated with iron ore blast furnace slag. The area immediately up-dip from the backfill area has been seismically active - with local rockbursting pillar spalling and heaving of the floor. Because of this, the

microseismic system was redeployed to provide better coverage of the active area. Denison Mines also decided to expand the area that would be filled as the backfilled panel is less seismically active than the surrounding area.

Project C.4.0: "Computer Program Specifications for the Ontario Mining Industry"

The industry, and particularly the smaller mining operations, are in great need of computer software packages which can be used to improve operating efficiencies and productivities and to reduce costs. The needs have been expressed to CANMET on many, many occasions. At the same time, the lack of standardization and compatability of software has been mentioned as a serious concern. The industry is in need of a systems approach.

Originally, during the conception of the Canada/Ontario MDA projects, it was planned to identify a number of specific requirements for software and to sponsor the development of the packages.

With the foregoing concerns in mind and at the urging of specialists, however, it was decided that the best, and necessary, first step would be the design of a protocol. Accordingly, a contract, in the amount of $50,000 was awarded to Mining Resource Engineering Ltd., of Kingston, Ontario. The firm was charged with the responsibility of determining the computing capabilities and needs of the industry and of recommending specifications which would ensure a high degree of universality of approach over the next few years (i.e., 3 to 5 years). Recommendations concerning the choice of an operating system and a computer language were also required. The intent was to develop specifications which could be used as a standard.

The project was completed about one year ago and the final report is available. In summary, UNIX was selected as the recommended operating system, and Fortran and C as the programming languages.

At present, because all of the funds available for mining research in the present Canada/Ontario MDA have been committed, it is not likely that this particular project will be continued through the development of specific software packages. Nonetheless, through the specifications which have been established, the results of the research should be of benefit to the industry through the provision of guidelines for the acquisition and development of software.

As is elaborated elsewhere in this report, software packages are under development in some of the other MDA projects.

Project C.5.0: "In-Situ Properties of Backfill Alternatives in Ontario Mines"

In spite of the fact that a wide range of materials has been used as backfills in mines (i.e., alluvial sand, waste rock, mill tailings, slags, and mixtures of these), very little is known concerning the relative merits or demerits of these. There is a need to determine the properties of various backfill alternatives and to establish general engineering specifications.

To accomplish this, a contract, in the amount of $470,000 was signed with Falconbridge Ltd. Much of the work is being carried out at the Kidd Creek operations.

In the research, which commenced about a year ago, various types of backfill are being emplaced in openings which have been surrounded by monitoring instrumentation. The results of this large-scale comparative study should permit a quantification of

the support characteristics of fills. Further, the relationships between laboratory and field properties, once established, will permit the establishment of specifications.

At present, both laboratory testing of various binder alternatives (including slags and flyash) and physical modelling trials are proceeding according to schedules. The installation of instrumentation and field trials are also underway. Laboratory trials on copper slag and fly-ash binders, as well as field trials involving layered fill, Reiss Lime, Slag and Monolithic Packing Materials have been completed. Field Instrumentation trials are continuing at Kidd Creek Mines. Additional trials are planned.

An evaluation of anhydrides as binder alternatives is also being carried out by McGill University under sub-contract. A report is expected by January 31, 1989.

It is now anticipated that the entire project will be completed early in 1990. The results should be reliable specifications for various filling materials. Additionally, less expensive alternatives to present methods and approaches may result.

Project C.6.0: "3-D Numerical Models for simulation of Bulk Mining at Depth"

During the past decade, especially, there have been rapid advances in the analytical tools which are available to rock mechanics specialists. Numerical modelling techniques have taken the place of experimental stress analysis and are now used for engineering design purposes.

The computing requirements for the larger models, however, can be far beyond the capabilities of most organizations. For this reason "mine wide" models are very rare and are mostly the property of large international-scale consulting organizations.

There is a need, both to advance the technology which is available and to investigate ways in which it can be transferred to smaller scale computers. By doing so, it would become available to the smaller organizations which do not presently possess the specialized skills necessary.

In order to develop a sophisticated three-dimensional model, applicable on a very broad scale, and suitable for simulating a wide variety of mining conditions including non-elastic and post-failure behaviour of a rock mass, a contract in the amount of $1,000,000 was signed with INCO Ltd. The contractor will not only develop the highly sophisticated model but will also calibrate it and refine it by making frequent reference to actual in-situ conditions and measurements.

The project is progressing according to schedule and within budget.

A review of bulk mining at depth was completed in June, 1988, and it is anticipated that a report will be available shortly. Two interim progress reports for the first year of the project (1986/87), are now available for distribution. The reports treat the numerical modelling and the instrumentation aspects of the work.

Two interim progress reports, covering work completed during the second year, (1987/1988) are expected shortly. One will cover numerical modelling while the second concerns instrumentation.

Simultaneously, the development of a two-dimensional plasticity model, capable of simulating the failure zones around excavations and localized shearing, is nearly completed. The development of a three-dimensional plasticity model will commence in 1989 and will require about 18 months to complete. A technology transfer seminar/workshop on the two-dimensional plasticity model will take place in the spring or summer of 1989. The final details will be established after consultations with the contractor.

Project C.7.0: "Liquefaction Potential of Dense Backfill"

One of the greatest concerns of any mine operator using mill tailings as a backfilling material relates to its liquefaction potential. Fine-grained materials, with a high moisture content, can liquefy under dynamic loading conditions. In a worst case scenario, a seismic disturbance could cause the fill in a recently-filled stope to liquefy, break the bulkheads due to the resulting sudden increasing pressure, and to flood out into the openings below. The results, as at Belmoral (but with overburden rather than fill) could be catastrophic.

In order to define the engineering parameters involved, and to study such behaviour of fill, and particularly densified fill, a contract in the amount of $125,250, was signed with Dome Mines Ltd. The objectives were to study the liquefaction potential of dense backfill, and to develop procedures for determining the safe limits for various types of fill materials.

The project is now nearly complete. A draft final report is being prepared by Dome and is expected to be completed by December 31, 1988. A report on the Laboratory and field tests has been received from McGill University, the sub-contractor on the project. This report is currently being reviewed by CANMET staff.

The results of the research should assist the industry in establishing safe limits for evaluating the liquefaction potential of dense backfills.

CANADA/ONTARIO/INDUSTRY ROCKBURST RESEARCH AND RELATED PROJECTS

Government

As the result of the seismic events which took place in Ontario mines, in the early 1980's, an intensification of rockburst research became necessary. In May of 1984, at a consultative meeting between CANMET, industry, and representatives of the Ontario Government, this was identified as the highest priority for research.

During the following months, a number of meetings were held with representatives of the Government of Ontario and of the companies which had experienced severe rockbursting. The result was a proposal for a major tri-partite research project, in which each of the federal and provincial governments, and the industry would contribute funds and/or services to the value of $1.4 million (1).

A Memorandum of Understanding was subsequently signed in September, 1985. Under it, CANMET is providing a team of 5 persons dedicated to the project for 5 years, together with operating funds. The Government of the Province of Ontario, is contributing up to $1.4 million for the purchase of capital equipment and services. The Industry of the province of Ontario is also providing a matching contribution, with a value of up to $1.4 million, through the provision of monies, goods, and services, to the project.

Now in the fourth year of the project, it is clear that more is being committed to the research by all parties than was originally visualized. The industry, in particular, is making a major commitment to the installation and upgrading of local mine monitoring systems.

Given the needs of the industry for more rapid and precise mine monitoring, and the technological short-comings which have been identified, the research has proceeded along three lines:

1) By enhancing the seismic monitoring capabilities in all Ontario mining camps. A very high priority is to develop a seismic monitoring system that will capture wave forms (as compared with triggered first arrivals) and provide information on first motion, peak particle velocity and seismic energy.

2) By alleviating the problem of local mine monitoring systems being saturated with the signals coming from large rockbursts. Improved local coverage is being incorporated into the Eastern Canada Seismic Network by the of addition of monitoring stations in the Sudbury basin. Data from these stations are being transmitted to Science North, in Sudbury, and also to the Geophysics Division of the Geological Survey of Canada, in Ottawa. Seismograph stations will also be installed at Red Lake and Kirkland Lake to provide improved coverage for these mining camps.

Through the generosity of Denison Mines Ltd., a short-period seismograph has been installed in the Mining Research Laboratory of CANMET, at Elliot Lake. This is used to monitor events occurring both in Elliot Lake, and as far away as Sudbury.

3) Between the seismic stations of the Eastern Canada grid at one end of the scale, and the local mine microseismic monitoring systems at the other, there is a need for an intermediate out-of-mine system having the capability of being able to record the complete waveforms of large seismic events.

Macroseismic systems of this kind have now been installed; at Falconbridge's Strathcona Mine and INCO's Creighton Mine, both in the Sudbury basin (Fig. 3); at Rio Algoma's Quirke Mine, at Elliot Lake; at Campbell Red Lake Mines, at Balmertown; and at the Macassa Mine, in Kirkland Lake. Waveforms from large local events is being stored on computers at these sites and down-loaded daily to CANMET's Elliot Lake Laboratory via telephone.

The objectives of the Canada/Ontario/Industry rockburst research project are to add to our knowledge of the causes, origins, effects, energy sources, and mechanisms of rockbursts.

The information to be derived from the three levels of monitoring systems mentioned will permit much greater accuracy in locating the origins of mining-induced seismic events. Macroseismic systems, in particular, will be very valuable when events occur outside of existing microseismic sensor arrays.

Likewise, the recording of waveforms will permit determinations of peak particle velocities and seismic energies liberated. This will add considerably to our knowledge of the driving forces and the mechanisms which may be involved.

Related Projects

During the early years of the project two Canadian organizations were involved in the design of improved systems for mine monitoring. These were completely complementary inasmuch as one system was intended for macroseismic monitoring applications, while the other was intended for use in underground mine microseismic monitoring. Both involve improved sensors and recent advances in communications, such as fibre-optics technology.

The first system mentioned, for out-of-mine local macroseismic monitoring was developed by the Noranda Research Centre of Noranda Mines Ltd. The newly-developed system has now been installed and is being field tested at the Quirke Mine in Elliot Lake. The system will permit the recording of complete waveforms of large seismic events.

The second system, for in-mine monitoring, was developed by Instantel Inc., of Kanata, Ontario. Involving tri-axial sensors with local microprocessors, fibre optic data transmission, more intelligent triggering algorithms, and dedicated computers, the system is intended to be the next generation of monitoring equipment. The prototype unit has now been installed and is being field tested.

Both systems were developed with financial assistance from the Government of Canada - the former through the Unsolicited Proposals Program of the Department of Supply and Services; the latter through the Projects for Industry/Laboratory Participation (PILP) program of the National Research Council.

CANADA/NEW BRUNSWICK MDA - PROJECTS ON POTASH MINING AND CO_2 SURROGATE

Nearly all of the sectors of the Canadian mining industry, with the exception of gold, suffered terribly from the depressed metals prices of the early 1980's. In New Brunswick, because of a narrower resource base, the problem was especially acute. In the base metals category only Brunswick Mining and Smelting was operating during that period.

As elsewhere in the industry, the key to continued operations lies in improved efficiency and productivity. Costs of operations continue to rise while the prices realized for output remain at low values. Long-term viability will depend, in large measure, on a continuing ability to reduce the unit costs of production.

At Sussex, a new potash mine, owned by the Denison Potacan Potash Company is now in production. The mine came into production concurrently with the decline in the prices paid for potash. Consequently, the same considerations of improving efficiency and productivity also apply.

It was against this background that the conception of mining research projects took place. Unlike the discussions in the other provinces, however, there were two stages in project implementation. In the first, during the original planning cycle, research was to be directed exclusively towards potash. Later, as additional funding became available, the projects were expanded to include metal mining. As will become clear after reading a later section of this paper, on the Canada/Saskatchewan MDA, the initial focus on potash permitted a maintenance of the momentum of research that had been developed in the mines of Saskatchewan, and which was in danger of flagging because of the completion of those research projects. The MDA with New Brunswick, and an early emphasis on potash mining technology, fitted nicely into the overall pattern of national needs.

The potash-related project now in progress in New Brunswick is:

Project II.5: "Use of Backfill in New Brunswick Potash Mines"

Potash mining in Canada is essentially a "one-pass" type of operation. Rooms are mined in a series of passes using highly mechanized boring machines. The rate of advance is very rapid and total extraction of mineral probably averages about 40%. The intervening pillars between rooms are not mined, nor is backfill used. The present economics of potash mining are said to preclude the use of fill. The extraction ratio is low by design in order to provide long-term stability both of the rooms and of the overlying strata.

In the long-run, however, the low extraction ratio will result in a loss of reserves.

A second problem is that the potash is interbedded with salt. Because of contamination with other minerals this salt is not usable for any purpose. After separation during milling, therefore, it is transported to storage piles on the surface. In the future the ultimate disposal of the waste salt will pose a number of environmental concerns.

The project in New Brunswick was designed to address both of these concerns. Under a $214,740 contract with the federal government the Denison Potacan Potash Company is evaluating the stabilizing effect of waste salt as a backfill in mined openings.

In the first phase of the work, now completed, a study was made of the engineering properties of waste salt backfill, and of the effects of additives on strength. The costs and benefits of alternative stowing procedures have been assessed. Finally, using numerical methods of stress analysis, determinations were made of the effects of backfilling upon convergence and the creep of mine openings. The results have shown that at least ten years are required before backfill provides roof support.

A debriefing session for the first phase of the project was held on September 4, 1987.

At present, a second phase of the work, at a contracted cost of $199,130 is in progress. This aspect of the project is scheduled for completion by the end of March, 1989. To date: the instrumentation around a trial stope has been installed; computer modelling to identify suitable mining geometrics and permissible ground relations for mining long secondary stopes in pillars; and laboratory determinations of the properties of highly consolidated fills, are in progress.

A third phase, at a contracted value of $150,500, is also in progress and scheduled for completion on June 23, 1989. In this phase, CANMET is contributing $63,370 to the work while the company is contributing the remainder. A microseismic monitoring system, to identify the reactions of the hanging wall to mining will be installed after an evaluation of presently-available technology has been completed. A comparison will also be made of the outputs resulting from computer simulations of a standard mining sequence using both the GEOROC and VISCOT codes.

Other projects, including: the calibration of a subsidence model for potash mines; the monitoring of strain energy release with potash mining; the improved transmission of rock mechanics monitoring data; and improved cutting technology in order to reduce dust production, have been prepared as possibilities for inclusion in a renewed MDA. Discussions with industry, to define research needs and priorities, are on-going.

Project: "CO_2 Surrogate"

In Canadian mines recirculation ventilation offers the possibility of achieving substantial savings on the costs of heating mine air. One of the key concerns, however, is the extent to which air can, and should, become polluted.

Previously, in a cooperative project on diesel emissions (involving Canadian and American scientists), it was demonstrated that the concentration of all of the major exhaust pollutants were functions of CO_2 concentations. The measurement of carbon dioxide concentrations, therefore, offers the possibility of simple and less expensive systems for mine monitoring and, eventually, automated control. Measurements of all of the pollution constituents is laborious, costly, and expensive.

In this study, which is the subject of a $107,000 contract with Brunswick Mining and Smelting through the Canada/New Brunswick MDA, the pollutants in the air in a mine level on which several machines are operating is being characterized. The objective is to determine the limits of the relationships between concentrations.

As a second stage, assuming that positive results are obtained, an automated ventilation system will be designed. The results and the technology will be applicable to many Canadian mining operations - and especially to those in the north in which the conservation of heat is a key issue.

As a part of the project "CO_2 Surrogate" considerable emphasis has been put on the ventilation modelling aspect of the project. The design of a ventilation model using the CANMET Thermodynamic ventilation model as the engine, along with AutoCad as the user-interface, has been completed. Programming has started and the first version will be computed in January, 1989.

Noranda comments that the CANMET ventilation program finds application in all of their operations.

Project II.14: "Non-destructive Testing of Mine-Shaft Wire-ropes

The objectives of this project is to enhance the understanding of the basic capabilities of various mine shaft wire rope non-destructive testing (NDT) instruments, and of the associated chart evaluation techniques which are used in Canadian practice in general, and New Brunswick in particular.

A series of laboratory and in-situ non-destructive wire rope examinations will be performed on ropes that characterize the sizes (from 1/2 inch to 2-1/4 inches) and constructions most widely used in New Brunswick mines. Many of the rope samples needed will be tested in-situ in New Brunswick. Laboratory tests will also be performed on rope samples exhibiting both operational and artificial anomalies. It is intended that the instruments to be used for the NDT of the wire ropes include the Canadian testing instruments, Rotesco AC, Rotescograph and Magnograph, the American LMA series instrument of NDT Technologies Inc., and the latest version of the German WBK-Seilprufstelle instrument. The European tester is of interest because it has recently been redesigned at a heavy cost. It is desirable that this project benefit from any such improvements.

The instrument Performance Standards and the number of rope samples tested will be in accordance with "The Performance Requirements for Electro-Magnetic Mine Shaft Wire Rope Testing Devices" of the Ontario Ministry of Labour, Mining Health and Safety Branch.

Instrument operators will be nominated by the instrument designers/makers themselves.

Destructive testing of wire ropes will be done in the laboratory of Wire Rope Industries Ltd. at Montreal in a manner designated by provincial legislation.

The project is being monitored and controlled by a steering Committee composed of representatives of the Province of New Brunswick, CANMET, Tektrend (the principal contractor) and one or two experts from the principal sub-contractor (Wire Rope Industries Ltd.).

After signing the contract for this project on July 4, 1988, progress has been very satisfactory. Field tests have, so far, been performed on five operational ropes at several mine sites, including two in New Brunswick. Some of these ropes are already on their way for laboratory testing. Moreover, details have been settled of the type of artificial defects that are to be introduced in the test ropes. The latter are to be produced by late December, 1988.

The Steering Committee has met twice so far (on July 28 and October 3, 1988). Minutes of these meetings are available on request. They contain detailed information about progress to date.

CANADA/NORTHWEST TERRITORIES EDA - PROJECTS ON PILLAR RECOVERY

At present, it is too early to report on progress being achieved on projects which are being implemented in the Northwest Territories. The Canada/NWT EDA was signed in mid-1987 and many discussions have been held at various mines to determine research needs and priorities. Because of the vast distances and the logistics of travel in the Arctic some time has been required.

Project: Pillar Recovery in Permafrost

The second project will involve the design of a pillar recovery system for Nanisivik Mines Ltd., at Nanisivik, on north-western Baffin Island in the high Canadian Arctic. Up to the present, mining of the horizontally-oriented tabular deposit in permafrost has involved primary stoping. Approximately 800,000 tonnes of ore (roughly 15% of the original reserves) is committed to pillars. If total recovery can be achieved, the life of the operation can be extended by at least one year.

In this project, which will cost an estimated $70,500, the Company will contribute $17,600 and the Northern Technology Assistance Plan, NTAP, a further $52,900. The objective is to develop a conceptual mining plan.

Project: Numerical Modelling of Pillar Recovery in Permafrost

In a directly-related project, which is a second phase of the above, a numerical model will be developed as a tool to aid mine operational personnel in monitoring the effects of pillar recovery, calibrating the model, and adjusting recovery strategies as necessary and appropriate.

The research challenges are very great and involve applying the entire rock mechanics technology from in-situ stress determinations and laboratory strength measurements onwards to perennially frozen deposits. In essence the frontiers of rock mechanics will be pushed to geographical frontiers.

The project is estimated to cost $235,000 and should be completed by mid to late 1989. Of the total, the company will contribute $67,600 and CANMET/MRL $51,000. Funding of $116,400 is being sought from NTAP.

CANADA/SASKATCHEWAN MDA - PROJECTS FOR POTASH MINING

The federally-funded mining research which has taken place in recent years in the Saskatchewan potash mines can be divided into two phases. In the first of these, which preceded the Mineral Development Agreements by about two years (i.e., 1983 to 1985), approximately $443,000 was committed to mining research through the START (Short-Term Assistance for Research and Technology) program. Many of the immediate needs of the industry were perceived as having been met, therefore, when the discussions leading to an MDA took place. As a consequence, the amount allocated through the MDA was much reduced from the previous level.

In a strict sense the purpose of this paper is to review the work in progress under the various federal/provincial MDA agreements. By doing so, however, without reference to the major commitment of funding to the START projects which immediately preceded the MDAs, one could give the wrong impression that a major area of research needs is not being addressed. Thus, for purposes of record, a list of the START mining research projects is given in Table 1. No descriptions are provided in this paper as doing so would involve considerable space and would duplicate reporting which has taken place elsewhere. For further details the reader is referred to the proceedings of a technology transfer seminar which took place, in Saskatoon, in 1984 (2).

The two projects now in progress were implemented after discussions with, and on the recommendations of, the Research Committee of the Saskatchewan Potash Producers' Association (SPPA). During the past two years that group has achieved consensus on the needs and priorities for research in the potash mines of their province. Discussions are now taking place regarding a possible third phase of research for the not-too-distant future.

The present projects under the MDA are:

Project: "Research on Microseismic Technology"

As mentioned earlier, the problems of rockbursting have been acute in the hard rock mines of Ontario in recent years. Research has also taken place in Saskatchewan, with a microseismic monitoring system having been installed at one of the Potash Corporation of Saskatchewan (PCS) mines.

In this project, the objectives are to participate in the important microseismic research projects which are currently in progress at McGill and Queen's University and at the University of Saskatchewan. These address research into low frequency microseismics (Saskatchewan), geotomography (Queen's), and high-frequency acoustic emissions (McGill). The research is in progress.

The federal contract in support of this work, in the amount of $40,000, is in place with the Potash Corporation of Saskatchewan. This funding is matched by the SPPA.

Project: "Regional Subsidence Related to Potash Mining"

The objectives of this project are to update the analysis methodology applied to subsidence data from the potash mining fields and to improve the capabilities in prediction. Current methods of collecting subsidence data are very labour-intensive and require long traverses over mining areas. Simultaneously, there is a need for a predictive model applied specifically to potash mining.

TABLE 1

CANMET/MRL Mining Research Projects Completed in Saskatchewan Under the START Program

1983-1985

Title	Contractor	Value of Contract
Alternatives to Present Potash Mining in Canada	MONENCO	$ 52,040
Assessment of Possible Problems in Regional Mine Stability with Future Mining of Saskatchewan Potash	Potash Corp. of Saskatchewan	$ 89,879
Creep Cell Evaluation and Laboratory Testing of Large Evaporite Samples	Saskatchewan Research Council	$39,938.50
Numerical Modelling Package to Design Underground Openings in Potash	RE/SPEC Ltd.	$ 47,579
Determination of Engineering Properties of Waste Salt for Backfilling Underground Potash Mines	RE/SPEC Ltd.	$ 25,250
Dust Measuring Techniques and Dust Levels in Potash Mines	The Cambrian Eng. Group Ltd.	$ 27,000
Absolute Convergence Measurements in Potash Mine Openings	Cominco, Ltd.	$ 41,717
A Field Test Program to Evaluate the Use of Waste Salt Backfill in Saskatchewan Potash Mines	Central Canada Potash	$ 120,000

The work has commenced, through a federal contract, in the amount of $50,000, with Central Canada Potash. The funding is also matched by the SPPA. Progress on the project is reported to be proceeding according to plans with computer programs having been successfully modified for "friendliness" and interactiveness.

CONCLUSIONS

The entire process of conceiving and implementing mining research projects through the federal/provincial MDA agreements cost-sharing arrangements has had several significant effects on both the pattern and quality of mining research in Canada. It is to be hoped that the trend will continue because change in direction has been highly desirable. Some of the key features have been:

1) The projects have, usually been designed through a consultative process involving two levels of government and representatives of either provincial mining associations or industry, or both.

   The process of determining research priorities has improved with each successive agreement. Increasingly, consultations commence earlier and involve more people.

2) Because of this, the work that is initiated is in direct response to the needs of industry. Relevance of the work and applicability of the results is virtually guaranteed.

3) The work itself is mostly being accomplished by industry through government contracts. During the past four years this has meant that the percentage of MRL's financial responsibilities allocated to extramural research have increased from about 5% to about 50%.

4) Further, the scale of the typical research project has changed. Not so long ago, research contracts of the order of $10,000 to $20,000 were the norm. From an inspection of the projects listed in this paper it can be seen that there has been an almost tenfold increase (on the average). Many of the projects listed are in the vicinity of a quarter to a half of a million dollars each. The first million dollar contract has now been signed (under the Canada/Ontario MDA, for the development of a large-scale numerical model).

5) Largely as the result of the MDAs, mining research has come out of the laboratories and into the mines. Bench-scale projects have been replaced by full-scale field demonstration projects. The impact of this is bound to be colossal.

6) The consultations involved in designing, implementing, and monitoring of the projects has led to vastly improved communications between government and industry. Communications with industry have generally been good in the past. At present, however, in many areas these are now outstanding.

7) These communications have led to an increased collaboration and partnership in research. This is financial as well as physical. Nearly all of the projects mentioned in this paper involve not only federal funding but also substantial commitments on the parts of the companies involved. "Dollar matching" is common; in many cases companies are contributing substantially more.

8) The MDA agreement discussions have created a new framework within which research needs can be defined and priorities attached to these, and then followed with project implementation. This has instilled confidence and trust in working with government. The MDA process has been spectacularly successful. It is to be hoped that the model will be continued.

At the time of writing, discussions have been underway with many of the Provinces and Territories, concerning the projects which might be included in second-round successor MDA's (i.e., MDA IIs). Because of the confidential nature of such discussions, it is not appropriate to list the projects which have been proposed at this time. It can be said, however, that MRL has been involved in technical discussions with all of the political divisions in which MDA I projects are nearing completion and also with the Atlantic provinces of Newfoundland and Nova Scotia. Likewise, talks have also taken place with counterparts in Quebec, Alberta, and the Yukon Territory. Meetings in B.C. are expected in the near future.

Should the second round of MDA's be signed and should our discussions result in projects, the result will be a further major shift in the pattern of mining research in Canada. Not only will more funds be devoted to industry-driven and performed research but also the geographic distribution will be altered towards a wider regional coverage. In so doing, MRL will achieve a truly national mandate.

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