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SMALL MINES: THE IMPORTANCE TO CANADA'S MINING INDUSTRY, THE CHARACTERISTICS, THE PROBLEMS, AND THE NEEDS FOR TECHNOLOGY

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October 1987

To be presented at the "Second Canadian Symposium on Mining Automation"
October 21, 1987

MINING RESEARCH LABORATORIES
DIVISION REPORT MRL 87-115(OP)

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ABSTRACT

In this paper an attempt is made to estimate the importance of small mines to the Canadian mining industry. An assessment is made of the features which are characteristic of small mines, and of the implications that these have on operations. The authors then review the needs for technology which are particular to small mines, and elaborate a number of ways in which government, and particularly CANMET, can assist.

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Keywords
Canada, mining industry, mining research, small mines, technology

LES PETITES MINES: LEUR PLACE DANS L'INDUSTRIE MINIERE CANADIENNE, LEURS CARACTÉRISTIQUES, LEURS PROBLEMES ET LEURS BESOINS TECHNOLOGIQUES

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RÉSUMÉ

La présentation essaie de préciser l'importance des petites mines dans l'industrie minière du Canada. Les auteurs ont essayé de cerner les caractéristiques particulières des petites mines, et leurs conséquences sur la façon d'opérer de ces entreprises. Ils passent ensuite en revue les besoins technologiques spécifiques des petites mines, puis définissent différents modes d'intervention gouvernementale, particulièrement par l'entre mise de CANMET.

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Mots-Clés
Canada, industrie minière, recherche minière, petites mines, technologie

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A Brief Overview of the Canadian Mining Industry

The Canadian mining industry, which produces some 60 minerals, is both vast and diverse. In 1986, it has been estimated (1) that Canada's 305 mines (including: metal, non-metal, structural materials, coal) employed 77,350 people and produced products with a total value of approximately 15.5 billion dollars. Metal mines, excluding uranium, employed about 46,000 and contributed about $8.9 billion to the total.

At present, Canada is the world's leading producer of uranium and zinc. It is ranked second as a producer of potash, nickel, elemental sulphur, asbestos, and gypsum. It is third-ranked for gold, platinum group metals, metallic aluminum, cadmium, and titanium concentrates. copper, molybdenum, lead, and cobalt, are produced in sufficient quantitites to rank Canada as fourth among world producers of these commodities.

With the exception of Prince Edward Island, Canada's mines are located in all of the provinces and territories. Virtually all types of mines and mining operations may be found within Canada. There are very broad ranges of: sizes of deposits and operations; methods of extraction and practices; geological conditions; and availability of personnel, goods, and services to operators. For these reasons it is exceedingly difficult, if not impossible, to make statements which are representative of the entire industry.

Some appreciation of the great diversity of the Canadian mining industry may be gained from the data which are given in Tables 1 to 4. These relate to: the daily productions of operations, the numbers of employees, productivities, and the mining methods used. Regarding the latter, a very simple classification, between open pit and underground methods, has been used. Underground methods are described as being either "selective" or "bulk".

Before commenting on the data in the tables, however, a few words of caution are necessary. These concern the lack of data and the ability to combine it in simple, meaningful ways. All of the data needed are simply not readily available for all Canadian mining operations. Thus, the figures are presented not as a definitive statement, but, as a rough, but probably reasonably accurate, guide.

In compiling Table 1, an attempt has been made to classify mining operations according to daily productions. The results are interesting, for these demonstrate that daily production is less than 1,000 tonnes at about one-third of the operations for which data are available. Likewise, at another one-third of mining operations, daily production exceeds 5,000 tonnes. The rest are grouped in between, with the median being slightly in excess of about 2,000 tonnes per day.

In Table 2, operations have been classified according to the number of employees. At the lower end of the scale, the classifications have been based on the criteria which are used by the Ministry of Industry and Commerce of Québec in establishing whether a non-mining business is a "small" or "medium" enterprise. A "small" business is said to be one which employs 50 people, or less, and has annual sales not exceeding 2 million dollars. The corresponding figures for a "medium"-sized business are 100 people, or less, and less than 20 million dollars in annual sales, respectively.

MINING IN CANADA

PRODUCTION

	TONNES PER DAY			
PROVINCE	Under 500	501-2500	2501-5000	Over 5000
Newfoundland			1	3
Prince Edward Island				
Nova Scotia	1		3	1
New Brunswick	2		1	2
Quebec	6	18	2	6
Ontario	7	18	2	6
Manitoba	4	6	1	3
Saskatchewan	1	4	1	9
Alberta			2	8
British Columbia	8		4	13
Northwest Territories		4	1	1
Yukon Territory	3			1
Total	32	51	29	55

TABLE 1

Daily production at Canadian Mines

MINING IN CANADA

EMPLOYMENT

	NUMBER OF EMPLOYEES			
PROVINCE	Under 50	51-100	101-500	Over 500
Newfoundland			2	1
Prince Edward Island				
Nova Scotia			2	3
New Brunswick	1	1	2	1
Quebec	2	2	23	2
Ontario	2	5	21	14
Manitoba	4	4	2	1
Saskatchewan	1	3	11	
Alberta	1	3	3	2
British Columbia	6	2	9	5
Northwest Territories			6	
Yukon Territory	1	1	2	
Total	18	21	83	29

TABLE 2

Employment at Canadian Mines

Very few mines could probably be classified as small businesses using the Province of Québec criteria. Several, however, would probably be within the "medium" category and would satisfy both sales and employment criteria. For our purposes, we feel most comfortable in thinking of a small mine as having a daily production of less than 500 tonnes.

In Table 3, mines have been classified according to productivities. It is interesting to note that there are no fewer than 44 operations at which productivity is said to be less than 5 tonnes per manshift. The skewness of the data towards low productivity is very evident.

Finally, in Table 4, we have presented a simple summary of the mining methods used at the operations for which data are available. These show that about 40 percent of the mines are open pits, with the rest being underground operations. Of those, approximately 40 percent are mining by selective methods.

Attempting to combine all of this information into a simple portrait of a small mine is by no means easy. Nonetheless, the picture that emerges is a low daily-rated tonnage operation utilizing relatively labour-intensive selective methods. It is anyone's guess as to how many Canadian operations would fit this description exactly. Our guess is that the number is more than a few.

MINING IN CANADA

PRODUCTIVITY

	TONS PER MANSHIFT				
PROVINCE	Under 5	5.1-10	10.1-20	20.1-50	Over 50
Newfoundland		1		2	
Prince Edward Island					
Nova Scotia	4			1	3
New Brunswick		2	2	1	
Quebec	7	13	6	3	
Ontario	21	12	6	3	
Manitoba	1	6	3	1	
Saskatchewan	2	3	3	4	3
Alberta				2	7
British Columbia	5	3	6	4	4
Northwest Territories	2	1	2	1	
Yukon Territory	2		1	1	
Total	44	41	29	23	14

TABLE 3

Productivities in Canadian Mines

MINING IN CANADA

MINING METHODS

			UNDERGROUND		
	OPEN PIT			BULK	
PROVINCE	MINERAL	ENERGY*	SELECTIVE	MINERAL	ENERGY
Newfoundland	3			3	
Prince Edward Island					
Nova Scotia	7		1	3	3
New Brunswick	3	1	2	2	
Quebec	18		17	13	
Ontario	15		15	30	
Manitoba	5		7	5	
Saskatchewan	2	4	2	8	
Alberta	3	7		1	1
British Columbia	17	7	5	6	1
Northwest Territories			4	2	
Yukon Territory	3		1		
Total	76	19	54	73	5

TABLE 4

Mining Methods in Canadian Mines

*Coal and Tarsands

A PROFILE OF A SMALL MINE - CHARACTERISTICS AND IMPLICATIONS

The picture of a small mine which we present can be made more meaningful by considering the factors which may cause a mining operation to be small and the implications that these have subsequently. In the following section of this paper we will attempt to translate those implications into statements of technological shortcomings. The factors are addressed in Tables 5 to 11 and are: (1) the orebody; (2) the setting; (3) manpower; (4) development; (5) the mine network; (6) materials handling; (7) equipment.

After a glance at the tables it will be evident that there is considerable overlap and inter-relationship between the various facts and the resulting implications. For example, the dimensions of an orebody may dictate the mining method used. This, in turn, limits the choices of equipment, the mine layout, availability of services, and so on. These then translate into reduced productivity.

In attempting to sort out the details one can easily fall into a "chicken and egg" type of argument. We have, in spite of this, attempted to do so in order to crystallize our thinking. At the risk of some duplication it is a valuable exercise to try to list all of the possibly relevant factors, and the impact of these on an operation.

The first "fact of life" for any operation, large or small, is the orebody. A mine operator must do the best work with what is available and to mine the ore safely and at a profit. Almost inevitably, a small orebody implies small working places in which there is a low degree of mechanization. There is a conspicuous lack of equipment which is designed for this kind of situation. We shall discuss that in a subsequent section of this paper. The factors which we have identified with "the orebody" are listed in Table 5.

In Table 6, we present a list of the facts, and the implications of these, which we believe to be related to the setting of an orebody. Once again, an operator has little or no control over these. The fact is, a small orebody results in a small mine. The life of such operations is always short and/or uncertain. Capital may or may not be scarce and there is probably a lack of infrastructure. All of these result in a transient, very young workforce with exceptionally high turnover. The fact that there is no assurance of long-term viability probably results in morale problems and recruiting difficulties.

The factors which we believe to be important as regards the manpower implications are given in Table 7. Prominent amongst these are the fact that small mines are usually labour-intensive operations. Even though turnover is high and there are recruiting difficulties, there is a need to hire the most skilled workers that are available. There are probably few resources available for training, and little available in the way of central support facilities. Perhaps many operators of small mines may be described as being "single-mine companies", or perhaps the operators of several small deposits. With a few exceptions, the major players in the Canadian mining industry are probably excluded from our assessment.

The developmental implications of small mines have been listed in Table 8. We visualize that the typical operation is probably characterized by a lack of long-term reserves and a need for continuing exploration and development. Because of the low availability of capital, mine expansions tend to be taken in small increments. The implications of this and metal prices often lead to erratic mine layouts with all of the resulting operational difficulties.

SMALL MINES IN CANADA

OREBODY

Facts	Implications
Narrow vein, varying dips, and strikes	Small working places
Selective mining methods	Isolated working areas
Small Tonnage	High operating costs
High grade	Low tonnage per manshift
Start with limited basic data	Technology level difficult to modify
	Low level of mechanization
	Lack of suitable equipment

TABLE 5

Facts of small mines - the orebody

SMALL MINES IN CANADA
SETTING

Facts	Implications
Short/uncertain life	Recruiting difficulties
Marginal operation	Day to day operation
Low capital availability	Difficult to meet needs
Likely remote location	High turnover
Lack of infrastructure	Morale
	Younger work force

TABLE 6

Facts of small mines - the settings

SMALL MINES IN CANADA

MANPOWER

Facts	Implications
Labour intensive operations	Difficult to recruit skilled people
Skilled/flexible crew needed	Limited resources for training
Small technical group available	No central technical support
Single mine companies	Need for technology transfer
Low supervisor to crew ratio	Communications problems
Expanding service crew	

TABLE 7

Facts of small mines - manpower

SMALL MINES IN CANADA
DEVELOPMENT

Facts	Implications
Low capital availability	Limited ability for pre-planning
Low ore reserve levels	Complex erratic mine plans
Frequent shaft deepenings	Ventilation difficult to pre-design
On-going mine development	Extensive openings to maintain
On-going underground exploration	Difficult to upgrade track

TABLE 8

Facts of small mines - development

Some of these difficulties, in turn, are listed in Table 9. Small mines are often characterized by small openings, long and complicated mine networks and travel distances, and a lack of services. The most important implications are: that costs are probably much higher than could be the case; that maintenance is a pressing problem; and that communications and the provision of centralized services are exceptionally difficult.

Materials handling problems are probably symptomatic of small mines. Because the openings and the shaft are inevitably small, there are limitations on hoisting capacity. Bottlenecks at the shaft may be common. Equally, there is extensive movement of both men and materials. Supplies, including backfill and support materials, are probably difficult to obtain when needed. The results may be that maintenance is poor and that conditions underground reflect this. Some of the facts and implications are listed in Table 10.

Finally, we have listed the equipment considerations of small mines in Table 11. It has already been noted that there is a lack of equipment which has been developed specifically for small underground openings. Because of this, there is much emphasis on the older rail-mounted technology, and on physical effort. Under these circumstances there is much need for coping with changing conditions and for local innovations. We suspect that there are probably many small but useful innovations which have been made in small mines and which could be profitably applied to the benefit of the entire industry.

SMALL MINES IN CANADA

MINE NETWORK

Facts	Implications
Indeterminate life	Increasing ventilation friction
Longevity	Increasing haulage and materials tram
Long travel distances	With time workings deeper & more extensive
Services constantly being extended	Complex mine networks
Complex ventilation system	Many satellite warehouses
Complex mine dewatering system	Difficult to centralize services
Small openings	Communications difficult
	Captive equipment
	Extensive ground maintenance

TABLE 9

Facts of small mines - networks

SMALL MINES IN CANADA
MATERIALS HANDLING

Facts	Implications
Limited hoisting capacity	Difficult to implement new technology
High U/G waste to ore ratio	Less time for ore movement
Extensive materials handling	High maintenance of track beds
Extensive man movement	Slime accumulation in ditches
Backfill delivery problems	Slime accumulation in sumps
Long delivery lead times on supplies	High pump impellor wear
Shaft bottlenecks	Unknown breaks in backfill lines
	Lack of suitable equipment

TABLE 10

Facts of small mines - materials handling

SMALL MINES IN CANADA
EQUIPMENT

Facts	Implications
Low level of mechanization	Large service crews
Rail equipment predominates	Reliance on compressed air
Hand held drills	Slow battery charging
Low bit and steel life	Poor loco remote control
High maintenance	High loco battery inventory
	Need greater loco speed
	Local innovation

TABLE 11

Facts of small mines - equipment

THE TECHNOLOGICAL NEEDS OF SMALL MINES

Many of the implications which we have listed can be translated into technological and human-resource needs which are particular to the operators of small mines. Quite evidently, there are factors for which there can be no solutions. The orebody, which is a fact of nature, dictates these.

Other factors, however, such as the organization of a mining operation, the equipment used, and the efficiency with which it is used, are within human control. Within this framework, then, in this section of the paper, we have attempted to make statements of needs which are particular to small mines.

Canadian mining has evolved very quickly during the past decade. Without having done so Canadians could not have maintained their share of world markets during a prolonged period of depressed metals prices. "Productivity" has been of the watchwords of the industry in the 1980's.

Now, in the late 1980's, the industry has become more competitive on a global scale. New bulk methods of mining are replacing the less productive selective methods wherever possible. Mining practices are being revised to include the new items of highly specialized equipment which are becoming available. The practices of engineering design are becoming much more comprehensive, detailed, and sophisticated. The managerial style is changing, too, with much more emphasis on training, education, teamwork, and communications.

Unfortunately, though, for the reasons which are listed in Tables 5 to 11, the newest technology has not been implemented in many of the smaller mines. At some, it is unaffordable. At others, it is because of traditions established through many years of mining. At still others, it is because of a lack of skilled support staff and professionals. In the final analysis, the efficiencies at such mines must become less and less as the underground operations and communications extend and mining becomes more difficult.

In attempting to define the needs of the operators of small mines we commenced our exercise by trying to define, as a first step, the "facts of life" for such operations. These operational or cultural factors were then translated into the implications that these are thought to have on an operation. The final step is to convert the implications into the needs, which if satisfied, will address the problem areas.

In assembling the lists of needs it became evident very quickly that the items tended to fall neatly into either of two distinct categories. These were "Equipment" and "Technical Support". The results are shown in Tables 12 and 13.

In our view there is no doubt but that the greatest and most pressing needs of the operators of small mines are for items of equipment which are designed specifically to suit the conditions which are characteristic of such mines. "Small", "miniaturized", "multi-purpose", "more efficient", "improved", are all keywords and key phrases which suit these needs. The list is shown in Table 12 and, it must be stressed, is by no means complete. It is presented as a starting point in order to focus thinking and to initiate discussion.

SMALL MINES IN CANADA
POTENTIAL SOLUTIONS

EQUIPMENT
Miniaturized equipment
Multi-purpose equipment
Voice communications
Data communications
Electronic survey tools
More efficient U/G core drills
In-the-hole metal analyser
Improved track maintenance methods
Improvements in development mucking
Variable speed fan motors
Centralized fan control
On-line turbidity analyser
Shaft boring methods
Containerized materials handling
Improved remote control operation of battery locomotives
Batteries to take faster charges
Monitoring backfill line pressures
Paste fill preparation and delivery
Robot bit sharpener

TABLE 12

The equipment needs of small mines

The second list, concerning the perceived needs for technical support, is shown in Table 13. Some of the items shown are unique to the table but others appear also in the previous table. The reasons are that improved methods of doing something better involve not only equipment but also aspects of engineering design and technical support services. Improved track maintenance methods, and the other "methods" shown, are good examples of this.

Nonetheless, our opinion is that the most pressing needs of the operators of small mines are for support services which are not available locally. Very often, the operators of such mines are forced into a level of technology which can not be modified easily. In the older mines, particularly, because of a lack of support staff, there may be very little motivation and/or time available in order to upgrade skills and to introduce the newest technology.

How can a government research and technology delivery vehicle, such as CANMET, assist such operators?

CANMET ASSISTANCE TO SMALL MINES

Because small mines are virtually forced, by the factors and circumstances that were listed previously, into a particularly vulnerable position, it is of critical importance that support should be available when it is needed most. Some of this, such as the application of the latest design techniques to particular and local problems, may be obtainable from other mining companies and/or consultants. Even here, however, government can assist by evaluating a problem, counselling on the way to proceed, and identifying possible alternatives.

SMALL MINES IN CANADA

POTENTIAL SOLUTIONS

TECHNICAL SUPPORT
Computerized mine management system Software; ventilation, surveying, ground control... Information on standard practices Development of miner training programs Improved track maintenance methods Improvements in development mucking Reduced reliance on compressed air Improved methods for cleaning spillage, ditches, sumps

TABLE 13

The needs of small mines for technical support

In areas such as technology transfer, and in the development of newer approaches and techniques, however, government has a major role to play in assisting small mines. The Mining Research Laboratories of CANMET consider this to be a most important part of their role and mandate.

The first item that comes immediately to mind is the "Index of Mining Technology Development". Now being printed in its third annual edition, the Index was created in response to the urging of the Mining Sub-committee of the National Advisory Committee on Mining and Metallurgical Research (NACMMR), now known as MNACC (Minister's National Advisory Committee for CANMET). That body recognized that much research and development is taking place throughout the industry. In the interests of technology transfer, communications, and avoidance of unnecessary duplication, it was considered to be urgent that an assessment of the total national effort be made as soon as possible.

The current edition represents three years of persistent effort in encouraging all of the stakeholders to participate. In the "Index", all of the projects are listed by company and cross-indexed by subject area. The name and telephone number of the contact person for each organization is listed.

Thus, a mine operator is able to obtain a very rapid overview of what is taking place in a subject area of interest and a list of contacts. CANMET has received very favourable and enthusiastic reviews concerning the value of the Index. It should be of interest to know that a sister division, the Mineral Science Laboratories, is starting a companion Index, for mineral processing projects, this year.

CANMET also serves the industry by stimulating advances in design techniques and methodologies. The "Pit Slope Manual", which was produced as several individual chapters - each devoted to a particular design aspect - several years ago, is probably the best example of this. The work became an international "best-seller", with over 35,000 copies of the various chapters having been sold. The effort had a major impact on the whole approach to the design of open pit mines. It was also estimated that the cost of the project was recovered several times over by the industry through improved efficiency and better-designed slopes.

In the not-too-distant future the Mining Research Laboratories of CANMET hope to be in a position to proceed with a companion series of chapters on the design aspects of underground mining. A start has been made through the production under contract of the manual "Estimating Preproduction and Operating Costs of Small Underground Deposits". The title is indicative of the commitment which CANMET has towards providing assistance to small mines. We believe that an "Underground Mining Manual", would be a very valuable instrument in transferring technology to small operations.

Likewise, there is a need for the development of a general computerized Mine Information System. Such a system, when developed, could reduce paperwork considerably, improve communications throughout an organization, and permit more efficient and cost-effective means of performing routine services.

Small organizations lack both the human and financial resources which are necessary for the development of such a system. It is for these reasons that such operations would probably derive the greater benefits.

At present, there are many specialized computer programs available to mine operators. There is a lack of standardization, however, which precludes the integration of all of the necessary pieces into a coherent whole. An overall mine information system would probably involve dozens of such programs, each addressing a particular engineering, personnel, or accounting, function.

As a first step, CANMET through Supply and Services Canada contracted for a study of the needs of the Ontario mining community and protocols which could be applied as a specification in subsequent contracts for the design of software packages.

This study should be particularly useful because it will facilitate the design of software to a standard which suits the needs of mine operators. Small mines, in particular, do not have the ability to handle a wide variety of software packages - no matter how applicable or valuable these packages may be. An effort towards standardization will be of the greatest benefit to the smallest operator.

It was mentioned previously that CANMET can also serve the industry by advising on the approach to the solution of a problem and by counselling on where to turn for help. The role of the organization is not to compete with consultants or others in the provision of testing or engineering services. Such services may be provided, however, when these are not available elsewhere or when there is a well-stated reason for CANMET's involvement. In some cases CANMET's expertise may be unique to the nation. In such cases, subject to operational requirements, the services can be made available on a cost-recovery basis.

The Mining Research Laboratories have responded to many requests for assistance to small mines, particularly in the past two or three years. The responses have varied according to the particular circumstances, but we believe that we have assisted to the extent of our ability to do so.

Finally, it is absolutely clear that there are pressing needs for equipment which is particularly suited for small mines. Up to the present, such operations have not been able to benefit from the advances in mechanization and automation that have taken place elsewhere in the industry.

Up to the present CANMET has not assumed a major role in the development of equipment. This is outside of the mandate of the organization.

It has, however, through a number of contracts, sponsored the development of incremental technology which can be applied to the development of mining equipment. Alternative rock cutting technologies are a good example to illustrate this point.

CANMET's role in equipment development is to encourage Canadian breakthroughs. Equipment which is better suited to the industry's needs will reduce operating costs. Simultaneously, the manufacturing of new equipment will create employment and have beneficial effects for all levels of government.

CONCLUSION

The implementation of the newest technology is essential if Canada's mining industry is to be able to maintain its competitive position in the world marketplace. The problem of doing this is particularly acute in small mines because of a lack of human and/or financial resources.

CANMET's role is to provide technical assistance and support for the technological needs of the industry. This is particularly important for smaller operations which lack the resources of the major players.

In this paper, the authors have identified some of the areas in which technical assistance is necessary, and the role which CANMET can play.

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