# DEFINITION OF AN ACTION PLAN IN RESEARCH AND DEVELOPMENT, TRIAL AND EXPERIMENTATION TO PROMOTE COMPETITIVENESS AND SAFETY FOR UNDERGROUND MINING OPERATIONS

**Final Report**

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**Work performed for:**
**SOREDEM Inc.**

**Project: 602441**
**Report CANMET-MMSL 04-037(CR)**

***Final Version:***
***September 28, 2004***

# EXECUTIVE SUMMARY

Although the mining industry rarely captures the attention of the public, of political and financial decision-makers, and the spoken and printed media, it remains an essential pillar of the economy. It has contributed significantly to the collective well-being by making the nation's rich mineral endowment available to society at large and allowing Canadians to maintain one of the highest standards of living in the world.

- In 2002, the mining and mineral processing industries contributed almost ***$40 billion*** to the Canadian economy, or ***3.6% of the GDP***. This is significantly more than the technology sector, which accounted for 3.0% of the GDP. The mining sector contributes more to the GDP than the communications sector;
- More than 2,200 small, medium, and large Canadian-based companies provide specialized services and equipment to the mining industry in Canada and abroad;
- Salaries in the minerals and metals industry are among the highest in Canada, averaging ***more than $60,000*** per year, compared to the national average of less than $35,000. Workers in this industry contribute in a significant way to government revenues. For example, in Quebec the ***15% of workers*** earning over $42,144 per year contributed ***70% of income taxes*** in this province;
- Fiscal contributions of the 350 employees at a typical underground mine amount to ***$155 million*** over ten years of operation;
- The Canadian mining industry is truly Canadian: 70% of the sector is controlled by Canadian as opposed to foreign companies;
- Over 100 communities, with a total of over ***600,000 inhabitants***, owe their existence to the mining sector. These centres range in size from a few hundred or thousand inhabitants, for example Ekati, Northwest Territories, or Trail, British Columbia, to several tens of thousands of people, such as Rouyn-Noranda, Quebec, or Timmins, Ontario;
- The mining industry also generates considerable benefits for urban areas which host research organizations, educational institutions, consulting and financial service companies, and the major companies involved in processing copper, zinc, iron and titanium ore and manufacturing of products using these metals. All industrial sectors operating in urban regions, and in particular the high-tech sector, use metals and minerals. Moreover, over 60% of the tonnage transported by rail and water comprises mineral substances; and,
- Exports of metals and non-combustible minerals in 2002 amounted to ***almost $50 billion***, or more than 10% of all Canadian exports.

This enviable situation in the Canadian mining sector is in danger of significant deterioration due to a crisis in the making looming on the horizon. Although Canada still has considerable mineral potential, changing social and economic conditions and foreign exchange market factors are creating a number of major challenges in the next decade for the mining industry: *operational constraints (mining methods, operational costs, underground environment, etc.); competition* *from developing countries; availability of qualified manpower; the industry's public image; availability of and access to mineral resources; variable metal prices.* To ensure its survival and to deal with fierce and rapidly increasing international competition, the Canadian mining industry must redouble its efforts. It must continue to increase its productivity while at the same time protecting the health of its workers and respecting applicable environmental regulations that are becoming increasingly complex. To discover and operate such mines the industry has to invest considerable amounts of money. In this context, R&D is a vital step for maintaining and improving the competitiveness of the mining industry. Moreover, leading edge technologies are required to be able to exploit low grade mines economically where grades cannot offset the numerous operational constraints. In spite of relatively small research budgets, mining research has produced meaningful results: development and application of the paste backfill technique, use of electronic detonators and research on hoisting systems have allowed, among other benefits, the preservation and improvement of several mining operations such as Chimo (Cambior), Brunswick (Noranda), LaRonde (Agnico-Eagle) and Golden Giant (Newmont Mining).

With the aim of better orienting required research efforts, at the request of SOREDEM[1], the research and development arm of the Mining Association of Quebec, CANMET-MMSL[2] undertook extensive consultations with representatives of the Canadian mining industry, to determine the principal axes of research that will lead to increased productivity and improve health and safety in underground mines. The consultations conducted in the framework of this project have led to the conclusion that the concerns of underground operations in Canada as a whole are very similar to those of Quebec. The aim of this report is therefore to elaborate the principal problems, both present and future, perceived as important by the Canadian mining community as a whole, propose solutions that mining research can bring, and suggest an R&D Action Plan.

Minerals are produced in all Canadian provinces and territories. In addition, the distribution of mineral resources is such that most mining operations occur outside the narrow zone north of the American border in which the Canadian population is concentrated. Mines in isolated areas thus permit active utilization of a large part of Canada's land mass. The economic survival of these regions is often closely linked to exploitation of mineral resources and, mainly, on the mining industry. Maintaining a critical level of mining activities and renewal of Canadian know-how are high priorities for these regions, for governments that reap several tens of millions of dollars annually from each operating mine, and for small and medium sized manufacturing and service companies that do business there.

In contrast to the manufacturing industry, which creates value by improving the quality of its products, the mining industry must add value by improving its processes, or, in other words, the methods used to extract ore and concentrate contained metals. Given the current and expected near-term economic situation, it is urgent that long-term applied axes of research are undertaken to develop new approaches to mining along with development of new mining equipment

[1] SOREDEM : Société de recherche et développement minier.
[2] CANMET-MMSL : CANMET Mining and Mineral Sciences Laboratories.

and technology. Increasing production capacity, improving health and safety underground, and reduction of labour costs are the ultimate objectives aimed for in developing innovative extraction methods. In the course of our consultations, participants identified the following axes of research as being the most important. In decreasing order of importance:

- **Drilling and blasting:** New methods and equipment;
- **Engineering and physical environment:** Improvement of underground living and working environment;
- **Extractive engineering:** Conceptual approach of mining methods; and
- **Backfill and related subjects:** Improvement of existing methods of production and transportation of backfill and development of new methods.

Optimal results will be obtained if each stakeholder assumes a specific role, which will serve to best orient and structure research efforts. The main roles are:

- **Mining companies:** Fund research initiatives and, in a collegial collaborative spirit, industry champions must clearly identify the short, medium, and long-term innovations that will have the most impact on production costs;
- **Research centres and universities:** These organizations should have a medium to long-term vision of R&D in order to propose innovative and realizable concepts;
- **SME and Manufacturers:** In partnership with all research stakeholders these entities should offer leading edge services, and develop and construct innovative equipment that meets the needs of mine operators; and
- **Governments:** Provide stable and continuous financial support to internal and external research initiatives, and support the required efforts for demonstration and implementation of new production processes.

Without stable and sustained funding, it is difficult to expect applicable R&D results. Due to the challenges and economic stakes involved, increased financial participation will be required by all levels of government, as well as by mining and manufacturing companies: the survival of the mining industry is at stake. In Canada, the equivalent of 1.9% of the GDP, taking into account all industrial sectors, is re-invested in R&D, of which approximately 50% comes from government. To ensure a Canadian presence and preserve Canada's leadership in the global underground mining sector, ***approximately $80 million per year should be invested in Canada for at least the next 10 years***. The underground mining industry already contributes $30 million per year, along with an additional $10 million in in-kind contributions by mines. Industry therefore already contributes its fair share, that is 50% of the required R&D investment. ***On the other hand, the only long-term commitment by the provincial and federal governments amounts to about $5 million per year*** in this sector. In addition, this industry benefits relatively little from research and development tax credits. Companies with mines in operation invest significant sums in R&D, directly via contracts with research organisations or internally, or through acquisition of R&D technologies developed by third parties but do not make use of any specific tax break. In view of the considerable benefits that accrue to them, federal and provincial governments should undertake ***a major additional effort to provide approximately $35 million annually to bring its participation up to the level of industry***. Analysis of a group of projects indicates that the return can be expected to considerably exceed the amounts invested. As well, as shown by the economic model, elucidation of a procedure that enables exploitation of only two new mines in Canada would generate fiscal revenues of over $300 million for governments and recuperate the initial investment.

Funds should be administered by a federal-provincial-industry partnership, and should aim to support in a tangible way the axes of research identified by industry as being of highest priority. In addition, formation of a corridor of excellence between northern Ontario and northern Quebec would be an interesting concept to develop, given the critical mass and the potential alliances that could be formed between mining companies, manufacturers, research centres, and educational institutions that occur there.

To summarize, stable and sustained funding is required for the next 10 years in order to establish a viable research program capable of ensuring the long-term survival of the mining industry and its host communities. This report recommends concerting the efforts of all research stakeholders and proposes a model of an Action Plan that would, ideally, allow optimal utilization of invested funds. The suggested structured system of coordination and exchange should have as its objectives:

- Orient funds towards highest priority axes of research;
- Elaborate and establish a fund allocation mechanism that minimizes the time required for fund raising;
- Select one or more industrial partners capable of ensuring successful introduction and follow up of new technologies underground; and
- Allocate R&D contracts according to the expertise of researchers, their ability to successfully complete projects, their access to equipment and laboratories, and their capacity to build strategic alliances in order to obtain concrete results in an established timeframe.

An innovative mining industry will ultimately be able to contribute to the life-blood of host regions by utilizing local labour, including native peoples, and thus retain high quality jobs along with the large number of small and medium sized businesses located there. In a word, the rejuvenation of the mining sector, and thus of regional economies, must begin with R&D.

# SOMMAIRE EXÉCUTIF

Même si l'industrie minière capte rarement l'attention du public, des décideurs politiques et financiers, ainsi que de la presse parlée et écrite, elle demeure toutefois un pilier indispensable et incontournable de l'économie canadienne; à même la richesse du sous-sol, elle contribue considérablement à la collectivité, en permettant aux Canadiens de maintenir un niveau de vie parmi les plus élevés au monde.

- En 2002, l'apport à l'économie canadienne des industries de l'exploitation minière et du traitement des minéraux a été près de ***40 milliards de dollars***, soit ***3,6 % du PIB*** national. Ceci est significativement plus important que le secteur de haute technologie qui contribue pour 3,0 % au PIB. Le secteur minier contribue plus au PIB que le secteur des communications;
- Plus de 2 200 petites, moyennes et grandes entreprises, basées au Canada, fournissent des services spécialisés et des équipements pour l'industrie minière au Canada et à l'étranger;
- Les travailleurs de l'industrie des minéraux et des métaux reçoivent les salaires parmi les plus élevés au Canada, soit en moyenne ***plus de 60 000 dollars*** par année, alors que la moyenne nationale annuelle est moins de 35 000 dollars. Ils contribuent ainsi significativement aux revenus gouvernementaux. Par exemple, au Québec, les ***15 % des salariés***, dont les revenus sont supérieurs à 42 144 dollars, ont contribué pour ***70 % des impôts*** sur le revenu de la province;
- Les contributions fiscales et parafiscales des 350 employés d'une mine souterraine type, cumulées sur 10 années d'exploitation, se chiffrent à ***155 millions de dollars***;
- L'industrie minière du Canada est une industrie véritablement canadienne : 70 % du secteur est contrôlé par des sociétés canadiennes, plutôt qu'étrangères;
- Plus de 100 collectivités canadiennes, regroupant une population totale de plus de ***600 000 habitants***, sont tributaires du secteur minier. Ces collectivités varient en grandeur, passant de quelques centaines ou milliers de personnes à Ekati dans les Territoires du Nord-Ouest ou Trail en Colombie-Britannique, jusqu'à plusieurs dizaines de milliers à Rouyn-Noranda au Québec ou Timmins et Sudbury en Ontario;
- L'industrie minière génère également des retombées considérables dans les régions urbaines où se trouvent des institutions de recherche, de formation, de consultation et de services financiers en plus de très grandes entreprises de transformation dans les secteurs du cuivre, du zinc, du fer et du titane. Tous les secteurs industriels situés dans les régions urbaines, et en particulier celui de la haute technologie, utilisent des métaux et minéraux. Par ailleurs, plus de 60 % du tonnage transporté par voie ferroviaire et maritime au Canada est constitué de substances minérales; et
- Les exportations des métaux et minéraux non-combustibles, en 2002, s'élevaient à ***près de 50 milliards de dollars***, représentant plus de 10 % de toutes les exportations canadiennes.

Cette position enviable du secteur minier canadien risque de faire place à une situation très morose d'ici quelques années alors qu'une crise en devenir se dessine à l'horizon. En effet, bien que le potentiel minéral du Canada soit encore présent, en raison de l'évolution du contexte socio-économique et de la dynamique des marchés mondiaux, l'industrie minière aura plusieurs défis majeurs à relever durant la prochaine décennie : *disponibilité d'une main-d'œuvre qualifiée; contraintes opérationnelles (processus d'extraction, coûts d'opération, environnement souterrain, etc.); exploration, disponibilité et accès à la ressource minérale;compétition des pays en voie de développement; raffermissement des législations; image de l'industrie; prix fluctuant des métaux.* Pour assurer sa survie et faire face à une compétition internationale farouche et en croissance rapide, l'industrie minière canadienne devra redoubler ses efforts. Pour ce faire, l'industrie doit encore accroître sa productivité tout en protégeant la santé de ses travailleurs et en rencontrant les normes environnementales en vigueur qui deviennent de plus en plus contraignantes. Depuis plusieurs années, on observe que l'exploitation des mines se fait en plus grande profondeur et aussi davantage en territoire nordique. Pour découvrir et opérer de tels gisements, l'industrie doit investir des sommes beaucoup plus considérables. Dans ce contexte, la R-D s'avère une démarche vitale pour maintenir et améliorer la compétitivité de l'industrie minière. De plus, de nouvelles percées technologiques sont requises pour permettre l'exploitation économique de gisements dont les teneurs ne peuvent compenser pour les nombreuses contraintes opérationnelles. En dépit de budgets relativement modestes, la recherche minière donne des résultats concrets : le développement et l'application de la technique du remblai en pâte, l'emploi des détonateurs électroniques et la recherche sur les systèmes de hissage ont permis, entre autre, le maintien et l'amélioration de plusieurs opérations minières telles que Chimo (Cambior), Brunswick (Noranda), LaRonde (Agnico-Eagle) et Golden Giant (Newmont Mining).

Dans le but de mieux orienter les efforts de recherche requis, à la demande de SOREDEM[1], organisme de recherche et développement de l'Association minière du Québec, une vaste consultation fut entreprise par les LMSM-CANMET[2], auprès des intervenants du milieu minier canadien, pour déterminer les axes de recherche prioritaires afin d'assurer une productivité accrue et améliorer la santé et la sécurité dans les mines souterraines. Les consultations menées dans le cadre de ce projet ont permis de conclure que les préoccupations des exploitations souterraines dans l'ensemble du Canada sont très similaires à celles du Québec. Ce rapport vise donc à exposer les grandes problématiques, actuelles et futures, jugées importantes par l'ensemble de la collectivité minière au Canada, à proposer des solutions potentielles apportées par la recherche et l'innovation dans les mines souterraines ainsi qu'à suggérer un plan d'action en R-D.

La production minérale s'effectue dans toutes les provinces et territoires du Canada. De plus, la distribution des ressources minérales fait en sorte que les exploitations minières sont situées loin de la bande peuplée longeant la frontière américaine. La présence des mines en région permet donc de mettre à profit une grande partie du territoire canadien. La survie économique de ces régions repose souvent sur l'exploitation des ressources naturelles, et, en premier lieu, sur

[1] SOREDEM : Société de recherche et développement minier.
[2] LMSM-CANMET : Laboratoires des mines et des sciences minérales de CANMET.

l'industrie minière. Le maintien d'une masse critique d'exploitations minières et le renouvellement du savoir-faire canadien sont primordiaux pour ces régions et les gouvernements qui en retirent des contributions fiscales et parafiscales de plusieurs dizaines de millions de dollars annuellement pour chaque mine en opération, mais également pour les PME d'équipements et de services qui y sont associées.

Alors qu'au sein de l'industrie manufacturière les travaux en R-D visent essentiellement à développer de nouveaux produits ou à accroître leur qualité, dans le secteur minier, la R-D s'intéresse plutôt à améliorer les procédés d'extraction et de concentration puisque les produits, eux : cuivre, zinc, or ou nickel par exemple, restent toujours les mêmes. Il est ainsi d'autant plus important de soutenir l'industrie minière dans ses efforts pour le développement, la démonstration et l'implantation de nouveaux procédés d'extraction.

Considérant la situation actuelle et future, il devient impératif que des travaux de recherche appliquée, d'envergure et de longue haleine, soient entrepris afin de développer de nouvelles approches d'exploitation combinées à la mise au point de l'outillage nécessaire. L'augmentation de la capacité de production, l'amélioration de la santé et sécurité des travailleurs en souterrain et la réduction du coût de la production sont les objectifs visés par le développement de méthodes d'extraction innovatrices. Lors des consultations, les intervenants ont identifié, par ordre d'importance, les principaux axes de recherche suivants :

- **Forage et fragmentation** : Nouvelles méthodes et nouveaux équipements;
- **Ingénierie de l'environnement de travail** : Amélioration des conditions de vie et de travail sous terre;
- **Ingénierie de l'extraction** : Approche conceptuelle des méthodes d'exploitation; et
- **Remblayage et sujets connexes** : Amélioration des techniques actuelles de préparation et de transport du remblai, et développement de nouvelles techniques.

Afin de réunir les conditions propices, chaque intervenant aura un rôle spécifique à assumer pour mieux orienter et structurer les efforts de recherche. Les principaux rôles sont :

- **Entreprises minières** : En plus de supporter financièrement la recherche, dans un esprit de collégialité, les chefs de file de l'industrie doivent identifier clairement les innovations requises à court, moyen et long terme, pouvant avoir un impact sur les coûts de production;
- **Centres de recherche et universités** : Avoir une vision de la R-D à moyen et long terme afin de proposer des concepts innovateurs et réalisables;
- **PME et manufacturiers** : En partenariat avec tous les intervenants en recherche, offrir des services à la fine pointe technologique, et développer et construire des équipements novateurs répondant aux besoins des exploitants; et
- **Gouvernements** : Supporter financièrement, de façon stable et continue, les initiatives de recherche interne et externe. Également, soutenir les efforts requis pour la démonstration et l'implantation de nouveaux procédés de production.

Sans financement stable et soutenu, on ne peut s'attendre à des résultats probants en R-D. Compte tenu des défis à relever et des recettes fiscales en jeu, une plus forte implication monétaire de tous les paliers de gouvernements, de l'industrie, des PME et des manufacturiers s'impose; la survie de l'industrie minière en dépend. Au Canada, tous les secteurs industriels confondus investissent l'équivalent de 1,9 % du PIB en R-D, dont 50 % proviennent des gouvernements. Pour assurer la présence du Canada et conserver son leadership sur le plan mondial dans le secteur minier souterrain, ***quelque 80 millions de dollars devront ainsi être consentis annuellement au Canada, sur un horizon d'au moins 10 ans***. La contribution des entreprises minières qui exploitent les gisements de type souterrain est évaluée à 30 millions de dollars annuellement, en plus d'une dizaine de millions de dollars pour des travaux en nature non comptabilisés et réalisés dans les mines. L'industrie investit donc déjà sa part des contributions, c'est-à-dire 50 % des sommes requises en R-D. ***Par contre, le seul engagement à long terme des gouvernements fédéral et provinciaux s'élève tout au plus à 5 millions par année*** dans ce secteur d'activités, sans compter que cette industrie bénéficie relativement peu des crédits d'impôt à la recherche. Les sociétés minières exploitantes investissent des sommes importantes en R-D, que ce soit directement par des contrats auprès des organismes de recherche ou à l'interne, ou par l'acquisition de technologies issues de la R-D de tierces parties. Cependant, les régimes fiscaux des gouvernements fédéral, provincial et des territoires ne privilégient pas le secteur minier malgré sa spécificité. Les gouvernements fédéral et provinciaux, compte tenu de tous les bénéfices qu'ils en retirent, devraient faire ***un effort majeur additionnel d'environ 35 millions de dollars annuellement afin d'atteindre le niveau des investissements de l'industrie***. L'analyse d'un groupe de projets indique que l'on peut s'attendre à un rendement dépassant largement les sommes investies. De plus, tel que démontré par les modèles économiques, l'unique développement d'un seul procédé permettant le démarrage, au Canada, de deux mines additionnelles étant le fruit des travaux de recherche, générerait des revenus fiscaux supérieurs à 300 millions de dollars pour les gouvernements, rentabilisant ainsi ces investissements publics.

L'orientation des fonds, provenant de partenariat fédéral-provincial-industrie, devrait viser à supporter tangiblement les axes de recherche identifiés comme étant prioritaires. De plus, la formation d'un corridor d'excellence entre les régions minières de l'Ontario et du Québec serait une avenue intéressante à développer étant donné la masse critique et les alliances potentielles entre l'industrie, les PME, les manufacturiers, les centres de recherche et les établissements d'enseignement qu'on y retrouve.

En résumé, un financement stable et soutenu est essentiel pour les 10 prochaines années afin de mener à bien le programme de recherche qui devrait assurer la survie à long terme de l'industrie minière et des régions qui l'accueillent. Ce rapport recommande la concertation et la collaboration de tous les intervenants impliqués en recherche minière et propose un modèle de Plan d'action qui devrait permettre une utilisation optimale des montants d'argent investis. Un tel système structuré de coordination et d'échange devrait :

- Orienter les fonds vers les axes identifiés comme étant prioritaires;
- Élaborer et mettre en place un mécanisme d'attribution des fonds minimisant le temps requis pour les montages financiers;
- Sélectionner les partenaires industriels capables d'assurer l'introduction et le suivi des technologies dans le milieu souterrain pour en assurer le succès; et
- Attribuer des contrats de R-D en fonction de l'expertise des chercheurs, de leur capacité de rendre les projets à terme, de l'accès probable aux équipements et aux laboratoires, et de leur capacité à développer des alliances stratégiques afin d'obtenir des résultats concrets dans les délais prévus.

Une industrie minière innovatrice permet de contribuer à l'essor des régions en mettant à profit la main-d'œuvre locale, incluant les autochtones, en maintenant des emplois de qualité et en soutenant une expertise régionale d'entreprises de sous-traitance, de transformation, de manufacturiers et de fournisseurs de services spécialisés. Bref, la relance du secteur minier, et donc des régions, doit passer par le biais de la R-D.

# ACKNOWLEDGEMENTS

First and foremost, our most sincere appreciation is extended to all of those who participated in the interviews for the precious time they gave us and for having shared their vision and their needs for research.

Secondly, we would like to formally recognize those who contributed financially to the project, namely: Canada Economic Development, SOREDEM, Ministère des Ressources naturelles du Québec, Canadian Mining Industry Research Organization (CAMIRO), The James Bay Joint Action Mining Committee, Hydro-Québec and Natural Resources Canada.

We cannot overlook Mr. Léo Couture's contribution, for having initiated the discussions and for having shared with us his ardour and vision. In addition, we wish to thank Messrs. Marcel Laflamme, Denis Lagacé, Kirk Stevens and Dan Tolgyesi, as well as the members of the Follow-up Committee and of the Review Committee who provided their remarks, comments and suggestions in regard to this report, and for the numerous discussions which we have had with them. We would equally like to underline the contributions of Mr. Maurice Boutin, of KPMG, and Mr. Gérard Laquerre, consulting economist, who provided us with extensive information of an economic nature. We also wish to acknowledge the work performed by Thérèse Vincent, Sonia David and Helen Hawkins-Lavoie for their valuable assistance in the compilation of the data and the editing, as well as Marilyn Harris for the graphic design.

In addition, we would like to thank CANMET-MMSL's management and, particularly, Messrs. Thomas Hynes and Jim Vance, who assumed the responsibilities for several files in order to allow the authors to concentrate solely on the writing of this report. Without them, this report would not have been as consistent.

Finally, we extend out thanks to our families, who never complained about the little time that we spent with them during the last six months. Without their understanding and cooperation, we would not have been able to complete this report within the established timeframe.

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# 1. INTRODUCTION

For more than a century, the Canadian mining industry has contributed significantly to the collective well-being by making the nation's rich mineral endowment available to society at large and allowing Canadians to maintain one of the highest standards of living in the world. During the last decade, several other sectors emerged and have diversified the economic activities of the country. In particular, the high-tech and communications sector has captured the attention of the public, investors, and political and financial decision-makers. The collective amounts allocated to research and development activities have been directed, more particularly, to these emerging sectors, thereby allowing them to grow significantly. In spite of its economic and social importance, as well as its growth and dependence on innovation, mining research in Canada has, consequently, been unable to benefit from the same wave of investment.

The mining industry, however, remains an important pillar of the economy. In 2002, its contribution represented 3.6% of the Canadian GDP, whereas the technology sector accounted for only 3.0% (5). In addition, the Canadian mining industry has become an important world player. Moreover, the innovative character of mine operators has allowed Canada to exercise a technical and scientific leadership role within the international mining industry.

Globalization is a phenomenon that has always been present in the mining sector. To ensure their growth, major companies operate in all areas of the world and are continually searching for deposits offering significant size and economic potential. Besides, many developing countries, whose mineral resources have thus far been extracted with artisanal methods, have very favourable geological settings. These countries, which are open to foreign investments, and in which access to minerals is open to mine operators, become very interesting for international companies. On the other side of the ledger, the increase in supply of metals on world markets has resulted in extended weaknesses of metal prices. In addition, large international mining companies, with their trained and qualified personnel, bring and implement technology and know-how in other countries, thus allowing the economic exploitation of these world-class deposits, and create competition for Canada. All of these factors have gradually affected the profitability of Canadian mining operations. Unfortunately, this has had adverse consequences on the economic activities of marginal operations and, ultimately, those of the country. Within this dynamic, the capacity to produce metals at the lowest possible cost, while at the same time guaranteeing the highest standards for the safety of employees, must remain a priority, both for the industry and governments.

Although Canada still has considerable mineral potential, the changing socio-economic context is such that the qualified manpower essential to ensure growth of the mining industry is becoming scarce and costly. Moreover, regulatory requirements in the various jurisdictions are necessarily becoming stricter, resulting in additional operational constraints. In Canada, the mineral potential found in deep mines or contained in low tonnage high-grade deposits is extracted mostly by underground methods (6). Notwithstanding the fact that these operations leave fewer footprints on the environment, they are normally more complex to operate due to the intrinsic problems encountered underground. Moreover, these problems are accentuated when operators want to have access to sizeable reserves located at great depths, i.e. below 2,000-3,000 meters. All of these drawbacks necessitate a wide-ranging development of technology, which must be directed, more specifically, at improving the operational conditions the mining industry is facing. With the appropriate innovative technologies, the extraction of this unique mineral potential appears to be an important business activity for the future well-being of the entire Canadian population.

Upon realizing the importance of this situation and following the initiative of the *Société de recherche et développement minier* (SOREDEM*), several industry members and other organizations, namely Canada Economic Development (CED), Canadian Mining Industry Research Organization (CAMIRO), The James Bay Joint Action Mining Committee and Hydro-Quebec have joined together to finance this project, which is aimed at supporting a request for a significant financial contribution in order to sustain research and development in the mining sector. As a first step, however, before it becomes possible to allocate the sizeable funds, which should eventually be granted towards R&D in this sector, an organizational effort is necessary. It is essential that a comprehensive view be developed, opinions exchanged and R&D efforts concentrated so that unnecessary project duplication will be avoided. In addition, the design of an effective selection process, aimed at supporting projects which could have the most impact on the productivity of mining companies, as well the health and safety of personnel, will improve the benefits generated by the sums allocated.

In this framework, a mandate was given to CANMET's Mining and Mineral Sciences Laboratories (CANMET-MMSL) to undertake this process and show, on the one hand, the importance and the contribution of the mining industry to the Canadian economy and, on the other hand, to recommend solutions through which the benefits of research can be maximized. Thus, the scope of the mandate required countrywide consultations to establish the requirements for research, to define priorities and to find the operating mode that will be the most consistent with Canadian reality. The importance of this process and the depth of the exercise required a national inquiry. Rather than using questionnaires, meetings were held with the main participants and their teams in their respective communities. The response rate to mailed questionnaires is typically rather low and the questions posed are open to interpretation by the respondents. On the other hand, the contributions of several participants, from different levels and ranks within various organizations, obtained in the meetings, have allowed the grasp of the different impressions which exist.

The various comments and responses that were gathered have allowed the identification of the problems and challenges which the mining industry will have to deal with in the next decade. Depending on the views and perceptions of each participant, research orientations can be drawn from the different priorities assigned to the axes of research presented to the respondents. Admittedly, the responses vary, based on operating conditions, the field of activities and the perceptions of the people interviewed, but, following the analysis of the feedback, a consensus was reached by all of the participants with regard to the order of priorities.

* SOREDEM: A non-profit organization made up of mining companies, with the mandate to support the development of new technologies for underground mines.

Finally, although it is difficult to determine accurately the sums required to achieve a broad and structured research program that would bring about concrete results, the analysis of research initiatives in other industries and in other countries allows to establish and propose an order of magnitude.  The sustainability of future resources is conditional upon the organized implementation and operation of the Canada-wide research program.  The expertise acquired at the different mine sites, by university and private research groups, by small and medium sized enterprises (SMEs) and manufacturers, is too precious to be diluted by diffused efforts. Meetings with the participants in different areas of the country suggested that the expertise is spread out in a complementary fashion amongst all operators, researchers, consultants, suppliers and equipment manufacturers.  With modern means of communication, it is possible to pool this expertise.  Thus, a research-monitoring model will be proposed to make better use of the expertise, stay the course and concentrate efforts towards priorities established by the participants.

## 2. Objectives

First and foremost, the purpose of this project was to provide some of the mechanisms, tools and techniques, which will be needed by Canadian mine operators to evolve in the social and economic setting which is anticipated for the next ten to twenty years. In order to meet this goal, the present study describes the main problems, both present and future, which were deemed to be important by the Canadian mining community as a whole and, to propose potential solutions, to be obtained through mining research.

Consequently, the present report is intended, more specifically, to:

i. Show the importance of the mining industry to the Canadian economy;

ii. Justify the reasons why mining research is essential in Canada;

iii. Identify the axes of research having the most potential impact on productivity, as well as on health and safety in the mines;

iv. Evaluate the research investment required for the next ten to twenty years; and

v. Propose an R&D action plan to obtain concrete results based on the axes of research identified and to provide a major impact for Canadian mines.

# 3. THE MINING SECTOR AND THE CANADIAN ECONOMY

## 3.1. Importance of the mining sector

The mining sector continues to be a pillar of the Canadian economy. Its main strengths are:

**Economy**

- In 2002, the Canadian annual value added for mineral production was almost $77 billion, $59 billion of which was for combustible minerals ($42 billion for Alberta alone), $10.2 billion for metallic minerals and $7.8 billion for non-metallic minerals [(12)].

- In 2002, the mining and mineral processing industries contributed $38.1 billion to the Canadian economy, or 3.6% of the GDP. This is significantly more than the high-tech sector, which accounted for 3.0% of the GDP [(1)]. The mining sector also contributes more to the GDP than the communications sector [(2)].

- The minerals and metals industry, together with related industries, contribute $1.4 billion to the Canadian balance of trade, which represents 2.4% of the national trade surplus [(4)].

- In 2000, 643 mining companies employed 75,515 workers and supplied raw materials to 10,135 other companies in the refining and fabrication sectors. All of these companies combined employed 274,338 workers. Salaries totalled $11.4 billion for a production valued at $110 billion, while the value added was estimated at $38.8 billion [(13)]. The national mineral production supplies a raw material source to protect jobs in this entire sector of the economy.

- The federal and provincial governments [(5)] receive $4.8 billion annually in capital taxes from the mining industry.

- SMEs [(5)] (Small and Medium Enterprises) in the mining sector create thousands of jobs in the high- tech and information product sectors. For $1 billion of produced minerals, when taking into account mining and primary metallurgy, direct demand for goods and services totals $615 million. If the entire production chain is factored in, i.e. exploration, mining development and operation, a $1 billion production generates economic benefits in the order of $1.3 billion for related sectors.

- Almost 200 mines operate in Canada, supplying materials to the fabrication, construction, automotive and chemical industries, as well as sources of energy. The coal and uranium exploited in Canada allow to produce one third of the power consumed here [(3)].

- Canada is one of the largest mining countries in the world. It produces over 60 minerals and metals [(1)].

- With regard to the value of Canadian production in 2002, the four most important minerals were: gold ($2.3 billion), nickel ($1.9 billion), potash ($1.6 billion) and copper ($1.4 billion). The value of the minerals produced in Canada amounted to $19.6 billion in 2002 [14].

- Over 500 companies sell, each year, more than $1 billion in goods and services produced in Canada [3] to the exploration and mining industries. More than 2,200 Canadian-based companies provide specialized services and equipment to the mining industry in Canada and abroad [4].

- The Canadian mining industry is truly Canadian: 70% of the sector is controlled by Canadian, as opposed to foreign, companies [3].

- Minerals and metals account for more than 60% of the volume of the goods being exported through ports and 55% of the revenues derived from rail freight transportation [4].

- Less than 0.03% of the Canadian landmass is exploited for mineral production [1].

- There are over 1,400 companies listed on the Canadian stock markets [6]. This is more than anywhere else in the world [15]. Canadian companies are involved in over 6,800 projects in Canada and abroad.

- In 2001, equity financing for mining companies listed on Canadian stock markets exceeded $1.3 billion [14]. In 1999, mining represented the third highest number of new offerings on the Canadian stock market [15].

**Employment**

- The payroll expenditures of the Canadian mining industry amounted to about $4.3 billion in 2000 [5].

- The metals and minerals industry provides 80,000 direct jobs and supports 300,000 indirect jobs in the procurement and services sector [3], representing a little less than 2.5% of the total of jobs [1].

- The mining industry supports, directly and indirectly, more than one million Canadians [3].

- Salaries in the minerals and metals industry are among the highest in Canada, averaging $1,169 per week, while the national average is $650 per week [4]. The salaries paid by the mines and primary production of metals are among the 10 best in the natural resources sector, while mining and the refining of metals are classified among the 10 best according to the Innovation Index from Industry Canada [2].

**Communities**

- Over 100 communities, with a total of over 600,000 inhabitants, owe their existence to the mining sector. These centres range in size from a few hundred inhabitants, for example Ekati, Northwest Territories (now closed), or Trail, British Columbia, to several tens of thousands in Rouyn-Noranda, Quebec, or Timmins, Ontario [(1)].

- Over 1,200 native communities are located within 200 kilometers of mining or metal-related activities.

- The Canadian mining industry [(5)] tends to satisfy one third of its requirements for products and services from suppliers located within 80 kilometers of its operations. Thus, mines are actual regional economic generators. Companies require the services of the technology sector, thereby promoting the creation of SMEs in the innovation sector in remote areas.

- The Toronto, Vancouver and Montreal urban centres also benefit from the mining sector by being at the heart of stock markets and brokerage firms. Several mining companies have set up their head offices there. In addition, mining activities generate a high level of activities for seaports and railway transportation in urban centres.

- Suppliers of mining goods and services are located in over 400 communities across Canada [(2)].

- Several communities and areas, such as Chibougamau, Quebec, or Red Lake, Ontario, have economies based almost entirely on natural resources.

**Exports**

- Exports of metals and non-combustible minerals in 2002 amounted to $49.4 billion, or more than 10% of all Canadian exports.

- Almost 80% of the entire Canadian mineral production is exported. Consequently, this sector ranks first in Canada, in terms of export revenues, followed closely by the forestry sector [(3)].

**Productivity**

- The minerals and metals industry is among the most productive in Canada. From 1981 to 1998, total productivity in the minerals and metals industry has increased on average 2.7% annually, while the global rate for Canada was 1% (Figure 6) [(4)].

- The mineral industry ranks among the 10 most productive Canadian industries if the GDP is calculated on an employee basis. For example, in Ontario, for $1 million of metals produced, 4.1 employees were required in 1993, but only 3.4, six years later, in 1999 [(15)].

## 3.2. Mining sector issues

### 3.2.1 Actual and future issues in the mines

During the interviews, the first concern that was discussed with the participants was:  what are the issues that jeopardize, or will jeopardize, the survival of the Canadian mining industry as a whole, and that of your company, in particular, in the next ten years?  Answers, classified by themes, are outlined below, together with some possible solutions.

**Availability of qualified manpower**:  The problem is very real in remote areas, such as in Thompson (Manitoba) and Chibougamau (Quebec).  However, even if in areas such as Sudbury or the Rouyn-Noranda/Val-d'Or axis, the availability of manpower may seem less problematic, its cost is relatively high.  Moreover, with an average age of workers of 51 in Ontario mines (7), the massive retirement contemplated in the next ten years will also present challenges.  Finally, the problem is all the more important for service companies to the mines since they have always had more difficulty to hire or retain qualified manpower.

Consequently, unless much higher salaries and benefits are offered in outlying areas, compared to the rest of the market, evidence suggests that the mining industry will have a hard time recruiting and retaining a sufficient quantity of qualified workers to ensure its prosperity, if not, its survival.  Further, as a result of international competition, among other factors, the remuneration capacity of Canadian companies is limited.  In other words, what will be the actual social and economic costs related to the lack of development of new technologies?  At the same time, Canadian mining operations will have to be easier to operate and be safer in the future.  The status quo is, therefore, not a feasible option.

One of the potential solutions is to train native peoples.  Since they already live close to mining areas, they are generally accustomed to the lifestyle in the northern regions, while workers from urban areas must adapt to it.  Companies that are seriously committed to this course have, therefore, found a solution, both for the enterprise and the employees.

Moreover, it would seem that with the progressive introduction of automation, gradually fewer personnel will be required underground, but the labour force will have to be more qualified.  Owing to the lack of availability of people on the market, companies must often provide the training for their specialized employees.

To attract and retain manpower in remote areas and to convince young students to study earth sciences, such as mining engineering, several fiscal and other incentives such as low-rent housing and appealing isolation premiums were once offered.  The reintroduction of these measures, combined with offers of stable and well-remunerated jobs, could contribute to resolve the manpower shortage.  However, the best way of guaranteeing that people will continue to live in remote areas is probably to ensure that a large number of high quality jobs are available in the long term.

**Operational constraints**: Undoubtedly, operational constraints, such as how to mine deposits and deal with obstacles, will significantly influence the health of the Canadian mining sector. The various constraints or *driving forces* raised during the interviews (Appendix A) are those in which the mining sector stakeholders have a certain power to undertake changes. For example, even though continuous improvement processes have been implemented in several companies, it is still necessary to optimize the time required to perform each operation and to minimize the losses of productivity between work shifts. In spite of all these efforts, there are limits to this optimization exercise. A substantial reduction in operating expenses requires the development of new equipment or new mining methods. Another example: a reduction in dilution could have a major impact on several underground operations.

Consequently, it appears that even though several operational constraints could be eliminated or minimized through focused and well-structured research work, very often the mining industry will not invest the funds into these initiatives since it can not assume this additional risk.

**Variable metal prices**: The depreciated prices of metals, combined with frequently high operational costs of Canadian deposits, compared to those of some other countries, result in a downward trend in Canadian mining production [8].

Mine operators have no control over the selling prices of their metals. However, by reducing operating costs, mines will be able to improve their competitiveness at the international level and ensure, at the very least, a profitability which will be equivalent to that of other producing countries (Figures 1 and 2).

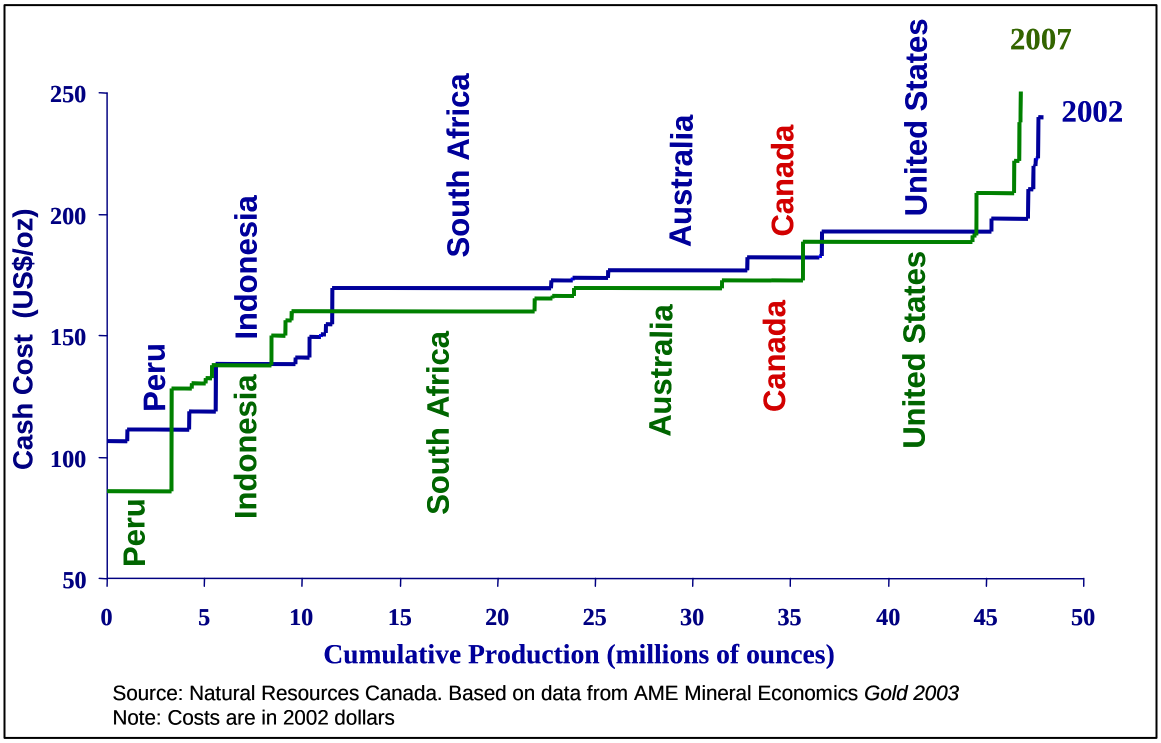



**Figure 1 – Average production cost of major gold producing countries**
*(Courtesy of the Economic and Financial Analysis Branch of the Minerals and Metals Sector of Natural Resources Canada)*

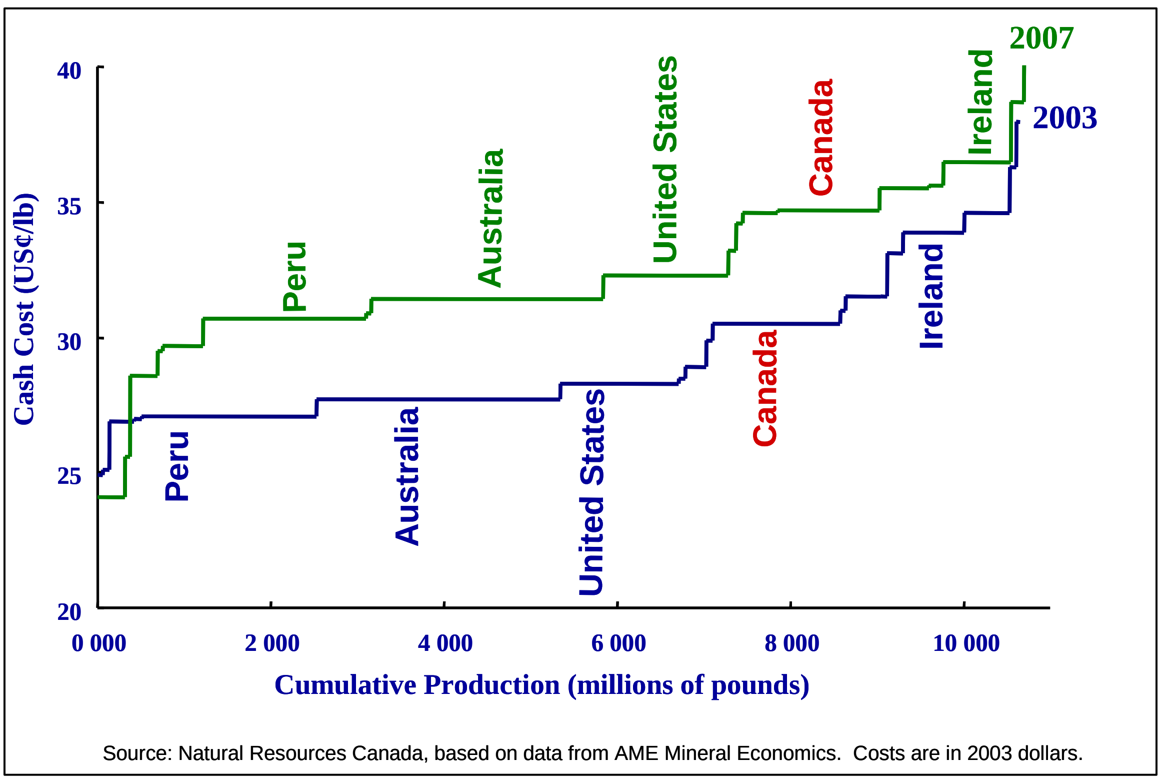



**Figure 2 – Average production cost of major zinc producing countries**
*(Courtesy of the Economic and Financial Analysis Branch of the Minerals and Metals Sector of Natural Resources Canada)*

**<u>Availability of mineral resources and exploration</u>**: It appears that the availability of mineral resources is directly linked to the number of discoveries, which itself is dependent on exploration efforts. Figure 3 clearly shows the extent to which actual discoveries were made up to 2000. The decrease has been dramatic.

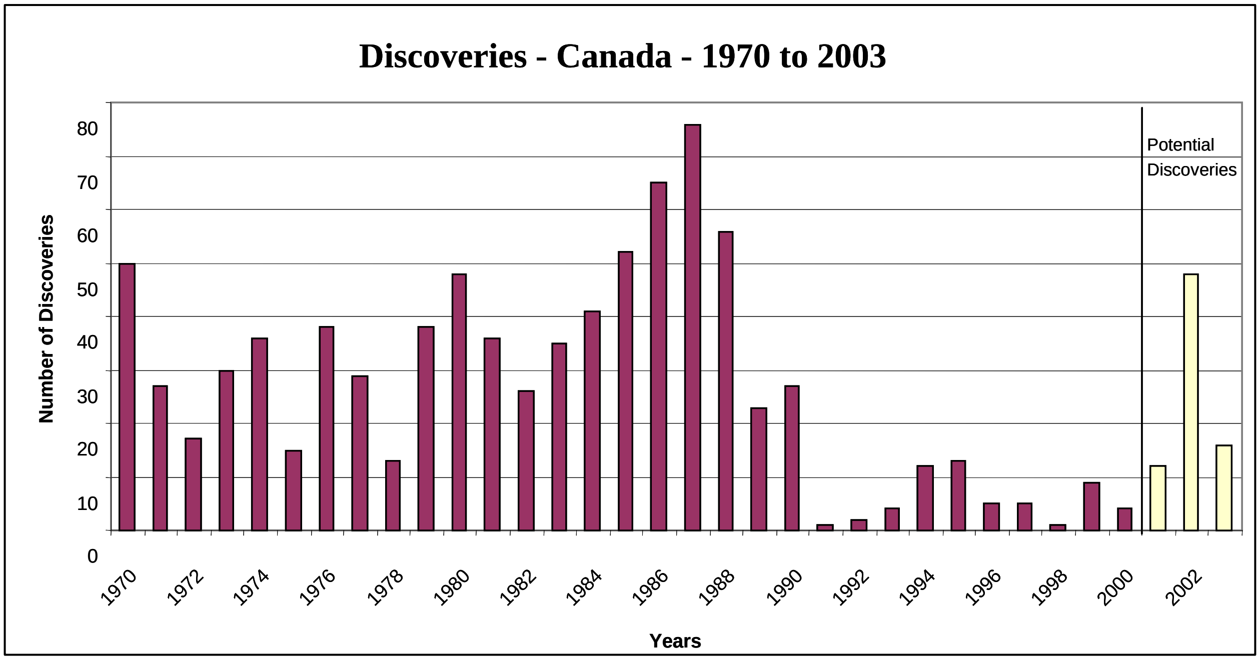



**Figure 3 – The low rate of discoveries will retard the growth of the industry**
*(Courtesy of the Economic and Financial Analysis Branch of the Minerals and Metals Sector of Natural Resources Canada)*

Because of the low price of metals and the lack of interest from investors, the anemic exploration efforts represent another problem which will affect the medium-term health of the mining sector (Figure 4). Fortunately, some recovery in 2003 was associated with a rise in exploration investments, mainly in gold and diamonds.

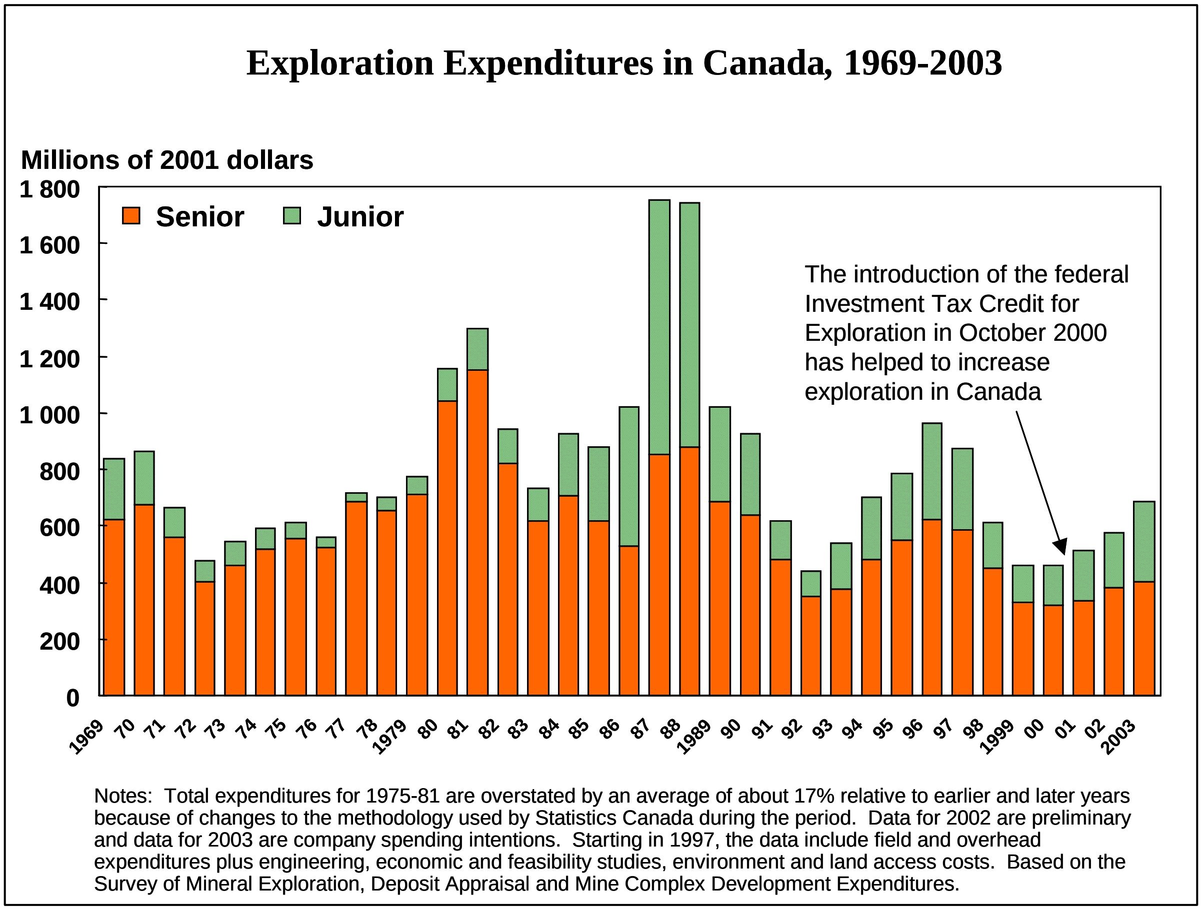



**Figure 4 – Cyclical nature of prices also reflected in Canadian exploration expenditures**

*(Courtesy of the Economic and Financial Analysis Branch of the Minerals and Metals Sector of Natural Resources Canada)*

Moreover, there are important mineral deposits across the country that cannot be mined efficiently with current mining techniques.  The same argument is true for deposits in deep mines in which the known resources are very important (Figure 5), but where current bulk mining methods are not necessarily adapted to such conditions.

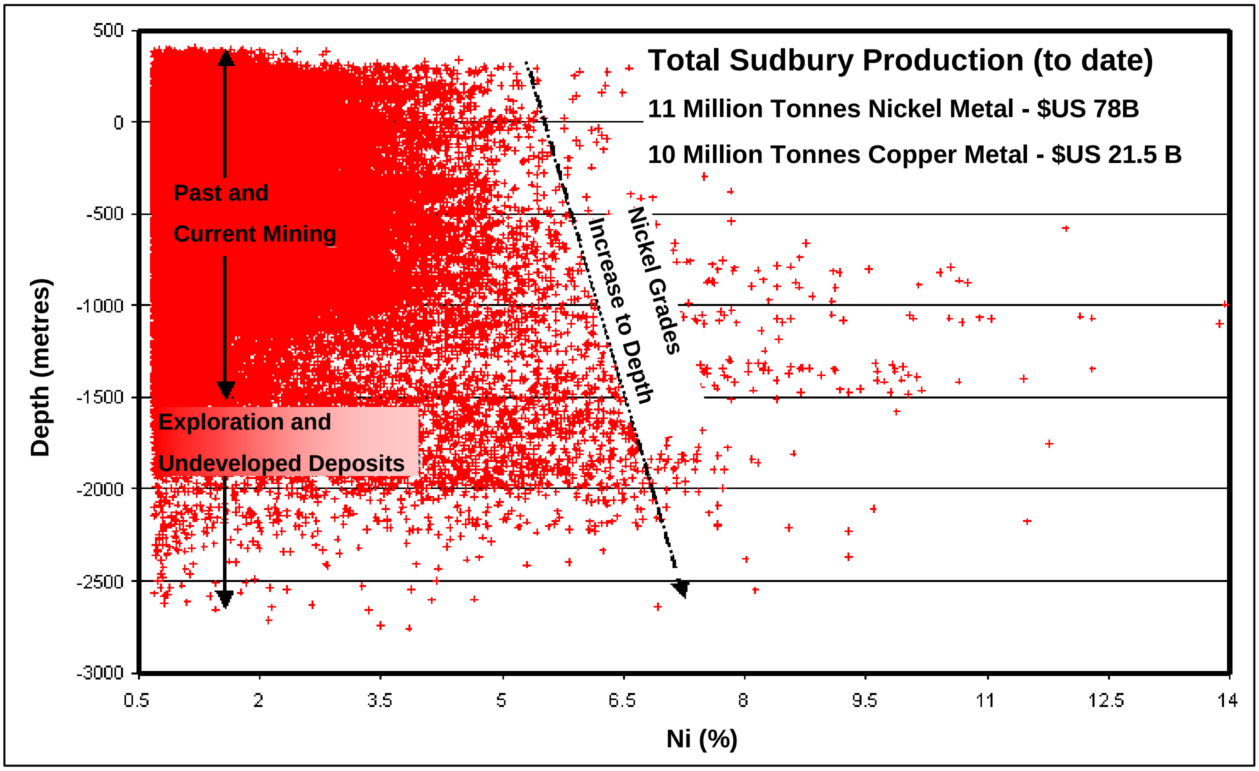



**Figure 5 – Composite assays of Ni grade (%) vs depth in the Sudbury basin**
*(Courtesy of Falconbridge Limited)*

**<u>Industry's public image</u>**: In spite of all of its efforts during the last few years, the mining industry must continue to improve its public image with Canadians, in general, as far as the perceptions of the environmental impacts and the working conditions underground are concerned. The wrong negative public image has an impact on investors, the recruitment of manpower and student enrolment in earth sciences programs (e.g.: mining engineering). The industry must, therefore, enhance its public image by highlighting the positive aspects of its contribution to the well-being of Canadians, while, at the same time, putting the emphasis on factors such as its respect of the environment, high wages, the sector's contribution to the GDP, job creation in remote areas, and the relatively low rate of occupational injuries [(9)]. Televised promotional campaigns, fashioned after those undertaken by the petroleum and forestry sectors, although costly, could provide significant benefits in the short and medium term.

**<u>Delay in obtaining permits</u>**: One of the problems frequently encountered in all provinces is the delay in obtaining the necessary operating permits. This is considered as a major drawback for companies operating in Canada.

**<u>Scope of environmental impacts</u>**: All of the mines consulted are in agreement that high environmental standards must be maintained, and that constructive research work is required to reduce the size of tailings sites and the cost of effluent treatment in the environment.

Moreover, environmental legislation must be based on concrete scientific information in order to avoid excessive regulations.

**Market access for minerals and metals**: A challenge that proved to be critical in the case of asbestos, for example, was the access to markets for minerals and metals. At present, nickel is under scrutiny since doubts have been raised as to its toxicity. It is essential that research work be undertaken to demonstrate the conditions under which metals can be used safely in order to prevent their banishment for reasons that have not been scientifically justified.

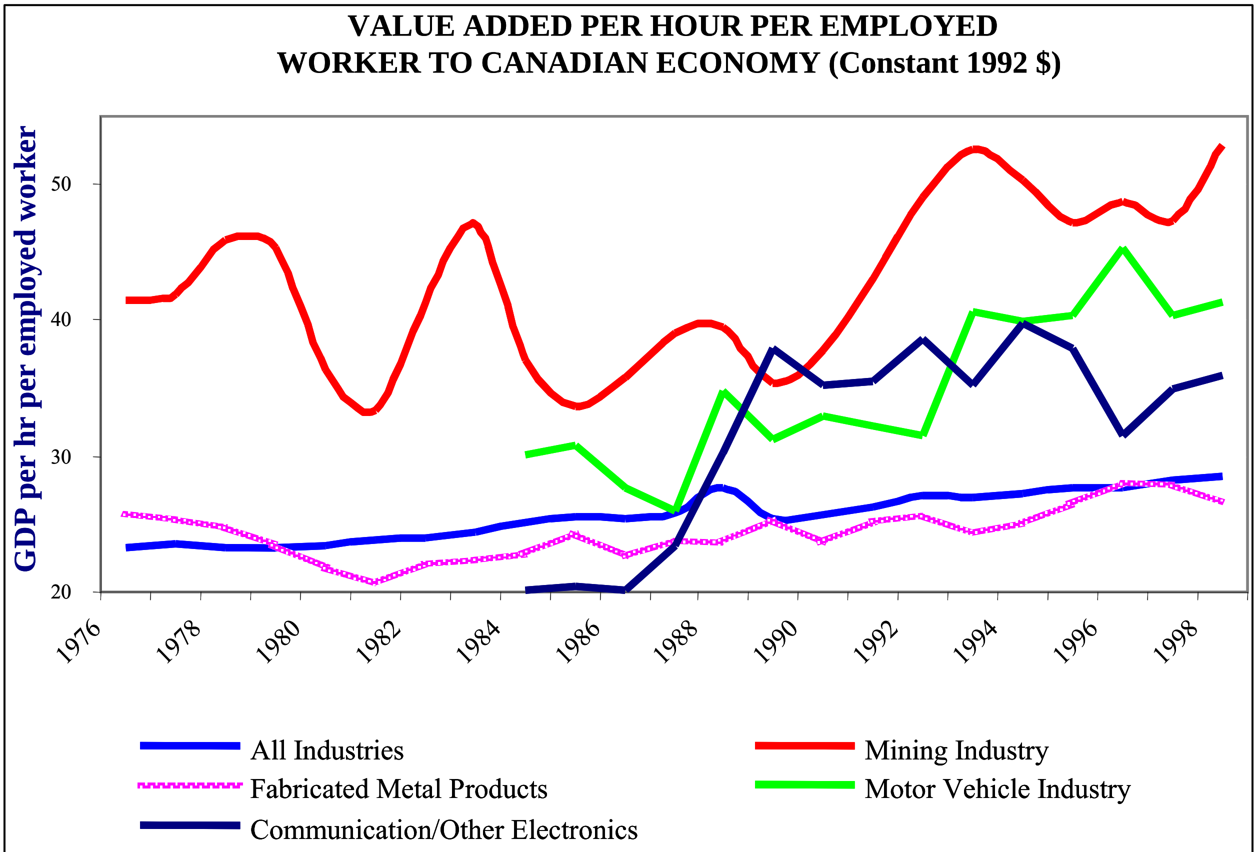
**Competition from new producing countries**: Some participants have stated that there has been strong competition from countries in which labour costs are less significant, environmental regulations are less stringent and labour standards are not as high. All of these result in lower operating costs. Moreover, capital costs are generally lower in those countries. However, Canadian companies, while operating abroad, generally follow the standards in effect in Canada.

Although these conditions are true for several countries, they are sometimes offset by a less qualified and unstable manpower base due, in part, to diseases, such as AIDS and malaria, a notable lack of infrastructure, laboratories, equipment, and the ability to maintain repair parts. In addition, some of these foreign operations, being financed by the World Bank, must subsequently comply with high environmental standards and human rights required. In other respects, the productivity of the Canadian mining industry (Figure 6) offsets some high operational costs, such as labour costs.

**Conclusion**

Manpower availability, the price of metals and their access to markets, the availability of mineral resources, the delays in obtaining the permits required, the costs associated with labour standards and the environment, as well as operational constraints, will have an impact on the growth of the Canadian mining sector in the next decade. Apart from the operational constraints, mines have little power to influence the other factors.

Since the only appropriate action must be directed at decreasing operating costs, while, at the same time, improving health and safety, the theme of productivity enhancement was chosen for this study. In other words, if the productivity of Canadian mines does not markedly improve in the next few years, especially with regard to mines that cannot easily be mechanized, they will no longer be able to exploit the available resources competitively in comparison with world markets.




1 Includes extraction and concentrating, smelting and refining, nonmetals and metal-based semi-fabricating industries, and metals fabricating industries. It also includes uranium and coal mining. Source: Centre for the Study of Living Standards

**Figure 6 – Value added to the Canadian economy per hour worked (1992 constant $)**

*(Courtesy of the Mineral Technology Branch of the Minerals and Metals Sector of Natural Resources Canada)*

On the other hand, the problem is not only economic; it also reflects a social reality. The younger generation, having a greater accessibility to education than the former one, actually has access to a wide choice of specialized occupations. At the same time, mechanization and robotization, which have generally spread throughout various industrial sectors, have progressed less rapidly in mining operations. This phenomenon is particularly obvious in the case of narrow-vein deposits which are, for the most part, more difficult to mechanize because of their small dimensions [(10)]. Thus, few equipment manufacturers are interested in this market. For that reason, the recruitment of manpower becomes more problematic in filling jobs that require a certain physical strength. Additionally, in very deep mines, the environment is more demanding physically due to the predominating intense heat and humidity. Moreover, the migration of workers to other sectors of the economy is due to the cyclical nature of the industry, where mining jobs are often short term and call for frequent relocations. The fragility and short lives of some operations do not attract manpower in remote areas. For these reasons, a gradual lack of interest in the traditional miner trade is observed.

These problems will certainly be magnified by the declining birth rate that is prevalent in Canadian society. Further, the average age of manpower being relatively high, a massive wave of retirement can be expected within the next ten years. Even though the problem may not be currently critical due mainly to the actual slowdown in the mining sector, narrow-vein operators, and mine operators in remote areas, are already facing this situation. The lack of qualified manpower was mentioned over and over again during visits; from the electrician to the mining engineer, and supervisors. Supervisory personnel, having the necessary leadership required for underground mining, are becoming a rare commodity. This seems to be a global problem in the mining sector [(11)]. Moreover, the number of admissions in engineering faculties is very low and, as soon as the mining sector recovers, the availability of engineers will also be a problem to contend with.

### 3.2.2 The challenge behind mineral potential development

The world demand for minerals and metals grows year after year, and is presently evaluated at US$200 billion per year [(16)]. Therefore, if Canada can produce minerals and metals at a competitive price, it will be possible to market its production on world markets. However, will Canada still be able to compete in the metals markets in the next ten years? Since the 1990s [(16)], there has been a steady decline (almost 23% up to now) in jobs in the mining sector in Northern Ontario. In Canada, the decline between 1989 and 2000 has been established at 34% [(13)] (Figure 8). This phenomenon is due to mine closures, the depths of some deposits, the weaknesses of metal prices and the increases in productivity of mine workers. Job losses in related sectors are far higher when considering the multiplier factors. In some respects, it is therefore possible to state that the Canadian mining sector is in decline [(16)]. The reserves of metals have continually decreased [(6, 17)] (Figure 7): since early 1990s in the case of gold, and since early 1980s in the case of the other metals.

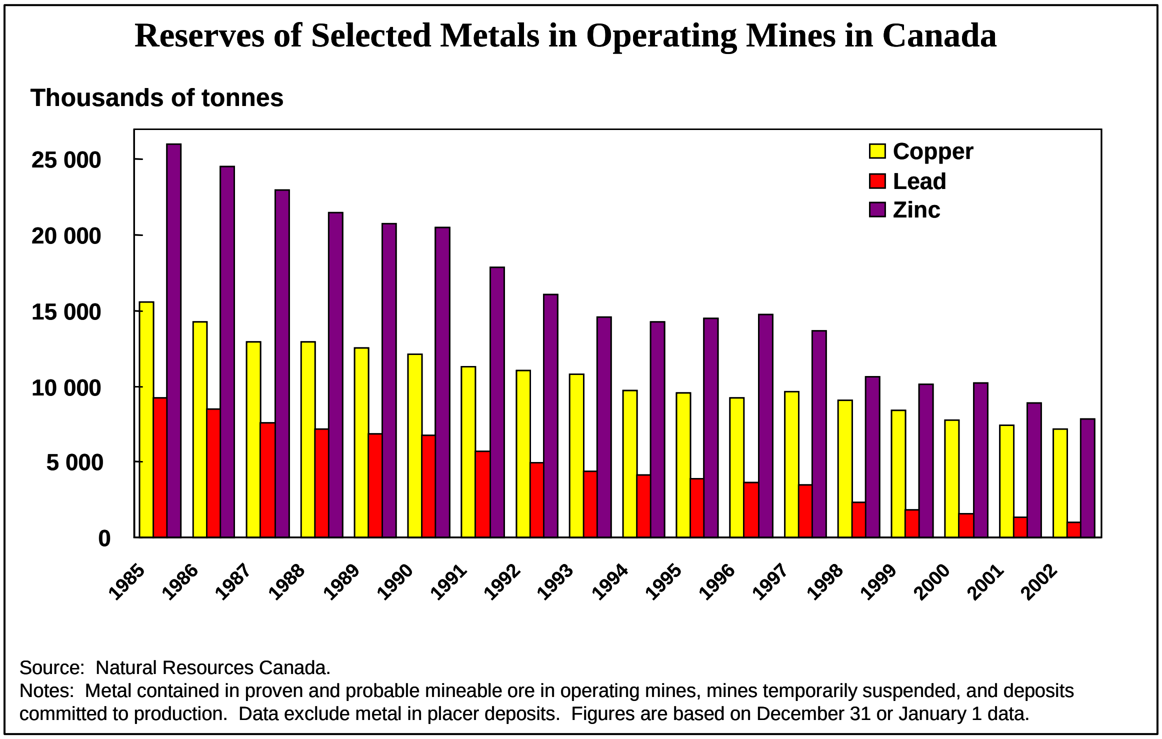



**Figure 7 – Reserves of certain metals in mines under production in Canada**
*(Courtesy of the Economic and Financial Analysis Branch of the Minerals and Metals Sector of Natural Resources Canada)*

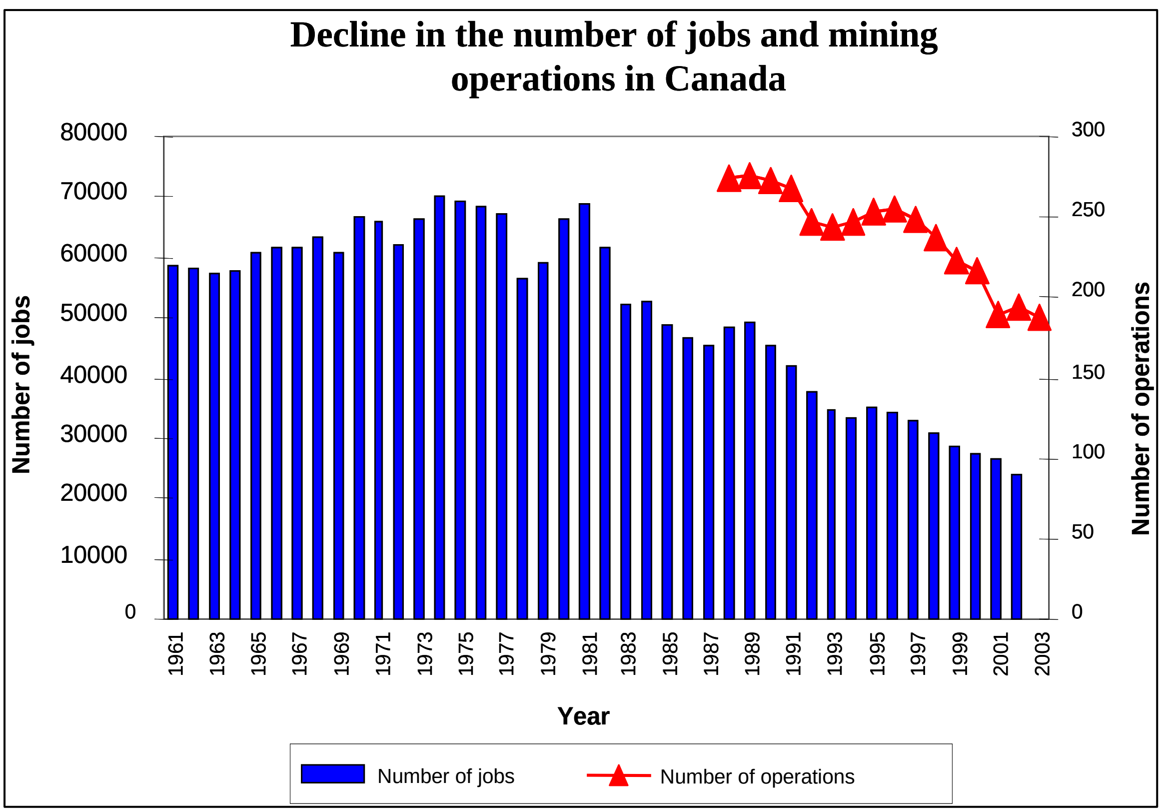



**Figure 8 – Decline in the number of jobs [13] and mining operations in Canada**

Also, according to Natural Resources Canada, if the sizeable nickel reserves of Voisey's Bay are excluded, the estimated reserves of some metals, in 2001, will be sufficient, at current rates of production, only for the number of years as shown below: (Table 1) [(13)]:

**Table 1 – Estimated reserves of Canadian metals**

| Metals | Number of years |
|---|---|
| Nickel | 21 |
| Copper | 10.5 |
| Molybdenum | 9.5 |
| Silver | 8.8 |
| Zinc | 7 |
| Lead | 7 |
| Gold | 6 |

Moreover, the proportion of investment-related exploration outside a mine site, carried out by large businesses, has continued to decrease since 1997, going from $455 million to less than $200 million in 2002 [(18)]. Concurrently, since 1998, the growing effort in diamond exploration conceals, in statistics, the important reduction in the sums allocated to the discovery and development of metal-bearing deposits. Consequently, as stated in subsection 3.2.1, the discovery of new deposits continues to drop (Figure 3).

Since it is impossible to control the selling price of metals, and in order for the mining sector to prevail in the Canadian economy, mine operational costs will have to remain competitive in comparison with international costs; hence, this would allow developing deposits which are currently subeconomic (Table 2) or extending the life of existing mines. To do so, mining companies will have to significantly improve their production processes and to develop innovative mining techniques. This will require a substantial research endeavor, which will have to be supported by all stakeholders.

**Table 2 – Mineral deposits in Northern Quebec and in Ontario**
*(Data courtesy of the Quebec Department of Natural Resources, Wildlife and Parks and the Ontario Ministry of Northern Development and Mines)*

| Regions | Deposits per sub-region | Total of deposits per region |
|---|---|---|
| Abitibi-Témiscamingue | | 151 |
| Northern Quebec | | 204 |
| Northeastern Ontario | | 143 |
| Kirkland Lake | 41 | |
| Sault Ste-Marie | 35 | |
| Sudbury | 17 | |
| Timmins - Wawa | 50 | |
| Northwestern Ontario | | 171 |
| Kenora | 51 | |
| Red Lake | 54 | |
| Thunder Bay North | 23 | |
| Thunder Bay South | 43 | |
| Southern Ontario | | 23 |
| **TOTAL of mineral deposits** | | **692** |

## 3.3. Contribution of the mining sector to regional economies

### 3.3.1 Introduction

Minerals are produced in all Canadian provinces and territories (Table 3). Except for combustible materials, the production of metallic and non-metallic minerals is essentially concentrated in the provinces of Ontario, Quebec and British Columbia. Uranium production in Saskatchewan and nickel-copper at the Thompson mining camp, in Manitoba, also represent important economic contributions to those two provinces. Natural resources, which benefit all Canadians, thus are spread throughout the vast Canadian territory. This distribution of natural resources, based on the country's geology, is such that most mining operations occur outside the narrow zone north of the American border in which the Canadian population is concentrated. Mines in remote areas thus permit active utilization of a large part of Canada's land mass.

**Table 3 – Estimated value of the Canadian mineral production per jurisdiction in 2002 [20]**

| Province/Territory | Metallic (million $) | Non-metallic (million $) |
|---|---|---|
| Newfoundland | 918 | 48 |
| Prince Edward Island | - | 4 |
| Nova Scotia | - | 247 |
| New Brunswick | 441 | 190 |
| Quebec | 2,349 | 1,342 |
| Ontario | 3,518 | 2,235 |
| Manitoba | 734 | 95 |
| Saskatchewan | 663 | 1,641 |
| Alberta | 1 | 594 |
| British Columbia | 1,248 | 542 |
| Yukon | 31 | 4 |
| North West Territories | 53 | 811 |
| Nunavut | 269 | - |
| **Total** | **10,225** | **7,753** |

Investment-related exploration and the development of existing mine sites, along with new exploration objectives, which are located throughout all geographic areas of the country, suggest that mining activities will continue to take place on the entire territory. From an historic point of view, it is relevant to underline the relative weight of exploration efforts and the development carried out in the Yukon Territory, in the North West Territories and in Nunavut, where mining activities play a major role in these regional economies [21].

Mining operations are located in remote areas from major urban centres. The economic survival of these regions is often based on the exploitation of mineral and forest resources, and to a much lesser extent, on agriculture, and perhaps even tourism. According to a study on problems encountered in such areas [22], the implementation of processing industries in outlying areas will always be problematic and they will always be adversely affected in comparison with urban centres. More particularly, it should be stated that the additional transportation costs and the necessary trips to and from consumer areas still represent a negative aspect. Deregulated transportation services, which are subjected to market forces, have actually emphasized this factor. The geography and sparseness of the population intensify the indirect effects on distance. In addition, the size and appeal of urban centres, both for the youth and highly qualified personnel, are such that manpower availability is definitely superior and more competitive there, than in remote areas. This reality adversely affects remote areas in sectors, such as high technology and very specialized services, as well as those related to the fabrication of low value-added products. Besides, in urban and peripheral centres, several of these high-tech industries are undermined by the competition from emerging countries, such as China and India. However, the natural economic strength in the regions is its access to mineral resources. The regions, hence, do not have to compete with urban centres, such as Toronto or Montreal, which do not have access to the same natural resources potential [(23)].

Also, other drawbacks can be attributed to prominent employers in the area. In actual fact, the high wages and fringe benefits offered by forestry, mines, metal processing and services [(13)], (Table 4) add an important constraint to the local entrepreneurship wanting to attempt to create an economic diversification.

As stated in the Polèse and Shearmeur study (2002) [(22)]:

*"This situation creates an additional obstacle for entrepreneurs in outlying areas. They must not only meet wages and fringe benefits, which local workers are expecting, but must also compete with lower wages and more flexible manpower which competitors in central regions are benefiting from."* (unofficial translation)

**Table 4 – Average weekly wages of hourly employees**

| Year | Metallic ore extraction ($) | Mining support ($) | Forestry operations ($) | All other industrial sectors ($) |
|---|---|---|---|---|
| 1996 | 1,078 | 895 | 746 | 586 |
| 1997 | 1,053 | 948 | 786 | 598 |
| 1998 | 1,127 | 978 | 766 | 606 |
| 1999 | 1,123 | 970 | 773 | 610 |
| 2000 | 1,169 | 1,014 | 810 | 626 |
| 2001 | 1,169 | 1,049 | 801 | N/A |

N/A – not available

However, the specific expertise acquired in remote areas, like in the forestry and mining sectors, can be the basis for the development of a manufacturing and service industry, which is very competitive and solid at the international level. Nonetheless, the mining industry must be bolstered financially with sophisticated and innovative mining techniques in order to continue exploiting these natural resources economically. Maintaining a critical level of mining activities and the renewal of Canadian know-how are equally high priorities for manufacturing and service industries that do business there. This approach continues to be the most desirable road for remote areas and Canada as a whole. The "clusters of excellence" approach promoted, among other things, by the Ontario government [(15)], gathers several favorable conditions offering a great potential for success [(23)].

### 3.3.2 Abitibi-Témiscamingue and Northern Quebec

The most produced minerals and metals in the Abitibi-Témiscamingue and Northern Quebec regions are gold, copper, zinc and nickel, the latter being produced at the Raglan mine located in the extreme north of Quebec. Apart from the open pit mining activities at the Troilus mine, North of Chibougamau, the extraction of these metals is achieved through underground methods.

Although distinct from an economic point of view, the interdependence between the different cities and the mining operations is such that the Abitibi-Témiscamingue and Northern Quebec regions must be considered as a single entity. In this way, it is possible to evaluate, more precisely, the mining sector contribution for the territory as a whole, based on the available statistics.

The *Association paritaire pour la santé et la sécurité du travail - Mines* (APSM) compiles the hours worked in mine sites, including underground and open pit mining operations, mills and mine contractors carrying out custom work, such as drilling boreholes, as well as other work performed on a contractual basis. These hours represent a reliable indicator of the number of direct jobs effectively linked to metal extraction. The compilation of hours worked in mining operations indicate that the Abitibi-Témiscamingue region, combined with Northern Quebec, constitutes the most important mining area in Quebec, with 57% of jobs coming from mining operations (Table 5).

**Table 5 – 2003 employment statistics provided by APSM**

| Distinct region | Direct jobs (2,000 hrs/yr) | % | Total jobs mining industry (multiplier 1.67) | Jobs - Total per region | Mining jobs per region (%) |
|---|---|---|---|---|---|
| Abitibi–Témiscamingue and Northern Quebec | 4,297 | 57.2 | 7,175 | 85,065 | 11.4 |
| North Shore | 2,344 | 31.2 | 3,915 | 46,810 | 11.3 |
| Asbestos region | 419 | 5.6 | 700 | 21,015 | 4.5 |
| Îles-de-la-Madeleine | 138 | 1.8 | 231 | 6,425 | 4.8 |
| Chicoutimi-Jonquière | 205 | 2.7 | 343 | 71,480 | 0.6 |
| Others | 110 | 1.5 | 184 | | |
| **Total jobs for Quebec mines** | **7,514** | **100** | **12,548** | | |

The compilation of direct and incidental jobs shows that, in Abitibi-Témiscamingue and Northern Quebec, mining operations represent 7,175 permanent jobs, or almost 11.4% of all jobs in that region. Almost 4,300 jobs are directly connected to mining. These jobs, including those in forestry, being by far the most highly remunerated in the region, constitute the economic skeleton of the Abitibi-Témiscamingue region. However, the labour market has deteriorated during the last few years due to the extended weakness of metal prices, as well as the depletion of mineral reserves and the low level of exploration to renew them. In addition to a high, but stable, unemployment rate (14% in 2001), the working population has declined and almost 2,000 jobs were lost between 1996 and 2001. To underline the problem, the forestry sector has had its share of difficulties as a result of the softwood lumber dispute with the United States and the raw material supply constraints. As a result, manpower in that region is more vulnerable to the variations of world conditions because its economic base relies, for the most part, on a high concentration of jobs in the primary sector. Owing to the fact that it was not possible to firmly establish an equipment manufacturing and mining services industry, as in North Bay and Sudbury, Northwestern Quebec, despite its significant mining activities, compared to Quebec as a whole, is still fragile, and dependent upon the price of metals and the good financial health of mining operations.

**Chibougamau region**

The economic activity of Chibougamau relies mainly on the development of natural resources. Its flourishing adventure tourism can also offer another form of diversification.

Chibougamau used to be a very active mining town. However, although this region has a good mining potential, few companies operate there because it is basically made up of narrow-vein deposits. Mining companies that continue operating in the Chibougamau region, at the moment, are Inmet-Troilus Mining Corporation and Campbell Resources.

Although it is still considered as a mining town, its economy has diversified over the years and its population has slowly taken root, developing a genuine regional sense of belonging. Today, forestry operations hire as many workers as the mines and Chibougamau has become the major service point for surrounding communities. In recent years, tourism has also evolved substantially through community efforts.

However, mining operations will continue to be the most important industry that will ensure a solid foundation to the economic activity of that region. Forestry can no longer grow as a result of reduced exploitation of forest resources in the years to come. The tourist industry cannot, by itself, justify the infrastructures that are required for the life of a community.

The local aboriginal population, composed of many young people, is also seeking employment and wants to work in their area.

### 3.3.3 Ontario

#### 3.3.3.1. Introduction

Three geographical areas characterize the Ontario mining industry:

- Northeastern Ontario – Sudbury, Timmins and North Bay areas;
- Northwestern Ontario – Red Lake area; and
- Southern Ontario – Toronto and its periphery.

The Ontario mining industry is prominent in Canada and employs 29% of workers in the Canadian mining sector, representing approximately 14,834 workers in 2001 (24).

In 2003, statistics from the Mines and Aggregates Safety and Health Association (MASHA)(25), compiling the hours worked particularly on mine sites, showed a relatively equivalent number of jobs, i.e. 14,513.

In monetary terms, these jobs represent the following, on a yearly basis, for the Ontario population (24):

- $1.4 billion in wages paid to employees by the mining industry;
- Average annual wages of $58,000 per employee;
- Benefits of $29,500 per employee, representing 33.7% of direct pay;
- Annual income taxes amounting to $200 million for the federal and provincial governments; and
- Municipal taxes in the amount of $40 million, contributing significantly to the revenues of municipalities.

**An equally crucial industry for Ontario**

Due primarily to its sizeable nickel deposits, Ontario has developed a world-class mining industry. This industry, with sales in the amount of $5 to $6 billion (13) is one of the most important high-tech producing sectors. The mining industry has always been exposed to a free and open-type market, controlled by world market laws. Between 1997 and 2001, the productivity of the Ontario industry has increased by approximately 25%, representing almost three times the rate of increase of average manufacturing sectors (24).

According to a study sponsored by the Ontario Mining Association (24), the Ontario mining industry consumes, on a yearly basis, almost $900 million in goods and services. Ontario benefits more than any other province from its mining industry as a result of the high proportion of purchases made within the province (86.9%), and 36.7% of purchases made close to mining centres. In 2001, despite difficult market conditions linked to the price of metals, mining companies spent approximately $320 million within 80 kilometers of mining operations. This results in a significant economic activity for the

North Bay/Sudbury regions, as well as for Toronto, where SMEs and manufacturers, as well as financial markets and head offices, related to the mining industry, are located.

Without overlooking the importance of the other sectors, the mining industry, with its high salary level and significant purchases, is an invaluable economic generator for over 50 Ontario communities.

**Employment enhancing the standard of living of the community**

As in the rest of Canada, the Ontario mining industry provides well-remunerated high quality jobs with many fringe benefits (medical benefits insurance, pension plan, disability insurance, etc.), thus relieving the government from a social burden in future years as far as pension funds are concerned.

The econometric study entitled "The Economic and Fiscal Contributions of the Mining Industry in Ontario" (9) shows that the Ontario mining industry contributes $242 million in taxes to the three levels of government:  of which $118 million is to the federal government, and $85 million to the provincial government.  In 2001, the mining industry also contributed $39 million in municipal taxes, representing a very important contribution to municipalities.

### 3.3.3.2. Northeastern Ontario

Northeastern Ontario, including the cities of North Bay, Sudbury, Timmins and Kirkland Lake, represents the principal mining area in Ontario, with 12,118 jobs in 2001, or 72% of available jobs.  Nickel mines (INCO and Falconbridge) and the Kidd Creek complex (24) are located there.

This mining area is certainly the most important in the country.  A total of 6,152 direct jobs are concentrated in nickel mines; INCO employs 4,500 workers in 10 mining operations and Falconbridge, 1,500 in 4 different operations, representing more than 43% over the entire mining operations in the Abitibi-Témiscamingue and Northern Quebec regions combined.

The intensity and diversity of mining activities in Northeastern Ontario have a significant and, above all, stabilizing positive impact on the social and demographic profile.  As a result of this stabilizing factor, this area represents the main focal point for the economic activity linked to the mining sector.  Over 30 manufacturers, along with more than 320 suppliers of mining goods and services, are located in Sudbury and North Bay.

Several educational and research institutions have been set up in Northeastern Ontario over the years:

- CAMIRO (Canadian Mining Industry Research Organization);
- Cambrian College and Collège Boréal;

- Geomechanics Research Centre;
- Centre for Mining Technology and Equipment;
- CANMET-MMSL, Natural Resources Canada;
- MIRARCO (Mining Innovation, Rehabilitation and Applied Research Corporation);
- NORCAT (Northern Centre for Advanced Technology Inc.); and
- Laurentian University.

To strengthen the sector, the Ontario government has also transferred the Ministry of Northern Development and Mines (MNDM) to Sudbury.

#### 3.3.3.3. Northwestern Ontario

The Red Lake mining region and the Hemlo gold camp constitute the main mining activities in Northwestern Ontario. The province gold production is primarily concentrated in that region (24).

Between 1992 and 2001, the number of jobs increased significantly. In that region, 14.7% of jobs came from mines, representing 2,569 workers. The Hemlo gold camp contributes extensively to the mining activity of that region. However, reserves are diminishing and Northwestern Ontario will have to rely on other mining camps, namely that of Red Lake, to ensure prosperity and the level of employment in that part of the province.

**Red Lake**

In 2001, the employment structure at that location was as follows (26):

| | | |
|---|---|---|
| Mining sector | 580 | 24% |
| Agriculture | 110 | 4% |
| Other industries | 145 | 6% |
| Industry total | 835 | |
| Services - public sector | 500 | 20% |
| Services - private sector | 1,115 | 46% |
| Total employment | 2,450 | 100% |

Each job in the industrial sector was consequently associated with 1.33 local jobs in the private sector services.

In the “other industries”, approximately 85 jobs come from forestry operations. Employment in the private sector services included an indeterminate number of jobs related to tourism, which has developed over the years.

The Red Lake situation tends to validate the assumption that each direct job in mining activities generates at least one additional local job in the service sector (see chapter 4). This case also supports the assumption that the mining activity creates high quality jobs.

Almost one inhabitant out of five (19%), 20 years of age or older, has received university training. This municipality, with less than 5,000 inhabitants, has a socio-demographic profile comparable to that of far more populated cities in Northeastern Ontario [27].

The recent history of the Red Lake mine conveys a message of encouragement towards extending the life of existing mines and current mining camps. This mine has been in operation since 1948 with limited investments. In 1996, it produced 53,000 ounces of gold at an operating cost of $360 per ounce. Meanwhile, the nearby Campbell mine was producing 320,000 ounces at an operating cost of $136 per ounce. The Campbell mine reserves were 3 times more important and 68% richer than those at the Red Lake mine. Nevertheless, after acquiring the mine, Goldcorp invested $7 million towards exploration on that site. This initiative was successful and reserves increased both in grade and volume. For the quarter ended March 31, 2003, the Red Lake mine produced 117,000 ounces of gold at an operating cost of $74 per ounce.

By May 2003, the two Red Lake mines had increased their work force by 200 workers with relation to the employment level stated in the 2001 census survey [27].

Approximately 4,500 people can thus continue living in a structured community that is large enough to offer its citizens a good quality of life.

#### 3.3.3.4. Toronto region

Over 50% mining companies head offices, such as Falconbridge and INCO, are situated in Toronto. In addition, several SMEs, manufacturers and consultants are located in the greater Toronto area. Ultimately, Toronto is the financial centre of Canada and thereby includes the mining sector.

### 3.3.4 British Columbia

At present, the value of the non-combustible mineral production in British Columbia ranks third in Canada [20]. In decreasing order of value, the most produced metals are copper, $500 million, gold, $300 million and silver, $200 million [28].

In 2002, according to the compilations prepared by The Mining Association of British Columbia [29], the mining industry contributed significantly to the economy of the province. The focal points of this contribution can be summarized as follows:

- Three billion dollars in revenues were generated within the province. This included all minerals.
- Together, with the production of minerals from neighboring provinces, the mining industry generated 58% of the tonnage shipped by rail and 69% of the tonnage exported through ocean ports.

- It is a major employer in the communities through the generation of 10,000 direct jobs and 20,000 indirect jobs. As elsewhere in Canada, wages and benefits offered by the mining industry (on average $81,100 per year) are the highest among all industrial sectors.
- Mining companies contribute significantly to the prosperity of the City of Vancouver through the establishment of various head offices, combined with all trading activities on foreign exchange markets.
- Considering all the benefits that it generates, the industry does not significantly damage the landscape. It only uses a very small portion of the Canadian territory, i.e. 280 square kilometers, for its activities. This represents less than 0.03% of the province surface, whereas the forest industry has cut an equivalent surface area of 2,216 square kilometers of woodland.
- The mining industry contributes to the governments $333 million in taxes, which are deducted from employee wages (30).

In 2001, nine metallic ore mines were exploited in that province. The three main exploration zones are located in the South Central region of Highland Valley, in the North Central region of Thutude Lake and in the Central region of Fraser Lake. In 2002, 12 mines were operating in the province. These represented less than half of the total number of operating mines in 1990 (28). Half of those operating in 2002 were coal mines and the other half were metallic ore mines. Two of the metallic ore mines were operated underground and the other four were open-pit mines.

### 3.3.5 Other provinces and territories

Other provinces or territories also produce a significant quantity of metallic ore (2002 estimates) (Table 6) (20):

**Table 6 – Mineral production by province and territory**

| Province/Territory | Metals | Value of production (million $) |
|---|---|---|
| Newfoundland | Iron<br>Gold | 900<br>23 |
| New Brunswick | Zinc | 314 |
| Manitoba | Nickel | 398 |
| | Copper<br>Zinc<br>Gold | 92<br>89<br>84 |
| Saskatchewan | Uranium<br>Copper<br>Gold | 608<br>25<br>23 |
| Nunavut | Zinc<br>Gold | 160<br>52 |

The keen interest regarding exploration and the development of diamond-bearing deposits open up possibilities in new areas of Saskatchewan, Alberta, Manitoba, Nunavut, the North West Territories, the Middle North Shore of Quebec and Northwestern Ontario.

Mining activity on remote northern sites is not without its share of new challenges.  The extreme fragility of the ecosystems, the occupation of land inhabited by native peoples, the cold climate and the difficulties connected with transportation bring new and very complex operational constraints.

**Uranium**

Uranium extraction accounts for most of the mineral production of Saskatchewan.  Uranium ore is primarily mined by Cameco at the McArthur River mine and processed at the Key Lake mine mill.  In view of the very high grade of the ore and the resulting radioactive emanations, extraction is by highly mechanized means in order to avoid any exposure for workers.  The extremely rigorous constraints imposed to adequately control the risks associated with radioactivity have forced Cameco to develop and use very advanced techniques.  In fact, it constitutes one of the most innovative mining methods in the world.  This company has invested considerable sums of money in research to develop a process allowing for the remote and safe extraction of these deposits.  Consequently, the approach used by the company demonstrates the relevance of, and return on, R&D investments.  This also confirms that the expertise in the field of innovative methods is not held in a single region of the country and that it is important to have a structured research organization that will allow the country to share the extensive knowledge acquired in each mining camp.

### 3.3.6 Scattered small communities

The location of mines is dictated by geology.  As a result, deposits are not often located close to urban centres where the economy is diversified and, therefore, less vulnerable to cyclical effects.  Except for the regions of Sudbury, Timmins and the Rouyn-Noranda/Val d'Or axis, where relative concentrations of deposits can be found, the great majority of operating mines are located in rural or sparsely populated areas.

Despite their remoteness, these cities and towns offer a good quality of life for those who take advantage of the existing lifestyle.  These cities and towns equally offer a bridgehead for other activities related to the exploitation of mineral resources.  However, they often owe their existence to a single mining operation.  The dependence issue of a community in regard to major employers is not only restricted to the mining sector.  There are actually many single-industry towns, where the main employer operates in a sector other than mining and where, sometimes, the mining industry brings a critical mass to ensure the financial health of the town and the quality of life of its citizens.  Lebel-sur-Quévillon, Matagami and Chibougamau are typical examples in Quebec.  The same is true regarding Red Lake, Wawa, Marathon and Manitouwadge in Ontario.  Moreover, the citizens in those towns and villages contribute to the occupation of Canadian territory.

#### 3.3.6.1. The Murdochville example

The town of Murdochville, in Quebec, is a classic case of a single-industry mining town. In 2001, the average wage of full time workers was $52,600 [(31)], providing a high standard of living, compared to La Haute Gaspésie as a whole, where the average wage was only $31,000. In 1999, the underground operation was closed due to the depletion of the ore reserves and, in 2002, the open pit mine and the smelter were closed completely. At the time, the smelter had been operating with imported copper concentrate as the feedstock. This closure forced the exodus of citizens who were enjoying a good quality of life.

The Association Paritaire du Secteur Minier (APSM) statistics, in which the hours worked at the Noranda operation were recorded, show the decline in the number of direct jobs:

**Table 7 - Direct and indirect jobs – Gaspé mine**

| | Direct jobs 2,000 hrs/yr Gaspé mine | Indirect jobs (Multiplier 0.67) | Total jobs (Multiplier 1.67) |
|---|---|---|---|
| 1999 | 500 | 335 | 835 |
| 2000 | 337 | 226 | 563 |
| 2001 | 315 | 211 | 526 |
| 2002 | 70 | 47 | 117 |
| 2003 | 0 | 0 | 0 |

The loss of 285 jobs between 1999 and 2001 led to the exodus of 424 people from Murdochville alone, that is, without taking into account those leaving the neighbouring villages. In 2002, the final closure of the smelter resulted in a massive exodus of the town's mobile working population and brought into question the very existence of this mining town. The result was a significant decline in the economic activity of La Haute Gaspésie as a whole.

Based on the employment level provided in the Quebec cross-sectoral model, which is described in chapter 3.4, the closure of the Gaspé mine and the loss of 500 jobs resulted in the following economic losses:

- Annual tax loss of $6.8 million for the Quebec government;
- Annual tax loss of $5.8 million for the federal government;
- Annual shortfall of $5.7 million in tax revenues for the Quebec Pension Plan, as well as contributions to health care and to the C*ommission de la santé et de la sécurité du travail*;
- Shortfall of $1.8 million for the employment insurance fund; and
- Shortfall of $1 million in municipal taxes, or 50% of the town's revenues [(32)].

The ripple effects were felt as far as the city of Gaspé where the port lost 80% of its business volume. On a national scale, the closure of the Gaspé mine, followed by the closure of its smelter two years later, also emphasize the importance of mining operations in supporting a rural community and maintaining the smelters and metal refinery plants in operation.

## 3.4. Economic benefits from mining operation activities

The purpose of this section is to provide estimates of the economic impact generated by new mining operations through the quantification of economic benefits. The argument is based on a model that is specific to metal mines. The impact will be used to stress the economic and, most of all, the fiscal importance for all levels of government.

### 3.4.1 Methodology

The economic benefits are reproduced from an internal report prepared by Mr. G. Laquerre (2003) [(33)], on behalf of SOREDEM, and within the framework of this project. This study of impacts was conducted by using a cross-sectoral model based on detailed exchanges of goods and services between financial stakeholders. The cross-sectoral model, specific to Quebec, but equally valid for the other provinces and territories, provides measures of the spin-off effects of the demands generated by a mining operation. The model provides a measure of the fiscal and parafiscal impacts generated by expenditures, such as payroll, services and materials, together with their impact on equipment and consumer goods imports. In order to cover the most wide-ranging mining operations, two models of underground mines were examined: in the first, a mechanized mine, where bulk mining methods are normally used. In the second, conventional narrow-vein mining methods, with a lower level of production, replicated those normally used in such deposits.

The cross-sectoral model shows orders of magnitude rather than precise or absolute values. It is based on assumptions of constancy of financial relationships between the various sectors and does not make any subtle distinction between the different types of mining operations, namely those being highly mechanized and those using conventional methods. In financial jargon, the model is described as being linear. In addition, the model takes into account the different benefits derived from fixed capital expenditures and operating expenditures. In spite of its limits. However, the cross-sectoral model represents a reliable economic analysis tool, provided that the results are properly interpreted.

### 3.4.2 Estimate of the economic impact generated by a new mining operation

During the tour of consultations, the data gathered allowed the writers to establish the average characteristics of both types of mining operations which were analyzed by the model. The quantity of data gathered was such that the average values established characterize rather well these two types of operations. The economic and operational parameters, for both types of mining operations, are summarized in the following Tables (Tables 8 and 9).

**Table 8 – Economic parameters for a highly mechanized gold mine and a conventional gold mine**

| | Highly mechanized mine | Conventional mine |
|---|---|---|
| Deposits: proven reserves | 12.5 million tonnes | 1.0 million tonnes |
| Estimated duration of operation | 10 years | 5.5 years |
| Daily tonnage at the mill | 3,450 tonnes/day | 500 tonnes/day |
| Initial capital assets | $150 million | $50 million |
| Number of jobs (person-years) | 350 | 136 |
| Gross annual sales[3] | $106.5 million | $33.5 million |
| Wage costs | $27.0 million | $10.8 million |
| Annual purchases – goods and services | $36.7 million | $9.6 million |

**Table 9 – Operational parameters for a highly mechanized gold mine and a conventional gold mine**

| | Highly mechanized mine | Conventional mine |
|---|---|---|
| Annual tonnage at the mill (tonnes/yr) | 1,259,000 | 182,000 |
| Grade (gr Au/tonne) | 5.95 | 12.95 |
| Mill recovery | 95% | 95% |
| Ounces of recovered Au equivalent/yr | 228,786 | 71,965 |
| Productivity Tonne/manshift | 9.86 | 3.67 |
| Operating costs (CAN$/tonne) | 50.60 | 112.10 |
| (US$/oz.) | (209.34) | (213.14) |
| Amortization costs (CAN$/tonne) | 12 | 50 |
| (US$/oz.) | (66.03) | (126.41) |

#### 3.4.2.1. Economic benefits at start-up

In light of the results provided from the model, it is possible to observe that the benefits related to fixed capital expenditures, for the start-up of both types of mines, generate an important number of jobs, not only for the immediate area, but also for Canada as a whole. These include urban areas from which the majority of a mining operation's needs for goods and services, and equipment, are met.

[3] Sales in gold equivalent are based on a projected price of US$350 per ounce and an exchange rate of Can$1.33

**Impact of fixed capital expenditures ($150 M), highly mechanized mine**

| | |
|---|---|
| - employment in Quebec, in person-years, spread over two years | 1,384 |
| - purchases of goods and services in Quebec (including indirect taxes) | $80.12 M |
| - purchases in Canada outside Quebec | $21.74 M |
| - international imports ($31.1 M of which in machinery) | $48.14 M |
| - tax revenues (Quebec and federal) | $23.37 M |

**Impact of fixed capital expenditures ($50 M), conventional mine**

| | |
|---|---|
| - employment in Quebec, in person-years, spread over 20 months | 553 |
| - purchases of goods and services in Quebec (including indirect taxes) | $36.07 M |
| - purchases in Canada outside Quebec | $4.35 M |
| - international imports ($5.8 M of which in machinery) | $9.58 M |
| - tax revenues (Quebec and federal) | $9.16 M |

It is important to underline that mining facilities require a vast number of pieces of equipment of all kinds, including not only large and heavy-duty mechanical equipment, such as mine hoists and grinding mills, but also more delicate and sophisticated electronic components. Therefore, in addition to benefiting local manpower, the opening of a mine also benefits all of the suppliers of specialized products and services, which are established in over 400 locations, throughout Canada. It should be mentioned that about half of these are established in Sudbury - North Bay, in Vancouver, and Toronto and its suburbs.

#### 3.4.2.2. Economic impact of operating expenditures of a mine under production

**Highly mechanized mine**

The direct and indirect impacts of operating expenditures for annual sales of $106.5 M are:

| | |
|---|---|
| - direct jobs | 350 |
| - indirect jobs, in person-years, employment multiplier: 1.67 | 236 |
| - direct wages | $21.60 M |
| - wages and indirect income, income multiplier: 1.45 | $9.83 M |
| - purchases of goods and services in Quebec | $18.15 M |
| - purchases in Canada outside Quebec | $18.55 M |
| - international imports (including $4.92 M in machinery) | $11.99 M |
| - annual tax revenues (Quebec and federal combined) | $14.10 M |
| - **tax revenues (Quebec and federal) cumulated during the start-up period and 10 years of operation** | **$155 M** [4] |

On the subject of job creation, in addition to the 350 annual direct jobs generated by mining operations, the purchases of goods and services for each year of operation ($37 M) generate, without even taking into account the spin-off effects, a total of 236 person-years among suppliers directly related to the mining industry. In the same way, in addition to the $21.6 million in wages paid directly by mining operations, an income multiplier effect of 1.45 allows the generation of an additional income of $9.8 million.

[4] Calculated in 2003 constant dollars by discounting an average inflation rate of 2% annually. In current dollars, this amount is equivalent to $164 million.

For a better understanding, the different multiplier factors and terminology are summarized in the following Table (Table 10):

**Table 10 – Multiplier factors and parafiscal contributions**

| | |
|---|---|
| Employment multiplier – mechanized mine | 1.67 |
| Employment multiplier – conventional mine | 1.65 |
| Wage and income multiplier – mechanized mine | 1.45 |
| Wage and income multiplier – conventional mine | 1.53 |
| Mandatory contributions by employers and employees to the two levels of government Provincial: Pension Plan, RAMQ, CSST Federal: unemployment insurance | Parafiscal contributions |

**The economic impacts of a conventional mine with a lower production level:**

| | |
|---|---|
| - direct jobs | 136 |
| - indirect jobs, in person-years (employment multiplier 1.65) | 89 |
| - purchases of goods and services in Quebec | $7.6 M |
| - purchases in Canada outside Quebec | $4.04 M |
| - direct wages | $8.34 M |
| - wages and indirect income (income multiplier 1.53) | $4.46 M |
| - gross value of mineral production | $33.5 M |
| - international imports | $2.80 M |
| - annual tax revenues (Quebec and federal combined) | $6.04 M |
| - **tax revenues (Quebec and federal) cumulated during the start-up period and 5.5 years of operation** | **$41.3 M** |

Notwithstanding the fact that the production level is lower and the initial life expectancy of such a mine is shorter (5.5 years), these types of operations are, all the same, very appealing. As a result of the conventional methods used, and being more labour-intensive, these generate more employment in terms of extracted tonnage. In spite of their abundance in the Canadian Shield and their relatively high grades, such deposits are ignored by the majority of senior mining companies because of the criteria used during the capital investment evaluation.

**Non-evaluated spin-off effects**

Although the existence of spin-off effects is generally recognized, the controversies surrounding the methods of estimation hamper a widespread acceptance by economists. For that reason, these were not included in the financial estimates. There is, however, a series of important studies that allows one to establish the spin-off effect multipliers for Quebec and its administrative regions. The employment multiplier for most industrial sectors of the Abitibi-Témiscamingue region was estimated to be 1.35 [(34)].

Be that as it may, the closure of a mining operation in single or quasi single-industry towns, such as Schefferville (end of 1982) or Murdochville (beginning of 2002), and the massive exodus of residents, demonstrate that the importance of ripple effects is probably far greater.

**Cumulative tax benefits**

The modelling of the tax benefits resulting for the two types of mining operations is shown in the following Tables (Tables 11 and 12). In the model it was assumed that the length of mining activities, the prices of metals, the operating costs and the tax rate would be constant. The parafiscal (defined in Table 10) contributions were presumed to be constant even if these are adjusted from time to time to the cost of the programs which these are financing, for example, the unemployment insurance program.

**Table 11 – Fiscal and parafiscal contributions cumulated over 10 years of operation of a highly mechanized gold and associated metals mine with annual sales of $106.5 M**

| *(in thousands of 2003 dollars)* | ***Quebec*** | ***Federal*** | ***Total*** |
|---|---|---|---|
| ***Tax category – operational phase*** | | | |
| Income taxes | 42,625 | 36,200 | 78,825 |
| Parafiscal contributions | 40,520 | 12,340 | 52,860 |
| ***Total-operational phase*** | **83,145** | **48,540** | **131,685** |
| ***Tax category – amortization phase*** | | | |
| Income taxes | 6,754 | 4,523 | 11,277 |
| Parafiscal contributions | 9,814 | 2,280 | 12,094 |
| ***Total-amortization phase*** | **16,568** | **6,803** | **23,371** |
| **Grand total** | **99,713** | **55,243** | **155,056** |

*Source: Institut de la statistique du Québec*

From Table 11 it is clear that, under the Canadian taxation system and a stable economic setting, a highly mechanized mine, with a 10-year life, will create a cumulative fiscal and parafiscal impact, over the life of the mine, in the amount of $155 million for the provincial and federal governments.

The same exercise was applied to the conventional mine model in Table 12. The result shows that, at the end of the 5.5 years of operation, the sum of the direct and indirect tax products related to production, with the corresponding parafiscal revenues, along with the fiscal and parafiscal revenues generated by the capitalized expenditures, was almost $41.3 million. However, in the case of the narrow-vein mines represented in the model, it is a fairly common occurrence to see mineral reserves being renewed, following exploration work carried out close to the infrastructures. In the event that the life of the mine is extended beyond what was originally expected, the total sum of the fiscal and parafiscal impact is consequently increased by $32 million per additional year of operation. For example, the Sigma mine in Val-d'Or, with reserves initially estimated at approximately 5 years, was actually in operation for over 60 years. The same is true for the development of the Red Lake mine and the Campbell mine in Red Lake.

**Property taxes**

The cross-sectoral model for Quebec, like the one for Canada, does not take into account tax contributions other than those imposed by the provincial and federal governments.

The data from the Quebec Mining Association allow one to establish an order of magnitude for the contributions of property taxes. This was calculated in proportion to the production value. These data were then compared with that from the Ontario Ministry of Northern Development and Mines for the production value of metals in the northeastern region of that province. This was applied to the results of research conducted by Datametrics Consulting and the University of Toronto [(24)] (2001), which published the amount of municipal taxes paid by metal mines in that part of Ontario. These data are presented in Table 13.

When applied to the mine models in the present study, these data allow one to establish an order of magnitude of the property taxes which could be attributable to these. Consequently, the highly mechanized mine would contribute $1.033 million annually in property taxes for a production value of $106.5 million, while the conventional mine would contribute $0.325 million for a production value of $33.5 million. As a rule of thumb, it is useful to keep in mind that the annual property taxes paid by the mining industry amount to almost 1% of its production value.

**Crucial participation to support the income tax system**

The income tax system analysis made by the Department of Finance of Quebec shows that 15.4% of Quebecers, or less than one out of six (earning over $42,144), have contributed 71% of the $15.9 billion in income taxes [(35)]. The situation is similar as far as the federal tax is concerned, and is probably the same for the other provinces. In view of the high wages in the mining industry, employees of mining companies contribute significantly to government revenues. This reality of the income tax system is worth mentioning and puts even more emphasis on the results presented in the above Tables.

**Table 12 – Fiscal and parafiscal contributions cumulated over 5.5 years of operation of a conventional gold and associate metals mine with annual sales of $33.5 M**

| *(in thousands of 2003 dollars)* | ***Quebec*** | ***Federal*** | ***Total*** |
|---|---|---|---|
| ***Tax category (operational phase)*** | | | |
| Income taxes | 10,326 | 8,206 | 18,532 |
| Parafiscal contributions | 10,824 | 2,766 | 13,590 |
| ***Total–operational phase*** | **21,150** | **10,972** | **32,122** |
| ***Tax category (amortization phase)*** | | | |
| Income taxes | 2,652 | 1,944 | 4,596 |
| Parafiscal contributions | 3,514 | 1,049 | 4,563 |
| ***Total-amortization phase*** | **6,166** | **2,993** | **9,159** |
| **Grand total** | **27,316** | **13,965** | **41,281** |

**Table 13 - Production value and property taxes paid by metal mines in Quebec and Ontario in 2001**

| | *(in thousands of 2001 dollars)* | | |
|---|---|---|---|
| | **Production value of metal mines** | **Property taxes paid by metal mines** | **Property taxes per $100 M of production value** |
| **Ontario** | 3,388,000 | 31,700 | 936 |
| **Quebec** | 3,050,000 | 29,600 | 970 |

# 4. STRATEGIC IMPORTANCE OF MINING RESEARCH

## 4.1. Introduction

In contrast to the manufacturing industry, which can be characterized by the quality of its products, mining can be distinguished by its processes or by the way in which the ore is extracted and concentrated at the mill. Several mining methods have been developed throughout the years, based on the type of deposits and the available equipment. The characteristics of the deposits generally dictate the method that will be used and later adapted to specific conditions. These methods can be grouped in two broad categories; bulk methods for typically massive mineralization and selective methods for generally small concentrated tonnage, such as narrow-vein deposits. Unlike equipment and product manufacturers who can protect their inventions by obtaining a patent, companies are only protected by a mining lease giving them access to mineral reserves. The improvements that they bring to a mining method are, in general, easily shared with other companies. Better still, mining companies often willingly share their know-how among themselves, through informal exchanges or symposiums. Companies operating worldwide transfer their knowledge from one operation to another through their corporate technical services and the relocation of personnel.

The objectives driving the development of innovative mining methods are:

- An increase in production capacity;
- An improvement of health and safety underground;
- A reduction in labour costs;
- An increase in production flexibility; and
- A decrease in energy consumption.

Initiatives, like Six Sigma, re-engineering or Kaisen, show the importance that companies attach to process improvement. For senior executives of mining companies, these initiatives represent an excellent investment and the most reliable and practical way of reducing mining costs in a relatively short time. Moreover, process modifications [(36)] are rarely recorded as R&D despite the fact that a significant number of innovations are linked to these. Very often, these are the result of small progress achieved in the course of daily activities. In fact, Dennison (1985) [(37)] has suggested that specific R&D projects, clearly tagged as such, would account for only 20% of technical progress. With respect to the development of mining methods, one of the main sources of improvement in mining operations stems from the creative minds of mine personnel at all stages and takes place through the acquisition of, or improvements on the existing machinery, equipment or other technologies. These development efforts, however, are limited, and applied research initiatives, on a larger scale and longer term, will be necessary to develop new approaches to mining, along with the development of new mining equipment and technology, for a more efficient exploitation of mineral resources.

In fact, the mining industry can be characterized by the mining methods it uses rather than by its products.  After selecting a mining method, companies seek, first and foremost, to produce metals at the lowest possible cost through improving their processes, while, at the same time, improving safety.

## 4.2. Inherent risks in the mining industry

The mining industry is presently perceived as being conservative, with mine operators often seeming to be reluctant to invest in research and development in order to innovate and improve, or to significantly modify their mining methods.  The following points illustrate the reasons:

- The nature of mining operations requires permanent infrastructures even if the exploitation of the mineral resource is only temporary.  These infrastructures, being built in the rock and allowing access to the deposits, cannot subsequently be modified without incurring substantial costs.  If errors occur at the beginning, the mine could suffer potentially very costly consequences, which could affect the operations for the remainder of its life.  For that reason, during the initial approach and whenever possible, the known and tested processes of other mining operations, are often used.

- The mining industry is already exposed to the inherent risk associated with extracting deposits, more particularly, while evaluating the reserves, the strength of the rock mass and the future prices of metals.  At the start, the estimate of the entire mineral potential of a mining project, often involving several millions of tonnes, clearly depends on the right interpretation of the geological and structural information from diamond drilling and the samples used to evaluate the grade and the tonnage of the deposit.  Occasionally, despite the use of proven and tested techniques, unexpected circumstances can occur.  In order to minimize these possibilities of error, an underground exploration phase is usually carried out to systematically verify the quality of the mining reserves.  This work will extend the life of the exploration program and improve the value of the project.  To add to the adversities which may be faced, the rock mass behaviour may not be as expected, thus leading to a reduction in the recovery of mining reserves, and, consequently, in an increase in operating expenses.  As a result, the longer period of capital recovery considerably reduces the rate of return of the project.  In short, all of these factors have a significant impact on the economic return from a mining project.

- When the financing must be secured through a feasibility study, the financial world and all of the consultants involved, besides requiring a reliable evaluation of the mining reserves, want to be reassured that proven techniques are used, consequently reducing the perception of risk.  This factor, combined with all of the others, often impedes any innovation from the start [38].

In fact, mining companies take many risks during the different phases of exploration and development of a mine, when considerable sums of money have already been invested. Initially, they must use proven technologies, failing which investors will not be interested or the board of directors will be reluctant to approve the project. However, once the start-up phase is completed, companies seek to continually improve their methods afterwards. Also, when geological conditions are such that proven techniques are not adequate, it then becomes essential to invest in research in order to find new mining methods.

## 4.3. Access to mineral resources

*"Despite the significant economic contributions of the U.S. mining industry, returns on investment have not kept pace with competing industries. Capital inflows are the lifeblood of the mining industry and the industry must become more attractive to investors by using technologies to increase returns by lowering costs, increasing the quality of the output and developing new markets and products while simultaneously reducing workplace hazards and minimizing negative environmental impact* [39]".

This is a statement which could very well be applied to the Canadian mining industry. To achieve this goal, the industry must, first and foremost, have access to mineral resources. There are then two choices: 1) to rely on exploration; 2) to rely on resources that are currently not economically viable. Figures 3 and 4 clearly show that both exploration investments and new discoveries are critically low. Furthermore, exploration work often requires a long-term effort before being successful. Moreover, there are important resources that have already been identified, but which are presently subeconomic (Table 2) with the current mining techniques and equipment.

### 4.3.1 Mineralization of subeconomic resources

Subeconomic resources, either in grade or in tonnage, can be found everywhere on Canada's land mass. For example, the Quebec and Ontario Departments of Mines have evaluated 355 and 337 such deposits, respectively, on their territories. Moreover, there is always some mineralization that is left in place in each operating mine, due to the fact that it is noneconomic. Rather than relying solely on exploration to discover the next mine, it would definitely be wise to attempt to develop technologies which would allow to exploit all of the potential mineral resources which are already identified and known.

The development of a number of small deposits in existing mining camps would certainly be a way of alleviating the dramatic impact of mine closures in these areas. A continuous presence of mining activities in those camps, even on a smaller scale, would maximize the chances of making new and significant discoveries, and would contribute to retain the available expertise in the camps.

In February 2003, the *Fonds régional d'assistance à la prospection minière de la Gaspésie et des Îles-de-la-Madeleine* set forth, in a position paper, the expectations in regard to an economic development strategy aimed at developing overlooked deposits:

*"Gaspésie [40] is known for its numerous small metal deposits which could be profitably extracted in a spirit of sustainable development, without the visual and environmental impacts which can result from mining infrastructures such as Mines Gaspé, in Murdochville, for example. There is an important quantity of these small deposits, which are low in size and rich in base and precious metals, in the area and they are unique in the Appalachian Mountains. These deposits have to be reviewed and evaluated with the perspective of producing ore on a smaller scale. These small mining operations are not consistent with the strategy of large companies and multinationals, like Noranda, which extract and search for mega deposits. This approach, being feasible in the medium-term (3-5 years), would lead to the development of several small deposits in the region, thus creating steady and well-remunerated jobs. As a result, the region would develop an expertise which could be exportable, material and manpower included. Upon knowing that these small deposits can now be exploited economically, the prospectors and the junior mining companies could shift their orientation towards finding small mineral deposits. The royalties paid towards the exploitation of these resources could be reinjected in prospecting and in the exploration of small deposits".* (unofficial translation)

Thus, the importance of the direct and induced contribution of mining activities in small remote areas involves finding new means of stabilizing the level of employment of mine workers in those areas by maintaining minimum and continuous activities through the efficient extraction of deposits which do not meet the criteria of large mining companies.

#### 4.3.2 Deposits with massive mineralization

The comments which were gathered during the interviews with mine operators who are mining massive deposits, with geomechanical constraints under control, lead to believe that the techniques and equipment are adequate for an economical and efficient exploitation as long as the metal prices do not drop. Admittedly, it is always possible to optimize the current mining methods, but it is very unlikely that this will lead to a significant reduction in operating costs. The challenge for these mining operations actually lies in the optimization of mining methods as a whole, and the tight management of operations. This type of mining operation normally uses state-of-the-art equipment. For example, some of this equipment, such as drills for the production holes used to load explosives and to break the rock in the stopes, can be operated automatically, thus reducing the idle time between work shifts. Mining companies, such as INCO and Falconbridge-Noranda, can even tele-operate scooptrams from the surface. Several mine operators who were visited have stated that the technical possibilities of making progress in equipment are evolving more rapidly than the corporate culture. The training of specialized personnel in equipment maintenance can, equally, become the limiting factor for these operations.

Moreover, the same mining equipment, used in Canada for bulk mining, is also available in competing countries. It is therefore imperative to always stay at the forefront of technology. In the case of massive deposits, the only benefit for the Canadian industry then lies in the quality of the deposits, both geologically and structurally, as well as the quality of the human resources who must mine these deposits with efficient, safe and innovative methods.

Except for nickel, the availability of world-class deposits in other countries, along with the access to the same production methods, is such that the average production cost of metals in other countries is lower than in the Canadian mining industry (Figures 1 and 2). This reality makes the Canadian industry more vulnerable to the production capacity of those other countries.

In contrast to the situations in emerging countries, the costs of labour in Canada represent a large portion of operating costs. Moreover, the regulatory setting is proving to be increasingly complex. The trend is constantly leaning towards tighter regulations, especially those in relation to the environment, labour and health and safety standards. Additionally, in the near future, the scarcity of labour, particularly for the recruitment of technical and trained personnel, will put more pressure on mining companies. For all of those reasons, they will have to use even more sophisticated techniques to deal with international competition. The development of better follow-up methods and the control of operations will most likely be essential and systematic. Evidently, training will also become even more important and crucial to ensure the preservation of a successful mining industry in Canada.

#### 4.3.3 Very deep deposits

The future of world-class deposits in Sudbury, Timmins and Northwestern Quebec is conditional upon the exploitation of mining reserves located at great depths, i.e. from 2,500 to 3,000 metres and more. New operating methods will be required to extract the ore at such depths. Although the size and grade of these deposits are favourable, those mining them will have to deal with additional and inevitable operational constraints. In particular, the geomechanical constraints, namely high rock stresses, will inescapably increase and necessitate innovative mining techniques. In addition, the heat from the strata and production equipment used in deep mines will necessitate new methods or, at the very least, new equipment. These deposits will have to be mined with even more finesse by relying on the best technologies possible as far as the approach to the deposit, the design and production equipment are concerned. Some of these operating conditions, such as the state of stresses in the rock, can probably only be found in Canada. Consequently, an exclusive Canadian expertise, specifically adapted to future operating conditions in deep mines, will have to be developed. Also, it is expected that international manufacturers will have little interest in developing the equipment required for such markets since the potential for sales will not necessarily be high.

To summarize, the preferred approach remains the exploitation of Canadian resources with the best techniques possible.  The pursuit of advanced technology remains the best solution in the face of international competition.

### 4.3.4 More complex and overlooked deposits

Despite their abundance, narrow-vein deposits in the Canadian Shield and in other geological areas in Canada are often unexploited.  In general, there is a lack of interest for such resources due to the initial low level of mining reserves and the absence of equipment and techniques that will permit the extraction of these deposits with mechanized methods. Additionally, the risks undertaken are considered to be too significant in comparison with the expected benefits.  The future exploitation of these deposits lies, in particular, on innovative mining methods, and on new rock breaking techniques.  In the first instance, however, these new methods must be suited to the geological realities of the deposits.

On the other hand, as shown in chapter 3.3, these types of smaller deposits, could represent a significant contribution to the regional economies.  Their development could alleviate the dramatic impact of mine closures in remote areas, thus ensuring a continuous presence of mining activities in existing mining camps.  Due to the very promising geological potential close to existing mining operations, the start-up and continuation of such mines would maximize the chances of making new and significant discoveries through the pursuit of exploration efforts.  This contribution from smaller operations is essential to stabilize and maintain the expertise available in the mining camps.

It must be pointed out that the solution for the mining industry lies in the discovery of deposits of equal or superior quality to those in competing countries.  However, the geological reality puts emphasis on the fact that, even with a high level of exploration, the discovery of these types of deposits, containing a significant quantity of metal, and mineable in open pits, is not very common.  The deposits being discovered today in the Canadian Shield are usually located at depth and, in general, their grade is not exceptionally high.  In order for these deposits to be of economic value, the mining industry will have to optimize the current underground mining methods and develop suitable equipment.  This still represents a huge challenge for the Canadian mining industry.

# 5. AXES OF RESEARCH

## 5.1. Methodology aimed at defining the axes of research

As a first step, a bibliographic research was conducted on the importance of the mining industry to Canada, and on the different operating modes of research at mining and other centres. Secondly, through consultative visits, of an average duration of three hours each, the problems and requirements for research were evaluated. Additionally, a first analysis of the needs and priorities of mine operators was developed from a summary of all the problems that had been identified in previous studies. Moreover, during the interviews, the mine operators brought up their operational constraints and their specific requirements for research and development, which are summarized in this report.

Usually, a few weeks before the interviews, the potential participants received a letter of invitation, a description of the project, a proposed agenda, as well as the four documents, which would be the subject of discussions during the meetings (Appendix A). By doing so, the participants were able to familiarize themselves with the documentation prior to the meeting, thus allowing them, based on their own needs, to validate, modify or add to the topics addressed.

In the first of the four documents, “Driving Forces” (Appendix A), an attempt was made to identify the major problems which the Canadian mining industry, as a whole, will have to deal with in the next 10 to 20 years: such as, the weakness of the prices of metals and the availability of manpower.

The second document (Appendix A) contains a list of axes of research which seemed, at first, to have some relevance and importance in relationship to the two themes previously identified. This list, based on the bibliographic study and the knowledge of the environment by the authors, would ensure a coverage of all the topics and provide consistency while conducting the interviews. If some of the participants brought up important items, which were not included in the list that was submitted to them, these were subsequently added.

The third document included in Appendix A, “Table of costs” was only intended for mine operators. In it an attempt was made to identify the main expenditures in a mining operation and to quantify the importance of the economic benefits of the different axes of research to the cost structure. This exercise has allowed the writers to subsequently rate the importance of some of the initiatives based, on their importance to the cost structure of a typical mine.

Finally, the fourth document in Appendix A relates to an action plan. In it different scenarios, intended to maximize the chances of success, were investigated in order to ensure that the R&D results would have a real impact on the productivity and the health/safety of Canadian mines.

The selection of the participants was done to provide coverage of a wide range of visions and situations. It was considered as being essential that the writers should cover the two major types of underground operations, namely the larger mechanized mines and the more conventional ones, with smaller narrow-vein deposits.

Moreover, since universities and research centres are further away from the daily operational constraints, these have, in general, a longer-term vision. In addition, depending on their fields of activities and expertise, the consultants, mining associations, SMEs and manufacturers also have different approaches and views as far as the requirements for research and development are concerned. Consequently, the latter groups were also included in the consultation process.

### 5.1.1 The organizations consulted

**Consultations with mining operations**:

- LaRonde Mine - Agnico-Eagle Mines Ltd.
- Louvicourt Mine - Aur Resources Inc.
- Bouchard Hébert Mine - Breakwater Resources Ltd.
- Meston Mine - Campbell Resources Inc.
- Copper Rand 5000 Project - Campbell Resources Inc.
- Doyon Mine - Cambior Inc.
- Mouska Mine - Cambior Inc.
- Sleeping Giant Mine - Cambior Inc.
- Bell-Allard Mine - Noranda Inc.
- Casa Bérardi Mine - Aurizon Mines Ltd.
- Kiena Mine and East Amphi Mine - McWatters Mines Inc.
- Seleine Mines - The Canadian Salt Company Ltd.
- Red Lake Mine - Goldcorp Inc.
- Dome Mine - Placer Dome Inc.
- Campbell Mine - Placer Dome Inc.
- McArthur Mine - Cameco Corporation
- Kidd Creek Mine - Falconbridge Ltd.
- INCO Corporate Group
- Sudbury Operations - Falconbridge Ltd.
- Vanscoy Potash Operations - Agrium Inc.
- Rio Tinto Iron & Titanium Inc.
- Société minière Raglan du Québec Ltée

**Research centres, consultants and other organizations involved in the mining sector**:

- Noranda Technology Centre - Noranda Inc.
- Dyno Consult - Dyno Nobel Inc.
- Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST)

- CANMET Mining and Mineral Sciences Laboratories (Experimental Mine, Val-d'Or)
- CANMET-MMSL, Ottawa
- CANMET-MMSL, Sudbury
- The James Bay Joint Action Mining Committee
- Léandre Gervais & Associates
- Ross Finlay 2000 Inc.
- Cambior Inc. - Technical Services
- MIRARCO (Mining Innovation, Rehabilitation and Applied Research Corporation)
- Inco Ltd. - Research Centre
- NORCAT (Northern Centre of Advanced Technology Inc.)
- CAMIRO (Canadian Mining Industry Research Organization)
- CAMESE (Canadian Association of Mining Equipment and Services for Export)
- MTI (Mining Technologies International Inc.)
- Noranda Inc. - Falconbridge Ltd.

**Governments and mining associations**:

- Quebec Mining Association (QMA)
- Mining Association of Canada (MAC)
- Ontario Mining Association (OMA)
- The Mining Association of British Columbia (MABC)
- FedNor
- Government of British Columbia
- Government of Ontario - Ministry of Northern Development and Mines (MNDM)
- Government of Ontario - Ministry of Labour
- Government of Québec - Ministère des Ressources naturelles, de la Faune et des Parcs (MRNFP)

**Universities**:

- McGill University
- École Polytechnique
- Université du Québec en Abitibi-Témiscamingue
- Université Laval
- Laurentian University
- University of Alberta
- University of British Columbia
- University of Toronto
- Queen's University

The complete list of participants who were met is presented in Appendix B.

## 5.2. Definition and importance rating of the axes of research

### 5.2.1 Definition of an axis of research

A research initiative is considered to be a group of projects under the same theme. Additionally, in view of the fact that each initiative covered a wide field of activities, it seemed necessary to divide these into sub-initiatives and to provide examples. The sub-initiatives are not meant to be an exhaustive list, but are, instead, meant to group projects under different themes which are consistent with the desired goal. For example, the "Material and mining equipment: "Drilling and rock fragmentation" initiative should provide for the possibility of including a broad range of innovative projects, such as continuous rock fragmentation, an initiation system, drilling with very great precision, etc. It should be pointed out that the initiative relating to mining engineering is more conceptual and is particularly broad since it deals with a wide variety of subjects. Its overall purpose is to equip the technical services personnel with the proper tools so that they may extract the deposits more efficiently.

The goal sought by the writers was to make room for any innovative concept that could significantly improve either the productivity or the health and safety in underground mines. The proposed action plan is contemplated for a period of 10 to 20 years. For that reason, projects will necessarily have to be added through the years. The axes of research, therefore, were not intended to be restrictive. Consequently, the mandate proposed for the Technical Committee (see chapter 7) will be to approve or refuse the projects proposed within each initiative, based on their relevance and potential for success in relationship to the investments required. This research management mechanism will be developed in detail in chapter 7.

### 5.2.2 Importance rating system

**<u>Capturing the respondents' perception</u>**

In order to assign an importance rating to the elements discussed and to the axes of research, a simple system was explained and used during the interviews. Throughout this exercise, the perception of the persons or teams interviewed was validated and captured, rather than attempting to arrive at precise and absolute values. Therefore, the importance rating is limited to a system which would allow, above all, a validation or rejection of the proposed themes.

| Importance rating | Symbols | Absolute value |
|---|---|---|
| Vital for the next 10 or 20 years | *** | 3 |
| Very important | ** | 2 |
| Desirable | * | 1 |
| Not applicable | 0 | 0 |
| Inadequate | - | -1 |
| No opinion | n.o. | |

A total of 120 respondents, split into 43 groups from all circles, participated in this exercise. This has allowed the writers to set priorities. The groups were from:

| | |
|---|---|
| Mining companies | 16 |
| Universities – mining engineering programs | 9 |
| Private or public research centres | 12 |
| SMEs, manufacturers, contractors and consultants | 4 |
| Mining associations and government agencies | 8 |

In obtaining the overall average (Table 14), each respondent was assigned equal importance (see the last column of the Table). For example, the overall average for the mining engineering initiative was 1.9. Moreover, it also seemed important to establish an average value for each different group of participants, i.e. mining companies, universities, research centres and consultants, SMEs, manufacturers and others (including governments and mining associations). It should be pointed out, however, that some participants indicated that they did not have sufficient information to evaluate the importance of the axes of research and, as a result, they did not complete the questionnaire. Consequently, the approach used by the writers permitted a comparison between the visions of researchers and mine operators.

**Table 14 – Overall average assigned by the respondents for each research initiative and average by group of participants**

| | Av / Cies | Av / Univ | Av / R.C. | Av / Manuf | Av / Others | OVERALL AVERAGE* |
|---|---|---|---|---|---|---|
| **Mining engineering** | 1.7 | 2.2 | 1.8 | 1.9 | 2.0 | 1.9 |
| Integration of all available information | 1.8 | 2.2 | 2.1 | 1.4 | 1.8 | 1.9 |
| Geological definition | 1.7 | 2.3 | 1.9 | 2.6 | 2.0 | 2.0 |
| Geomechanics and excavation support | 1.7 | 2.4 | 1.9 | 1.4 | 2.0 | 1.9 |
| Underground preconcentration | 1.1 | 1.9 | 1.0 | 1.9 | 1.8 | 1.4 |
| Optimization of existing mining processes/methods and design of new methods | 2.0 | 2.2 | 2.1 | 2.1 | 2.3 | 2.1 |
| **Engineering related to the physical environment** | | | | | | 2.0 |
| Improvement of the underground environment-human factors | 2.1 | 1.9 | 2.1 | 2.0 | 1.8 | 2.0 |
| **Material and mining equipment: Drilling and rock fragmentation** | | | | | | 2.2 |
| Drilling and blasting | 2.0 | 2.4 | 2.4 | 2.0 | 2.8 | 2.2 |
| **Material and mining equipment: Waste and ore handling** | | | | | | 1.8 |
| Tele-operation and semi-automatic operation of equipment - video communication and others | 1.9 | 2.0 | 1.5 | 1.8 | 2.3 | 1.8 |
| **Material and mining equipment: Support equipment and ground control for development** | 1.7 | 1.7 | 1.8 | 1.4 | 1.2 | 1.7 |
| Ground bolting and other support system | 2.1 | 1.5 | 1.8 | 2.0 | 1.3 | 1.8 |
| Scaling | 1.6 | 1.9 | 1.8 | 0.8 | 1.0 | 1.6 |
| Rock mass quality assessment tools | 1.5 | 1.8 | 1.7 | 1.5 | 1.3 | 1.6 |
| **Material and mining equipment: Backfilling and related subjects** | 1.9 | 1.9 | 1.7 | 1.2 | 1.8 | 1.8 |
| Backfill preparation techniques | 2.0 | 2.1 | 1.8 | 1.4 | 1.8 | 1.9 |
| Backfill transportation and placement techniques | 1.9 | 1.8 | 1.7 | 1.0 | 1.8 | 1.7 |
| Backfill techniques | 1.8 | 1.8 | 1.7 | 1.2 | 2.0 | 1.7 |
| **Logistics and service** | 1.3 | 1.2 | 1.9 | 1.5 | 1.6 | 1.4 |
| Vehicle tracking system | 1.4 | 1.4 | 1.9 | 1.5 | 1.8 | 1.6 |
| Underground communications | 1.3 | 1.3 | 1.9 | 1.8 | 1.8 | 1.5 |
| Logistics (equipment components) | 1.0 | 0.9 | 1.8 | 1.5 | 1.5 | 1.3 |
| Logistics (underground material) | 1.4 | 1.2 | 1.8 | 1.3 | 1.5 | 1.4 |

* Overall average of ratings assigned to each initiative and sub-initiative by all the respondents

At first glance, there appears to be very little difference between the responses from the different groups. The less obvious differences between the results can be explained by the selection of the research themes right at the beginning. The list that was proposed initially proved to be quite exhaustive and only a few subjects were added in the course of the consultations.

**Classification based on the importance rating in the structure of operating costs**

**How to read the Table**

For the purpose of supporting the responses gathered during the consultations, a second exercise was carried out to obtain an order of axes of research weighed according to the importance rating of possible reductions in operating expenses (Table 15). In this table of costs, each of the 7 axes of research was evaluated by the authors, based on its impact on the cost structure. An importance rating from 0 to 3 was again used (where 0 has no effect on the costs and where 3 is extremely important). For example, conclusive research findings in "Drilling-Rock Fragmentation" would have no impact on the costs related to "definition drilling" (assignment of a 0 rating), but could be particularly important in reducing the development costs and the expenses attributable to ground support (hence the rating of 3 for those 2 items). After having assigned a rating to each initiative, based on each expenditure item, the rating obtained was then multiplied by the percentage of the costs of each expenditure item. By using the same example with the "Drilling-Rock Fragmentation" axis of research, which was assigned a rating of 3, this value was multiplied by 8.1% due to the importance of the "Development" expenditure item. The result, reproduced in the sub-total lines, is obtained by calculating the sum of the previous multiplications for each expenditure theme, i.e. Stope extraction, Underground services, Surface services, Technical & administrative services and Ore processing. The final rating reproduced in the "Total - Direct operating costs" line, is obtained by adding all the sub-totals.

**Interpretation of the Table**

By comparing the results in Tables 14 and 15, a greater difference can be seen in the importance of the axes of research when the rating of the impact on operating costs is added. Nevertheless, the order of importance of the axes of research remains very similar. The responses from the participants also integrated the notion of the influence of the axes of research on the operating costs of a mine, since mine operators were asked to prioritize these, based on their importance on mining operations. Even if, on the sole parameter of operating costs, the "drilling-blasting" step only represents 6.2% of the total costs, this activity is at the very heart of the mining method and it has quite an impact on the entire work sequence that follows. For that reason, an improvement in rock fragmentation will result in significant savings in the other cost centres.

Although its impact on operational costs is more intangible, financially speaking, the research initiative dealing with "Engineering of the physical environment" is still very important since it affects the indirect costs related to the health and safety of workers.

# Table 15 - Compilation of the recorded costs in the long-term plan

Natural Resources Canada — Ressources naturelles Canada

**DEFINITION OF RESEARCH INITIATIVES PROJECT**

**Rating**

0 no impact
1 not very relevant
2 very important
3 extremely important

**AVERAGE OF MECHANIZED MINES**

**Compilation of the recorded costs in the long-term plan**

| | Tonnage (Tonnes) |
|---|---|
| Recorded reserves in the long-term plan | 12,500,000 |
| Estimated duration of operation | 10 years |
| Daily tonnage | 3,450 |
| Annual tonnage at the mill | 1,259,000 |
| Recovered metal, oz Au and Ag or metric tonne for all base metals | |

**Research initiatives** — Importance rating in the operating costs structure

| Cost centre<br>Direct operating costs | CAN$ | US$ | % costs | CAN$/MT | Drilling and rock fragmentation | Engineering of the physical environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Short-term development** | | | | | | | | | | | |
| **Stope extraction** | | | | | | | | | | | |
| Definition drilling | $974,876 | $731,157 | 1.5% | 0.77 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| Development | $5,150,607 | $3,862,955 | 8.1% | 4.09 | 3 | 2 | 3 | 0 | 0 | 3 | 2 |
| Ground support | $1,738,436 | $1,303,827 | 2.7% | 1.38 | 3 | 2 | 2 | 1 | 1 | 3 | 2 |
| Drilling and blasting | $3,953,574 | $2,965,181 | 6.2% | 3.14 | 3 | 2 | 3 | 1 | 1 | 2 | 2 |
| Mucking | $5,656,693 | $4,242,519 | 8.9% | 4.49 | 3 | 2 | 1 | 2 | 3 | 2 | 2 |
| Backfilling | $5,699,254 | $4,274,441 | 8.9% | 4.53 | 2 | 1 | 2 | 3 | 2 | 1 | 1 |
| Extraction supervision | $2,196,133 | $1,647,100 | 3.4% | 1.74 | 0 | 2 | 2 | 1 | 1 | 1 | 1 |
| Others | $1,511,019 | $1,133,264 | 2.4% | 1.20 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| **Sub-total Extraction** | **$26,880,592** | **$20,160,444** | **42.2%** | **21.35** | **1.0** | **0.8** | **0.9** | **0.6** | **0.6** | **0.8** | **0.7** |
| **Underground services** | | | | | | | | | | | |
| Crushing/hammer/grizzly/hoisting | $2,603,122 | $1,952,342 | 4.1% | 2.07 | 2 | 1 | 2 | 1 | 3 | 0 | 0 |
| Mobile equipment maintenance | $1,230,845 | $923,134 | 1.9% | 0.98 | 2 | 1 | 1 | 1 | 1 | 0 | 1 |
| Stationary equip. maintenance and infrastructure | $3,511,328 | $2,633,496 | 5.5% | 2.79 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| Equipment and material handling | $844,649 | $633,487 | 1.3% | 0.67 | 1 | 2 | 2 | 1 | 0 | 0 | 2 |
| Ventilation and heating of the mine | $3,354,106 | $2,515,579 | 5.3% | 2.66 | 1 | 3 | 2 | 0 | 1 | 0 | 1 |
| Supervision of underground services | $1,369,961 | $1,027,471 | 2.2% | 1.09 | 1 | 2 | 1 | 1 | 1 | 0 | 1 |
| Others | $1,231,839 | $923,880 | 1.9% | 0.98 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| **Sub-total Underground services** | **$14,145,851** | **$10,609,388** | **22.2%** | **11.24** | **0.3** | **0.4** | **0.3** | **0.2** | **0.3** | **0.0** | **0.2** |
| **Surface services** | | | | | | | | | | | |
| Building maintenance and guarding | $854,575 | $640,931 | 1.3% | 0.68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stationary and mobile equipment maintenance | $315,854 | $236,891 | 0.5% | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mining camp operation/Transportation to site | $0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Surface supervision | $112,997 | $84,747 | 0.2% | 0.09 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Others | $329,436 | $247,077 | 0.5% | 0.26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Sub-total Surface services** | **$1,612,862** | **$1,209,646** | **2.5%** | **1.28** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| **Technical & administrative services** | | | | | | | | | | | |
| Engineering | $1,810,076 | $1,357,557 | 2.8% | 1.44 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| Geology | $1,169,461 | $877,096 | 1.8% | 0.93 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| Human resources & health and safety | $2,119,736 | $1,589,802 | 3.3% | 1.68 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| Consultant | $1,198,035 | $898,526 | 1.9% | 0.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Management & clerical/accounting | $2,664,091 | $1,998,068 | 4.2% | 2.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Others | $492,665 | $369,499 | 0.8% | 0.39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Sub-total Tech. & adm. services** | **$9,454,065** | **$7,090,549** | **14.8%** | **7.51** | **0.0** | **0.1** | **0.1** | **0.1** | **0.0** | **0.0** | **0.0** |
| **Total - Operating at the shaft collar** | **$52,093,369** | **$39,070,027** | **81.8%** | **41.38** | | | | | | | |
| **Ore processing costs** | | | | | | | | | | | |
| Transportation to the mill | $317,289 | $237,967 | 0.5% | 0.25 | 1 | 2 | 2 | 1 | 0 | 0 | 0 |
| Milling | $8,887,798 | $6,665,848 | 14.0% | 7.06 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| Environment | $2,029,034 | $1,521,775 | 3.2% | 1.61 | 2 | 0 | 2 | 3 | 0 | 0 | 0 |
| Others | $372,511 | $279,383 | 0.6% | 0.30 | 2 | 0 | 2 | 2 | 0 | 0 | 0 |
| **Total - Ore processing** | **$11,606,631** | **$8,704,973** | **18.2%** | **9.22** | **0.4** | **0.3** | **0.4** | **0.4** | **0.0** | **0.0** | **0.0** |
| **Total - Direct operating costs** | **$63,700,000** | **$47,775,000** | **100.0%** | **50.60** | **1.7** | **1.6** | **1.7** | **1.3** | **0.9** | **0.8** | **0.9** |
| **GRAND TOTAL** | | | | | | | | | | | |

**Exchange rate US: 0.75** — CAN$/MT Unit cost in Canadian dollar per metric tonne milled

Finally, since the breakdown of operating expenses was derived from their detailed analysis of an overall average for mechanized mines, it should be noted that, according to the percentage of the costs in Table 15, 81.8% of the overall operating expenses is required to bring the ore to the shaft collar. Thus, the ore concentration at the mill, including the costs associated with tailings disposal, only represents 18.2% of the operating expenses. Without denying the importance of ore processing, the fact remains that the mining process requires the largest sums of money in a mining operation.

### 5.2.3 Highest priority axes of research

The compiled detailed results, aimed at prioritizing the axes of research, are presented in Appendix C. Table 16 summarizes the highest priority axes of research.

**Table 16 – Summary of highest priority axes of research**

| Research initiative | Rating | Rating /Costs | Definition and examples |
|---|---|---|---|
| Drilling and rock fragmentation | **2.2** | 1.6 | New drilling or rock fragmentation methods or equipment. Ex.: drilling techniques, development of explosives, blasting techniques, innovative rock fragmentation methods without explosives. |
| Engineering of the working environment | **2.0** | 1.5 | Improvement of the underground environment-human factors. Ex.: development of low emissions motorized equipment, working techniques and more ergonomic equipment, control of temperature and the effects related to heat exposure, ventilation control. |
| Mining engineering | **1.9** | 1.7 | Conceptual approach to mining methods. Ex.: strategic planning and mining sequences, design of stopes and development work, engineering related to the stability of mine openings. |
| Backfilling and related subjects | **1.8** | 1.2 | Improvement of the current backfill preparation and transportation techniques, and development of new techniques. Ex.: development of portable and less expensive equipment for paste backfill preparation, optimization of backfill transportation and placement techniques. |
| Waste and ore handling | **1.8** | 0.9 | Tele-operation and semi-automatic operation of transportation and mucking equipment. |
| Support and ground control - development | **1.7** | 0.8 | Equipment, methods and other systems, which can improve the work cycle and the stability of the development work. |
| Logistics and service | **1.4** | 0.9 | Techniques and equipment, which can optimize the underground management of material: production equipment and production support. |

*Rating: average value assigned by all the participants.*
*3 = vital technologies to ensure prosperity or survival, 2 = very important, 1 =desirable, 0 = not applicable, -1 = inadequate, and n.o. = no opinion.*

## 5.3. Material and mining equipment: Drilling and rock fragmentation

### 5.3.1 Definition as submitted to the participants

All research related to the development of new drilling and rock fragmentation methods or equipment. In its most general sense, this initiative includes all of the drilling techniques, the development of explosives and blasting techniques, and all the innovative rock fragmentation methods not requiring explosives.

### 5.3.2 Needs and comments expressed by the participants

The drilling and rock fragmentation steps, including the equipment connected with these, have a significant impact on the mining operation, as a whole. For example, the size of the equipment and the drilling performance will quite often influence the drift dimensions. The low level of precision and the deviation of drill holes usually limit the spacing between the drilling sub-levels. It is certain that the precision with the drilling is carried out has a direct impact on the dilution rate. In actual fact, the deviated holes, which end up outside the desired drilling plan, subsequently produce breaks beyond excavation limits, which result in the collapse of walls. Unfortunately, this causes additional dilution. On the other hand, it is important to recognize that the mucking, hoisting and crushing activities must be designed to accommodate the sizes of the broken materials to be hoisted at the surface. Of course, all of the additional waste material to be handled must also be taken into account.

Due to the more important deviation of small-diameter drill holes and the complexity of the shape of narrow-vein deposits, mine operators dealing with this type of deposit have considered this initiative to be of a somewhat higher priority than those who mine massive deposits. However, several operators who mine massive deposits have pointed out that the stability of underground openings, at great depths, would be considerably affected by the challenges associated with drilling and rock fragmentation.

Rock breaking, which is presently being carried out with explosives, prevents any operation from being done in a continuous mode, since the work is performed in a cycle. A breakthrough in the field of continuous rock fragmentation, possibly without the use of explosives, would allow operators to continuously break the rock and produce pieces of a regular size. This would certainly facilitate mechanization and robotization. Consequently, this would have a significant impact in reducing operating expenses.

However, to this day, explosives are still incontestably the most economical means of breaking hard rock in very large quantities. Moreover, the recent introduction of electronic detonators shows that it is still possible to achieve innovations in this field and that it is important to pursue the research. Notwithstanding this statement, for particular uses, such as tunnelling and the excavation of raises, rock breaking with mechanized methods has proven to be economical. Also, recent innovations have shown that it would be possible to break the rock with thermal methods in order to replace explosives in the mining of narrow-vein deposits. However, there is still a lot that has to be done before explosives can be removed from the extraction cycle in mining operations. Significant sums will have to be invested in order to allow a major breakthrough in this field.

During development, a continuous advance would be particularly advantageous. Today's cycle of operational steps, including unproductive time required for evacuation of blasting fumes, displacement of equipment and installation of ground support, limits underground productivity. Of particular note, blasting activities usually take place at the end of the shift and, when, for whatever reason, these are delayed, the activities of the following shift are disrupted. It must be stressed that activities taking place in a captive environment are affected by the fact that the equipment cannot be moved easily to alternative working areas.

As far as mining in the stopes is concerned, the cyclical nature of the operations strongly affects mine operators using selective methods. Each drilling/blasting operation must be carefully planned and sequenced. A great deal of coordination between the different work shifts is required in order to maximize the operational sequence through minimizing the non-productive waiting periods.

For operators using long-hole methods, in addition to the quality of drilling specifications, the precision of drilling seriously affects the blasting performance. Hole deviation, compared to the drilling specifications, critically affects the stability of the walls, the dilution rate, the size of the broken ore and, overall, its recovery. Additionally, through the use of new types of explosives and blasting accessories, or with new rock breaking techniques without explosives, the dilution problems and those related to the unavoidable fracturing of walls, could be minimized at the source. Further benefits could be realized through reductions in the requirements for support.

The tele-operation of drilling equipment between work shifts could also significantly reduce drilling costs. Moreover, in some situations, such as the drilling of long holes with the Alimak method, tele-operation could lead to an important improvement in working conditions and productivity.

### 5.3.3 Strategic importance in the cost structure

In quantitative terms, the expenses directly related to stope extraction normally represent a range of between 40% and 50% of the total expenses (milling included). The proportion of drilling costs is between 6% and 15%, depending on the type of operation.

During the mining of deposits, the precision and quality of the blasts have a direct influence on the dilution by waste rock and on the stability of the walls, and, ultimately, on the structural integrity of the mine openings. The percentage of ore recovery also depends upon the precision of drilling and the ability to follow the geological boundaries between ore and waste. Finally, the quality of the product created by the drilling and rock fragmentation directly influence the remaining hauling, crushing, hoisting and milling activities.

### 5.3.4 Analysis

This research initiative is considered as being of the highest priority on the list, and particularly so by universities and research centres. Consequently, in view of the fact that dilution is a widespread problem in Canadian mines, an improvement with respect to drilling and rock fragmentation would have a significant impact on the overall productivity of operations.

## 5.4. Engineering related to the working environment

### 5.4.1 Definition as submitted to the participants

Development of equipment which can improve living and working conditions underground, such as the development of low emissions motorized equipment, working techniques and more ergonomic equipment, the control of temperature and the effects related to heat exposure. Consequently, this initiative deals with improving the health and safety of workers in a relatively long term and the comfort of the personnel when performing tasks.

### 5.4.2 Needs and comments expressed by the participants

Although mining regulations generally end up by adapting to the availability of existing technologies (otherwise mining operations would cease), the fact remains that mines must work within the regulatory context and the cultural changes which continually take place. On the one hand, and for various reasons, there is generally a propensity to regulate all underground mining activities in order to eliminate risks. On the other hand, the physical work carried out in conventional mines will become culturally less acceptable and is actually becoming less valued in society. Despite the fact that there has been much progress in underground working conditions over the last 20 years, the process must continue. This approach will create a more interesting environment, particularly for young workers.

Without being prejudicial to the current regulations, it might be justified to proceed with a Pan Canadian analysis of the risks associated with mining activities, in order to encourage the several responsible provincial and territorial authorities to legislate and regulate based on more quantitative evaluations of the actual risks associated with working practices. In several instances, risk analyses, based on concrete scientific information, would lead to regulations which are better adapted to the operating conditions. As a result of the distinct cultural environments in the several Canadian jurisdictions, significant differences can be noticed in the regulations. The different practices in the management of explosives, in the provinces of Quebec and Ontario, is a good example.

### 5.4.3 Strategic importance in the cost structure

This initiative is often in response to new regulations and standards advanced by governments. Because of this, it does not necessarily result in reducing operating expenses, or, if it does, it may be very difficult to quantify these. Nonetheless, it is required to allow operations to comply with new requirements.

At the same time, the improvement in the quality of working life underground also allows to reduce the expenses related to some occupational diseases, such as “white hands” (Raynaud’s Syndrome, due to vibrations) and respiratory problems.

In addition, the replacement of the fuel used underground with cleaner sources of energy would have an impact on the quantity of the ventilation required to dilute pollutants, such as those produced by the combustion of diesel fuel. This would, therefore, reduce operating costs since the costs of energy, which include ventilation and heating costs, amount to approximately 10% of the operating expenses in Quebec. This figure is probably higher for other provinces.

It should be noted that the proportion of the costs associated with manpower generally represents between 40% and 60% of operating expenses. In this context, this research initiative takes on a strategic significance, from a financial perspective. Moreover, it is clear that the average age of miners is increasing and, consequently, the costs related to the health of workers are also increasing.

### 5.4.4 Analysis

The overall value of this initiative is very important. There is no apparent difference between the ratings assigned by the various groups of participants. However, it should be noted that the operators of narrow-vein mines and deep mines, in which there are more difficult underground working conditions for personnel, are much more aware of the importance of improving the techniques in which the human factors are prominent.

## 5.5. Mining engineering

### 5.5.1 Definition as submitted to the participants

This initiative refers to the conceptual approach to mining methods and, more specifically, to strategic planning and mining sequences, to the design of stopes, including development work, as well as all engineering related to the stability of mine openings. This initiative also involves the design and location of major infrastructures, such as shafts, ventilation raises and other permanent openings (e.g.: ore and waste, passes). The purpose of this initiative is to gather and analyze all the data that is required to allow an improved design of the operation. The approach must be consistent with the geological realities and the specific constraints associated with the operating environment.

Since this initiative is particularly broad, each sub-initiative will be treated separately, under the following themes:

A) Integration of all available information (geomechanics, ore grade, etc.)
B) Geological definition
C) Geomechanics and excavation support
D) Underground preconcentration
E) Optimization of existing mining processes/methods and design of new methods

### 5.5.2 Needs and comments expressed by the participants

A) Integration of all available information

During the course of operations, the updating and transferring of information between the various departments takes on a significant importance with regard to planning and optimizing the mining operation. Even though much information is available within each technical and operational department of a mine, in many organizations, the work is still being done on multiple platforms: one for the geological interpretation of the deposit, another for the preparation of engineering plans (development work and stope plans), and still another for information on ground control. However, the transfer of information from one sector to another, even if always desirable, often depends on the determination of the technical team, on the “silo effect” between the departments and on the rigour of the working procedures.

Software programs, such as Promine® and A-Mine presently seem to be essential for planning. However, even now, these software programs are not being used extensively for the input and integration of all of the geological data. Often, the modeling of the deposit is performed with another specialized software. Further, the process of integration is laborious and involves bringing together the basic geological data, the structural characterization, the current or short-term plans and the geomechanical and seismic information (which is integrated in real time). In another approach, MIRARCO provides a multiple data display system to mining companies, based on the GoCAD software. This initiative is quite interesting despite the fact that it seems to be limited to facilitating three-dimensional display. Likewise, a more comprehensive pursuit of this work is certainly recommended. Moreover, none of the above-mentioned systems are integrated into the accounting software programs of companies or are capable of being used for making financial analyses; for which the Excel spreadsheet program is commonly used. In short, the different technical services manage to operate with the software programs available to them, but all are limited in scope.

At first sight, the design of a superior software, in which all of the available data can be integrated and which is capable of being used to carry out a detailed and intelligent analysis, such as an expert system, could be an avenue to be explored. In view of the complexity of such a software program, it would probably be more appropriate to choose solutions that would facilitate the import and export of all the data and results from the different software programs available. It might be preferable to rely on reading tools for the different data formats at the input of software programs and on the uniform formatting of data at the output. If this option forges ahead, it should definitely be supported by a group or an alliance of user companies in order to ensure its uniformity.

B) Geological definition

The design of a mining operation and the choice of the most appropriate mining method are based on the accuracy of the available geological information. During the exploration phase, the drilling strategy and the mapping efforts seek, first and foremost, to properly define the mineralized zone. Any adjacent zones, situated in the upper and lower walls, are generally less scrutinized by geologists. For that reason, there is a lesser coverage of information outside of the mineralized zone, which is of primary interest. Also, during the observation and analysis of drill cores, less emphasis is put on the identification and recording of ground conditions. Quite often, owing to the lack of sufficient and accurate geomechanical information, the operational parameters dictate the location of the infrastructures instead of the ground conditions. For example, the ore and waste pass system is often located in such a way as to minimize the distances to be covered, while it might rather be preferable to locate it in zones where the most favourable geomechanical properties would increase the chances of preserving its stability and integrity in the long run; a better knowledge of the geology would therefore permit one to make, from the start, a more informed and more efficient decision.

In spite of the significant cost of diamond drilling, not all of the information that is available from it is used. While knowing that the core recovered only represents a relatively low tonnage of rock, in comparison with the size of the deposit, it is surprising that the geomechanical data from these cores is not retrieved and systematically transferred to the subsequent steps for design engineering work. It would therefore be useful to study and keep all of the available data. The development of tools that would allow this would certainly be profitable. Moreover, the accurate interpretation of a deposit greatly depends on the precise location of the interception of the drill hole with the mineralized zone and, this is particularly so for narrow-vein deposits. There still seems to be a lot that has to be done in this field. During the interviews, several people expressed doubts as to the accuracies of the current systems of locating core intersections. This problem is even more critical when a deep deposit, or one that is far from the infrastructures, has to be defined.

Finally, in view of the high costs related to geological definition and the time required to do so, it would probably be preferable to rely on the methods used during exploration drilling, where geophysics is regularly used to obtain more complete and accurate information on drill holes in order to have a better knowledge of the deposit.

C) Underground preconcentration

Underground preconcentration could represent an interesting concept towards optimizing the transportation of ore and waste and in resolving problems related to the limitations of hoisting systems capacities and the final emplacement of backfill underground. The principle is interesting but, overall, could it be profitable? The moderate reaction and the very low support obtained for this concept leaves doubts as to its appropriateness as a topic for research. First and foremost, an economic study is necessary to provide guidance on this question. If this option seems to be advantageous financially, this sub-initiative should be pursued.

D) Geomechanics and excavation support

Everyone agrees that the basic information is available via, in particular, the ground control guide by Charette and Hadjigeorgiou (1999)[(50)]. Additionally, a great deal of specialized and in-depth information already exists, and is being generated by many scientists. However, this information does not always make its way to the daily planning and production activities. Some mining companies sometimes benefit from important technical support at the corporate level and share that expertise among their operations. Unfortunately, this is not necessarily the case for smaller mining companies.

During the planning of a mining method or the design of a long-term operational plan, some mines, however, make a more elaborate analysis with numerical models. On the other hand, even though these numerical models are very useful, there are limits to the predictability (the imprecise nature of the structural geology and multiple constraints inherent to the deposits) and applicability (the time required for the results of the analyses, the significant costs of the instruments, and equations which are difficult to resolve between the ideally zero risk and the one which an operation must, by definition, assume). With sensors and various instruments, a great deal of information concerning the stability of mine openings can be gathered and integrated into these models. However, in the operational context, the relatively long time elapsed between the recording of the data and the interpretation of the results considerably limits the effective use of the information.

As far as development work is concerned, the time and sums of money allotted to ground support take on a crucial significance in the mining cycle. Very complex installations of support will often shorten the time available for the other parts of the mining cycle. This step then becomes a limiting factor. In terms of costs, ground control represents between 25% and 50% of the development costs. Moreover, the use of appropriate supports, at the beginning of the operations, would minimize the prohibitive costs of remediation, allowing mining companies to continue operating.

In spite of the high quality of the Canadian expertise in geomechanics and in the control of the stability of mine openings, research requirements are still important, especially for deep mines where the pressures are even greater. An array of tools still has to be developed. For example:

1) Effective, quick, inexpensive and simple to use tools for the continuous evaluation of the stresses in three dimensions (x, y, z, t).
2) Integration of geodynamic and geomechanical information into numerical models to foresee the shifting of stresses and displacements, based on mining activities which are carried out underground.
3) Tools that are better adapted to evaluate the performance of the different supports available, both for dynamic loading and those which accumulate stress more or less constantly over longer periods.

E) Optimization of mining methods and design of new methods

The selection and development of the most appropriate method is of crucial significance to efficiently mine a deposit. Multiple factors, such as the shape of the deposit, the geomechanical properties and the selection of suitable equipment are such that the mining of each deposit is a specific case. There are also many variants of the same method which may be used in a single deposit. The development of an innovative mining method often allows one to efficiently mine a deposit which had previously been deemed to be marginal with the use of existing methods.

The development of new mining methods often calls for the modification and improvement of existing equipment, or the development of new equipment. Moreover, equipment designers need to know the required specifications which will be defined by the new mining method. With these available, they will then evaluate the possibilities of recovering the significant development costs through an adequate market study (in essence, there is a chicken and egg situation between the equipment and the method).

Similarly, the extraction of deep deposits will certainly require the development of innovative mining methods which will be suited to both the characteristics which are specific to each deposit and the high in situ rock stresses. This reality is all the more true for deposits with a complicated geology.

The development of a method, which is specific to a deposit, usually results from the importation of concepts and the transfer of knowledge from other mining operations which are faced with similar conditions. This transfer generally takes place through the employment of persons who possess the required expertise and through exchanges with other mine operators. However, during the interviews, mention was made of the sometimes difficult exchanges of information and expertise between the different mining camps and, particularly, between those in Quebec and the Sudbury region. The great distances between the mining camps, together with the heavy work loads on the technical and supervisory personnel would probably explain this.

The mining methods applied to massive deposits are usually effective and optimized, and benefit from the automated equipment which is available on the market. However, to obtain a major breakthrough in automation, the tele-operated methods will have to take into account the interactions between the persons and the equipment, i.e. an in-depth reengineering, aimed at maximizing productivity, to allow the simultaneous use of remotely controlled equipment and activities requiring human intervention.

This is quite different for the situation in narrow-vein deposits (1 to 2 metres in width) where selective methods (shrinkage stope) or small diameter long-hole methods are used. For reasons of productivity and those discussed in the initiative with regard to engineering of human factors, it will inevitably be necessary to develop new mechanized selective mining methods to make the miner's work easier.

### 5.5.3 Strategic importance in the cost structure

Mining engineering, including its zone of influence, represents between 75% and 85% of the operating expense of which 40% to 50% results from the costs associated with stope extraction. This initiative is also important in view of the fact that at least 25% of the unit costs of the drifts are attributable to the installation of ground support, which is necessarily defined by the mining method. In addition, it will never be stressed enough that health and safety, as well as the optimization of a mining operation, always start on the drawing board, followed by an effective implementation underground. For example, planning errors due to an erroneous evaluation of the stope outline, or the size of the reserves, can result in significant financial losses and even, sometimes, lead to the closure of the mining operation.

### 5.5.4 Analysis

This initiative is deemed to have a very important relative value. However, the big difference between the evaluations assigned by the mines, either mechanized or conventional (1.7), and that assigned by the universities (2.2) (Table 14) should be noted. This can be explained by the fact that universities focus more on long-term projects of a more conceptual nature, such as the development of software programs and geomechanical concepts. In addition, the state-of-the-art expertise in geomechanics in Canadian universities is very important.

This initiative is also significant for the development of Canadian expertise that is exportable internationally.

## 5.6. Material and mining equipment: Backfilling and related subjects

### 5.6.1 Definition as submitted to the participants

Improvement of the current backfill preparation techniques and development of new techniques, including the development of portable and less expensive equipment for paste backfill preparation. Plus, the optimization of backfill transportation and placement techniques.

### 5.6.2 Needs and comments expressed by the participants

**Conventional mines with a low level of production**: Operations with a lower level of production are disadvantaged by the costs of construction of sites for tailings disposal and for a paste backfill mill. A significant reduction in the costs associated with paste backfill would, therefore, have a considerable impact.

**Mechanized mines**: In general, the challenge lies in the reduction of the cost of binders, which guarantee a sufficient resistance to stresses to ensure the integrity of the walls, and allow an optimal recovery of ore. In comparison with conventional backfill, the introduction of paste backfill has considerably modified and improved the mining process, particularly by reducing the setting time, by facilitating its confinement and by increasing the rigidity of the backfill. An additional improvement in the setting time and mechanical properties of the backfill was greatly desired by all of the respondents and, particularly, by those who expect, at some point, to mine at great depths. However, in view of the chemistry of the available materials and the geomechanical properties of the rock mass, which are particular to each deposit, the research requirements are site-specific. In general, mine operators invest considerably in order to optimize their backfill recipes. Moreover, it was pointed out by professors from Queen's University that the mining industry consumes approximately 70% to 80% of the cement used in Canada and that a breakthrough in reducing this consumption could have a significant impact in the reduction of greenhouse gas, since the production of cement generates an important quantity of $CO_2$.

### 5.6.3 Strategic importance in the cost structure

Not all of the respondents use backfill in their operations. For those who do, these costs represent about 9% of the total operating expenses. In bulk mining operations, with a high level of production, an optimal use of binders results in significant savings. Backfilling is an integral part of the mining method, which represents about 50% of the operating expenses. More particularly, backfilling can have an important influence on the stability of the walls, the total recovery of mineral reserves and the speed of the operating cycle.

### 5.6.4 Analysis

This initiative was evaluated as being very important by some, in comparison with the mean value of the scores. Universities and research centres deemed it to be more important than did the mining companies. In addition, those operating conventional mines evaluated it as being significantly more important (2.2) than those from mechanized mines (1.3). This can be explained by the fact that the mechanized mines usually have the financial resources which allow them to use backfills, such as paste backfill. This is not always the case for smaller operations.

However, even for mechanized mines, the development of the ideal technique is very costly. These techniques are, for the most part, based on numerous trials and errors. Moreover, they must be modified throughout the years.

Finally, unless a totally new product is proposed, the costs of such developments can hardly be shared by a group of companies, since the backfilling materials available are specific to each mine.

## 5.7. Material and mining equipment: Waste and ore handling

### 5.7.1 Definition as submitted to the participants

Tele-operation and semi-automatic operation of transportation and mucking equipment.

### 5.7.2 Needs and comments expressed by the participants

Several of the respondents mentioned that the tele-operation technology, particularly in the field of rock handling, is already available and no longer depends upon research. However, before implementing tele-operation or semi-automatic equipment, each mine must make an economic analysis to evaluate the situations where tele-operation would prove to be economically beneficial (ex.: savings on transportation over short distances or obtained with stationary equipment, such as crushers and hoisting systems). Moreover, although the automatic operation of equipment is now possible between work shifts, its economic viability for the industry at large has not been demonstrated. At present, only the major companies seem to benefit from it. Additionally, unless the path taken by the equipment lends itself particularly well to automation, there are still several obstacles and details which have to be dealt with. In particular, the reliability of the systems must be demonstrated. In the day-to-day activities at several mining operations, the tele-operation of scooptrams over short distances is a part of the current mining process and appears to be very economical. The capacity to draw the ore, by remote control, from inside a stope has resulted in modifications to the mining methods. However, the tele-operation of scooptrams, far away from the position of the operator, leads to high costs due to the difficulties of the remote control operation. Since the operator does not have a peripheral vision of the environment and the rock mass close to the equipment, there is interference with the maneuvers.

The fact remains, however, that the tele-operation of equipment, with its limits of application, definitely forms part of the day-to-day activities today, and in the future, in underground mining operations.

#### 5.7.3 Strategic importance in the cost structure

The handling of waste and ore represents approximately 5% to 9% of all of the costs of underground mining. This proportion varies according to the features of the operation, in particular the size of the deposit and the systems in place, such as the proximity of ore and waste passes to the areas being mined. In this, the hoisting of ore and waste represents between 3% and 4% of the total costs, or, about half of the costs of transportation. Based on the cost structure, the importance rating was established at a value of 0.8 on a scale of 3. In contrast to the drilling and rock fragmentation initiative, which is often the critical element in an operation, the handling of the ore, once fragmented, does not usually cause too many problems in the mining process. However, this situation was not common to all of the operations.

#### 5.7.4 Analysis

The importance rating of this initiative was average and the majority of operators seemed to share that opinion. Nevertheless, this initiative seems to have a higher priority for mechanized mines since greater tonnages of rock must be handled. Today, the main equipment used to handle the material in underground mines is the scooptram. However, in contrast to the space which is available in open pit mines, the size and capacity of underground mining equipment will always be limited by the possible dimensions of mine openings and the capacity of the ventilation system. In addition, the present view is that the development and improvement of this type of equipment has been completed; with manufacturers presently offering mine operators a wide range of models and capacities. In this area, tele-operation offers the best potential for achieving further productivity improvement.

### 5.8. Material and mining equipment: Support equipment and ground control for development

#### 5.8.1 Definition as submitted to the participants

All equipment, methods or other systems, which can improve the work cycle and the stability of the development work.

### 5.8.2 Needs and comments expressed by the participants

Quite often, in mechanized operations, the size of the support equipment which is chosen dictates the dimensions that will be required for the mine openings. The general opinion is that the step dealing with support or ground control always presents risks for the safety of workers. While some equipment exists (e.g.: mini Bolter), it is expensive and its availability, as a result of the numerous breakdowns, is not seen to justify its purchase. Moreover, this equipment cannot be used for the complete sequence of operations in installing support: screening, shotcreting, bolting, etc.

The industry is still waiting for a smaller, more reliable and affordable scaling/bolting system which is designed to support the ground, while, at the same time, the miner is not exposed to the risks associated with this step. Moreover, scaling work, carried out manually, is physically exhausting and the work would surely be more thorough if it could be done mechanically with adequate equipment.

### 5.8.3 Strategic importance in the cost structure

This initiative is important from an economic point of view, since from 25% to 30% of the cost of the development of drifts is related to support. Furthermore, when ground conditions are difficult, this step represents a limiting factor in the mining advance which can be achieved. To this, must be added the remediation work which is required when it is necessary to return to areas which have been abandoned for a long time. The weight of its impact on the structure of operating expenses resulted in the assignment of an importance rating of 0.8 for this initiative. The main impact is certainly a long-term one and harder to assess, but it is aimed at ensuring the stability of the drifts and has an effect on the mining operation as a whole. Finally, this step could also have an important positive impact if it allowed one to accelerate the cycle of mining operations.

### 5.8.4 Analysis

The importance rating assigned to this initiative was average, in comparison with those for all of the various initiatives. There was no difference between the views of those from mechanized and conventional mines. However, those from universities assigned a greater value to this item than did those from the mines. This can probably be explained by the fact that several of the professors/researchers who participated in the exercise are ground control specialists. Just as for the drilling and rock fragmentation initiative, a constant improvement in the ground control process will be even more necessary for the extraction of very deep deposits.

## 5.9. Logistics and service

### 5.9.1 Definition as submitted to the participants

Development of techniques and equipment, which can optimize the underground management of material, including production equipment and those for production support.

### 5.9.2 Needs and comments expressed by the participants

This initiative relates far more to technology transfer than to research and development. With regard to managing the transportation of material, the mining industry would have everything to gain by importing and adapting the technologies that were developed for the transportation of the mail (i.e., the tracking of packages and of important components in the assembly lines). The operators of underground mines are falling behind with respect to managing their fleets of equipment, in comparison with those from open pit mines, in which fleet management is done in real time. The importation and adaptation of scheduling techniques, as used in open pit mines, could represent an interesting avenue and could rectify this shortcoming. Research projects in underground telecommunications should possibly be contemplated under this initiative.

It should be noted, however, that several respondents mentioned that it might be possible to minimize both the waste of time and materials by simply exercising proper control of underground operations.

### 5.9.3 Strategic importance in the cost structure

The accounting system of a mining operation does not generally allow one to quantify the losses of time and materials underground. For accounting purposes, once the material has reached its destination, it is deleted from the inventory system and is recorded as expenses. The management of this material then becomes entirely the responsibility of the underground supervisory team. An improvement in management underground would most likely allow one to generate significant savings, both in materials and in the wastage of time, as a result of trying to find materials which may be in the wrong locations.

As regards the management of production equipment, such a system could have a positive impact on costs because it would allow supervisors to improve their management of human and material resources during work shifts. The importance rating of 0.9 (see Table 16) reflects these comments.

### 5.9.4 Analysis

While this initiative was assigned ratings varying between very important and desirable, its average rating in comparison with those for the other initiatives was relatively low. The conclusions to be drawn for this initiative are to the effect that very little research is required. It is rather a matter of achieving a certain level of development and, especially, in the transfer and adaptation of technologies. Respondents from mines indicated that these tools would be useful, but that this type of advancement would not permit them to be significantly more productive in the next 10 years.

### 5.10. Energy consumption

Electricity consumption represents approximately 10% of the production costs for mining operations in Quebec. This proportion increases in provinces where the electrical energy costs per kWh are higher. Mining alone represents 60% of the energy consumption, while ore concentration at the mill consumes the rest. Even if research, designed to reduce energy consumption, did not seem to be both a priority and distinct item during the consultations, the fact remains that the consumption of energy will become an important issue in the future. Consequently, it is important to tie this element to the axes of research which have been identified by the industry as being of the highest priority.

Making up an overall balance sheet of the energy consumption at a mine would have exceeded the framework of the present report. For this reason the analysis of the importance of energy on the operational costs was based on the study by Met-Chem Pellemon(41). Even though it dates back to 1996 and since then, some gains were realized at the energy efficiency level, the distribution of energy consumption has probably not changed significantly. In broad terms, this report points out that the potential savings for all the respondents represented 8.4% of the total energy bill, where 4.3% was quickly achievable. Since the production of this report, steps have probably been taken to realize these savings.

As an example, Table 17 presents, based on the type of operation, the average unit consumption per tonne of milled ore, obtained from data gathered from 1994 to 1996 (41). The energy consumption of a site includes electricity and fuels, such as natural gas, propane gas and diesel fuel.

**Table 17 – Average electricity consumption for a mechanized mine and for a conventional mine**

| | Number of respondents | Hoisted ore and waste (MJ/T) | Milled ore (MJ/T) | Electricity consumption (kWh/T) |
|---|---|---|---|---|
| Mechanized mine | 7 | 340 | 414 | 115 |
| Conventional mine | 4 | 658 | 936 | 260 |

On the base of milled tonnes only, it is possible to notice that the specific consumption varies substantially between the different types of mining operations. Conventional mining methods, which are basically used in narrow-vein deposits, show a significantly higher consumption. The relatively low tonnage extracted, in comparison with other types of operations, explains this characteristic. However, if the data was again compiled on the basis of the energy required per quantity of metal extracted, the generally much higher grade of the ore extracted from narrow-vein deposits, and the normally lower one in bulk mining operations, would probably result in an equivalent level of consumption.

Table 18 summarizes the consumption of energy for various activities. These are similar to those identified in the highest priority axes of research of chapter 5.

**Table 18 - Distribution of energy in relation to the axes of research**

| Research initiative | Type of activity | Mechanized mine (%) | Conventional mine (%) |
|---|---|---|---|
| Working environment | Ventilation | 31.0 | 16.0 |
| | Heating | 20.7 | 25.6 |
| | Lights | 0.6 | 0.5 |
| | | **52.3** | **42.1** |
| Waste and ore handling | Loading | 7.8 | 11.0 |
| | Compressed air | 0 | 5.9 |
| | Transportation | 5.6 | 7.1 |
| | Crusher | 1.2 | 0.5 |
| | 80% of hoisting | 6.8 | 4.3 |
| | | **21.4** | **28.8** |
| Drilling and rock fragmentation | Drilling | 1.8 | 1.0 |
| | Blasting | 1.1 | 0.9 |
| | Compressed air | 13.3 | 5.9 |
| | | **16.2** | **7.8** |
| Service | Pumps | 4.8 | 5.7 |
| | 20% of hoisting | 1.7 | 1.1 |
| | Others | 3.6 | 14.5 |
| | | **10.1** | **21.3** |
| **Total** | | **100** | **100** |

### 5.10.1 Research and development to reduce the energy consumption

Since 1996, the different incentive programs have probably allowed mines to reduce their energy consumption by an estimated 8%. The activities, which have the greatest potential for reducing consumption, can be summarized as follows:

- Automated start-up of air compressors;

- Reduction of leaks in compressed air lines;
- Stopping or reducing mine ventilation during inactive periods;
- Reduction of the speed of ventilation fans during the winter;
- Control of auxiliary ventilation systems; and
- Replacement of electric motors with more efficient ones.

The comments gathered during the interviews show that a great deal of optimization has occurred in recent years, particularly in mechanized mines. Although there is always room for improvement, it will not be possible to realize considerable gains in the next few years unless the production process is substantially modified, including the production equipment which is related to it.

**Working environment**

Since it involves the whole aspect of ventilation, the working environment research initiative represents the research area that can have the greatest impact on the reduction of energy costs. The flow of air that is required is determined, through regulations, by the sum of the power of the diesel engines in the mine ventilation circuit. At the same time, the energy consumption for ventilation and heating clearly depends on the level of the ventilation required. Consequently, the development of technologies, through which one could reduce the ventilation rate, while, at the same time, maintaining air quality that meets the occupational health standards, constitutes by far the highest priority element for realizing significant energy gains.

**Drilling and rock fragmentation**

Even if, in Table 18, the “Drilling and Rock Fragmentation” theme ranks third on the table of energy consumption; it is nevertheless at the beginning of the entire mining process and ahead of the ore concentration at the mill. It is, actually, the highest priority in terms of energy conservation. The selectivity between the ore and the waste, which is carried out in the rock fragmentation process during blasting, has a direct influence on the quantity of waste which is mixed with the ore. Consequently, the energy required to hoist surplus waste to the surface and to treat it at the concentration mill is wasteful in terms of energy. The quality of the rock fragmentation during blasting also facilitates the loading operations when the size of the blocks is reduced. A better fragmentation results in energy savings in the loading of rock material and its crushing through mechanical means with a percussion drill or a crusher.

To conclude this subject, although there still are possibilities of optimizing the consumption of energy, important and significant reductions in the operating expenses of mining operations depends upon the development of new production processes and equipment.

# 6. INVESTMENTS REQUIRED FOR THE IMPLEMENTATION OF THE ACTION PLAN TO OBTAIN AN IMPACT IN UNDERGROUND MINES

## 6.1. Current investments in research

In 2002, the gross domestic expenditures in R&D in Canada, all industrial sectors included, amounted to $20.8 billion. Of this, $11.2 billion was made by business enterprises (42), indicating that a little more than 50% of the funding came from companies. In other words, the total sums invested in research, all funding sources included, represented 1.9% of the GDP (45), with 1% coming from the private sector.

Worldwide, this investment is comparable to that of the business enterprises in Italy, Norway, the Netherlands, Denmark, the United Kingdom and France. However, the private sectors of some countries are more active in investing in R&D: Germany with 1.7% of its GDP, the United States with 2%, Japan with 2.2% and, in particular, Sweden with 2.9% (44).

In Canada, the mining sector, including the combustible minerals sub-sector, invests more than 5 times (46) the total expended by all of the other resource sectors combined. Equally, it is far more than what is expended in the sector of automobile parts and accessories, or in the combined sectors of construction, transportation equipment, communications and utility services (telephone, gas, electricity). When taking into account all of the areas of activities of the mining industry, the latter ranks as the ninth of the most important Canadian investors in R&D. Therefore, the natural resources sector is a substantial innovation generator, expending more than $34 billion per year (47) for state-of-the-art technologies and for other capital investments (22% of the Canadian total) - more than for any other sector in Canada.

However, when examining that part of the industry related to the extraction of metallic and non-metallic minerals only, the picture is completely different. Out of the $11.5 billion that Canadian companies from all sectors allocated to R&D in Canada in 2000, only a relatively small fraction, $30 million, came from that part related to the extraction of non-combustible minerals. This R&D accounted for $22 million in Ontario, $1 million in Quebec and the rest elsewhere in Canada (44). This amount, however, does not include all of the tests, the research and development done internally in the mines. In several companies these are recorded as current expenditures and not as research expenditures. For example, during the tests and experimentation to develop a new rock fragmentation process, Campbell Resources chose to make its contributions to a research project that was being conducted at the Meston Mine, near Chibougamau in Quebec. Because they were not accustomed to account for this type of expenditure, they then realized with astonishment that they had made a research investment in the amount of $250,000 over a period of approximately 6 months.

Unfortunately, R&D expenditures (46) in the natural resources sector tend to follow the variable metal prices. Overall, 76% (43) of all Canadian companies conduct R&D. However, only a minority have their own research centres. In the mining sector, this phenomenon has been exacerbated in the last few years with the closure of the INCO research centre in Sudbury and of the Noranda Technology Centre in Pointe-Claire.

## 6.2. Research benefits

Several studies have evaluated the social benefits of R&D. The findings have been that the return on investment for fundamental research projects is generally between 20 and 50%. Moreover, Salter and Martin [36] identified 6 main types of social benefits:

- Increases in knowledge;
- Training of qualified graduate students;
- Development of new scientific instruments and methodologies;
- Creation of stimulating social exchange networks;
- Increases in the capacity to resolve problems; and
- Creation of new companies.

Furthermore, to assign an order of magnitude to the value of its research projects, an impact study [(48)], conducted on 21 mining-related projects carried out by CANMET-MMSL, has quantified the research benefits for the mining industry. Any benefit estimate has an intrinsic subjectivity, but this analysis, based on evaluations made by the engineers who had recommended the work, provides an order of magnitude of the return on the investment. The following trends can be drawn from this analysis:

- the ratio of benefits to average costs represented a return of 2.5 times of the sums invested;
- the duration of the projects varied between 1 and 10 years, with an average of 3.5 years; and
- the average cost of the projects was $1,200,000.

Three examples among many others illustrate, in concrete terms, the research benefits.

1- Paste backfill

The operation of the Chimo Mine, near Val-d'Or, was extended as a result of an innovative technology regarding the use of paste backfill. After 26 years of operations, a rock burst, which occurred in September, 1992, forced the temporary closure of the mine. Two scenarios to allow the resumption of operations were contemplated. These were the abandonment of 25% of the mineral reserves through pillars to support the walls, or the use of a new paste backfill technology. With the first alternative proving to be less economical, Cambior chose to use a high-density backfill production process. The safe continuation of operations then depended upon the use of a process which would produce a backfill with very high mechanical strength. This would prevent the degradation of the rock mass and, accordingly, reduce the accumulation of stresses. This process resulted from research over a period of 10 years, conducted jointly by INCO and

McGill University, in which investments exceeded $10 million. This technique resulted in an extension of the operations at the Chimo Mine for four additional years. The use of this innovative backfilling technology also proved to be a very environmentally-friendly solution through achieving a significant reduction in the quantity of mine tailings that were being discarded. Moreover, this process has been duplicated elsewhere; through it, Cambior has used this technique at three of its other operations, thus allowing a significant decrease in its operating expenses, while, at the same time, maintaining several hundreds jobs in remote areas. In addition to Cambior, many other Canadian companies benefit today from this technique, most particularly those which mine at depth.

2- Electronic detonators

In October 2000, a major rock burst at the Brunswick Mine, near Bathurst, New Brunswick, completely blocked the access to the mineralized zone. Fortunately, there were no casualties, but, a production drill, worth $800,000, was destroyed. To prevent such bursts, destress blasts are designed to break the rock mass and hence prevent the accumulation of stress. These blasts must be particularly well controlled to fracture only what is required in order to achieve the destressing. The Brunswick Mine, consequently, broke new ground by using the recently-developed electronic detonators, which allowed an accurate control of the delays between the detonations. This would have been impossible with conventional techniques. In July 2001, the mine staff accurately sequenced the blasting of 353,000 tonnes of rock with the use of 1,504 electronic detonators. One week thereafter, it was once again possible to have access to the mineral resources and to resume normal operations. Although these detonators are more expensive, the life of the mine has nevertheless been significantly extended. The staff of the Brunswick Mine now regularly use electronic detonators, thus allowing the recovery of mineralized areas which once would have been extremely difficult.

3- Hoisting system

In 1994, following a successful deep exploration program at the LaRonde Mine, Agnico-Eagle undertook the sinking of the Penna shaft. In order to be efficient, it became necessary to deepen the shaft and to achieve a hoisting capacity of more than 4,500 metric tonnes per day, at a depth of 2,240 metres. This had not been done previously in Canada. The alternative, the sinking of an additional hoisting shaft, at a cost exceeding $100 million, was not economically viable. In this particular case, Agnico-Eagle was able to benefit from mine hoisting research that had already been carried out in South Africa. Subsequently, the technology was transferred, thereby allowing an increase in the ore hoisted, while, at the same time, providing compliance with the most stringent safety standards. By achieving the optimal use of a single hoisting shaft, the research carried out in South Africa allowed the company to limit its capital expenditures to $10 million and, consequently, to maximize its returns from the LaRonde Mine, at which close to 500 workers are presently employed, and over 7,000 tonnes per day of ore are extracted.

In the industrial sectors, in general, where merchandise is sold, the research is aimed at developing new products which will ensure the survival of companies. However, in the mining sector, since minerals and metal products are not differentiated between one company and another, the competition is based on the costs of production. Consequently, the reduction in operating expenses by research and the development of more effective methods and tools is a key element.

R&D is also required to go beyond the limiting conditions, such as those that are encountered in permafrost or in deep mines. To be able to safely mine these complex deposits, it is imperative to increase the level of knowledge in the fields of ground control, grade variation, quality of the rock mass and rock fragmentation, among other things.

To remain a worldwide leader in the mining sector, research in Canada is needed to support Canadian SMEs and manufacturers which will, subsequently, be able to develop an exportable state-of-the-art expertise. Moreover, the great majority of equipment, presently used in Canadian mines, comes from foreign countries. These are not specially designed to meet the characteristics of Canadian mines. During the interviews, the mine operators pointed out that, owing to the lack of an alternative, they were compelled to use equipment that is presently available on the market even if it often did not entirely meet their requirements. The large size of the equipment compared to the size of the openings and their reliability were often the main subject of their comments. In addition, in order to be able to attract and retain young and eager personnel, it will be necessary to continue improving and offering underground working conditions that will be similar to those in other industrial sectors. The pursuit of best practices and increased research, to improve working conditions, are inevitably the best way to achieve this.

### 6.3. Required investments

In Canada, in 2002, the sector involved in the extraction of metallic and non-metallic minerals contributed $8.5 billion to the GDP (49). Consequently, in order to support a research endeavour equivalent to that of other industrial sectors, i.e. ***1.9% of the GDP,*** the mining sector needs to make an investment of $162 million annually.

On the same basis, when considering only the metal mining part of the industry, where *the contribution to the GDP is $5.2 billion* (49), the research endeavour should then be equal to $*99 million*. However, if it is estimated that *approximately 20%* of the operating costs are incurred for ore concentration, as well as the treatment and disposal of mine tailings, the research endeavour, solely for exploitation, then ***should be $79 million***. According to Statistics Canada, ***the industry presently invests $30 million*** (44) towards research and development each year. These crucial investments must definitely be maintained.

In addition, as mentioned in the previous section, significant sums of money are frequently invested in R&D underground but are not recorded as such. By having projects controlled within a structured organization, as proposed in chapter 7, the official recognition of research investments and in-kind contributions, regularly made by the industry, could then be facilitated since all of the projects would systematically be documented. Thus, by recording and recognizing all of these investments as research initiatives, it would be very apparent that *the industry is already contributing close to its fair share* of the $79 million, that is *about $40 million, thus **representing 50% of the funds*** normally invested in R&D by business enterprises in Canada.

On the other hand, both the federal and provincial governments hardly ever invest in mining research. Further, the industry benefits relatively little from research and development tax credits [(51)]. Companies with operating mines invest significant sums in R&D, externally through contracts with research organizations or internally, or through the acquisition of R&D technologies developed by third parties, but rarely make use of any specific tax break. According to information obtained from mining companies, it seems that some provincial governments grant a refundable tax credit. However, at the federal level, it seems that, in view of the high accumulated tax credits derived from other investment sources, which mining companies use, it would be much more difficult to obtain a refund in the short term for research. Also, to obtain these tax credits, all of the costs related to administrative expenses must be deducted.

When short or medium-term initiatives are not considered, such as: Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCO, based in Sudbury, approximately $1M/year); SOREDEM ($180K/year); and the Canadian Deep Mining Consortium (with a yearly government investment of $1.1M; and where the funding is not guaranteed in the long term, thereby compelling the researchers to constantly struggle to renew the applications for funding), *the only **continuous and long-term** government funding seems to be that derived partly from CANMET-MMSL*, that is about $6 million annually, allocated to mining programs. Out of this $6 million dollars, the federal government receives over $1.5 million from its different partners through cost recovery for contractual work in R&D. Hence, the federal government invests *about $4.5 million annually*, thus reflecting a long-term commitment. It is suggested that the different levels of ***governments** should undertake a major additional effort, of about $**35 million** annually*, if a contribution of at least 50% can be expected from a partnership between the industry and the federal and provincial governments. All must participate if the effort is to be successful.

In section 3.3, it was demonstrated that the start-up and operation of a mechanized mine will generate, over a period of 10 years, revenues of $155 million for the different levels of governments. Consequently, a fruitful research initiative resulting in the opening or the extension of the lives of two additional mines during that same period, the R&D governments' investment would be covered solely from a financial point of view. Also, the recording of all of the tax benefits, such as the wages related to spin-off effects, the other social benefits mentioned above [(36)] and the municipal taxes, would further support this financial justification. Finally, although these are more difficult to quantify, the benefits, such as the preservation of an exportable state-of-the-art expertise and the occupation of the territory, must be included in the equation.

# 7. RESEARCH ALLIANCE MODEL

## 7.1. Introduction

The successful application of the financial resources to be invested in research will be conditional upon there being an organized country-wide operation. In this study, the structures of several Canadian and foreign research organizations, operating in the mining sector and in other natural resources sectors, such as forestry, or even agro-industry, were studied (see Appendix D – Internet sites). All of these groups or organizations were either associated with universities or governments, or were non-profit corporations. Of these, two models stand out: one having permanent employees and infrastructures, and the other, more flexible, in which research contracts are awarded, on a piecework basis, depending on its needs. The latter model allows access to a very wide pool of researchers and equipment. The principal, however, or possibly, the only mandate of all these organizations, was to increase the productivity of the industry which these serve. All carried out research work on a contractual basis, working in partnership with the industry, the different levels of government and the universities. In the flexible model, a reference is often made to SMEs, equipment manufacturers and research centres which also operate in the same field.

There are several benefits to be derived from a structured research alliance, operating in its own field of activities:

- Providing a common vision in R&D for the mining sector;
- Defining leading edge projects which correspond to the axes of research identified;
- Providing the industry with access to state-of-the-art, and multidisciplinary, expertise;
- Sharing the costs and the risks associated with R&D; and
- Benefiting collectively from other sources of financial support.

Based on what is described in the literature, research organizations generally provide one or several of the following services:

- Technical studies;
- Technology watch;
- Evaluation, improvement and adaptation of products;
- Development of technologies, including the development of commercial products;
- Implementation and in-situ demonstration;
- Consulting services; and
- Networking between the various stakeholders.

## 7.2. Status quo?

Mining research in Canada is presently broken into segments, with each group working independently as far as the selection of themes and fundraising are concerned.

Fundraising is particularly problematic. First, the financial resources must frequently be negotiated, project-by-project, and, moreover, often annually. In the absence of a concerted action, research budgets are relatively small in comparison with the needs. For example, MIRARCO receives annual funding of approximately $1 million, which must be renewed each year, CAMIRO receives approximately $200,000 and, the deep mining consortium has a guaranteed annual funding of $1.1 million (Ontario government and the industry) over a period of 5 years, as long as the various federal departments provide an additional annual funding of $400,000. SOREDEM also operates on a project basis, allocating an average annual funding of $180,000. The funds thus allocated are difficult to obtain and often give rise to considerable delays before the start-up of projects. Moreover, the exercise is all the more difficult as each organization allocating funds uses different criteria which are based on their specific mandates. Therefore, the source of funds quite often dictates the research orientation, rather than addressing the actual needs of the industry. It must be pointed out that the Natural Sciences and Engineering Research Council of Canada (NSERC), which is an important source of academic funding in many scientific areas, hardly ever contributes to mining projects.

Finally, SMEs do not have the resources required to venture into the intricacies of fundraising for their projects and cannot fully assume the cost of the work, given that the potential short-term market is too small, compared to the potential risks.

Moreover, the present process offers neither a concerted approach nor a global vision of the needs and solutions. Thus, the common objectives are not targeted and very little information is available regarding the execution of projects. For that reason, the mining industry is subjected to a significant silo effect as far as research is concerned. In addition, owing to the lack of regular exchanges with the operators, researchers often have difficulty in clearly understanding the needs of the industry, while, on the other hand, the industry is not sufficiently aware of the expertise that is available in Canada.

For all of those reasons, the status quo is ineffective. Consequently, it is recommended that an alliance of research participants be formed in order to facilitate communications between all of the stakeholders, as well as to join forces regarding the allocation of funds and the selection of projects, based on the highest priorities for research.

### 7.3. Mission of the alliance

**Mission**

To coordinate mining R&D, and to ensure technology transfer, so that the Canadian mining industry stays at the forefront of innovation, by increasing the competitiveness of the Canadian industry, while, at the same time, assigning high priority to the health and safety of underground mine workers. The details of such an organization are presented in Appendix E.

### 7.4. Intellectual property and patents

Research often leads to the creation of products or technologies which are patentable. When required, these patents could be obtained on behalf of the Alliance, or, at the very least, some clauses to that effect should be included in the R&D contractual agreements. When agreed upon, the Alliance could then assume the responsibility for the costs associated with obtaining and maintaining the patents. Moreover, poor management of intellectual property (IP) can result in projects being nipped in the bud. Thus, it is essential that special attention be paid to this point on a continuing basis.

In addition, the Alliance will have to decide on the type of license agreements that it will agree to execute with its partners. For the active members, one of the preferred approaches would be the non-exclusive license, without royalty, for the use, without right of resale, in Canada, of patents which are the fruit of research financed jointly by industry and governments. No guarantee will be given with the right to use, nor any right with the issuance of a sub-license. Moreover, in the case where the IP belongs to the Alliance, a commercialization license will have to be concluded and royalties negotiated, if a manufacturer or other stakeholder wishes to commercialize such technology.

Any member who examines any intellectual property should sign a confidentiality and non-disclosure agreement.

# 8. ACTION PLAN FOR MINING R&D IN CANADA

In view of the above, in order to allow the optimal implementation of the axes of research identified in chapter 5, an action plan will be recommended in this section.

In order to ensure that Canadian mines remain competitive, two wide approaches to the technology issue are required:

1) the introduction of technologies developed in other sectors, which could be adapted to the mining sector; and
2) the development of new technologies.

## 8.1. Introduction of existing technologies and the sharing of information

**Dissemination and use of best practices**

The development of the best operating practice within an organization is often the result of several years of research and optimization. For this reason, within the Canadian mining industry, companies frequently exchange their best operating practices. It may be desirable to promote this practice even more. Some operators, however, particularly those mining and processing industrial minerals, are unwilling to share information, especially when the results of the research are disseminated internationally. In some foreign countries, the innovative techniques and equipment are appropriated in order to compete with Canadian mines. Accordingly, patents should be obtained, whenever appropriate. In spite of this, and even with a patent, it may be difficult to protect Canadian intellectual property in foreign lands. This aspect will require continuous vigilance on the part of all of the stakeholders.

**The sharing of knowledge**

One of the most practical means of sharing knowledge and expertise occurs through national and international forums. It could also be very beneficial for the industry to import technologies already developed in other industrial sectors or by manufacturers. An effective way to achieve this would be through the establishment of a technology watch to disseminate all of the practices which could be useful to the mining industry. Technologies evolve rapidly, but the useful and relevant information may not be well disseminated through refereed journals.

## 8.2. Development of new technologies

**Alliance of stakeholders**

In order to remain competitive, it is clear that new technologies, that will allow operators to significantly improve productivity, are essential. To facilitate this development, it is recommended that the common problems, that are encountered in several mines, continue to be clearly identified and addressed (see chapter 5). Moreover, the alliance of companies and manufacturers in projects allows all to share the costs of research and development and to be in partnership with the different levels of governments. In the past, it has been demonstrated that it is possible to bring mining companies together to discuss some problems when the economic issues are important and the costs of the research must be shared. This approach, through a research consortium, promotes the achievement of research projects and often allows the partners to obtain results in a relatively short term.

On the other hand, the awarding of research and development contracts should be done on the basis of the respective expertise, capacities and achievements of the researchers and on the likelihood of their making strategic alliances to obtain concrete results within the prescribed time. The selection of a funding partner is also a key element that is needed to ensure the success of R&D initiatives.

## 8.3. The role of research stakeholders

The success of an extensive and ambitious research program is based on the participation of several stakeholders, among which, primarily, is the mining industry, as a whole. In order to obtain optimal results, it is suggested that the roles of each stakeholder should be as follows:

### 8.3.1 The role of mining companies

Mining companies must deal with various problems underground and, consequently, their requirements have to be addressed. Thus, it is essential that they clearly define the technological innovations which can have a significant impact on their production costs. Under this heading, the representatives of the industry do quickly identify their short-term requirements since these are usually due to emergency situations occurring in their operations.

However, by the very nature of its mandate to produce minerals, it is more difficult for the industry to have a long-term 10 to 20-year vision. This is often due to the short lives of mines with lower productions, in which the reserves are often estimated to last for only a few years. This also reflects the financial atmosphere of some mining companies, in which investors seek short-term returns. For these reasons, it seems to be difficult for the industry to identify its medium and long-term requirements and to convey these to the research community.

Many companies mining metallic ores consider that their mission consists of extracting minerals through relatively proven techniques. Several major companies extracting world-class deposits believe that the techniques and mining equipment used in their operations have been perfected. Except for some relatively minor modifications, and periodic incremental improvements, these techniques and equipment have not changed substantially since their introduction and, consequently, nothing can justify extensive modifications of either the equipment or the mining methods and processes. However, even in these mines, the operators must deal with non-productive time, particularly between the work shifts; this later offers the possibilities of achieving significant reductions in non-productive time. In contrast, the operators of more complex deposits believe that it is appropriate to pursue the axes of research in order to innovate in the areas of production processes and the related equipment.

To conduct such research, an alliance of university expertise and research centres, grouped either by themes or by research projects, and under the supervision or mentorship of an industry champion, is essential. This representative of the industry must be a visionary and must possess the appropriate leadership skills to ensure that projects may evolve properly, and to promote the application of the new technology within his company. Ideally, each project should have a champion who will ensure its follow-up and introduction in the operation which he or she represents. Tight supervision of each of the projects will be essential. Moreover, a detailed schedule should be established for each project, with steps having clearly defined criteria for achievements so that it can be determined, during its execution, whether or not it is meaningful to continue. Despite the fact that operators have little time to devote to research, if they want the results needed to meet their requirements, they will have no choice but to become involved.

It is equally essential that the industry select the right champions (those who believe in research and development) to sit on the various committees. These must have both a vision of the research and development needed and an overall understanding of the actual requirements of mining operations. In addition, these must also be able to exercise some kind of influence within the company which they represent. Unfortunately, due to issues of workloads and availability, the key personnel from the industry are frequently unable to participate, in view of the fact that their time is often monopolized by short-term high-priority matters.

On the other hand, however, the industry also has an intrinsic mandate to properly manage its operational activities. It should not rely on research to ensure the effective management of the information, and the human, material and financial resources needed in mining operations to improve productivity. For example, in highly mechanized mines, control of logistics seems to be an important requirement, which could often be addressed by means other than by research. Normally, the importation of the technologies used in other industrial sectors, or the simple application of best practices, could succeed, both effectively and economically in addressing such requirements.

Finally, the industry often expects a quick, if not immediate, response to its requirements. Research is normally based on a process of experimentation, which includes numerous trials and errors, and which require some time before concrete solutions to problems are obtained. Unfortunately, this often results in a lack of interest or long term support on the part of the industry.

### 8.3.2 The role of research centres and universities

First, in research, the main role of universities and research centres consists of developing knowledge by proposing innovative concepts and approaches, that are both practical and achievable, to address the problems of today and tomorrow. Their staff must also clearly define the objectives of a project and the deliverables, as well as the schedules to be followed and the budgets required. Second, universities must also educate and train graduate students by associating them with projects, which, preferably, have been established with the industry's cooperation.

Even if, ideally, an alliance of forces increases the potential for success, the alliances between universities and other research partners are not necessarily easy to establish. Over the years, researchers develop their own networks and tend to maintain these, despite the fact that the requirement for specialist expertise in a project often varies according to the project to be carried out.

There may also be a lack of continuity in projects as a result of priorities which vary, depending on the changing of industry representatives. Thus, the mandates given to researchers may not always be clear. Moreover, it is often not easy to achieve both the funding required for the project and its realization, without taking into account the administrative and academic tasks which must also be pursued in parallel with the research. To summarize, the expectations of the industry can be too great and can result in a lack of interest in the face of projects of a more fundamental nature.

On the other hand, researchers from academia and research centres should leave their laboratories to visit the industry on a regular basis in order to better understand the needs in their field and to be aware of operational realities.

### 8.3.3 The role of SMEs and manufacturers

On the innovative side of the extraction process, one of the main needs for mining operations is the acquisition of machinery, equipment or other technologies through which the mining methods can be improved. At present, the development of new mining methods or the improvement of the existing ones is generally conditional upon the development of new equipment. Manufacturers are, therefore, important actors in research as a result of their capacities to develop innovative equipment. These also are often entrepreneurs, which is a key element for the development of projects. Manufacturers of mining equipment are usually on the lookout for business opportunities and are in touch with the needs of the industry. However, they, too, encounter problems in funding their research projects. The construction of innovative equipment often results from a particular request from a client (mine). However, before proceeding, manufacturers must ensure that there is a minimum potential market for that equipment so as to be able to amortize the research and development costs required to develop it.

Several small manufacturers are overflowing with imagination that can lead to the realization of innovative equipment. However, these do not have the resources necessary to carry out both their regular production activities and research and development projects. Even in an alliance of partners, their involvement may often be "in-kind" as the result of the lack of funds. In addition, whenever a major contract is obtained, research is often relegated to a position quite far down on the scale of priorities. Moreover, even when the expertise of some manufacturers and entrepreneurs complements that of each other, an alliance is not always possible for reasons of competition.

To summarize, equipment manufacturers are key stakeholders in the development of new technologies. Networking should be established between the SMEs and equipment manufacturers, research centres and universities, and mining operations.

### 8.3.4 The role of governments

First and foremost, the mining research and development community relies on the different levels of governments to provide long-term funding for its initiatives, in addition to sustaining the efforts required for the demonstration and implementation of new production processes.

The general opinion of all of the respondents was that it is absolutely necessary to achieve a simplification and harmonization of the processes needed to obtain research and development funds through the different government authorities, both federal and provincial.

Finally, the respondents agreed that there is a need for one or more government research centres. They also shared the opinion that the researchers involved must work on matters of mutual concern, i.e. common problems. In that case, the funding of projects carried out by federal/provincial laboratories should be reviewed in the spirit of what is proposed in this report. Consequently, governments should maintain a leadership in mining research, particularly on health and safety issues, in order to properly support the regulations which are related to the technical and scientific aspects of mining.

## 8.4. Actions to be undertaken

The specific actions for each stakeholder can be summarized as follows:

**Mining companies:**

- To participate and finance research in a sustained fashion;
- To clearly define the technological innovations that can have a significant impact on their operating costs;
- To select industry champions, who believe in research and development, to become members of the various committees; and
- To establish, with the partnership of other stakeholders, a structure to facilitate the delivery of the R&D initiative (see Appendix E).

**Research centres and universities:**

- To propose innovative concepts and approaches, both practical and achievable, to address today's and tomorrow's problems;
- To clearly define project objectives and deliverables, as well as the schedules and the budgets required;
- To train and educate graduate students and associate them with projects, which have, preferably, been established with the co-operation of the industry; and
- To establish a close communication with the industry in order to properly understand its needs and operational realities.

**SMEs and manufacturers:**

- To set up a solid network between the SMEs, equipment manufacturers, research centres, universities and mining operations in order to improve the chances of success for the fabrication and introduction of new equipment aimed at improving the mining methods; and
- To be on the lookout for business opportunities and in touch with the needs of the industry.

**Governments:**

- To provide long-term funding for the initiatives and efforts from research partnerships for the demonstration and implementation of new production processes;
- To simplify the process needed to obtain research and development funds; and
- To disseminate information at the national level and to conduct research on matters of national concern.

As mentioned above, all of the participants agreed that the monetary issue is the main obstacle to the proper conduct of R&D work. Researchers are presently spending a considerable proportion of their time in the search for funding. In addition, the effective pursuit of projects requires more assurance as far as the continuity of funding sources is concerned.

Following the meetings with the participants, it was determined that the funding of research projects could be facilitated through the following steps:

- **First and foremost, to become organized collectively in order to establish an industry-government partnership, which will provide stable and sustained funding, allocated through at least two commitments of five years each, over the next 10 years, towards the achievement of the research program.**

- Regroup companies and manufacturers, by project, thereby allowing these to share the research and development costs in partnership with the different levels of governments;

- Orient the funds from the various sources towards the axes of research identified by the mining industry, the associations, SMEs, manufacturers, governments and research organizations as being of highest priority;

- Develop and establish a mechanism for the allocation of funds to minimize the time required to obtain the money necessary for the execution of the project (practice of a one-stop funding service);

- Select funding partners who can assure the follow-up and monetary support of projects in order to ensure their success; and

- Award research and development contracts on the basis of the respective expertise of research centres and universities, and their likelihood of making strategic alliances to obtain concrete results within the prescribed time table.

# 9. CONCLUSIONS

With an annual production of $77 billion, the Canadian mineral industry remains, as a whole, one of the essential pillars of the Canadian economy and continues to contribute significantly to the prosperity of the country. It generates 80,000 direct jobs and 300,000 indirect jobs. The incidental annual payroll expenditures are of the order of $4.3 billion. More than one million Canadians and over one hundred communities owe their existence, one way or another, to the mining sector.

Even if it is less visible than other sectors to political decision-makers and citizens, the contribution of the mining and mineral processing industries represented, in 2002, $38.1 billion, or 3.6% of the Canadian GDP, while the prominent high-tech sector only contributed 3.0%. The natural resources generated by the mining industry also represent an important source of revenues contributing to the income taxes of the country. In particular, throughout its life, an average size mechanized mine, by virtue of its payroll expenditures and initial capital investment, will contribute over $155 million in income taxes to the two levels of governments. It provides urban areas of the country with demands for their goods and services, and the use of facilities for the refining and further processing of metals and minerals. Moreover, the mining and forestry industries are the heartbeat of remote areas. Without life in these remote areas, the occupied part of the Canadian territory would be reduced to the narrow zone north of the American border in which most of the Canadian population is concentrated.

Substantial Canadian mineral resources are found in deep mines and 75% of mining operations use underground mining methods. Those methods, which have less impact on the environment in comparison with open pit mines are, however, more complex. Moreover, an important quantity of the mineral potential is often located at great depths, in high-grade deposits and of lesser tonnage, and where less favorable geomechanical conditions make their extraction more complex. These characteristics of the Canadian mineral potential, combined with the changing socio-economic context, require companies to innovate and improve their mining methods if they wish to preserve an active and economically efficient mining industry in Canada. The accelerated pursuit of the development of new technologies aimed at improving productivity, and the health and safety of those who work in Canadian mines, appear to be the key element to ensure the survival of the industry in the face of international competition and to ensure its prosperity in the next 10 to 20 years.

Following extensive consultations with the mining industry, research centres, universities, consultants, SMEs, manufacturers, mining associations and governments, it was demonstrated that research, aimed at improving mining methods, has been identified as being of the highest priority in maximizing the impact on the mining process. The four most important axes of research identified were:

- ► Drilling and rock breaking;
- ► Engineering related to the working environment;
- ► Mining engineering; and
- ► Backfilling and related subjects.

Moreover, the leadership and financial participation of the industry continue to be key elements in facilitating the technological developments which it requires and in improving the chances of obtaining significant results. In addition, excellent communications between researchers and operators are essential in order to promote a better and mutual understanding of the requirements, challenges and schedules. Due to the importance of the equipment to be used in the choice of the mining methods, manufacturers are also key players in the development of new mining techniques. In order to successfully develop innovative equipment, it is essential that a network be established between mining companies and equipment manufacturers, and also the researchers in the private sector and academy. Moreover, mining research should be structured in such a way as to promote the exchange of expertise across Canada. The creation of solid partnerships will avoid unnecessary duplications and will promote a crucial level of knowledge. In view of what is being done internationally, this R&D initiative should be implemented through the establishment of research structures which will facilitate the sharing of the risks and the costs of development. As an example of a proposed research organization based on consideration of other such organizations elsewhere in the world, is presented in Appendix E.

Finally, without stable and sustained funding, no significant results from R&D should be expected. Due to the challenges and the economic stakes involved, an increased financial participation will be required from both the federal and provincial levels of government, the industry, and manufacturers.

In order to preserve its global leadership, a minimum of $79 million will have to be invested annually in Canada for at least the next 10 years to finance projects aimed at improving mining methods and technologies. Of this, it is estimated that the industry already contributes $30 million per year, along with an additional contribution estimated at $10 million for manufacturers and for in-kind work in the mines.

All things considered, if these investments were acknowledged, it would be very apparent that the industry probably already contributes its fair share, that is, about half of the sums required for mining research and development. On the other hand, the federal, provincial and municipal governments (in their respective mining areas), because of the considerable benefits that accrue to them, should undertake a major additional effort to provide approximately $35 million annually to bring their participation up to the level of that of the industry.

The funds, from both the private and public sector, should be administered by a industry-federal-provincial partnership, and should be aimed at supporting, in a tangible way, the axes of research identified by both the mining industry and the other research stakeholders as being of highest priority. In addition, the formation of a “corridor of excellence” between the mining centres of northern Ontario and northern Quebec would be an interesting concept to develop, given the critical mass and the potential alliances that could be formed between the industry, the SMEs, the manufacturers, the research centres and the educational institutions that are located there.

Many years ago, in the face of international competition and a decline in mining in the country, the Swedish mining industry, its manufacturers and research centres, joined together to provide the world's mining operations with improved and more productive equipment and techniques that could be aimed at reducing operating expenses. The exercise proved to be profitable for them, and established Sweden as one of the world's pre-eminent manufacturers of mining equipment. In spite of its smaller territory, compared with that of Canada, and its much lower mineral production, Sweden is now a dominant player in the international mining equipment market.

It is hoped that a similar important research initiative can make Canada more competitive, not only for its mineral production, but also for its manufacturers of mining equipment and other manufacturers and consultants. The sums invested in Canada will subsequently be rewarded by an important economic contribution, through the number of well-remunerated jobs in a vibrant mining sector. Today, in Canada, a similar situation to that of Sweden arises as a result of the particular mining conditions which are being faced. To reaffirm Canada's global leadership in mining techniques over countries, such as Australia and South Africa, and to stop the erosion of the Canadian mining industry, it is urgent to act now.

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# APPENDIX A
# Documents used during the Consultations

Natural Resources Canada | Ressources naturelles Canada

CANMET-MMSL Experimental Mine | Mine-laboratoire LMSM-CANMET

P.O. Box 1300 | C.P. 1300
Val-d'Or, Quebec J9P 4P8 | Val-d'Or (Québec) J9P 4P8
Tel.: (819) 736-4331 | Fax : (819) 736-7251

Subject: Cooperation required from your mining operation to prepare a research and development plan

Dear Sir or Madam,

As you have undoubtedly noticed, the extended weakness of metal prices in the last few years has, in general, considerably affected the competitiveness of the Canadian mining industry. To deal with this situation, your corporation has probably optimized its operational effectiveness in a significant way and continues to do so. In spite of all these efforts, it remains inevitable that the future of the mining industry is based on ongoing investment in research and development of innovative methods and equipment.

In order to promote research and development, numerous members of the mining industry and other organizations, such as CAMIRO (Canadian Mining Industry Research Organization) and the ministère des Ressources naturelles du Québec (MRN), grouped under SOREDEM (Société de recherche et développement minier), will submit a request to various federal and provincial decision makers for a significant contribution to support research and development in the mining sector. To achieve a concerted approach, SOREDEM has mandated CANMET Mining and Mineral Sciences Laboratories to define an action plan in research and development, as well as to justify its recommendations on an economic basis.

To properly allocate the substantial funds which may eventually be granted towards research and development, it is imperative to develop a structured overview so as to avoid project duplication in certain areas. Moreover, the carefully selected research direction with the most significant impact on profitability and safety for mining operations is one of the main objectives of this project. Your participation will therefore be essential to establish this selection.

In summary, this project is intended to:

- Index and classify current research projects, especially those having a significant impact and most likely to succeed.
- Define the research direction priority to improve competitiveness and safety for underground mining operations.
- Assess the investment level and time frame required to achieve a significant impact, i.e. to complete the research and implement the results.
- Quantify the economic benefits of technological innovations to employment, the start-up of new mining operations, the communities and the economic structure of the regional mining industry.

- Present critical and backing arguments to support requests submitted to industry decision makers and other participants.

To facilitate and accelerate the process during meetings, we have examined the needs and priorities of mining operators by summarizing problems identified in previous studies. Furthermore, mining operators have informed us of their various operational constraints and their specific needs in research and development, which are summarized in the enclosed document. Consequently, we wish to obtain your cooperation to validate, modify or complement the already identified research direction, based, more particularly, on your specific requirements. To do so, we would like to meet some of your line managers to gather your comments and your point of view on the research orientations in relation to your problems.

To support our line of reasoning, we would also like to obtain a profile of your main cost centres for the purpose of targeting the sectors where you consider that technological innovations are possible, and which could significantly increase productivity. To do so, you will find attached hereto tables which should ideally be completed before our meeting. Furthermore, to support the econometric study, it is essential that we obtain specific production data as well as your economic criteria so as to justify the required investment. Of course, this information will remain confidential and will be used solely for directional purposes.

You will find enclosed herewith another document providing further details on the objectives and development of this project.

In anticipation of a favourable reply to our request, we remain,

Yours sincerely,

Jean-Marie Fecteau, Eng. Louise Laverdure, Eng., Ph.D.

**CANMET MINING AND MINERAL SCIENCES LABORATORIES
SERVICE AGREEMENT**

**PROJECT DESCRIPTION**

[redacted]

**1.0 Title:** **Definition of an action plan in research and development, trial and experimentation to promote competitiveness and safety for underground mining operations.**

[redacted]

**2.0 Objectives:** This project is intended to:

1. Index and classify current research projects, mainly in Canada, to categorize them in accordance with certain defined criteria outlined in item 2 below.
2. Define the most pertinent and priority research direction to improve competitiveness and safety for underground mining operations.
3. Assess the investments and research schedule, as well as the implementation of the results in order to achieve a significant impact.
4. Quantify the economic benefits of technological innovations to employment, the start-up of new mining operations, the communities and the economic structure of the regional mining industry.
5. Present critical and backing arguments to support requests submitted to industry decision makers and other participants.

[redacted]

**3.0 Background:** The extended weakness of metal prices, as well as the discovery and the exploitation of substantial deposits in new producing countries have considerably affected the competitiveness of Canadian mining companies. Furthermore, the depreciated price of metals, combined with a low tonnage of our deposits, in comparison with those of other countries, has resulted in a continual and significant decrease in mining production in Canada, and mainly in Quebec and Ontario. In actual fact, due to the geologic context, the deposits in Abitibi-Témiscamingue and in the Northern Quebec region are mainly narrow-vein. Major corporations have shown little interest for this type of deposit because of their exploitation complexity and their low production volume. On the other hand, the renewal of Canadian mineral resources is also conditional on the exploitation of very deep deposits. Among other things, at those depths, the work environment is very hot and humid and the rock mass stresses are very high; those additional particularities create new exploitation challenges.

The survival of the mining industry requires innovative methods and equipment which would allow to exploit our deposits. However, the development of new technologies definitely requires a substantial investment. This need in R&D exacts a dual burden on the mining industry; on the one hand, substantial investments to explore and find deposits and, on the other hand, extensive expenses to develop and introduce new technologies and equipment to exploit them. Considering that the exploitation is conditional on the discovery of deposits, the investment in R&D is proportionately much lower.

The low profit margin of current producers prevents them from participating in a substantial research endeavour; many worthwhile and technically sound files are presented to research organizations, such as SOREDEM, but cannot be financed due to the lack of funds. Most small-sized mining operations have restricted resources, with the result that funds earmarked for research and development are limited due to the necessity of meeting urgent needs in the short term. Moreover, the lack of interest of major companies towards the exploitation of small deposits intensifies this problem even more; in view of the fact that they are more financially self-sufficient, they could more easily be in a position to contribute to the innovation undertaking. Consequently, the search for funds for each project, on an individual basis, requires much time and effort from the participants.

On the other hand, the problem is not only of an economic order; it also reflects a social reality. The younger generation, having a greater accessibility to education than the former one, actually has access to a range of specialized occupations. Yet, mechanization and robotization, generally spread throughout industrial spheres, have progressed more rapidly than in mining operations. This phenomenon is particularly obvious in the case of narrow-vein deposits which are more difficult to mechanize because of their small dimensions (Drouin, 1991). For that reason, the recruitment of manpower becomes more problematical in filling jobs that require physical strength. Also, in very deep mines, the environment turns out to be harsher due to the predominating intense heat. For these reasons, we have observed a particular lack of interest for the traditional miner trade.

The problems mentioned above will certainly be magnified by the denatality that is prevalent in our society. Even though the slowdown in the mining sector is not too obvious for the time being, it remains that the narrow-vein deposit operator, or the deep mining operator, is already facing this situation. Consequently, unless the mining industry can offer a higher remuneration rate than the rest of the market, it will not be able to recruit and keep a sufficient and qualified labour force to ensure its survival. Furthermore, in view of the competition from new producing countries, the remuneration capability of Canadian companies is limited. In other words, what will be the actual social and economic costs connected to the lack of development of new technologies which could make our mining operations easier to operate and safer? In view of the above, the status quo is not an acceptable alternative.

**4.0 Benefits:**

To facilitate the financing of research projects, SOREDEM plans to request a major contribution from other influential partners, such as Canada Economic Development (CED). The outcome of these projects could have a decisive impact on the profitability of the mining operations and the growth of the peripheral manufacturing industry and would be a real asset for the support and economic development of the regions.  Furthermore, the injection of these funds should boost the international competitive ability of companies in Quebec and Canada. Also, this contribution will alleviate the financial burden of a struggling mining industry.  While supporting the research projects, companies will thereby be able to share the financial risks associated with the research efforts.

The development of a detailed global view of the research will allow to eliminate project duplication in certain areas.  Moreover, the elaboration of an effective selection process aimed at promoting projects which could have the most impact on profitability and safety for mining operations will capitalize on the sums allocated to research.  This approach will allow to promote constructive and beneficial alliances between the different national and international research agencies.  Consequently, since each project is presently subsidized separately, the simplification of the financing process will be aimed at maximizing the hard work dedicated specifically towards the advancement of technologies rather than the constant search for financial support.

Finally, the survey of econometric data, economic benefits and the impacts brought about by the introduction of new techniques and technologies in the regions, as much on employment as on the increase of Canadian manufactured products, will provide critical and backing arguments to support requests submitted to industry decision makers and other participants.

**5.0 Facilities:**

As a result of its mission, contacts and alliances with many technological centres and universities, CANMET is well-informed regarding various research projects undertaken in Canada and other countries.

Furthermore, CANMET has acquired an expertise within the scope of a research project in narrow-vein mining, whereby numerous mining operations were visited worldwide in order to inquire into their problems and needs in research and development.  In view of the quantity of narrow-vein deposits in Canada, this expertise will be a real asset for the present project.

However, CANMET does not have any expertise in evaluating impacts through an econometric study.  Consequently, this part of the work will be done by econometric analysts, in cooperation with and under the supervision of CANMET.

**6.0 Work Scope:**

**Part 1 – Bibliographic research and consultation visits**

Firstly, a bibliographic research will be conducted.  Secondly, through consultation visits, the main ongoing projects and the evaluation of research needs will be analyzed.  The main projects and agencies involved are:
Projects such as:

- Deep mining (Industry, CANMET, CAMIRO)
- Diesel Emission Evaluation Program (Industry, CAMIRO, CANMET)

- Safe Rapid Development (Industry, CAMIRO)
- Mining Automation Program (MAP) (Inco Limited)
- Protective coating (Falconbridge Limited)

Agencies such as:
- Noranda Technology Centre
- Inco Research Centre
- The University of British Columbia
- McGill University/École Polytechnique
- Université du Québec en Abitibi-Témiscamingue
- Université Laval
- CANMET Mining and Mineral Sciences Laboratories
- CAMESE and other manufacturers
- Ministère des Ressources naturelles du Québec
- COREM
- Hydro-Québec

Consultations with some mining operations, other than narrow-vein. The main ones involved are:

- Fraser Mine, Falconbridge Limited
- One mine from Inco Limited
- One mine from the Noranda Group in Matagami
- Goldcorp and Campbell Mines in Red Lake
- Others, as required

**Part 2 – Elaboration of research direction**

- Evaluation and collation of common problems for the whole industry
- Evaluation of the relevance
  - on the exploitation costs
  - on health and safety
- Evaluation of the economic impact on the regions and on the industry

The classification and prioritization of the research direction will be established on the basis of the financial impact on the production cost structure or on health and safety. The concerned mining companies, as well as the potential favourable impact on job creation and the development or preservation of communities, will also be included in the selection criteria.

**Part 3 – Evaluation of the cost associated with the implementation of the research direction as well as the time required to achieve a significant impact**

A review of former projects will be done, including those which are almost completed and the required research for each project will be analyzed and quantified. This research endeavour will be stated in terms of research hours to evaluate 1) the schedule and 2) the costs required for its execution. The cost allocation will include the evaluation of indirect contractual and material costs.

**Part 4 – Econometrics: Evaluation of economic impacts**
The survey of economic benefits will be evaluated based on payroll expenditures incurred by the regional mining industry. This evaluation will also take into account the multiplying effects in terms of direct and indirect employment.

In anticipation of the beneficial impact of the introduction of new technologies in current exploitations, an estimate of the reduction in development and exploitation costs will be prepared. This evaluation will be made based on normal costs identified in current exploitations.

In anticipation of a reduction in the initial production and capital costs, an evaluation will be made to determine the number of deposits most likely to be exploited.

Finally, on the basis of the factors enumerated above, the economic benefits will be estimated and quantified, in terms of employment and the eventual increase in the need for manufactured products.

In view of the fact that the econometric evaluation is beyond CANMET's field of expertise, this part will be entrusted, with the cooperation and under the supervision of CANMET, to a consulting firm chosen in accordance with a meticulous selection process to carry out this type of evaluation.

**7.0 Deliverables:** The final report will include:

1) the research direction statement and examples of related projects.
2) the schedule and global quantification of required amounts to ensure a significant impact in mining operations.
3) the evaluation of economic benefits resulting from the implementation of the defined research direction.
4) Critical and backing arguments to support requests submitted to industry decision makers and other participants.

**8.0 Reference:**

Drouin, C., 1991. Les innovations dans le monde minier québécois, chapitre 14: Quelques réflexions sur les innovations dans le monde minier, Gaétan Morin, éditeur. P. 255-270.

# RESEARCH DIRECTION

Company/University/Research Centre: ________________________________________

Date, time: ________________________________________

Location: ________________________________________

## AGENDA

1. Project introduction
2. Driving Forces
3. Table of costs
   - Following the analysis of production costs, what are the possible reductions per cost centre?
   - What amounts do you invest yearly in research and development?
4. Axes of Research
5. Questionnaire
6. Summary of meeting
7. Next steps
   - interim report
   - validation of research direction
   - final report with econometric study

Name of organization:



## DRIVING FORCES

| Importance rating | | |
|---|---|---|
| *** | = | vital |
| ** | = | very important |
| * | = | significant |
| 0 | = | not applicable |
| - | = | inadequate |
| n.o. | = | no opinion |

- **Availability / Cost of human resources**
  - **Competition from other sectors / Migration to other sectors**
  - **Availability of trained work force**
  - **Denatality / Aging of the population**
  - **Low renewal rate of the labour force**

- **Soft markets / Economic setting**
  - **Lower cost of the labour force of other producing countries**
  - **Good availability of mineral resources of other countries**
  - **Less strict environmental regulations in some producing countries**
  - **Labour Code regulations less binding in developing countries**
  - **Investors not very motivated to support an industry not well perceived from an environmental point of view**
  - **Marginal exploration caused by the weakness of metal prices and the lack of interest from investors**

- **Sociocultural and political setting**
  - **Remote location in relation to major centres**
  - **Lack of tax benefit associated with remoteness**
  - **Negative perception of the mining industry**
  - **Perception of underground quality of life**
  - **Perception of underground safety**

- **Availability of mineral resources**
  - **Deep deposits**
    - **High cost of access to ore**
    - **Increased geomechanical constraints**
    - **More problematic work environment**
  - **Narrower deposits**
  - **Lower grade deposits**

- **Operational constraints**

  - **Productivity and safety**
    - **Time required for each operation while ensuring safety**
    - **Sustained effort to maintain thoroughness in daily operations**
    - **Under-utilization/idle time of equipment and infrastructures between work shifts**
    - **Under-utilization of manpower**
      - **Painstaking management of activities during work shift**
      - **Time waste due to the displacements of personnel, material and equipment between working areas**

  - **Mining engineering**
    - **Equation difficult to resolve between**
      a. **High cost per unit for selective mining**
      b. **Bulk mining with a high dilution rate**
    - **Inaccuracy of reserves**
      - **Precise location**
      - **Volume and grade**
      - **Geomechanical properties**
      - **In situ constraints**

    - **etc.**

- **Others**

  - ____________________
  - ____________________
  - ____________________
  - ____________________
  - ____________________

| Importance | | |
|---|---|---|
| *** | = | vital |
| ** | = | very important |
| * | = | desirable |
| 0 | = | not applicable |
| - | = | inadequate |
| n.o. | = | no opinion |

Name of organization:

**Mining Engineering**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Integration of all available information | · Visualization in real time of mine planning/modelling and mining development<br>- geological structure<br>- mining information, such as: ventilation parameters, backfill, RMR, etc.<br>- location + magnitude of seismic events<br>- inclusion of modelling in real time to support planning<br>- Improved design and control of ventilation systems by software development | · Integration of all information designed for the planning/management of the mine, productivity wise as well as health and safety wise<br>· Savings and sharing of information between departments<br>· Refinement of the global view for the management of the mine | | |
| Geological definition | · Development of devices/probes using various physical and geological properties, etc. for the detailed characterization of the deposit<br>· Maximum use and reinforcement of acquired data based on diamond and production drilling | · Enhancement of the geological environment definition of the mine and, more particularly, the stope outline | | |
| Geomechanics and excavation support | · Detailed guide based on ground examples and pictures illustrating the different characteristics or geomechanical properties of the rock<br>· Compilation of different types of support in relation to the mechanical properties observed in mines<br>· Presentation of the results by way of an electronic blackboard<br>· Development of new technologies to measure the stress state in an extreme stress environment | · Improvement of available techniques for ground control and support | | |
| Underground preconcentration | · Development of methods for ore/waste separation on the basis of geophysical characteristics, either through better mining methods or underground separation<br>· Conceptual study on grinding, flotation and underground pumping | · Decrease in the costs associated with the transportation of waste material | | |
| Optimization of existing mining process/methods and design of new methods | · Based on practices observed in the mines, compilation of problems and achievements<br>· Design of new methods aimed at improving underground productivity and safety<br>· Design of equipment aimed at selective mining | - Optimization and design of mining methods using the experience acquired in the operations throughout the years based on the typical characteristics of each deposit, as well as health and safety requirements at work<br>- Increase of profitability, i.e. exploit at a lower cost per unit of extracted metal<br>- Maximization of the recovery of mining resources | | |

**Engineering related to Physical Environment**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Improvement of the underground environment-human factors | · Development of new tools to promote health: reduction of noise, vibrations, pollutants, gases, etc.<br>· Development and/or adaptation of effective and inexpensive refrigeration systems to the Canadian context<br>· Database creation to compile provincial approaches on the health and safety risk analysis<br>· Development and/or adaptation of equipment to the Canadian context which will meet the new environmental standards for polluting emissions and/or improve productivity<br>· Adaptation of new energy sources less polluting for the underground mining environment<br>· Improvement of underground communication systems<br>· Development of country wide regulations based on sound science | - Meeting of requirements in occupational hygiene for deep mining (e.g. thermal stress)<br>- Promote the decompartmentalization of remedial measures introduced in each province<br>- Meeting of future pollution standards<br>- Design of equipment to minimize the impact on the health and safety of workers | | |

**Material and mining equipment: Drilling and rock fragmentation**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Drilling and blasting | Development of innovative techniques for rock breaking such as:<br>Thermal method<br>-diesel burners and plasma torch<br>Chemical method<br>-injection of styrofoam<br>Electric blasting<br>Remote blasting<br><br>Small size equipment allowing to combine precision and penetration speed (2-inch hydraulic down-the-hole hammer of small diameter)<br><br>Pursue the Research and Development to improve the performance of explosives (e.g. blasting precision and vibration control) | - Reduction of dilution<br>- Improvement of the possibilities to operate on a continuous basis<br>- Exploitation of non-economical resources with innovative fragmentation methods<br>- Improvement in the control of traditional drilling and blasting | | |

**Material and mining equipment: Waste and ore handling**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Tele-operation and semi-automatic operation of equipment<br>- video communication and others | Development of equipment which will allow the handling of waste rock (waste and/or ore) in a semi-autonomous way. | Improvement of profitability and productivity between work shifts | | |

**Material and mining equipment: Support equipment and ground control for development**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Ground bolting and other support system | Development of small size equipment which can remotely install the ground support | - Reduction of the risks associated with the task<br>- Reduction of the costs related to the task | | |
| Scaling | Mobile and small scaling equipment with an adequately balanced power for its use | - Reduction of the risks associated with the scaling task<br>- Reduction of the costs related to the task | | |
| Rock mass quality assessment tools | Review and evaluation of the geophysical methods to identify the fracturing level near the walls of the mining openings | - Development of a portable probe using the best possible geophysical methods to characterize the structural quality of the rock<br>- Best ground evaluation and type of bolting to be selected | | |

**Material and mining equipment: Backfilling and related subjects**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Backfill preparation techniques | Portable and less expensive equipment for backfill preparation<br>Addition of waste crushed rock to the paste backfill<br>Recycling of haulage mud in the backfill<br>Recycling of acid waste rock and neutralization of the inner backfill | - Reduction of the capitalization costs related to the use of backfill, particularly for low tonnage deposits<br>- Increase in the mechanical properties of the paste backfill for the same cement ratio<br>- Disposal of waste constituting an environmental constraint | | |
| Backfill transportation and placement techniques | Development of alternative backfill transportation methods and mechanical pouring<br>- pneumatic conveyor<br>- special conveyor | - Reduction of capitalization and operating costs related to transportation and pouring of backfill | | |
| Backfill techniques | - Construction of inflatable or portable barricades<br>- Artificial opening raise technique by inflatable and reusable pipe techniques | - Reduction in the construction costs of barricades<br>- Reduction in the excavation costs of primary openings | | |

**Logistics and service**

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| Vehicle tracking system | · Development of a simple and inexpensive vehicle tracking system | · Management of the fleet of vehicles<br>· Control of the ventilation system<br>· Time and motion study | | |
| Underground communications | · Development of a video transmission system as well as robust and inexpensive sensors which can transmit different operating parameters and ensure visual monitoring | · Preventive supervision of mobile and fixed equipment to reduce maintenance costs and improve their mechanical availability | | |
| Logistics | · Standardization of equipment manufacturing, as well as mechanical and electrical components<br>· Improve the interchangeability of parts between suppliers | · Serviceability of equipment to reduce inventory charges and improve mechanical availability | | |
| Logistics | · Development of an automatic inventory system (bar code) as well as the instrumentation which can transmit information to the required areas (central control position) | · Reduce the possibility of inventory shortage and ensure a better service at the working face | | |

**Others***

| Research and Development direction | Explanations – Examples | Purpose | Validation/ support | Importance |
|---|---|---|---|---|
| | | | | |
| | | | | |

*Research and Development direction to be developed to meet operational constraints for the next 10 years
*which problems will have to be solved so as to remain a viable Canadian industry in 10 years from now?

Natural Resources Canada / Ressources naturelles Canada

**PROTECTED BUSINESS INFORMATION**
**DEFINITION OF RESEARCH DIRECTION PROJECT**

MINE ______________________________

## Compilation of the recorded unit costs in long-term plan

**Allocate the costs if possible, otherwise directly insert information in «Others»**

| | | Tonnage Tonnes | | | Grade g Au/t | g Ag/t | % Cu | % Zn | % Pb |
|---|---|---|---|---|---|---|---|---|---|
| Proven reserves | | | | | | | | | |
| Probable reserves | | | | | | | | | |
| Resources | | | | | | | | | |
| **Recorded Reserves in long-term plan** | | 0 | | | 0 | 0 | 0 | 0 | 0 |
| **Metal recovery, "oz" for Au and Ag ; "metric tonne" for the base metal** | | | | | 0 | 0 | 0 | 0 | 0 |
| **Direct operating costs** | **$ CDN** | **$ US** | **%** | **$US/ TM** | **$US/ oz** | **$US/ oz** | **$lb Cu** | **$lb Zn** | **$lb Pb** |
| **Short term Development** | $0 | $0 | | | | | | | |
| **Stope extraction** | | | | | | | | | |
| Definition drilling | | $0 | | | | | | | |
| Development | | $0 | | | | | | | |
| Ground support | | $0 | | | | | | | |
| Drilling and Blasting | | $0 | | | | | | | |
| Mucking | | $0 | | | | | | | |
| Backfilling | | $0 | | | | | | | |
| Extraction Supervision | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Sub-total Extraction** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Underground Services** | | | | | | | | | |
| Crushing/hammer/grizzly/hoisting | | $0 | | | | | | | |
| Mobile equipment maintenance | | $0 | | | | | | | |
| tationary equip. maintenance and infrastructure | | $0 | | | | | | | |
| Equipment and materiel handling | | $0 | | | | | | | |
| Ventilation and Heating | | $0 | | | | | | | |
| Supervision of Underground services | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Sub-total Underground Services** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Surface Services** | | | | | | | | | |
| Building maintenance and guarding | | $0 | | | | | | | |
| Mobile and Stationary equip. maintenance | | $0 | | | | | | | |
| Mining camp operation/Transport to site | | $0 | | | | | | | |
| Surface Supervision | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Sub-total Surface Services** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Technical & Administrative Services** | | | | | | | | | |
| Engineering | | $0 | | | | | | | |
| Geology | | $0 | | | | | | | |
| Human resources & Health and safety | | $0 | | | | | | | |
| Consultant | | $0 | | | | | | | |
| Management & clerical/accounting | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Sub-total Tech. & Adm. Services** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total - Operating at the shaft collar** | $0 | $0 | | | | | | | |
| **Ore processing costs** | | | | | | | | | |
| Transportation to mill | | $0 | | | | | | | |
| Milling | | $0 | | | | | | | |
| Environment | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Total - Ore processing** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total - Direct operating costs** | $0 | $0 | | | | | | | |
| **Dépreciation and Depletion** | | | | | | | | | |
| Exploration and mining excavation | | $0 | | | | | | | |
| Underground Infrastructure | | $0 | | | | | | | |
| Surface Infrastructure | | $0 | | | | | | | |
| Mobile and stationary equipment | | $0 | | | | | | | |
| Mill | | $0 | | | | | | | |
| Tailings site and environmental provision | | $0 | | | | | | | |
| Others | | $0 | | | | | | | |
| **Total - Depreciation and Depletion** | $0 | $0 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **GRAND TOTAL** | $0 | $0 | | | | | | | |
| **US Exchange rate** | 0.63 | | | | | | | | |

| **Name of organization:** |
|---|

# Questionnaire intended for companies

| **Importance rating** | | |
|---|---|---|
| *** | = | vital |
| ** | = | very important |
| * | = | desirable |
| 0 | = | not applicable |
| - | = | inadequate |
| n.o. | = | no opinion |

**1. What actions will be required to remain competitive in the face of future constraints?**

________ 1.1. Innovative management and training of human resources.
________ 1.2. Optimization/improvement and better management of existing technologies.
________ 1.3. Importation of technologies from other sectors.
________ 1.4. Development of new technologies.
1.5. Others.
________ ______________________________

**2. Most appropriate ways to promote the development and introduction of new technologies:**

________ 2.1. Coalition of companies to share research and development costs in partnership with different levels of governments.
________ 2.2. Coalition of university centres by topics and research projects under the supervision or mentoring of an industry champion to promote the application of a new technology within his company / excellence centres.
________ 2.3. Awarding of research and development contracts to university and research organisations on the basis of the company's specific needs.
________ 2.4. Elaboration and establishment of a system listing the available expertise as well as the different needs.
________ 2.5. Elaboration and establishment of an allocation mechanism of funds to minimize the time required for the necessary financing packages for project execution (practice of a one-stop funding service).
2.6. Others.
________ ______________________________

**3. Main causes of financial losses in your mining operation which could be resolved by technological innovations:**

________ 3.1. Low recovery of mining reserves.
________ 3.2. Inordinate dilution in relation to initial planning.
________ 3.3. Poor mining and financial planning caused by volume and grade unpredictability and the location of mining reserves.
________ 3.4. Unsuitable equipment for the task.
________ 3.4.1. Inadequate mechanical availability.
________ 3.4.2. Capitalization too costly.
________ 3.4.3. Unacceptable dilution caused by the size of equipment.

__________ 3.4.4. Marginal productivity as a result of the design.

__________ 3.5. Time wasted as a result of unsafe equipment / health problems and safety of workers.
__________ 3.6. Ground control problems.
3.7. Others.

__________ ______________________________________________

__________ **4. Percentage of the reduction in the costs required to ensure an acceptable performance for shareholders and secure the start-up of new exploitations or, at the very least, maintain those already in operation.**

**5. Main economic criteria used to justify the start-up of a new exploitation or the investment to have access to new reserves.**

__________ 5.1. Achieve the in-house rate of return established in accordance with predetermined criteria. Rate?
__________ 5.2. Acceptable payback period.
__________ 5.3. Acceptable risk related to the content of the mining reserves.
__________ 5.4. Degree of confidence in relation to the renewal of mining reserves.
__________ 5.5. Expectation of a recovery in the price of metals.
__________ 5.6. Acceptable risk in connection with extraction techniques (e.g: quality of the rock mass).
__________ 5.7. Do you presently have sub-economic deposits? If you answered in the affirmative, what makes them sub-economic: grade, location, metallurgy too complex, …?
5.8. Others.

__________ ______________________________________________

**6. In-house research projects.**

__________ 6.1 What projects reached completion?
__________ 6.2 How much time was required?
__________ 6.3 What were the costs?
6.4 Others.

__________ ______________________________________________

**7. Action plan designed for a healthy and competitive mining industry within a long-term perspective (10 and 20 years).**

**7.1 Technological development**

__________ 7.1.1 Orientation of funds from various research and development sources towards the directions identified as priority by the mining industry and research organisation.

__________ 7.1.2 Combination of expertise from the different research centres (private or public) for the development of new technologies so as to share the expertise and avoid unnecessary duplications.

__________ 7.1.3 Networking between equipment manufacturers, some research centres, mining operations, regulators and Labour organisations.

__________ 7.1.4 Partnership between funding organisations to support the research and development directions identified by the mining industry and reduce the numerous technical and administrative questions to finance the research and development projects.

__________ 7.1.5 Awarding of research and development contracts on the basis of the respective expertise of research centres and their likelihood of making strategic alliances to obtain concrete results within the prescribed time table.

__________ 7.1.6 Combination of research and development efforts with the other research centres at the international level (e.g. Global Mining Research Alliance).

**7.2 Technological transfer**

__________ 7.2.1 Transfer of technologies and best exploitation practices within the mining industry.

__________ 7.2.2 Importation of technologies which can be relevant with the directions already identified.

__________ 7.2.3 Establishment of a technology watch to disseminate all practices which can be useful to the industry.

**7.3 Suppliers and equipment manufacturers**

__________ 7.3.1 Access to a research fund for equipment manufacturers interested in the development of new products and promote networking between research centres, mining companies and manufacturers.

__________ 7.3.2 More communications between manufacturers and industry representatives to target technological development projects.

**7.4 Governments**

__________ 7.4.1 Simplification and harmonization of the process to obtain research and development funds through the different government authorities, federal as well as provincial.

__________ 7.4.2 Harmonisation of mining regulations across provinces.

__________ 7.4.3 Dissemination and barrier lifts of acquired information at the provincial level which could be worthwhile Canada wide.

**7.5 Training and knowledge transfer**

__________ 7.5.1 Review the content of university programs to meet the needs of the industry.

__________ 7.5.2 Training of a skilled labour force for the maintenance of technologically more complex mining equipment.

__________ 7.5.3 Review of the content of secondary/college programs to train technicians and miners so that they may be able to operate complex equipment.

**7.6 Industry**

__________ 7.6.1 Clearly define the research and development needs.

__________ 7.6.2 Select industry champions who believe in research and development to sit on various committees:

__________ - to point out the actual needs of mining operations.

__________ - having a thorough vision with regard to the research and development required for the whole mining industry.

__________ 7.6.3 Should be more supportive to collectively address the critical industry-wide issues.

__________ 7.6.4 Actively promote with Canadians the benefits of having a healthy mining industry.

# APPENDIX B
# List of Organizations and Participants Consulted

## Organizations consulted in Canada

### Consultations with mining operations

| | |
|---|---|
| LaRonde Mine - Agnico-Eagle Mines Ltd. | Jean Bastien<br>Rosaire Émond<br>Paul-Henri Girard<br>Christian Provencher |
| Louvicourt Mine - Aur Resources Inc. | Denis Fleury<br>Michel Rodrigue |
| Bouchard Hébert Mine - Breakwater Resources Ltd. | Langis Saint-Pierre |
| Meston Mine and Copper Rand 5000 Project - Campbell Resources Inc. | Claude Bégin<br>Marcel Saint-Laurent<br>Jacques Tremblay |
| Doyon Mine - Cambior Inc. | Bertrand Potvin |
| Mouska Mine - Cambior Inc. | Patrick Godin |
| Sleeping Giant Mine - Cambior Inc. | Serge Blais<br>Denis Gourde<br>Daniel Vallières |
| Bell-Allard Mine - Noranda Inc. | Michel Boucher<br>Carol Plummer |
| Casa Bérardi Mine - Aurizon Mines Ltd. | Michel Gilbert |
| Kiena Mine et East Amphi Mine - McWatters Mines Inc. | Michel Sirois |
| Seleine Mines - The Canadian Salt Company Ltd. | Mark Joncas |
| Red Lake Mine - Goldcorp Inc. | John Aoams<br>Bob Carter<br>Eric Hinton<br>Everett Hobbs<br>Claude Lemasson<br>Peter Mah<br>Klaus Tietz |
| Campbell Mine – Placer Dome Inc. | Peter Busse<br>Martin Raffield |

| | |
|---|---|
| Porcupine Joint Venture - Placer Dome Inc. | Raymond R. Corbeil<br>John Folinsbee<br>Gary Halverson<br>Paul Miller<br>Jim Mimordston<br>Dominic Rizzuto<br>Bill St-Onge<br>Boyd Timler |
| McArthur Mine - Cameco Corporation | Doug Beattie<br>Jacques Perron<br>Martin Quick |
| Kidd Creek Mine - Falconbridge Ltd. | Dave Counter<br>Dan Gignac<br>Alex Henderson<br>Bill Mracek |
| INCO Corporate Group | Peter Dietrich |
| Falconbridge Ltd. – Sudbury Operations | Parviz Farsangi<br>Graham Swan<br>John Vary |
| Vanscoy Potash Operations - Agrium Inc. | Jacques Gagné<br>Dave Mac |
| Placer Dome Corporate | Colin I. Seeley |
| Noranda Inc. - Falconbridge Ltd. | Alex Balogh |
| Rio Tinto Iron & Titanium Inc. | Allan Moss |
| Société minière Raglan du Québec Ltée | Denis Lachance |

**Research centres, consultants and other organizations involved in R&D**

| | |
|---|---|
| Noranda Technology Centre - Noranda Inc. | Véronique Falmagne<br>Julia Martin<br>Brad Simser |
| Dyno Consult - Dyno Nobel Inc. | Daniel Roy |
| Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) | Louis Bousquet |

| | |
|---|---|
| CANMET Mining and Mineral Sciences Laboratories (Experimental Mine, Val-d'Or) | Robert Boucher<br>Richard Cormier<br>Daniel Côté<br>Martin Côté<br>Gaétan Desrivières<br>Chantale Doucet<br>Roger Lacroix<br>Marcel Laflamme<br>Michel Laganière<br>Gilles LeBlanc<br>Sylvain Ouellette<br>Éric Vinet |
| CANMET-MMSL, Ottawa | Marc Bétournay<br>Denis Labrie<br>Michel Plouffe<br>Brent Rubeli<br>John Udd |
| CANMET-MMSL, Sudbury | Alfred Annor<br>Gary Bonnel<br>Michel Grenier<br>Steven Hardcastle |
| Table jamésienne de concertation minière | Florent Gauthier<br>Régis Simard |
| Léandre Gervais & Associates | Léandre Gervais |
| Ross Finlay 2000 Inc. | Paul Bonneville<br>Marcel Labonté<br>Serge Lévesque |
| Cambior Inc. - Technical Services | Serge Vézina |
| CAMESE (Canadian Association of Mining Equipment and Services for Export) | John Baird |
| CAMIRO (Canadian Mining Industry Research Organization) | Charles Graham |
| Noranda Inc. - Falconbridge Ltd. | John A. Vary |
| Inco Ltd. - Research Centre and Thompson | Allan D. Akerman<br>Samantha Espley<br>Brian Maynard |

| | |
|---|---|
| MIRARCO (Mining Innovation, Rehabilitation and Applied Research Corporation) | Ming Cai<br>Paul G. Dunn |
| NORCAT (Northern Centre of Advanced Technology Inc.) | Darryl Lake<br>Dennis Shannon |
| MTI (Mining Technologies International Inc.) | Marcel Demers<br>Don Sissons |

**Governments and mining associations**

| | |
|---|---|
| Quebec Mining Association (QMA) | Dan Tolgyesi |
| Mining Association of Canada (MAC) | Elizabeth Gardiner<br>Dan Paszkowski<br>Gordon R.Peeling |
| Ontario Mining Association (OMA) | Barbara Mossop<br>Patrick Reid |
| The Mining Association of British Columbia (MABC) | Gary Livingstone |
| Government of British Columbia | Fred Hermann |
| Government of Ontario - Ministry of Northern Development and Mines (MNDM) | Dick Cowen<br>Leo Owsiacki |
| Government of Ontario - Ministry of Labour | Bernie Deck |
| Government of Québec - Ministère des Ressources naturelles, de la Faune et des Parcs (MRNFP) | Louis Bienvenu<br>Martin Dumas<br>André Jean<br>André Lemay |
| FedNor | Paul Podstaka |

**Universities**

| | |
|---|---|
| McGill University | Ferri Hassani<br>Hani Mitri<br>Jacques Ouellet |
| École Polytechnique | Robert Corthézy<br>Paul Cohen<br>Bernard Giroux<br>Stefka Krivochieva |

| | |
|---|---|
| Université du Québec en Abitibi-Témiscamingue | Tikou Belem<br>Mostafa Bensaazoua<br>Denis Bois<br>Bruno Bussière<br>Mamadou Fall<br>Serge Ouellet |
| Université Laval | Kostas Fytas<br>Martin Grenon<br>John Hadjigeorgiou<br>Jacek Paraszczak<br>Stephan Planeta<br>Richard Poulin |
| Laurentian University | Greg R. Baiden |
| University of Alberta | Dwayne Tannant |
| University of British Columbia | Scott Dunbar<br>Robert Hall<br>Mario Morin<br>Enrique Rubio<br>Malcolm Scoble |
| University of Toronto | Will Bawden<br>Murray Grabinsky<br>Bibhu Mohanty<br>Paul Young |
| Queen’s University | James Archibald<br>Laeeque Daneshmed<br>George McIsaac<br>Stephen McKinnon<br>Charles Pelley |

# APPENDIX C
# Ongoing Projects and List of Research Expertise in Universities and Research Centres

**NAME: CAMIRO Mining Division**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Deep Mining Research Consortium** | | X | X | X | | | | 2003-8 | $ 17,000,000 | B, C | 30 | I,F,R,B,P,N,S, |
| **Foam Backfill** | | | | X | | | | 2004.0 | $ 32,000 | A, B | 1 | NOHFC, FedNor |
| | | | | | | | | | | | | DEC? |
| **Design of support** | | | | | | X | | 1989-91 | $ 2,300,000 | C,B | 10 | |
| **CRRP** | | | | | | | | 1990-95 | $ 10,000,000 | C, B | 40 | |
| **Design of cable bolts** | | | | | | | | 1996-97 | $ 300,000 | C,B | 4 | |
| **DEEP** | | | | | | | | 1999-2005 | $ 2,500,000 | C,B | 20 | |
| see also - www.deep.org and www.camiro.org, - /products and /reports | | | | | | | | | | | | |

* : *A) Reduction in operating costs*
*B) increased productivity*
*C) improvement in health and safety*

| FIELDS OF EXPERTISE | | | | | | | | Name of Researcher (s) | Information |
|---|---|---|---|---|---|---|---|---|---|
| Ground Control | | | | | | | | Mirarco - GRC | |
| Diesel Performance | | | | | | | | Brent Rubeli | |
| Backfill | | | | | | | | Graham Swan | |
| Hoist Rope | | | | | | | | Rotesco, C-Core | |
| Heat Stress | | | | | | | | NRCan, U of O | |
| Backfill | | | | | | | | Paul Rantala | 705-522-7631, prantala@parinn.com |

**NAME: Centre de Technologie Noranda (CTN)**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CMS** | | | X | | | | | | N/D | | | |
| **Bore Hole Camera** | | | X | | | | | | N/D | | | |
| **Logiciel Pro-Mine** | | | X | | | | | | N/D | | | |
| **Système d'auto loading** | | | | | X | | | | N/D | | | |
| **Système de guidage des camions** | | | | | X | | | | N/D | | | |

**NAME: LMSM-Canmet - Val-d'Or**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Robot** | | X | | | | | | | $ 90,000 | | | |
| **Vehicule tracking** | | | | | X | | | 1 an | $ 65,000 | | | |
| **Poignée anti-vibration** | | | X | | | | | 2,5 ans | $ 165,000 | | | |
| **Locomotive pile à hydrogène** | | X | | | | | | | | | | |

| FIELDS OF EXPERTISE | | | | | | | | Name of Researcher (s) | Information |
|---|---|---|---|---|---|---|---|---|---|
| Évaluation, application des nouveautés en matière de procédés, techniques, méthodologies et équipements reliés à l'extraction de minerai. DEC Technologie minérale. | | | | | | | | DESRIVIÈRES, Gaetan | |
| Technique d'extraction des gisements filoniens. Gestion opérationnel et financière des travaux miniers souterrains. B. Sc. en génie minier. | | | | | | | | FECTEAU, Jean Marie | |
| Développer des modèles technico-économiques pour les méthodes de minage et de développement pour les gisements filoniens. Développer et valider des concepts d'équipements miniers pour les gisements filoniens. M. Sc. en gestion de projet et ingénieur minier. | | | | | | | | LACROIX, Roger | |
| Cours en sciences pure. DEC en électronique option télécommunication. | | | | | | | | LAGANIÈRE, Michel | |
| Conception de circuits numériques, analogiques et mixtes. Conception et fabrication de circuits imprimés (PCB). Miniaturisation de circuits électroniques. Programmation de micro-contrôleurs et automates programmables. Recherche en automatisation et développement d'équipements miniers. Système d'acquisition de données et instrumentation. | | | | | | | | LALIBERTÉ, Pierre | |
| Ingénieur mécanique. Conception mécanique. Automatisation. Design d'expériences. | | | | | | | | LEBLANC, Gilles | |
| Ingénieur en génie mécanique. Conception mécanique. Hydraulique et pneumatique. Automatisation. | | | | | | | | OUELLETTE, Sylvain | |
| Ingénieure en génie des mines. Techniques d'extractions des gisements filoniens. | | | | | | | | POIRIER, Sylvie | |

**NAME: DYNO**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Others | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High Energy Packaged Emulsion | X | | | | | | | | 30/Jul/01 | 597,000 US$ | | 3.0 | |
| Emulsion/ANFO Blends with Bulking Agents (started on 09-10-02) | X | | | | | | | | 9/Oct/02 | 350,000 US$ | | 3.0 | |
| Aluminized DYNOSEIS and Process Development | X | | | | | | | | 1/Jan/01 | 180000$ | | 2.0 | |
| Emulsion Thickening | X | | | | | | | | 1/Jan/01 | 1,023,000 US $ | | 2.0 | |
| Automated Gassing System *( A,B,C,) | X | | | | | | | | 1/Jun/96 | 900,000$ | | 4.0 | |
| In-House Emulsifier Development | X | | | | | | | | 1/Dec/95 | 600,000$ | | 2.0 | |
| Coordinate DN Emulsifier Research | X | | | | | | | | 2/Oct/95 | 140,000$ | | 2.0 | |
| Screen Vendor Emulsifier Candidates | X | | | | | | | | 2/Oct/95 | 370,000$ | | 2.0 | |
| Screen Vendor Emulsifier Candidates | X | | | | | | | | 1/Sep/99 | 150,000$ | | 2.0 | |
| Global Dyno Nobel Explosives Team Involvement | X | | | | | | | | 2/Oct/95 | 486,000$ | | 3.0 | |
| Implement Improved Prodet Calculation Code | X | | | | | | | | 1/Aug/95 | 50000$ | | 1.0 | |
| New Bulk Emulsion Technology | X | | | | | | | | 2/Jan/97 | 1,150,000$ | | 4.0 | |
| Tech Support for DNNA Plants/Sites/Regions | | | | | | | | X | 2/Oct/95 | 2,502,000$ | | 6.0 | |
| Tech Support for Licensees/Distributors | | | | | | | | X | 2/Oct/95 | 3,572,866$ | | 6.0 | |
| Cost, Performance and Supply Optimization | | | | | | | X | | 2/Oct/95 | 3,147,000$ | | 3.0 | |
| Improved Surface/Underground Loading Systems * (A, B,C) | X | | | | | | | | 1/Oct/99 | 537,000$ | | 2.0 | |
| Local Safety (Reviews, Training, DOT Classification Tests) *(A,B,C) | | X | | | | | | | 2/Oct/95 | 1575000$ | | 4.0 | |
| Electronic Intiation Systems | X | | | | | | | | 1994 | 10,000,000$ | | 10.0 | |
| Ore Dilution Control Techniques | | | X | | | | | | 1998 | 2000000$ | | 4.0 | |
| Particle Flow Control PFC Code 2D & 3D (used for blast induced movement prediction) | X | | | | | | | | 1998 | 3000000$ | | 4.0 | |

**NAME: Mirarco**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Others | Start and End Date | Costs |
|---|---|---|---|---|---|---|---|---|---|---|
| **33 Contracts** | | | | | | | | | Year Ended Apr. 30, 2003 | |
| **The Use of VR for Design Review** | | | X | | | | | | | $ 9,363 |
| **Fluid Replacement** | | | | | | | | | | $ 7,725 |
| **Sample Digestion** | | | | | | | | X | | $ 63,048 |
| **Digestion of Agriculture** | | | | | | | | X | | $ 10,217 |
| **Capacity-Building Project in Mining and Environmental Research** | | | | | | | | X | | $ 306,055 |
| **Monitoring Technology Infrastructure Project** | | | | | | | | X | | $ 275,417 |
| **MIRARCO manages a Research Programme to establish mining excellence in Northern Ontario, made possible through a ~ $10 million investment , including funding from the mining industry, Laurentian University, and grants from the provincial, federal and municipal governments, including:** | | | | | | | | | | |
| **Ontario Research and Development Challenge Fund** | | | | | | | | | | $ 2,200,000 |
| **Northern Ontario Heritage Fund Corporation** | | | | | | | | | | $ 1,600,000 |
| **Canada Foundation for Innovation/Ontario Innovation Trust** | | | | | | | | | | $ 3,800,000 |
| **FedNor, Sudbury Regional Development Corporation (now Greater Sudbury Development Corporation) and others** | | | | | | | | | | $ 600,000 |
| The results of this Research Programme was the creation of at least 250 jobs/year, three research centres, a network of more than 50 companies and other research groups from around the globe, >40 graduate students, >$300,000 in revenues to other small business in Northern Ontario. Also, MIRARCO's staff spearheaded the creation of new technologies and processes that would not be possible without the support from both the public and private sectors, such as being pioneers in the development of virtual reality for the mineral industry (now considered one of the leading groups in the world in this field). | | | | | | | | | | |

| FIELDS OF EXPERTISE | | | | | | | | Name of Researcher (s) |
|---|---|---|---|---|---|---|---|---|
| Geomechanics, tunneling and new mining technologies/Switzerland, Germany | | | | | | | | Peter K. Kaiser |
| Effects of acidification and metal insult on pedologic processes/US | | | | | | | | Graeme Spiers |
| Water jet drilling technologies and line of sight safety issues in mining/Australia | | | | | | | | Paul Dunn |
| Micro-seismic event interpretation, numerical modeling, and rock support design/Japan | | | | | | | | Ming Cai |
| Rockmass characterization and effects of discrete geological structures on stope design/Ghana | | | | | | | | Fidelis Suorineni |
| **MIRARCO focuses on the following research areas:** | | | | | | | | |

Geomechanics, Mining Methods and Technologies, Terrestrial and Aquatic Biology, Ecology, Environmental Chemistry and Toxicology, Earth Sciences, Data Integration, Data Modelling, Visualization and Interpretation

**Research equipment/infrastructure is a valued at over $6 million**

Virtual Reality Lab (managed by MIRARCO for Laurentian University), Borehole Acoustic Televiewer, Crack Identification Systems Ground Penetrating Radar, Large Scale Drop Test Facility, Hyperion Acoustic Emission Measuring System, Lab Test Equipment for Performing Drillability Assessment, Borehole Camera, Borehole Ground Penetrating Radar, Velocity Probe, Ion Chromatography, Graphite Furnace and Flame Atomic Absorption, Microwave Digestion System, Water Sampling Apparatus, 3D Environmental Laser Scanner, Waterjet Laboratory, Plotter and Graphical Equipment, ICP-MS, ICP-AES Ultrasonic Nebulizer, Hg Analyzer, XRF-EMMA, XRF-PHILIPS, C/N/S, Mercury Analyser, CHN Analyser, Water Quality Instruments: sondes, flow meter, acoustic mapping.

**NAME: POLYTECHNIQUE**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Détection des mouvements des parois des excavations souterraines par imagerie numérique | | | X | | | | | 2001 | $ 114,000 | | 3 chercheurs | IRSST |
| Développement d'une méthode de mesure de contrainte à grande profondeur dans les sondages inondés | | | X | | | | | | | | | EACL |
| Optimisation de l'utilisation du ciment dans les chantiers remblayés | | | | X | | | | | | | 2 chercheurs | --- |
| Coups de terrain 1 | | | X | | | | | 1988 | $ 20,000 | | | |
| Coups de terrain 2 | | | X | | | | | 1993 | $ 35,000 | | | |
| Coups de terrain 3 | | | X | | | | | 1997 | $ 98,700 | | | |
| Coups de terrain 4 | | | X | | | | | 1998 | $ 38,000 | | | |
| Endommagement roche | | | X | | | | | 2001 | $ 97,000 | | | |
| Sautage adouci | | | X | | | | | 2001 | $ 65,000 | | | |
| Détection des mouvements des parois des excavations souterraines par imagerie numérique | | | X | | | | | | | | | |
| Développement d'une méthode de mesure de contrainte à grande profondeur dans des sondages inondés | | | | | | | | | | | | |
| Optimisation de l'utilisation du ciment dans les chantiers remblayés | | | | X | | | | | | | | |
| Utilisation de l'imagerie numérique pour la détection de mouvement autour des excavations souterraines (Chercheurs: Robert Corthésy et Maria Helena Leite) | | | X | | | | | | | | | |

**NAME: LAURENTIAN UNIVERSITY**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Automatic Truck | | | | | X | | | 5 ans | $ 6,000,000 | | | |
| | | | | | | | | | | | | |

**NAME: SOREDEM**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Others | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hydrolification** | X | | | | | | | | 1998-2003 | $ 1,743,000 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 20,000 | | | |
| **Plate-forme mobile** | | | | | | | X | | 1998-1999 | $ 123,000 | | | |
| **Analyseur portable d'or** | | | X | | | | | | 1998-1999 | $ 67,570 | | | |
| **Détecteur-roches branlantes** | | X | | | | | | | 1999 et 2001 | $ 17,000 | | | |
| **Permascan** | | | | | X | | X | | 2002-2003 | $ 55,200 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 20,700 | | | |
| **Communications souterraines sans fil** | | | | | | | X | | 2002-2003 | $ 418,400 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 219,400 | | | |
| **Piles à hydrogène** | | X | | | | | | | 2000-2003 | N/A | | | |
| | | | | | | | | | 1999 | $ 22,286 | | | |
| **Éclatage** | X | | | | | | | | 1998-1999 | $ 87,500 | | | |
| **Raclage automatisé** | | | | | X | | | | 1998-2000 | $ 115,000 | | | |
| **Poignée de foreuse à béquille moins vibrante** | | X | | | | | | | 1999-2003 | $ 280,000 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 30,000 | | | |
| **Chargeuse-navette hybride** | | X | | | | | | | 2001-2003 | $ 169,000 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 74,000 | | | |
| **Gisements filoniens** | X | X | | | | | | | 1999-2003 | $ 2,010,000 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 100,000 | | | |
| **Fragmentation thermique** | X | | | | | | | | 2002-2003 | $ 2,099,000 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 1,899,000 | | | |
| **Axes de recherche** | | | | | | | | X | 2002-2003 | $ 298,500 | | | |
| Pour 2003 seulement | | | | | | | | | 2003 | $ 243,000 | | | |

**Liste des projets de Soredem, basé sur leur dernier rapport mensuel**

- projet Permascan (LMSM-CANMET)
- projet de communications sourterraines sans fil (UQAT)
- projet de la poignée de foeruse à béquille moins vibrante (LMSM-CANMET)
- projet hydrolification (LMSM-CANMET)
- projet de fragmentation thermique (LMSM-CANMET) - avec Rocmec et Soredem
- projet de la chargeuse-navette hybride (LMSM-CANMET)
- projet de la sonde photonique (Instrumentation GDD)

**NAME: UNIVERSITÉ LAVAL**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Développement d'un logiciel de simulation de réseaux de ventilation des mines souterraines | | X | | | | | | 2,5 an | $ 108,000 | | | IRSST |
| An investigation on slope stability through fracture systems modelling | | | | | | | | 2002-2005 | $ 76,000 | | | Conseil de recherches en sciences naturelles et génie Canada |
| Conception des cheminées à minerai et à stérile | | | X | | X | | | 2000-2003 | $ 154,000 | | | IRSST |
| Design of excavations in jointed rock masses based on realistic 3-Dimensional joint models | | | X | | | | | 2000-2004 | $ 92,000 | | | Conseil de recherches en sciences naturelles et génie Canada |
| Développement d'un système d'analyse d'images pour la caractérisation des massifs rocheux | | | X | | | | | 2002-2004 | $ 124,000 | | | IRSST |
| Innovative rock characterization techniques | | | X | | | | | 1997-2000 | $ 260,000 | | | NSERC & Noranda |
| Les systèmes du boulonnage | | | | | | X | | 1999-2000 | $ 118,000 | | | IRSST |
| Détermination du potentiel d'éclatage en tant que technologie d'abattage des roches dures sans explosifs | X | | | | | | | 2000-2001 | $ 23,075 | | | MRNQ |
| Enhancement of Mining Design by Combining Empirical and Numerical Methods | | | X | | | | | 1998-2002 | $ 10,000 | | | Gouvernement du Nouveau Brunswick |
| Evaluation of the Program of Copper Ore Mines Abandonment in Poland | | | | | | | | 2000 | $ 70,000 | | | KGHM Polska Miedz S.A. |
| Étude de préconcentration du minerai dilué par triage photométrique | | | X | | | | | 1999 | $ 11,200 | | | MRNQ |
| Séquences optimales d'exploitation dans le cas des gisements très inclinés | | | X | | | | | 1997-1998 | $ 118,000 | | | MRNQ |
| Étude technique et économique de préconcentration du minerai par triage photométrique | | | | | | | | 1998 | $ 22,975 | | | MRNQ |
| Études des méthodes d'exploitation du projet Akka Gold Mining au Maroc | | | X | | | | | 1998 | $ 20,000 | | | Holding ONA/Pôle Mines en Maroc |
| Ventilation Mine 2 | | X | | | | | | 2003 | $ 90,000 | | | IRSST |
| Soutènement Mine | | | X | | | | | 1999 | $ 104,000 | | | IRSST |

| FIELDS OF EXPERTISE | Name of Researcher (s) | Information |
|---|---|---|
| Ventilation minière, environnement minier, optimisation des systèmes miniers | Kostas Fytas, Ph.D. ing | |
| Modélisation des réseaux de discontinuités; stabilité des pentes | Martin Grenon, Ph.D. ing. | |
| Caractérisation des massifs rocheux par l'analyse d'images, modélisation numérique, soutènement des massifs rocheux; conception des cheminées à minerais; modélisation des réseaux de discontinuités | John Hadjigeorgiou | |
| Fiabilité, maintenance et performance des équipements, miniers et de construction, méthodes d'abattage des roches dures sans explosif, manutention des matériaux, mécanisation des mines | Jacek Paraszozak | |
| Conception, suivie et optimisation des méthodes d'exploitation souterraine, Dilution et pertes de minerai, Coûts opératoires en présence de la dilution et des pertes de minerai, Conception des infrastructures souterraines des mine, Études de faisabilité des projets miniers, Santé, sécurité et hygiène industrielle | Stefan Planeta | |
| Économie des ressources naturelles, marché des granulats, gestion des déchets miniers, géo-environnement, politiques minérales | Richard Poulin | |

**NAME : Université McGILL / McGill University**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plate-forme cheminée** | | X | | | | | | 2001 | $ 140,000.00 | | | |
| **Tir de relaxation** | | | X | | | | | 2000 | $ 163,000.00 | | | |
| **Boulon instrumenté** | | | | | | X | | 2000 | $ 67,500.00 | | | |
| **Auscultation béton** | | | | | | X | | 2001 | $ 110,000.00 | | | |
| **Guide barricades** | | | X | | | | | 2001 | $ 135,000.00 | | | |
| **Subsurface sensing** | | | X | | | | | 2002 | $ 999,750.00 | | | |
| **Geo structure** | | | X | | | | | 2003 | $ 45,000.00 | | | |

** : A) Reduction in operating costs*
*B) increased productivity*
*C) improvement in health and safety*

| FIELDS OF EXPERTISE | | | | | | | | Name of Researcher (s) | Information |
|---|---|---|---|---|---|---|---|---|---|
| Rock mechanics | | | | | | | | | |
| Geo Radar | | | | | | | | | |
| Mine backfill | | | | | | | | | |
| Rock support system | | | | | | | | | |
| Non destructive testing | | | | | | | | | |

**NAME: Université du Québec en Abitibi-Témiscamingue (UQAT)**

| PROJECTS | Drilling and rock fragmentation | Engineering of the working environment | Mining engineering | Backfilling and related subjects | Waste and ore handling | Support and ground control - development | Logistics and service | Start and End Date | Costs | Benefits for the customer * | Number of Researchers | Source of Funds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stabilité remblai 1** | | | | X | | | | 1999 | $ 53,000 | | | |
| **Stabilité remblai 2** | | | | X | | | | 2002 | $ 80,000 | | | |

# APPENDIX D
# Additional References

**Additional documents**


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9. Développement économique Canada. (Octobre 1999) Financement de l'innovation dans les PME. Une recension récente de la littérature. 40 p.

10. Développement économique Canada. (Octobre 1999) Institution du savoir et PME. Développer des synergies. 94 p.

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L'Institut de recherche et de développement en agroenvironnement inc. (IRDA)
http://www.irda.qc.ca/propos/propos.htm

Centre québécois de recherche et de développement de l'aluminium(CQRDA) :
http://cqrda.qc.ca/

Le centre de recherche, de développement et de transfert technologique acéricole (Centre ACER)
http://www.centreacer.qc.ca/

COnsortium de REcherche Minérale (COREM)
http://www.corem.qc.ca

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
http://www.csiro.au

Forest Engineering and Research Institute of Canada (FERIC)
http://www.gov.ns.ca/natr/publications/newferic.htm

L'institut de recherche sur les produits du bois du Canada (Forintek Canada Corp.)
http://www.forintek.ca

Centre des technologies du gaz naturel (CTGN)
http://www.ctgn.qc.ca/

The Pulp and Paper Research Institute of Canada (Paprican)
http://www.paprican.ca/engl/index.htm

CAMIRO Mining Division
http://www.camiro.org/Mining/cammining.htm

The Mining Innovation, Rehabilitation and Applied Research Corporation (MIRARCO)
http://www.mirarco.org/

Technology road map for forest operations in Canada
http://strategis.ic.gc.ca/epic/internet/intrm-crt.nsf/en/Home

Ville de Chibougamau
http://www.municipalite.baie-james.qc.ca/francais/communautes/chibougamau/

Ressources naturelles, Faune et Parcs du Québec – Les mines ; é-sigeom à la carte : Gîtes
http://sigeom.mrnfp.gouv.qc.ca/signet/classes/I1102_index

# APPENDIX E
# Research Organization Proposal

# TABLE OF CONTENTS



# FIGURE

## E.1. Objectives of the Alliance:

- To provide its partners with research results, expertise and technologies aimed at improving the competitiveness of Canadian underground mines;
- To ensure that the research undertaken is consistent with the highest priority axes of research that have been identified by the stakeholders;
- To develop multidisciplinary partnerships between teams of researchers, mining companies, federal/provincial governments, SMEs and manufacturers, to avoid unnecessary duplication of efforts and to optimize the rate of return on research budgets;
- To target, intensify and accelerate the development and adoption of solutions to problems identified by the industry;
- To achieve effective transfers of knowledge and new technologies;
- To facilitate the exchange of scientific and technical information, through networking activities between the various stakeholders, and to maximize the impact of research work;
- To develop and maintain, in Canada, the expertise required by the underground mining sector and to support training within the industry;
- To identify and promote the export of Canadian expertise; and
- To provide technical support for the drafting of provincial regulations, when required.

## E.2 The Structure of the Alliance

To make better use of the expertise acquired at different mine sites by research groups from academia, the mining industry, manufacturers and other organizations, the creation of a national alliance (that is well coordinated, decentralized, but effective), is required to achieve the research priorities that have been identified by all of the stakeholders. From the literature (see Appendix D, additional web sites), the structure that seems to be the most appropriate is as follows (Figure E.2.a):

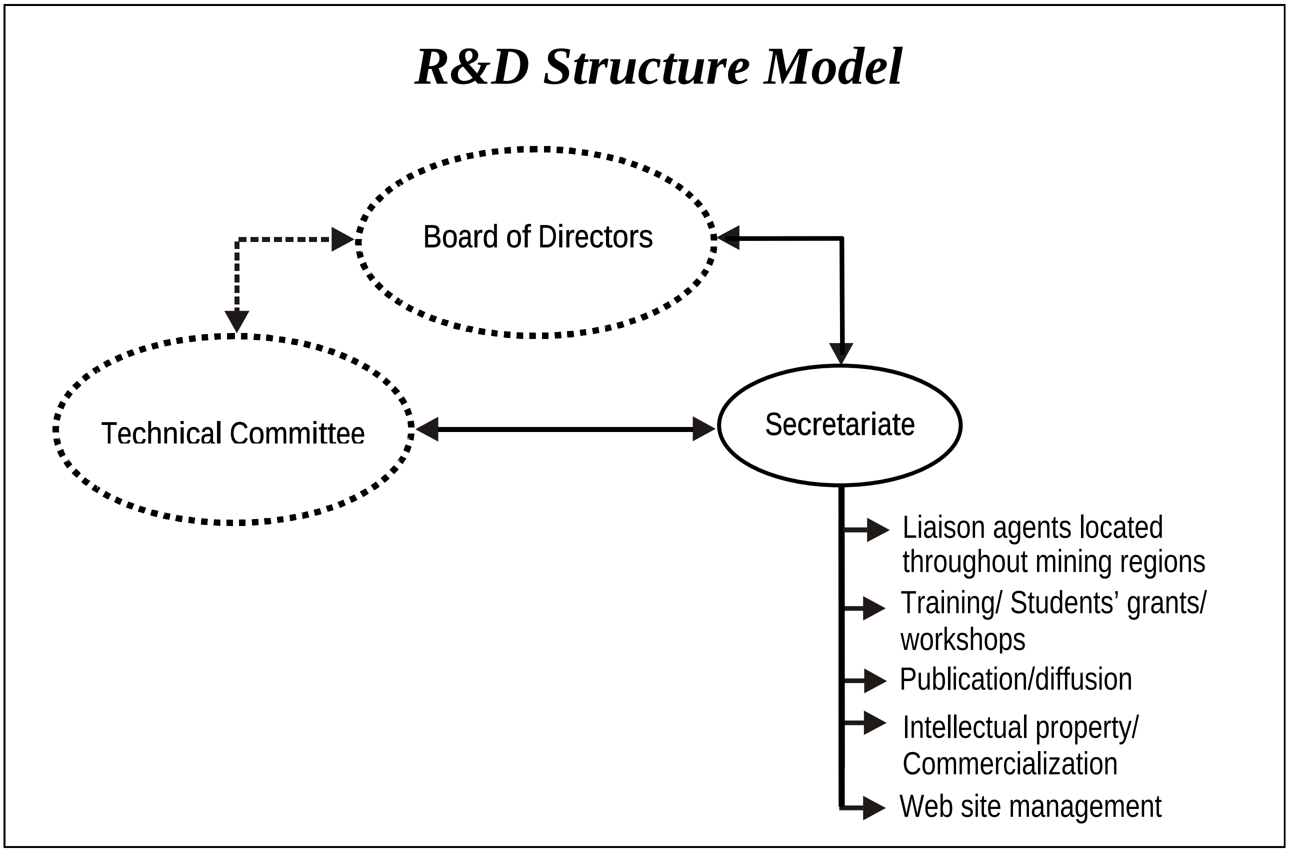


**Figure E.2.a – A decentralised model for the delivery of mining research and innovation**

### E.2.1 Board of Directors

In view of the geographic dispersion of the various stakeholders in the mining industry, the proposed management structure must be flexible and mobile, both in space and in time. This structure, hereinafter referred to as the Alliance, would be governed by a Board of Directors composed primarily of senior industry members. As such, it would be appropriate to include representatives not only from well-established industrial research groups, such as SOREDEM and CAMIRO, but also from government agencies (federal, provincial and even municipal) and the academic community. All of these stakeholders should be expected to present their positions, whenever necessary. Members would have sufficient authority to make the necessary decisions at the financial level and to allocate the required funds to support projects. The Board of Directors would be responsible for ensuring that research funds are directed towards those axes of research that have been identified as being of the highest priority by the stakeholders, i.e. those initiatives having a significant potential value added for mining operations. To that end, an economic evaluation and/or an evaluation on the impact on health/safety should be prepared in order to quantify the expected benefits for each of the projects.

The mandate of the Board of Directors would be to:

- Develop and approve short, medium and long-term strategic orientations;
- Develop and approve financial directions, including the national research program budget and the operating budget of the secretariate;
- Approve projects recommended by the Technical Committee;
- Manage the secretariate; and
- Manage the intellectual property (IP) based on the IP Committee's recommendations.

### E.2.2 Technical Committee

A flexible and responsive Technical Committee should be made up of members having a practical and technical vision of the concrete needs of mining operations in the short, medium and long-term. This committee should rely on industry and research champions having the leadership required to develop appropriate projects and to ensure their introduction into mining operations. The mandate of this committee would consist of selecting and recommending, to the Board of Directors, research projects having a potentially meaningful impact, as well as the best teams to implement each of these. It should be made up in such a way that the majority of the fields of specialization in mining would be represented. The Technical Committee, which should operate under the seal of confidentiality, could be divided into subcommittees reflecting the highest priority axes of research, as required.

The mandate of the Technical Committee would be to:

- Assess industry needs and develop a technical program based on the recommendations from liaison agents (see below);
- Establish clear project selection criteria which should include, among other things, the highest priority axes of research, technology transfer and a business plan;
- Prepare a guide for projects and reports submission;
- Bring together high calibre multidisciplinary teams, capable of assimilating, developing and utilizing expertise that is constantly evolving;
- Recommend research projects which address the highest priorities, both from national and regional perspectives, to the Board of Directors;
- Ensure that there would be a satisfactory potential economic impact for each project;

- Ensure an equilibrium between projects;
- Establish project objectives and budget allocations;
- Ensure project follow-up (schedule, budget, quality and technical follow-up); and
- Maintain bi-directional effective relationships and communications with the Board of Directors in order to facilitate the pursuit of the Alliance's objectives.

### E.2.3 Secretariate

If the requested research and development funds are allocated, the services of a secretariate will be necessary to deal with the requirements of coordination, the number of projects and the sums of money at stake. In view of the specific characters of the different committees, a reduced, but effective, team should be able to follow up on the research, while, at the same time, cementing the links between the two levels of management and the researchers. To ensure the success of the axes of research, a close follow-up will be required to monitor both the development and scheduling of projects. This team should, therefore, monitor contributions, expenditures and the progress of projects, and report on these to the Board of Directors and the Technical Committee. It should also ensure that researchers provide reliable economic evaluations, which will be reviewed by the Technical Committee and then submitted to the Board of Directors. The secretariate would also exercise the necessary leadership to ensure that all of the committees stay on course in addressing the priorities. This would involve setting up meetings so that critical issues, such as those relating to intellectual property, are discussed. The mandate of the secretariate would also be to guide the committees in their selection of projects and those involved, so as to avoid unnecessary duplications. For that reason, it should receive the proposals submitted and also inform the interested parties of the outcomes of their submission. This team, whose members would be selected by the Board of Directors, which is represented primarily by industry members, and should possess an extensive knowledge of the mining sector and be up to date on global research activities. Finally, the secretariate would be mandated to ensure the smooth operation of Satellite Committees, such as the Training and Liaison Committees (see below).

Furthermore, the mandate of the secretariate would be to:

- Ensure that results are achieved in accordance with the objectives defined by the Board of Directors;
- Act as liaison between the Board of Directors and the Technical Committee;
- Coordinate the various aspects of day-to-day management;
- Ensure the development of results and the transfer of technology within the industry;
- Set up special committees, whenever required;
- Prepare model contractual agreements, to be used as templates; and
- Introduce and ensure the smooth operation of a technology watch.

### E.2.4 Liaison Committee

Liaison agents would be assigned to the various parts of Canada to act as research ambassadors for their region. Liaison agents could be already functional and well established organizations in their respective sectors, such as the CIM, that have a special interest in mining research. The purpose of this committee would be to act, at both the local and regional level, to develop the means of disseminating information and the organization of events (e.g.: symposium, publication, project proposal solicitation). These activities would improve relationships, at the national level, amongst the different mining communities.

The mandate of the Liaison Committee would be to:
- Promote the exchange of information between the research community and the mines;
- Facilitate the transfer of results;
- Monitor the nature of research activities which are undertaken in their respective communities;
- Maintain an up-to-date list of ongoing projects and available expertise;
- Inquire into industry needs on their territory; and
- Receive industry requests and pass them on to the secretariate.

### E.2.5 Training Committee

The Training Committee would establish and support a student assistance bursary program, at the graduate level, in which the students would work under researchers having a clear understanding of the needs of industry. In addition, the purpose of these grants would be to establish a synergy between industry and academe. Master's degree and doctor's degree topics should be defined by the research supervisor in collaboration with the Technical Committee.

## E.3 Conditions regarding membership and partnership

If the alliance proposed under subsection E.2.3 is adopted, the benefits linked with membership, as described in the literature, would be:

To active members:
- The possibility of sharing valuable information with research professionals;
- Priority access to expertise, state-of-the-art technologies and any other information, including intellectual property developed with or without royalty interest;
- Decision-making authority concerning the orientation of strategic research;
- Significant leverage on the sums allocated to R&D;
- Recognition of R&D efforts in the mines (eligible tax credits for R&D related expenditures);
- Tax incentive eligibility for R&D activities;
- Access to training for mine personnel;

- Receipt of notices of meetings;
- Right to attend and vote at the annual general meeting;
- Eligibility to become a Director;
- The right to elect Directors;
- Access to balance sheet and financial statements;
- Participation in the activities organized by the consortium, such as conferences, training, networking, etc.; and
- The possibility of licensing the technologies developed.

To guest members:

- Invitation to participate in one or several projects;
- Participation in the development of a project, as far as the technical aspect, schedule and definition of deliverables are concerned; and
- Tax incentive eligibility on a project basis.