Energy, Mines and Resources Canada
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CANMET

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

Mining Research Laboratories
Laboratoires de recherche minière

CANMET-UNIVERSITY PROGRAMS IN MINING INNOVATION

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MINING RESEARCH LABORATORIES
DIVISION REPORT MRL 89-27(OP)(E)

CANMET–UNIVERSITY PROGRAMS IN MINING INNOVATION*

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Canada Centre for Mineral and Energy Technology

ABSTRACT

CANMET has been operating as a Government Technology Centre for two years. Many of CANMET's programs involve long-term research and require special expertise, often available at Canadian universities. CANMET's involvement with universities ranges from research grants and contracts to exchanges of scientists and joint use of research facilities.

Good examples of CANMET–university cooperation arise in the mining innovation field. Seismic monitoring research is carried out at the University of Saskatchewan to identify rock bursts in evaporite mines for their eventual prediction and control. Tomographic techniques developed at Queen's University offer greatly improved understanding of rock mass support characteristics. The University of Waterloo is involved in a study directed at using waste salt as backfill material to increase extraction ratios. Université Laval has recently completed a study on the impact of bonus and other factors on underground accidents.

Introduction

In the last two years or so CANMET has undergone a significant metamorphosis, resulting in greater emphasis on applied research that will enhance Canada's industrial capability. Specifically, CANMET has been designated as a technology centre under the Government's Technology Centres Policy. Under this policy, CANMET and other technology centres have a mandate to work directly with Canadian industries, to help Canadian companies become more competitive and innovative through the development and adoption of advanced technologies. As a technology centre, CANMET places considerable emphasis on joint projects with industry, to ensure that technologies developed during its research and development are transferred as quickly and effectively as possible to the industries involved.

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* *Ce texte est également disponible en français.*

CANMET's new mandate is reflected in the type of projects it undertakes, and in the priority assigned to work. Most emphasis is placed on two categories of projects: strategic R&D, which will enable CANMET to maintain the technological base that is key to future industrial development; and incremental R&D, which largely involves development and improvement of existing technologies and knowledge. The balance of CANMET's effort is allocated to providing Mandated and Specialized Services, and to Exploratory Research. Figure 1 shows the schematic relationship between these four research and development areas, and the timeframe and notional level of effort allocated to them.

large

short term	INCREMENTAL R AND D (35%)	STRATEGIC R AND D (45%)	long term
	MANDATED AND SPECIALIZED SERVICES (10%)	EXPLORATORY RESEARCH (10%)	

small

Fig. 1: CANMET's Categories of Projects

The paper reviews major interaction modes with universities, including contracts, research grants, exchanges of scientists, student employment and nomination of professors on CANMET's advisory council. The discussion then introduces various EMR research grants to university projects in mining. The last part of the paper deals with numerous modes of contracting or sub-contracting industrial research projects to university professors with specific mining expertise. Such expertise may stem from previous work initiated under EMR research grants.

CANMET-University interaction

Because of the emphasis on support to industry, CANMET also gives priority to projects that clearly have an industrial client. Often the relevance of research to industry is best manifested by having a client ready to contribute significantly to the project, either through funding or by performing part of the research. This is the principal reason for CANMET's current thrust toward joint work with industry.

This priority given to applied R&D that is directly relevant to industry has led to criticism that CANMET is neglecting long-term research, and in particular is neglecting the contribution that Canada's universities can make to the development of the mining, mineral and energy industries in Canada. While it is true that CANMET now gives high priority to cooperative R&D with industry, CANMET's interaction and cooperation with universities remain strong, and will continue to be a vital part of the total R&D program at CANMET. Major modes of interaction follow.

Contracts

CANMET relies heavily on universities to contribute to its program of contracted research. In fiscal year 1988-89 – from April 1, 1988 to March 31, 1989 – CANMET awarded research contracts worth nearly $15 million. More than $3.5 million, or 24% of the total contract budget, was allocated to 80 contracts with Canadian universities. In addition, universities often act as specialist subcontractors to CANMET's main contractors. While statistics on such subcontracts are not readily available, their value is estimated at another $1.5 million in 1988-89. Thus, about one third of CANMET's 1988-89 contract funds were spent at universities.

The criteria for awarding contracts and subcontracts to universities are the relevance of the proposed work to CANMET's mission, and the uniqueness of the research team's expertise and knowledge.

Allocating one third of its contract budget to university researchers demonstrates the importance both CANMET and its industry clients attach to involving university researchers in technology development for the mining, mineral and energy industries.

Research Grants

The Natural Sciences and Engineering Research Council (NSERC) is the major source of university research grants in the areas in which CANMET is involved. CANMET participates in the work of NSERC by evaluating proposals and by providing liaison officers to monitor progress of research, particularly under the NSERC university-industry program. In this way CANMET plays an important role in helping bring these joint projects between universities and industry to a successful conclusion.

CANMET also allocates a portion of the Research Agreement funds administered directly by Energy, Mines and Resources Canada. Although the funds available to CANMET are modest - $400,000 for 1988-89 - they are used to seed important research in universities. Unlike contracts, research grants are not tied to firm deliverables, and thus allow the recipient considerable flexibility in directing the course of his or her

research. In 1988-89 CANMET's direct research grants supported work at 41 Canadian universities.

University Exchanges

CANMET staff are very active in teaching at universities, and in supervising graduate students. At any time, there are typically 15 to 20 graduate students doing their masters or doctoral thesis work at CANMET's laboratories; their work is done under the guidance of CANMET's scientists. Many of these scientists are associated with universities; currently (spring 1989) CANMET scientists hold adjunct professorships and teach part time at 11 universities. Numerous others teach short courses and give seminars.

There is less movement of university staff to CANMET. Typically, only one or two professors at a time spend their sabbatical leave in CANMET's laboratories, or work there on secondment. CANMET would like to increase the number of university professors with projects in CANMET's laboratories, while continuing to encourage CANMET's personnel to work on secondment in universities. The cross-fertilization of ideas that comes with such exchanges is very valuable in stimulating research both in CANMET and in university laboratories. University researchers are also served well by the exposure they get to industry's needs, particularly when they are seeking industrial support for their research.

There are a number of secondments underway within the mining sector. One researcher is helping a Laval University professor coordinate a QMA project on narrow vein mining; three other mining scientists are part-time adjunct professors at as many universities; many other scientists help universities by teaching special topics or complete courses at various universities.

Student Employment

CANMET regularly employs students for both summer and term employment. Because of its diverse areas of research in its five main laboratories, CANMET has provided excellent training for graduate and undergraduate students in research, research administration, and technical services to researchers. Students are encouraged to participate in research projects that will lead to patentable developments and scientific publications.

In recent years CANMET has increasingly participated in cooperative student programs by providing term employment to students enrolled in cooperative study programs across Canada. Because of their concentrated work experience gained at the same time as they complete their formal studies, co-op students form a particularly valuable

pool of future researchers, both for CANMET and other laboratories in the public and private sector. In recent years CANMET has hosted co-op students from universities in Vancouver, Victoria, Sherbrooke, Laval, Waterloo, and Halifax, amongst other cities. In 1988-89, 197 students – including co-op, summer and graduate students – from 24 Canadian universities worked in CANMET's laboratories for periods ranging from one month to a year.

CANMET's Advisory Council

CANMET receives formal advice and guidance on its research programs from the series of committees that make up the Minister's National Advisory Council to CANMET (MNACC). While the majority of the members of MNACC are drawn from industry, reflecting CANMET's principal objective of supporting technology development in industry, academia plays an important role. At December 1988 the committees included ten full time university professors among their 69 members.

Mining Research Grants

As mentioned earlier, funds available under this program are modest. Mining related projects account for $135,000 out of the $400,000 available to CANMET, or 33.8% of the amount. In most cases, projects are of an applied nature and are out of NSERC jurisdiction, but are still too preliminary to receive assistance from industry. Most projects are subsidized for two or three years, according to the investigated subject importance and complexity. Table I lists mining related projects and shows their diverse interests.

Projects receiving a grant in 1988-89 cover almost all aspects of mining activities: drilling, fragmentation, rock mechanics, backfill, hoisting, ventilation, operation automation, selection of mining methods. When selecting projects of equal value, a fair distribution of funds is sought among universities across the country.

Over the last few years, quality of proposals has noticeably improved and, consequently, competition for funds has intensified. Some projects may be eliminated on the basis of similarity with ongoing projects elsewhere in Canada. Sometimes, financial limitations prevent subsidizing comprehensive proposals with innovation potential. Many projects subsidized under this program in the past have led to applied technologies useful to industry today.

TABLE I: Examples of 1988-89 Mining Research Grants involving university mining research groups

APPLICANT AFFILIATION	TITLE OF PROJECT	CONTACT OFFICER	FUNDS IN ($) AWARDED
V.K. Garga Ottawa	Application of hybrid district boundary element analysis on jointed rock masses to near-surface mine openings and related surface crown pillars	S. Vongpaisal	9,500
D.J. Gendzwill Saskatchewan	Natural and induced seismicity in Saskatchewan	D.G. Hedley	15,000
T.S. Golosinski Alberta	Investigating into continuous selective surface mining technology	R.K. Singal	13,000
A.E.Hall British Columbia	Study to investigate the feasibility of introducing controlled recirculation of air ventilation in Canadian underground potash and metal mines	S.G. Hardcastle	20,000
A. Piché Polytechnique	Automatisation de l'opération d'un brise-roches par rétroaction visuelle	N.R. Billette	13,000
G.A. Rubin Laurentian	Weakening and fragmentation of hardrock by high power sonic or ultrasonic resonance	J. Pathak	20,000
M.J. Scoble McGill	Application of automated blasthole drill monitoring to blast design in surface coal mines	D.B. Stewart	12,000

Contracts and subcontracts in Mining

This section is devoted to various modes by which CANMET contracts or subcontracts research or development work to universities. Three kinds of intervention in mining are shown hereafter: Unsolicited Proposals, Mineral Development Agreements, Industrial Research Assistance Programs.

Unsolicited Proposals

The Unsolicited Proposals Program is administered by Supplies and Services Canada. Two projects are described under this heading, one dealing with productivity, the other with geotomography.

Productivity in Quebec Mining Association Mines

Following the Belmoral crown pillar failure in 1980, a Royal Commission recommended the abolishment of mine bonus systems, because they were considered a major cause of accidents. The Université Laval undertook a study, partially subsidized by CANMET, that concluded in 1985 no linkage between accidents and bonus. A positive link, however, was noted when production activities were isolated from service and development activities. The correlation for this specific activity was suspected to rise from links with another one, namely the level of activity or productivity.

The Quebec Mining Association (QMA) studied the report and decided to investigate the subject. Member mines voted $40,000 to the project and asked equivalent amounts both from the Quebec and Federal Governments. The Unsolicited Proposal program was selected to tap federal financing: $45,000 was granted to the $122,914 project. The project was subcontracted to Université Laval. Work by the Mining Engineering Department must be completed by the end of March 1990.

The contract calls for the following tasks to be completed:

1. **Selection of participating mines.** Seven companies from three Quebec mining camps - Val d'Or, Matagami and Chibougamau - agreed to participate.
2. **Data collection.** Information such as mining methods, economic data, equipment used, rock quality and support, material consumption rate, dimension of openings and haulage distance is essential.
3. **Computerizing data.** Most information cannot be directly transferred to Université Laval's computers, due to incompatibilities, and much data must be manually transferred. Many checking steps must then be taken to ensure the integrity of the transferred data.
4. **Data processing.** Data needs to be modified to suit further statistical processing techniques. Qualitative rock quality data has been scaled from 0 to 1.
5. **Analysis of results.** The most important and trickiest part of the contract! Erroneous conclusions can so easily arise from superficial analysis of statistics.

The project must study the relations of a number of variables with underground productivity. Preliminary conclusions include:

1. The selected period of investigation is critical if aiming for significant results in bulk mined stopes.
2. At a mine where a winze is used to access a number of stopes, production is reduced by one third compared to stopes accessed by the main shaft (figure 2).
3. Bolting pattern should be affected by the rock quality encountered. In practice, however, each bolt supports about 10 tons (figure 3) in all rock conditions encountered. Posts installed vary with rock quality in room and pillar stoping.
4. One of the mines compiled statistics of scoop numbers and total tonnage hoisted to surface. Correlation of the two variables has shown a reduction in fill factor when the number of scoops per period increases (figure 4).
5. Production from a stope declines when increasing the number of miners in a period. Familiarization with the stope particular environment may be a major cause of reduced productivity.

Geotomography in hard rock mines

Geotomography is a developing technology very similar to the scanning electron microscopy used in medecine for locating brain tumors. For rock, the system operates much in the same way, with holes drilled a minimal distance apart. A small charge is detonated in one hole and seismic waves recorded at the others. Minute time variations occur in wave propagation due to joint encounter, and the method calls for finding these joints, their orientation and true length on various sections or planes, from which a three-dimensional image of the rock mass and joints emerges. Such a technique would offer greatly improved and cost effective understanding of rock mass behaviour.

Expertise in the field lies with Queen's University professor Paul Young, who is being supported by the Unsolicited Proposal program to assess the technical feasibility of the method in the Canadian Shield hard rocks.

The Pierre Beauchemin mine of Cambior Inc. in Rouyn-Noranda has been selected as a test site. Results obtained during a trial in late 1988 were excellent. Technical instrumentation resolution has been assessed with good signal to noise definition levels. Interpreted data should be available in the near future, with more tests to be carried out later in Val d'Or on a mine crown pillar.

Industrial Research Assistance Program

Kiena Mines of Val d'Or tried a small diameter tunnelling machine in the mid-eighties with relative success. From that experience, Falconbridge Ltd., the mine owner, decided to build an eight-foot diameter machine strong enough to cut Precambrian Shield hard rocks. The Federal Government contributed through the Industrial Research Assistance Program (IRAP) administered by the National Research Council to the feasibility of a full face tunneller in 350MPa/50,000psi rock. Federal participation to the project amounts to close to a million dollars or about 20% of total cost and covers mainly conceptual expenses and machine construction.

Engineering costs include rock quality assessment for correlation of machine performance to rock environment. Laurentian University, part of the Centre of Excellence in Rock Mechanics, has been subcontracted to develop appropriate tests and a data base for Precambrian rock drillability. Rock penetration criteria need to be standardized in a way useful to define Shield rock cutability.

If successful with the eight-foot tunneller, Falconbridge and its partners are interested in the data base for future development of the technology. Drifting of production openings would be the next step.

Mineral Development Agreement Programs

Two of many projects in mining are described under this heading, one dealing with seismic monitoring of mining induced earthquakes in Saskatchewan evaporites, the other investigating salt stowage in New Brunswick potash mines.

Seismic monitoring of mining induced earthquakes in evaporites

Professor Gendzwill of the University of Saskatchewan receives an EMR Research Grant, and receives support from the Saskatchewan Mineral Development Agreement (MDA) for $30,000 ($15,000 from federal funds). The cost shared contract calls for recording mining induced earthquakes in potash mines; recognizing earthquake potential threat to future operations; and analyzing earthquake patterns in various parts of the potash field.

To carry out the aforementioned assignment, seismic monitoring instruments have been installed in two Saskatchewan evaporite mines located at opposite ends of the field. Special monitoring equipment was developed for recording complete seismic waveforms as well as special software for proper data interpretation. On-going data analysis aims at defining potential long term occurrences, failure mechanisms, triggering modes and stress heterogeneous response within the field.

Although no immediate threat exists for potash miners because no damage has yet been caused by mining induced earthquakes, the aquifers overlying the evaporite layers represent a Damocles sword. Loss of a mine by inflows costs tens of millions of dollars in economic benefits and safety hazards may be greater than expected.

Potash Stowage in New Brunswick

New Brunswick potash mines are required to return waste salt underground to reduce surface storage. In 1985, the New Brunswick Mineral Development Agreement (MDA) provided funds to investigate if waste salt can provide underground support if properly stowed. Field and laboratory investigations were carried out, followed by numerical modelling to quantify the support provided to roof, wall and floor strata in mined out sections of the potash orebody. New Brunswick potash deposits are small and structurally complex; higher extraction ratios will result in important economic benefits.

Denison-Potacan Potash Company submitted a proposal in July 1985, jointly with the University of Waterloo and Mraz Project Consultants of Saskatoon, for the first Phase of a two-phase project.

i) Phase I

Phase I, a two year contract, amounted to $210,000. The University of Waterloo WATSALT laboratory had to conduct creep tests to establish steady state strain rates for the ore bed, and for the roof and floor strata (figure 5). Failure envelopes and elastic moduli were determined. Strength and deformation properties were then incorporated into a constitutive model to identify deformation and stresses in potash openings with the aid of numerical analysis. In addition, consolidation tests were carried out to identify the range of densities that may be achieved in-situ for the fill material. These tests were followed by surface and underground placement trials at the minesite. Tests highlighted that water content has a major influence on salt fill compaction (figure 6) and that placed fill has limited roof support capability prior to gap closure and significant elimination of porosity.

At the University of Waterloo, a number of two- and three-dimensional numerical models were also developed/modified and applied to the mining geometries of Denison-Potacan. A good agreement was obtained from comparison of numerical modelling output and in-situ deformation measurements by extensometers and convergence meters. The effect of backfill on roof and wall displacement is very noticeable and will create a problem for quick transfer of overburden load through roof strata to the backfill, unless closure rates are increased in first stage mining.

ii) Phase II

In 1987, the two-year $190,000 Phase II project was started to verify results of Phase I by conducting a field trial. Additional laboratory work and numerical modelling were identified to optimize mining sequence and backfill placement to achieve safely and economically second stage mining in Denison-Potacan pillars. The project Phase II called for execution of the following tasks:

1. Identify stress buildup, field porosity and in-situ density of waste salt backfill.
2. Determine roof, wall and floor convergence and stresses in a backfilled room and compare them to those of an empty mining room for the purpose of verifying numerical modelling results.
3. Analyze fill effect and mining geometry on hanging wall and footwall deformation, and the potential damage to hanging wall and surface strata.

The university share of the first phase contract was 36% and of the second phase 25%. The combination of university researchers and their special facilities, consulting experts and mining company professionals has been very effective to achieve practical results within a time frame valuable to potash mining in New Brunswick.

Conclusion

The preceeding overview of CANMET's involvement with universities across Canada has shown that its research mission is still very much alive. Universities find many ways of associating with CANMET in basic research and technology transfer. Interaction modes range from student employment and researcher exchanges to research grants and contracts. Sharing of expertise may be as much in fundamental as in applied research and technology development.

In mining, research grants allow university personnel to investigate more fundamental topics. A fair number of these have led to industrially applied technology, directly or through developing mining engineering skills needed to apply them.

Three additional funding programs were discussed in the paper: Unsolicited Proposals, Mineral Development Agreements and Industrial Research Assistance Program. Under these, a number of projects were highlighted, showing integration of university expertise to solving existing problems.

In the past, universities and CANMET have cooperated in research and development to better serve the mineral, metals and energy industries. University specialists are a reservoir of ideas in a number of technological areas useful to industries related to CANMET's technology mandate. In future, CANMET intends to maintain its privileged links with universities, for improving technologies used or needed in the mineral and energy industrial sectors.

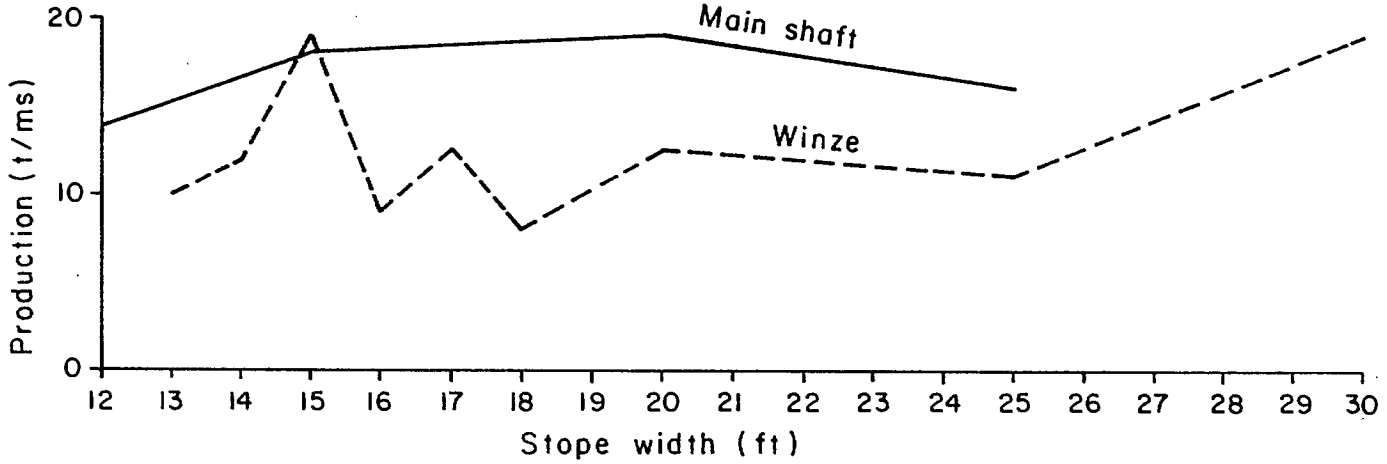

Fig. 2: Production from cut & fill operations at Mine A

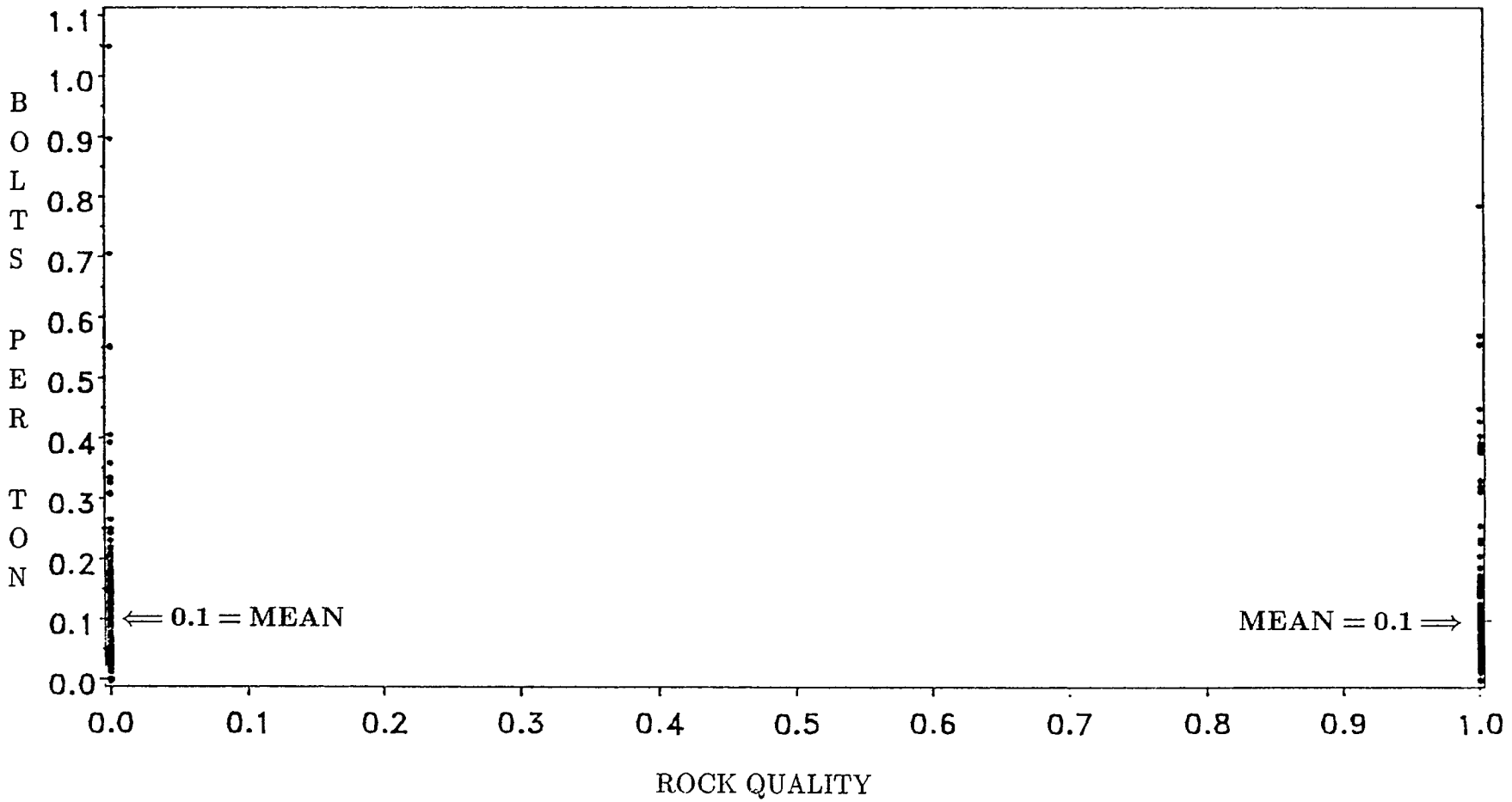

Fig. 3: Bolts installed in different ground conditions at Mine A, room & pillar operations

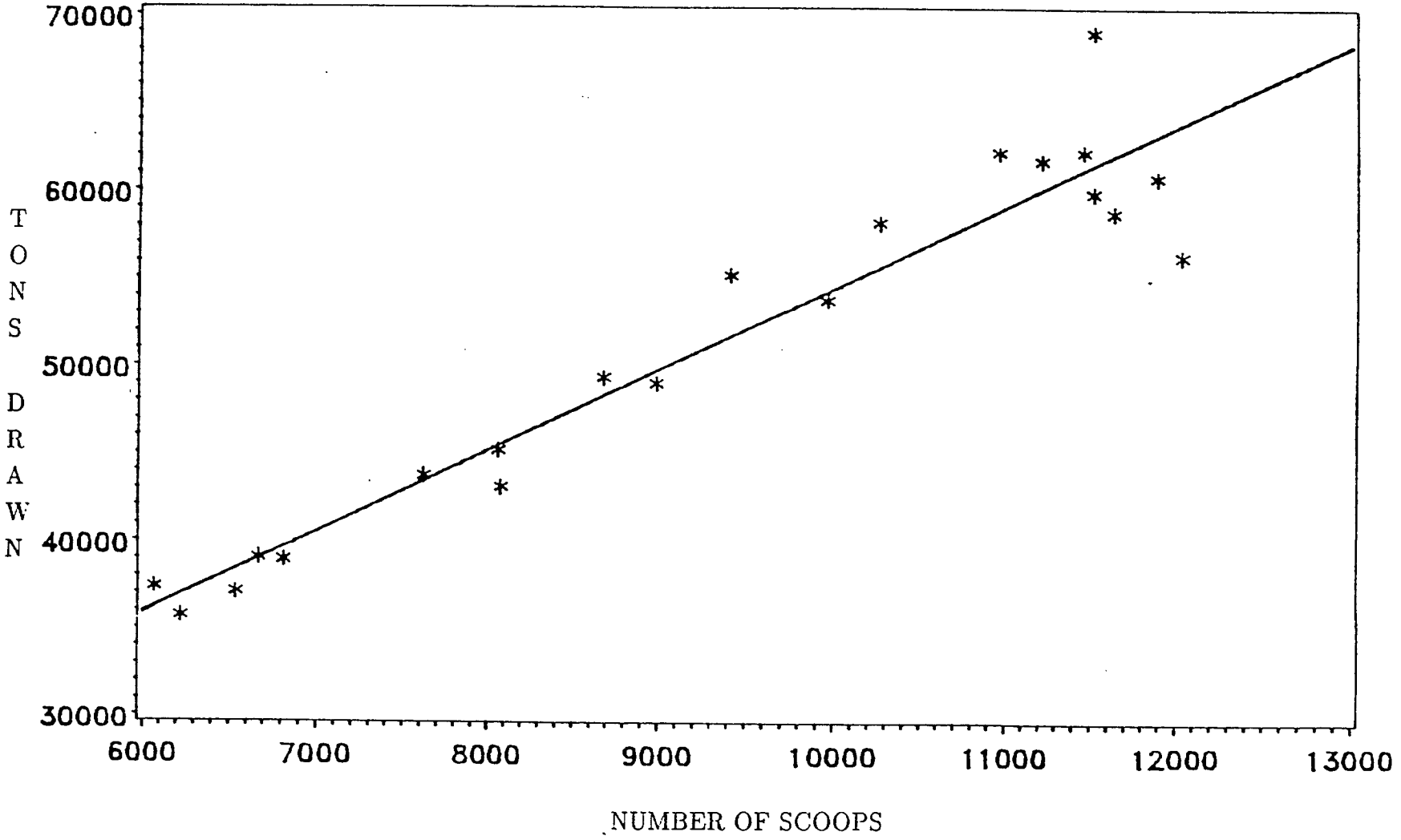

Fig. 4: Tons hauled vs intensity of activity at Mine D

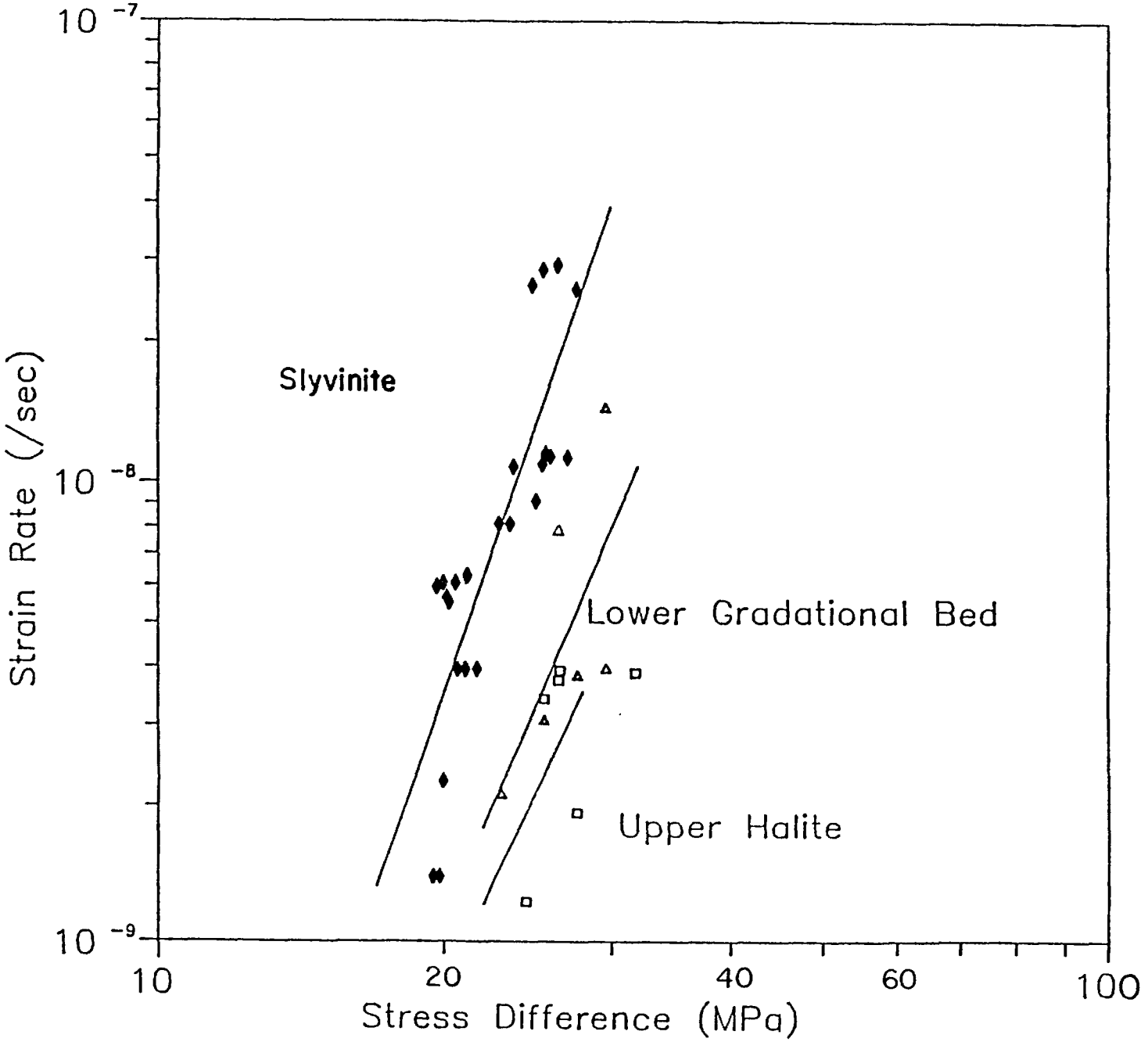

Fig. 5: Creep rate variation with stress difference for three evaporites

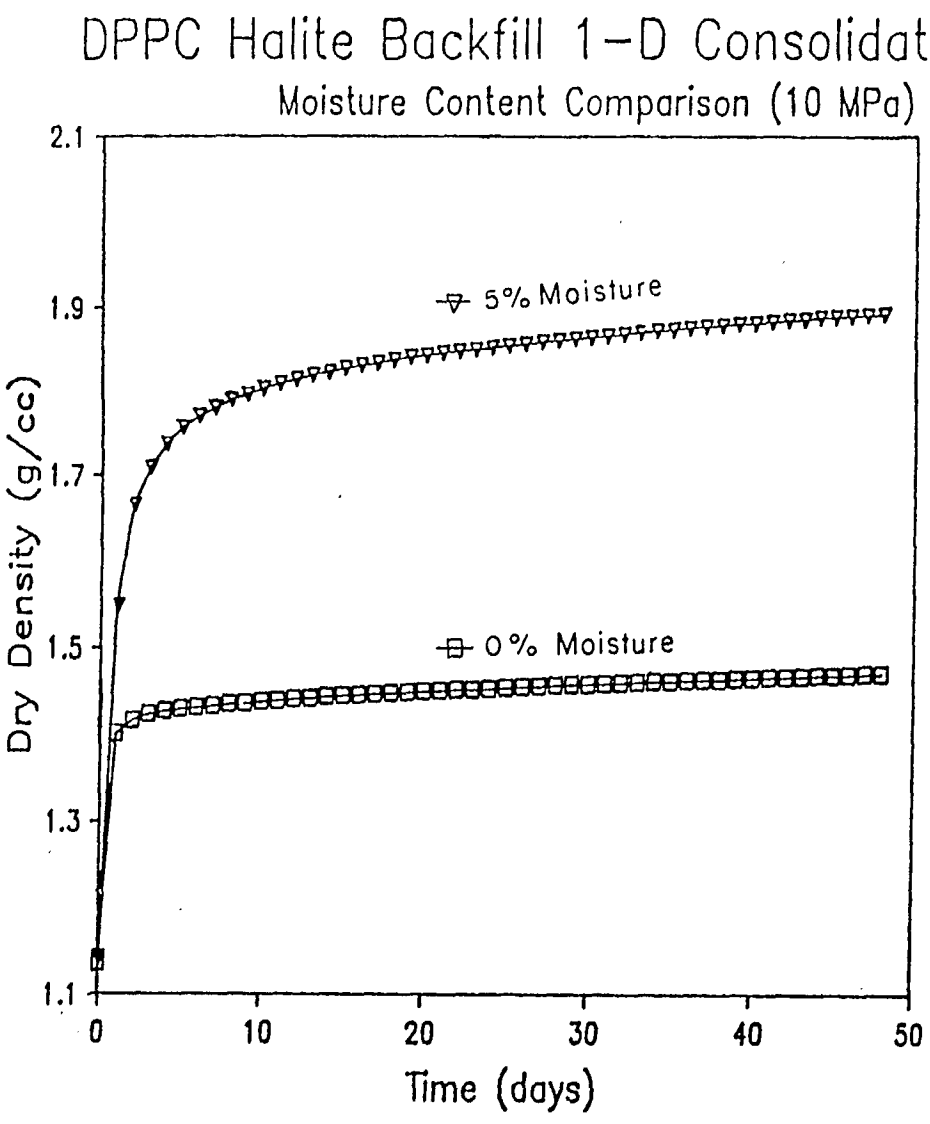

Fig.6: Consolidation tests on backfill with different moisture contents