CANADA'S "MINERAL CLUSTER:" STRUCTURE, EVOLUTION, AND FUNCTIONING

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A. R. M. Ritter **November 18, 2000**

I. INTRODUCTION

During the Twentieth Century, Canada developed a large mineral sector and a wide range of economic activities surrounding mining. In some respects, the extent to which linked economic activities have evolved on the foundation of the mineral sector is most impressive. However, Canada has also been singularly unsuccessful in establishing and developing capital goods industries producing machinery and equipment for some important areas of the mineral sector, most notably for surface mining.

The objective of this study is to analyze the character of the total "cluster" of economic activities around Canada's mining sector, labelled here as the "*mineral cluster*," to explain its evolution, and to evaluate its functioning and contribution to the Canadian economy generally. An important specific "*sub-cluster*" of economic activities founded on mining, namely mineral exploration is also examined. The efforts of Sudbury, the major urban centre in the Central Canadian hard-rock mining region, to strengthen its place in the "cluster" and to increase the net benefits flowing to the region are also explored.

More specifically, the objectives of this study are as follows:

1. To analyze the structure, evolution and functioning of the range of economic activities centred on mining in Canada (the "cluster") and the mineral exploration "sub-cluster;"
2. To explain why the "mineral cluster" or "sub-clusters" have emerged and developed as they have, identifying the character and interplay of the causal factors;
3. To analyze and evaluate the role of the public sector and government in this process; and
4. To assess some of the economic and social impacts of the broadening and deepening of the clusters examined in the study;

A mixed and largely qualitative methodology is employed in this study. The study synthesizes existing statistical, quantitative, institutional, technological and historical information in order to analyze the structure and functioning of the mineral cluster.

The study begins with a general analysis of Canada's mineral cluster, its structure, characteristics and performance. This includes an examination of the mining foundation of the cluster followed by an analysis of the other related parts of the cluster. An additional and very successful sub-cluster: mineral exploration is then presented in the following section. Some specific analysis of the Central Canadian hard rock underground mining part of the overall mining cluster presented subsequently. An attempt to explain the emergence of the cluster and sub-clusters is presented. Following this, some comments on the socio-economic consequences of the expansion and elaboration of the successful clusters in terms of employment, income generation and distribution, domestic value added, ownership patterns and regional development are tendered.

The "*mineral sector*" is defined here to include all mineral exploration, mine-site and related infrastructural development, mineral ore extraction, the handling and processing of mineral ores up to smelted and refined stages, metal recycling, mineral marketing, and mine closure, decommissioning and environmental reclamation. The term "*mining*" normally refers to the extraction of a mineral ore from the earth's crust together perhaps with exploration and the first stage of processing.

The "*mineral cluster*" or "*mining cluster*" or the array of economic activities surrounding and servicing or supplying the mining and the mineral sector includes a wide range of activities. As can be seen in Box 1 below, the "*cluster*" would include the production of machinery and equipment of all kinds used in exploration, mine development, ore extraction and processing, and environmental protection. A wide range of services are also included, such as exploration services, transportation, maintenance and repair, contract drilling, research, consulting of all sorts, financial services, education, legal services, marketing services, the press, and personnel services. The "mineral cluster" also includes the further processing of metals beyond mining (Stage 1) and smelting and refining (Stage 2.) Included in the next level of semi-fabricated products (Stage 3) would be wire and wire products, rolled, cast, forged or extruded products, and non-metallic mineral products. Stage 4, fabricated parts and simple products would include wire and cable (ready for energy transmission and communication) fabricated metal products

(structural products, hardware, plumbing supplies, hardware, and hand tools) and some automotive or transportation components or products.) A further important part of the minerals system is recycling, which includes significant values and volumes of metals as well as large numbers of enterprises and employees.

All minerals are included except natural gas and petroleum, which are substantially different in terms of extraction, processing, end-use and market characteristics. The minerals included encompass metals, non-metallic minerals and structural materials such as stone, cement, lime and aggregate. The tar sands, a major source of petroleum in Canada should probably be included with mining because the ore extraction is a type of open-pit mining. However, the tar sands operations are treated with petroleum in Canadian statistics and official analyses.

II. THE CANADIAN MINING CLUSTER IN GENERAL

1. Mining and the Mineral Sector: the Foundation of the Cluster

The foundation of the mineral cluster is mineral extraction and processing together with exploration and mine development. A broad range of minerals is extracted from the resource base in Canada, as summarized in Table 1. The total value of extracted minerals, excluding oil and natural gas ranged between $CDN 18,300 million and $19,400 million from 1995 to 1998. Especially prominent among Canada's mineral products are copper, gold, iron ore, nickel, zinc, potash, and coal. A variety of other minerals constitute a second tier in terms of their value. Those with annual production values exceeding $CDN 100 million include cobalt, lead, platinum group metals, silver, uranium, asbestos, peat, lime, sand and gravel and clay products.

In a few years, it is likely that diamond extraction will also exceed $1,000 million with the rapid rate of development of deposits in the North.

TABLE 1. MINERAL PRODUCTION OF CANADA, 1995-98p

	Unit	1995		1996		1997		1998p	
	(000)	(Quantity)	($000)	(Quantity)	($000)	(Quantity)	($000)	(Quantity)	($000)
METALS									
Antimony	kg	574	3 959	1 380	6 084	529	1 610	554	1 301
Bismuth	kg	159	1 815	150	1 598	196	1 956	217	2 431
Cadmium	kg	1 686	9 383	1 540	5 732	1 272	1 991	1 384	1 323
Calcium	kg	x	x	x	x	x	x	x	x
Cesium, pollucite	kg	x	x	x	x	x	x	x	x
Cobalt	kg	2 016	176 921	2 150	164 918	2 168	154 408	2 324	167 696
Columbium (niobium)	kg	x	x	x	x	2 253	x	2 200	x
Copper	kg	700 842	2 818 090	652 499	2 059 285	647 779	2 050 869	688 576	1 693 209
Gold	g	150 867	2 557 502	164 660	2 799 547	171 479	2 527 429	166 089	2 322 417
Ilmenite	t	x	x	x	x	x	x	x	x
Indium	g	x	x	x	x	x	x	x	x
Iron ore	t	36 628	1 291 474	34 400	1 321 727	38 928	1 571 741	38 908	1 584 146
Iron remelt	t	x	x	x	x	x	x	x	x
Lead	kg	204 226	176 656	241 751	254 564	170 847	147 612	151 708	118 029
Lithium	kg	x	x	x	x	x	x	x	x
Magnesium	kg	x	x	x	x	x	x	x	x
Molybdenum	kg	9 113	202 931	8 789	100 196	7 594	87 582	7 563	82 438
Nickel	kg	172 107	2 031 727	182 404	1 920 348	180 624	1 775 898	200 908	1 419 416
Platinum group	g	16 068	181 996	13 934	141 620	11 836	134 242	14 522	222 883
Selenium	kg	561	8 317	694	7 140	592	5 045	384	2 839
Silver	kg	1 245	285 136	1 243	282 510	1 194	260 024	1 115	293 468
Tantalum	kg	40	3 965	67	7 625	60	7 230	74	10 394
Tellurium	kg	102	2 074	59	1 744	59	831	57	860
Uranium	kg	10 238	526 448	11 348	620 880	11 127	553 900	9 984	x
Zinc	kg	1 094 701	1 549 004	1 162 720	1 625 482	1 026 864	1 870 946	987 361	1 486 966
Total metals			12 172 744		11 697 468		11 549 178		10 318 910
NONMETALS									
Asbestos	t	516	234 730	506	256 722	420	214 910	320	167 200
Barite	t	61	6 556	58	6 498	84	7 119	80	7 329
Diamonds	carats	–	–	–	–	–	–	278	53 425
Gemstones	kg	459	1 420	294	684	407	1 482	131	416
Graphite	t	x	x	x	x	x	x	x	x
Gypsum	t	8 055	88 417	8 202	85 415	8 628	95 263	8 095	87 972
Magnesitic dolomite	t	x	x	x	x	x	x	x	x
Marl	t	x	x	x	x	x	x	x	x
Mica	t	x	x	x	x	x	x	x	x
Nepheline syenite	t	617	37 098	606	46 690	648	51 319	617	50 190
Peat	t	886	139 154	901	141 019	1 054	146 404	1 127	169 747
Potash	t	8 855	1 424 344	8 120	1 277 860	9 235	1 528 341	8 969	1 666 978
Potassium sulphate	t	x	x	x	x	x	x	x	x
Pumice	t	x	x	x	x	x	x	x	x
Quartz	t	1 689	38 409	1 558	36 193	1 690	40 198	1 700	40 527
Salt	t	10 957	270 369	12 248	359 818	13 497	405 509	13 192	399 520
Serpentine	t	x	x	x	x	x	x	x	x
Soapstone, talc and pyrophyllite	t	108	16 243	77	15 151	72	14 908	74	15 471
Sodium sulphate	t	315	25 377	323	30 964	285	29 040	277	28 473
Sulphur, elemental	t	7 846	187 685	8 327	83 805	8 272	84 129	8 410	54 321
Sulphur in smelter gas	t	886	62 577	789	57 765	800	59 462	838	58 315
Titanium dioxide	t	x	x	x	x	x	x	x	x
Tremolite	t	x	x	x	x	x	x	–	–
Zeolite	t	x	x	x	x	x	x	x	x
Total nonmetals			2 906 085		2 765 775		3 026 971		3 277 231
MINERAL FUELS									
Coal	t	74 920	1 834 630	75 860	1 936 050	78 670	1 920 150	74 370	1 793 230
Natural gas	000 m^3	148 202	6 830 779	153 578	8 734 860	156 171	10 719 153	161 015	11 195 954
Natural gas by-products	m^3	25 040	1 772 424	26 657	2 838 702	26 427	2 599 598	26 612	1 790 640
Crude oil and equivalent	m^3	114 372	15 321 005	117 621	19 071 725	123 827	17 837 834	128 769	12 990 337
Total fuels			25 758 838		32 581 337		33 076 735		27 770 161
STRUCTURAL MATERIALS									
Clay products	$	. .	95 634	. .	110 218	. .	136 324	. .	135 319
Cement	t	10 440	842 492	11 587	964 380	11 736	1 062 708	12 064	1 126 875
Lime	t	2 462	206 933	2 402	202 579	2 477	213 038	2 514	220 509
Sand and gravel	t	225 991	793 489	213 831	772 590	225 495	829 190	217 650	819 893
Stone	t	98 578	591 255	92 331	592 547	99 265	644 162	95 998	646 198
Total structural materials			2 529 804		2 642 314		2 885 421		2 948 794
Total all minerals			43 367 470		49 686 893		50 538 306		44 315 096

Sources: Natural Resources Canada; Statistics Canada.
– Nil; . . Not available; p Preliminary; x Confidential.
Notes: Numbers may not add to totals due to rounding. Confidential values are included in totals.

The value of exports of minerals and mineral products exceeded $CDN 45 billion in 1998 as can be seen in Table 2. However, this included not only mineral ores and smelted or refined products, but also semi-fabricated and fabricated, that is mineral products from “Stage 1” to “Stage 4,” as these were defined in the Introduction. Among these exports, aluminum, copper, gold, iron ore, nickel, zinc, potash and coal again were prominent, and were accompanied by cement, iron and steel with exports exceeding $1,000 million.

Employment in the mineral extraction through to refining is presented in Table 3. Employment in extraction and processing - Stages 1 and 2 in the Table - stood at 107,612 in 1998. This represents a decline of about 38% since the 1970s, explained largely by labour-displacing technological change mainly in mineral extraction. On the other hand, employment levels have been maintained in semi-fabrication (Stage 3) and fabrication (Stage 4) and in fact were higher in the late 1990s than previously.

Minerals are extracted from large numbers of mines. Table 4 lists Canada’s major metals and presents some information on the related mine sites and processing facilities in an international context. There are some 67 mines in Canada producing more than 200,000 tons per year of ore, according to a recent survey (Mining Magazine, January 2000, 25-32.) There are also over 80 smaller mines, as well and very large numbers of quarries and even larger numbers of sand pits, perhaps over 2000 (NRC 2000, p.11.) These mines, which exist to tap into Canada’s mineral endowment are the foundation of the mineral cluster.

There are large numbers of mineral processing facilities as well. Most mines have adjacent or near-by processing plants, which extract a concentrate from the raw ore. For metallic minerals, there are also large numbers of smelters and refineries. For non-metallic minerals, there are usually processing plants at or near the mine site which produce a high grade product often close to the final product. In other cases such as diamonds, a good deal of further processing is required prior to the final product. In the case of aluminum, Canada has a large refining capacity but produces no bauxite. The reason for this ostensible anomaly is that the production of aluminum uses immense amounts of electricity, which some parts of Canada have had in

Table 2: CANADIAN EXPORTS OF NON-FUEL MINERALS:
Stage I to Stage IV, 1998
$CDN millions

METALS	$CDN millions
I. METALS	
Aluminum	$ 7,137
Cobalt	464
Copper	2,385
Gold	3,384
Iron and Steel	9,606
Iron Ore	1,286
Nickel	1,903
Silver	507
Uranium and Thorium	786
Zinc	1,526
Other	5,671
TOTAL	**$ 34,655**
II. NON-METALLIC MINERALS	
Potash	1,979
Salt & Sodium Compounds	542
Sulphur & Sulphur Compounds	356
Other	4,152
TOTAL	**$ 7,029**
III. STRUCTURAL MATERIALS	
Cement	629
Stone	153
Other	194
TOTAL	976
IV. FUELS	
Coal & Coke	2,505
Natural Gas & By-Products	9,719
Petroleum	12,978
Other	269
TOTAL	**$ 25,472**
TOTAL MINERAL EXPORTS	**$ 68,132**
TOTAL MINERAL EXPORTS Excluding Petroleum & Natural Gas	**$ 45,434**

Source: Natural Resources Canada, *Canadian Minerals Yearbook, 1998*, Ottawa, Canada, p. 64.14.

abundance, and this makes it economically reasonable to import the semi-processed alumina for

refining into aluminum in Canada. A similar situation exists for nickel concentrate imported from Cuba refining in Fort Saskatchewan Alberta.

The mineral sector is usually considered to include more than mineral extraction and the first stages of processing. Exploration and mine development are generally included as parts of the sector as well. Mineral exploration within Canada is undertaken by large integrated producers, large mine operators, middle-sized exploration companies, and small-scale explorers and prospectors. In all, there were some 609 enterprises involved in exploration in 1998, expending CDN $609 million in total. Of these, 108 firms had exploration budgets exceeding $1 million (Canadian Intergovernmental Working Group, 2000, p.9-10.) The pattern of exploration expenditures is particularly volatile or cyclical depending mainly on mineral prices. The changing volumes of exploration expenditures within Canada are illustrated in Figure 1. Mineral exploration activity of course generates a significant demand for a wide variety of inputs of goods and services.

Processing into Stage 3 and 4 might be included in the mineral sector or cluster but often is considered to be within the "industrial sector" demarcation as well. The further processing of metals beyond the refined stage is of major significance, and employs approximately twice as many persons as do Stages 1 and 2, as can be observed in Table 3 above.

2. The International Mineral Sector and Canadian Enterprise

The international mineral economy has also become part of the foundation of the Canadian "mineral cluster," largely because the Canadian mining economy has "gone global," or integrated itself to a large degree into the global mineral economy. Moreover, the various activities in the cluster surrounding mining now operate in the global arena and not solely inside Canada.

Table 3: EMPLOYMENT IN CANADA'S MINERAL SECTOR

	Stage I Extraction & Concentration	Stage II Smelting & Refining	Stage III Semi-Fabrication	Stage IV Metal Manufacturing	Total Stages I & II	Total Stages I-IV
1961	74,829	64,687	77,063	88,014	139,516	304,593
1971	86,445	86,046	95,831	120,248	172,491	378,570
1981	89,286	77,868	103,192	141,523	167,154	411,869
1991	57,930	66,943	87,091	141,001	124,873	352,965
1996	50,378	58,719	83,366	137,881	109,097	330,344
1998	48,024	59,588	94,134	157,764	107,612	359,510

Source: Natural Resources Canada, *Canadian Minerals Yearbook, 1998.* Ottawa, Canada, pp. 64.21 to 64.26.

Notes:
Stage I: Mine extraction and concentration
Stage II: Smelting and Refining
Stage III: Includes foundries, piping and tubing, rolling, casting and extraction, wire cement, concrete products,
glass, abrasives and other.
Stage IV: Includes metal fabricating, structural metal products, stamps pressed and coated products, machine parts, hardware tools, heating equipment and other.

Table 4: BASIC INFORMATION ON CANADIAN MINING AND MINERAL PROCESSING, 1998
(Major Minerals Only)

Minerals	Mines	Processing Plants	Mineral Production Volume, 1998	Proportion of World Output	
				Per Cent	Rank
Aluminum		11 Smelters	2.3m tons/year	10.7%	Third
Cement		17 Plants	12.0m tons/year	0.8%	
Coal	24		75.4m tons/year	1.6%	
Copper	27	6 Smelters 4 Refineries	688 thousand tons/year 565 thousand tons/year	5.8%	Fourth
Gold	40	3 Refineries	166 thousand kg	7.0%	Fourth
Nickel	22	3 Smelters 3 Refineries	201 thousand tons/year 144 thousand tons/year	18.3% (mine)	Second
Iron Ore	3 mines 5 by-product		38.9m tons/year	3.7%	Eighth
Potash	12	13 Processors	13.4m tons/year	35.5%	First
Salt (Rock Salt)	21		15.8m tons/year	7.5%	Fourth
Uranium	4	3 Processors	9,984 tons	33.7%	First
Zinc	20	4 Processors	1.1m tons/year	14.3% (mine)	Second

Source: Natural Resources Canada, *Canadian Minerals Yearbook, 1998*, Ottawa: Government of Canada, 1999.

Some Canadian enterprises have operated outside Canada for a number of decades. However, there has been a rapid internationalization of the activities of Canadian mining firms in the 1990s, as they have invested in projects abroad and in mineral exploration and mine development. By the year 2000, the sector had been "globalized" significantly.

The movement of Canadian enterprises into the international mining arena has important implications for the rest of the mineral cluster in Canada. Canadian enterprises abroad may have a bias towards purchasing a broad range of productive inputs of goods and services from domestic suppliers. The reasons for this would include:

- familiarity (including knowledge and personal relationships) with domestic suppliers;
- economies from buying known machinery and equipment due to standardization of equipment among operations in different countries, interchangability of replacement parts, technical skills, etc.;
- confidence in established long-term links with tried and true suppliers; and
- close communication with traditional suppliers permitting rapid adaptation of inputs to unique local circumstances.

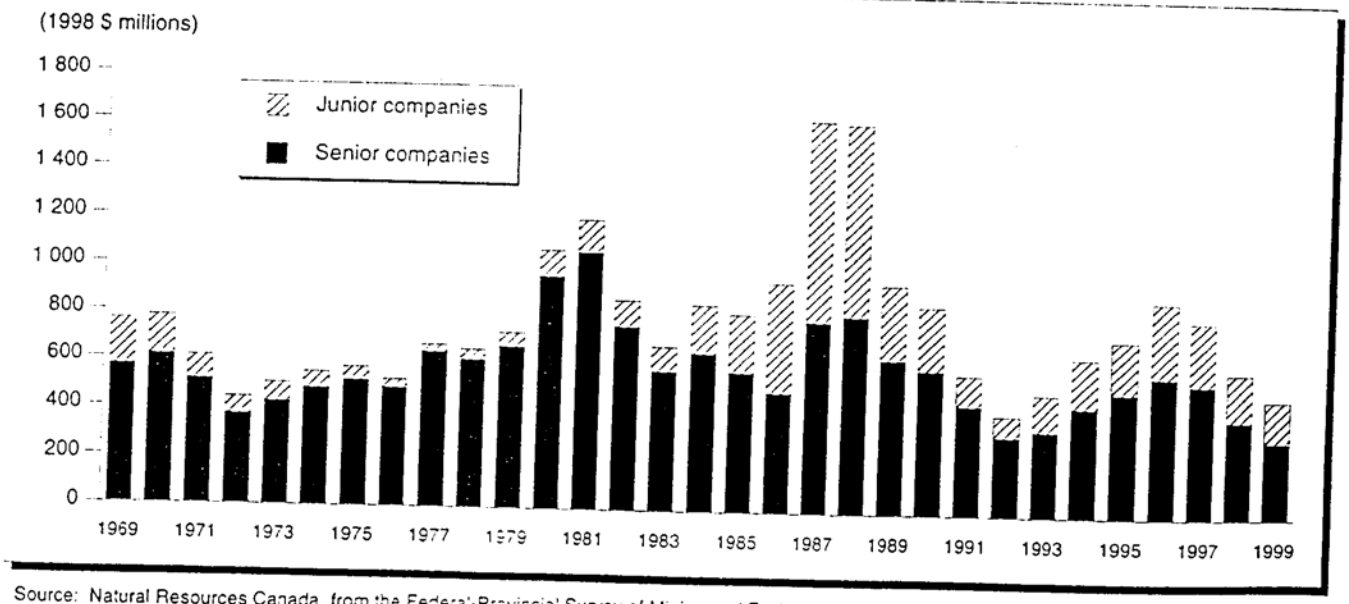
Mining activities abroad, in which Canadian firms have major participation, also serve as part of the foundation for the articulation and expansion of the mineral cluster within Canada. But at the same time, the strength of the broad cluster in Canada has supported and facilitated the outward thrust of Canadian mining firms other parts of the world.

By mid 2000, Canadian mining companies were involved in 148 mine production operations abroad, together with some 46 projects at the feasibility stage, and 13 at the mine construction stage in 54 different countries (Natural Resources Canada, 2000, *Canadian Suppliers…*, p. 9-13.)

Canadian enterprises were also active at the exploration phase, and were involved in approximately 6,600 exploration projects in around 100 countries. The share of Canadian firms in the exploration budgets of all larger enterprises was in the area of 31 to 34% in 1997-1998.

Figure 1

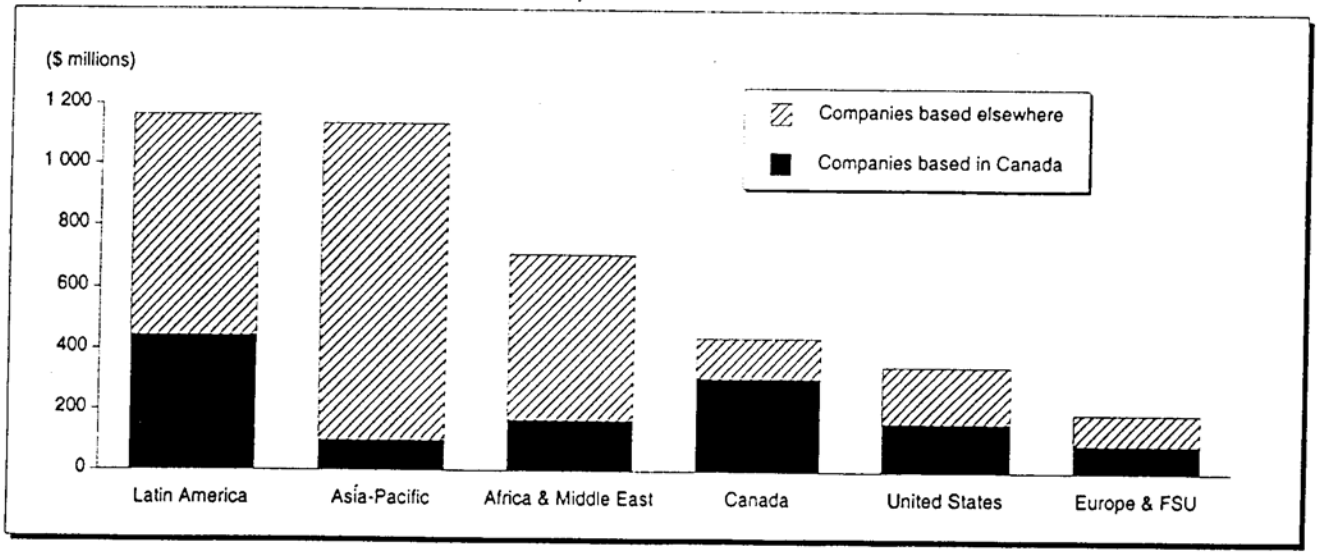
Exploration Plus Deposit Appraisal for Field Work Plus Overhead Expenditures[1] by Junior and Senior Companies, 1969-99



Source: Natural Resources Canada, from the Federal-Provincial Survey of Mining and Exploration Companies.
1 Includes on-mine-site plus off-mine-site activities.
Notes: Expenditures for 1997, 1998, and 1999 include both exploration plus deposit appraisal as per new definitions; up to and including 1996, most of the expenditures now included in the deposit appraisal work chase were reported under exploration (broadly speaking). Data for 1998 are preliminary; data for 1999 are forecast.

Figure 2

Exploration Budgets of the World's Larger Companies for Selected Regions of the World, 1998
Companies with Worldwide Budgets of at Least $4 Million (US$3 Million)
for Precious-Metal, Base-Metal or Diamond Exploration



Source: Natural Resources Canada, based on *Corporate Exploration Strategies: A Worldwide Analysis*, Metals Economics Group, Halifax, Nova Scotia.
Notes: The worldwide exploration budgets of companies that intended to spend less than $4 million (US$3 million) annually are excluded. The worldwide exploration budgets for other commodities such as uranium or industrial minerals are also excluded.

Table 5: PRINCIPAL MINE INVESTMENT PROJECTS BY MINERAL AND REGION, 2000 (Number of Projects and $US millions)

Minerals	Latin America and Caribbean						North America				Australia		Africa		Asia & Oceana		Europe		TOTAL	
	Total		Chile		Peru		U.S.		Canada											
Bauxite/ Aluminum	2	1,800									1	(542)	1	1,300	5	4,656	1	209	10	8,507
Copper	18	9,142	8	2,150	7	5,712	2	158					4	1,955	4	361			28	11,619
Nickel	2	803					1	81	2	(840)	2	(670)	1	135	2	1,958	1	1,700	13	6,187
Iron Ore	2	2,076							1	344	1	500							4	2,920
Lead & Zinc	2	474			1	341							1	350	1	188	2	484	6	1,496
Uranium									1	410	1	?							2	410
Light Metals									2	790	1	1,270	2	609					5	2,669
Industrial Minerals & Oil Sands	1	27	1	27			1	210	9	8,555	1	11			2	(535)			14	9,338
Gold	10	936			1	150	5	658	6	299	2	188	6	862	8	370	3	507	41	3,820
Other Precious Minerals	2	147					2	885					1	247			1	89	6	1,368
TOTAL	**38**	**$15,405**	**9**	**$2,177**	**9**	**$6,203**	**9**	**$1,992**	**23**	**$11,238**	**9**	**$3,181**	**16**	**$5,458**	**22**	**$8,068**	**8**	**$2,989**	**129**	**$48,334**

Source: *Engineering and Mining Journal*, January 2000, pp. 25-30.
Note: Projects are expansions, upgrades, new projects under construction, with announced development programs or proposed.
Brackets (...) indicate that values are particularly crude estimates.

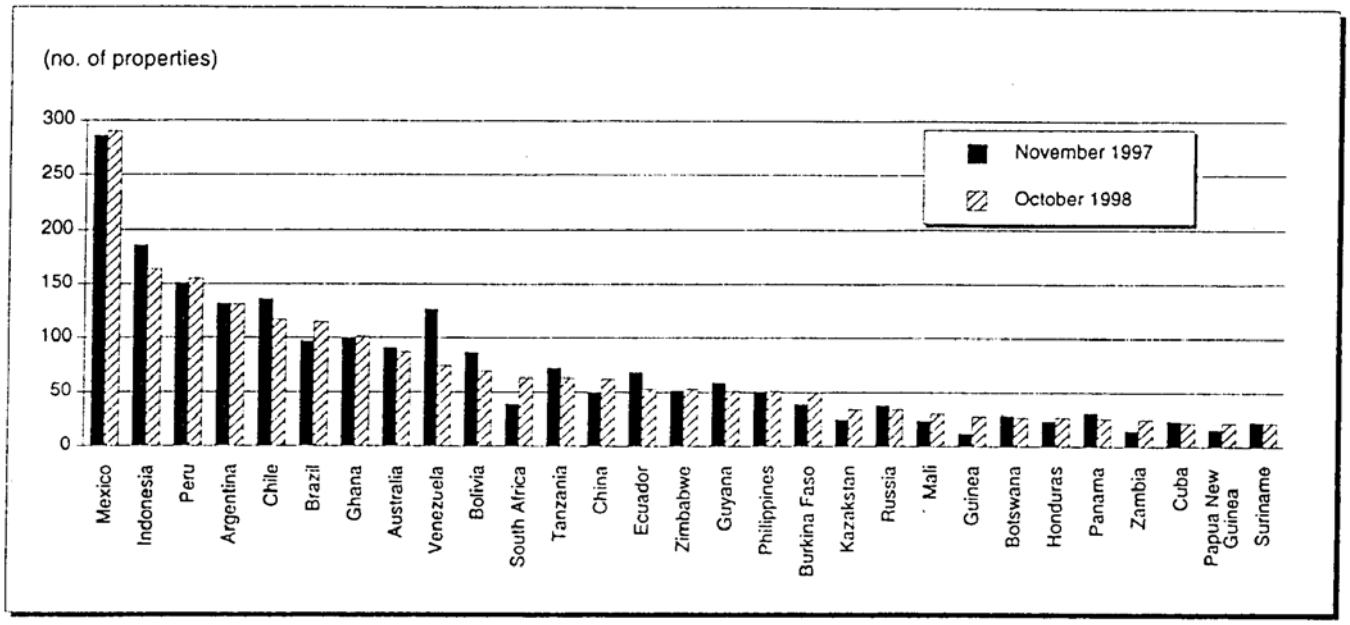
These estimates exclude the expenditures of small-scale exploration firms and prospectors with exploration budgets of less than CDN$ 4 million, and therefore understate the true value of total exploration expenditures. In dollar terms, the larger Canadian exploration firms planned to invest CDN $967 million outside Canada out of total exploration budgets of about CDN $1,300 million. The regional distribution of the exploration budgets of firms expending more than CDN $4 million are presented in Figure 2. The share of Canadian enterprises is especially striking for Latin America and North America as well. Greater detail regarding the pattern of exploration investment by Canadian firms is presented in Figure 3. Chile, Mexico, Peru, and Argentina – following the United States - were the largest destinations for exploration investment by larger Canadian firms. An additional idea of the international role of exploration enterprises can be derived from Mexican data on exploration. Of the total 109 foreign exploration firms active in that country in 1998, 71 were Canadian. Following Canada was the United States, with 27 exploration enterprises, and then Australia with three (*Gobierno de Mexico, Secretaria de Comercio,* 1998, Table 16.)

The pattern of mineral exploration will undoubtedly influence the future shape of the international mining sector activity. This in turn will influence the evolution of the broader clusters of mineral activity and the pattern of specialization among countries.

Estimations of prospective investment projects in the international mineral sector are presented in Table 5. These estimates are produced annually by the Engineering and Mining Journal, and are indicative probabilities rather than infallible certainties. Prospective projects represent the future demand for capital equipment and services in the construction phase of mining, and the future pattern of demand for inputs of goods and services for the mining, processing, smelting and refining. The shares of probable new investments in Latin America and Canada are especially striking at 31.9% and 23.3% of total global investment, respectively. They indicate that the probable market for many types of machinery, equipment, and production inputs of all varieties will be relatively dynamic in these regions in the medium term. In the case of Canada, however, the main prospective mineral activities appear to be in the oil sands category rather than metallic minerals. The shares of Australia, Asia and the Pacific region are also substantial, while those of Europe and the United States are smaller. The higher share for Africa is edifying, in view of the exceedingly small volumes of investment in that region in the 1970s

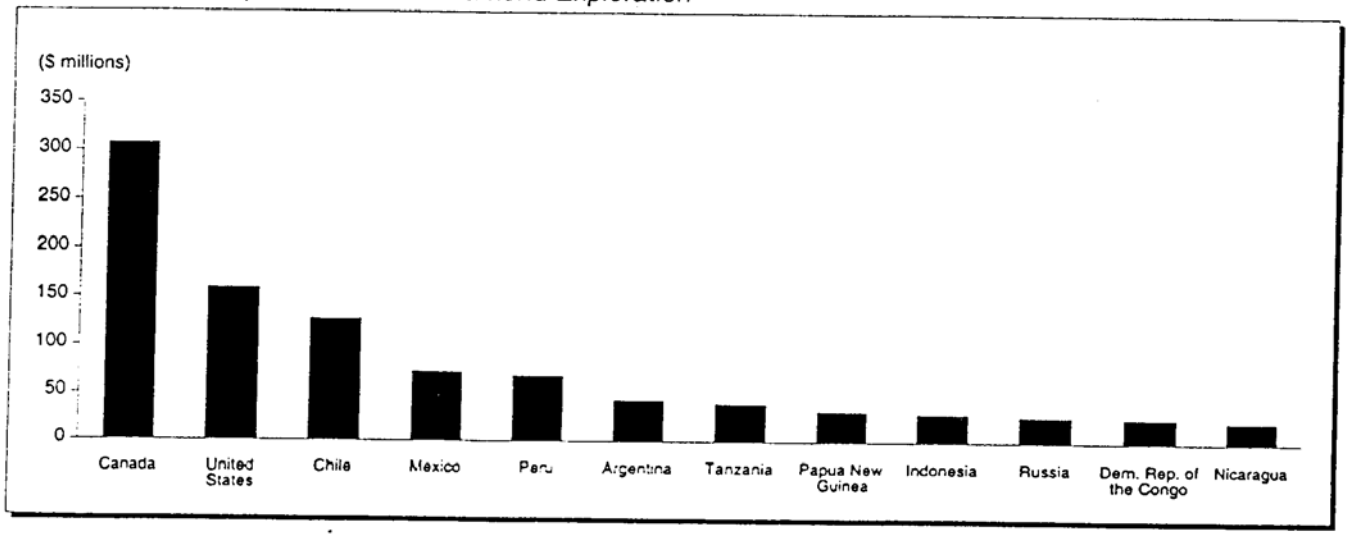
Figure 3

Canadian Mineral Property Portfolio Abroad, 1997 and 1998 – Countries Accounting for 80% of Canadian Holdings Located Outside the United States in 1998
Companies of all Sizes Listed on Canadian Stock Exchanges



Source: Natural Resources Canada, based on *MIN-MET CANADA* database for 1992-97 and Info-Mine database for 1998, ROBERTSON INFO-DATA Inc., Vancouver, British Columbia, and used under licence.

Exploration Budgets of the Larger Canadian-Based Companies, 1998 – Countries Accounting for 80% of Canadian Budgets
Companies with Worldwide Budgets of at Least $4 Million (US$3 Million) for Precious-Metal, Base-Metal or Diamond Exploration



Source: Natural Resources Canada, based on *Corporate Exploration Strategies: A Worldwide Analysis*, Metals Economics Group, Halifax, Nova Scotia.
Notes: The worldwide exploration budgets of companies that intended to spend less than $4 million (US$3 million) annually are excluded. The worldwide exploration budgets for other commodities such as uranium or industrial minerals are also excluded.

and the 1980s. The ability of countries, such as Canada and countries in Latin America, to develop their mineral clusters will depend on how well they are able to win their own and other emerging markets for the broad array of goods and services which are inputs into mining processes.

3. The Character of the Mineral Cluster, in the Year 2000

The mineral cluster includes all of the central mining activities such as xploration, mine development, mineral extraction and mineral processing activities, together with all the activities based on and surrounding this core. The central core activities are outlined in the previous section. The activities linked to the mineral foundation are summarized in Box 1 below.

Included in the mineral cluster is the production of capital goods of all sorts and physical production inputs. All types of machinery and equipment for the exploration phases, mine development, processing, smelting and refining are part of the cluster. Physical inputs, which are used and "consumed" in the various phases of mineral extraction and processing, i.e. "consumables" are also part of the material goods used in the sector. This would encompass such items as exploration drilling steel and bits, explosives, underground or surface drill steel and bits, grinding media (balls and rollers), and various chemicals used in processing. Other equipment for personnel, environmental protection, bulk handling, specialized transportation, and construction equipment would be included.

A wide variety of services are part of the mineral cluster, including exploration services of all kinds, aviation services, analytical laboratories, construction services of various sorts, transport services, contract drilling and mining, consultant services and maintenance and repairs. Some other types of services linked partially to the mineral sector could be considered as parts of the cluster as well. This would cover relevant education at various levels, the specialized press, financial services, marketing and legal services, software design and implementation services. Finally all research of relevance to the mineral sector could be included as part of the sector, including geological, exploration, mineralogy, mining systems, mineral processing and usage of mineral products.

Box 1. Economic Activities Linked To, or Based On Mining: The "Mineral Cluster"

Mineral Machinery, Equipment and "Consumables"

Exploration: Drill rigs, drill steel and bits;
Aerial exploration equipment;
Exploration instrumentation;
Instruments and equipment for laboratories

Mine Development:
Construction materials, for mining, processing, personnel and related activities;
Infrastructure and related building materials and equipment;

Underground Mining:
Drill rigs, steel, and bits;
Explosives and blasting equipment;
Continuous mining equipment and conveyor systems;
Shaft sinking and tunneling equipment;
"Shaft furniture" and Hoisting Equipment;
Underground transport systems, rail or wheel;
Equipment for ventilation, electricity, water-removal;
Mining instrumentation

Open Pit Mining:
Drill rigs, bits and steel;
Explosives and blasting equipment;
Excavators and front-end loaders;
Off-road trucks and "wheel loaders;"

Concentrating, Smelting, and Refining Equipment;
Bulk Handling Equipment;
Environmental and Safety Equipment;
Personnel Equipment;
Specialized Transportation Equipment, for Road and Rail.

Mineral Services

Exploration Services;
Aerial essaying, remote sensing, and cartographic services;
Analytical Laboratories, geophysical and chemical analysis;
Consultant Services: geological, exploration, mining, processing, management, financial, environmental; accounting;
Mine-Site Construction;
Contract Mining and Drilling Services;
Maintenance and Repairs;
Communication Equipment, Underground and Surface;
Transportation, for mineral ore, concentrate, machinery, and inputs;

Other Services

Research: **Geological, Exploration, Mining Systems and Processing;**
Aviation Services; For personnel, at mine-site and for fly-in: fly out mining
Education of specialized personnel:
Universities, Colleges, Trades training;
Financial Services, including the stock exchanges
Specialized Mineral Cluster Press;
Legal Services
Marketing and Export Consultants

One might also include such things as electricity generation, if the generation capacity is dedicated specifically to the various stages of mining and processing. On the other hand, other purchased inputs where mineral sector uses are but one of a number of market outlets probably would not be included as part of the cluster regardless of the value of the purchases. Petroleum, gasoline, water, and perhaps electricity would be in this category

The value of purchased inputs for mining smelting and refining is summarized in Table 6, which is extracted from an input-output study of the mineral sector (P. Dungan, 1997, pp. .) This analysis concluded that the direct impact on total demand generated by the mineral sector amounted to $11.3 billion for 1992. The employment generated for the production of the inputs used in the mineral sector was estimated at 149,284 persons. This compares with total employment in the mineral sector itself (from mining through to refining) of 107,612 persons. In 1998 (Table 3.above.)

The further processing of mineral products through the production of "semi-fabricates to metal manufacturing included an additional 251,898 workers (Table 3.) While some of these activities and workers may well have been employed in similar activities if there was no mineral production in Canada, it is likely that Stages III and IV in the mineral production chain (semi fabrication and metal manufacturing) would have been very small in that case. These numbers indicate the significance of the broader mineral cluster both in generating economic activity and in creating employment.

The relative significance of the activities outside of mining and processing themselves are apparent in Table 6. The most important activities in terms of the value, in order of magnitude, were found to be wholesale and retail trade (surprisingly,) financial institutions, "other business services," "professional business services," electric power systems, truck transport, repair and construction, services related to mining, accommodation and food services, and railway services.

Table 6: "BACKWARD LINKED" SUPPLIERS TO MINING, SMELTING AND REFINING 1992, Direct and Total $CDN of 1992, millions

Sector and Sub-Sector		Total Impact on Sector GDP $CDN 1992, millions	Total Impact on Employment persons
Agriculture, Fishing & Logging		49.4	1471
Mining and Processing		2,824.0	19,164
Services Related to Mining		212.5	4,674
Food Products		59.0	745
Rubber and Plastic Products		122.6	1,515
Machinery & Equipment		109.6	2,018
Aircraft & Parts		17.2	254
Motor Vehicle & Trucks		29.8	509
Electronic Equipment		21.2	301
Communications, Wire & Cable		21.5	362
Other Electrical Products		58.4	1,200
Non-Metallic Mineral Products		130.5	1,970
Refined Petroleum		47.9	587
Chemicals, Industrial Chemicals		214.3	2,282
Repair and Construction		323.9	6,735
Air Transport Services		49.8	781
Railway Services		219.1	3,209
Water Transport Services		94.4	1,438
Truck Transport Services		362.5	7,118
Other Transport		53.7	1,865
Telecommunications		256.0	2,196
Electric Power Systems		1,638.3	7,691
Gas Systems		106.6	577
Other Utilities		52.4	1,046
Wholesale & Retail Trade		1,585.0	39,498
Financial Institutions		838.9	12,365
Other Business Services		336.2	9,017
Professional Business Services		412.7	8,976
Accommodation & Food Services		85.4	4,212
Miscellaneous Services		344.0	12,801
Total		**$ 12,794.4**	**187,877**
Total Excluding Own Sector		**$ 9,075.2**	**149,284**

Source: P. Dungan, *Rock Solid: The Impact of the Mining and Primary Metals Industries on the Canadian Economy*, Toronto: University of Toronto Press, 1997

III. THE MINERAL MACHINERY AND EQUIPMENT INDUSTRY (MMEI)

Although it emerged principally to supply the Canadian mineral sector, Canada's mine machinery and equipment industry is fully integrated into the global industry, as is the case, of course, with the mineral sector itself. A typical mine in Canada and in most other countries will normally utilize equipment produced in many countries. The Canadian industry has evolved historically mainly to supply machinery and equipment to hard rock underground mines within the context of a relatively open trading environment and located beside the United States, which has been a leader in the minerals equipment industry.

In general terms, the Canadian MMEI is strong in all phases of prospecting, exploration and exploration drilling. It is also reasonably strong in a broad range of underground equipment. It appears to have reasonable strength in processing equipment production. However, it is surprisingly weak in most lines of surface mining equipment. This pattern can be observed in Table 7.

The development of a wide range of enterprises producing various types of airborne prospecting instruments together with relevant computer software, and exploration equipment of all sorts is a major Canadian success story, which is discussed in more detail in Section VII below. It involves a harmonious supply-side mix of geoscientific aerial survey and computer expertise on the one hand with a history of publicly financed geological surveys on the other hand all on the basis of a generous mineral endowment. These enterprises provide instrumentation and aerial services globally. The demand for this equipment should remain relatively strong as its sensitivity improves. Canadian production of prospect drilling equipment (exploration drills, rigs, bits and accessories, probes and instruments) and ground-based and laboratory geophysical instruments is also particularly strong.

In the production of drilling and blasting equipment, Canada has some areas of strength.. Mine development drilling equipment is quite strong. Underground drilling equipment for mineral ore extraction or "production drilling" is also reasonably strong, with a number of major internationally competitive firms involved (JKS Boyles, Breaker Technology Ltd., Svedala,

Table 7: CANADIAN CAPABILITIES IN MACHINERY EQUIPMENT AND SERVICES FOR THE MINERAL SECTOR

Activity and Type of Equipment or Service	Number of Suppliers	Overall Position
I EXPLORATION		
1. Airborne Mapping and Surveying		
Aircraft	2 or 3	Good
Equipment and Instrumentation	Numerous	Very Good
Aerial Services	Numerous	Excellent
2. Exploration Drilling		
Drilling		
Equipment	21	Excellent
Services	Numerous	Excellent
Diamond Drilling		
Equipment	Numerous	Excellent
Services	Numerous	Excellent
Reverse Circulation		
Equipment	4 +	Good
Services	Numerous	Excellent
3. Exploration Software	7	Excellent
4. Assaying		
Equipment	3 +	Good
Services	5 +	Excellent
5. Geophysical Surveying		
Equipment	13 +	Very Good
Services	11 +	Excellent
6. Geochemical Surveying	5 +	Excellent
7. Geological Surveying	5 +	Very Good
Equipment	Numerous	Excellent
Services		
II UNDERGROUND MINING		

Activity and Type of Equipment or Service	Number of Suppliers	Overall Position
1. Production Drilling		
Drill Rigs	9	Very Good
Custom Engineering Design	3 +	Very Good
Drilling Services	Numerous	Excellent
Drill Consumables		
Bits	10 +	Excellent
Steel, Rods, Couplings, etc.	9 +	Excellent
2. Underground Mine Development		
Drill Rigs and Jumbos	12	Very Good
Raise Borers	3	OK
Raise Climbers	3	Very Good
Tunnel Borers	4	Good
Shaft-Sinking Equipment	5	Good
3. Head frames, Winding and Hoisting		
Hoisting System Design	5	Very Good
Head frames, Cages and Shaft Equipment	3 + ?	Very Good
4. Underground Transport		
Rail Mounted		
Locomotives	-	Zero;
Mine Cars	1	Weak
Load-Haul Dump Vehicles	3	Very Good
Parts and Rebuilders	numerous	Very Good
Articulated Dump Trucks		
New	1	OK
Rebuilders	3	Good
Utility Vehicles		
New	3 +	Very Good
Rebuilders	2 +	Very Good
2. **Electrical Equipment**	Numerous	Excellent
III SURFACE MINING		
1. Drilling Equipment		
Blast Hole Drills	1	Weak
Drill Consumables: Bits, Drill Steel, Rods,		

Activity and Type of Equipment or Service	Number of Suppliers	Overall Position
Couplings	8	Good
Rock Boring Equipment	8	Good
Custom Engineering Design	Numerous	Good
2. Mine Excavators		
Front-End Loaders	0	Zero
Continuous Surface Miners	1	Weak
Draglines	0	Zero
Bucket-Wheel Excavators	0	Zero
Mining Shovels	0	Zero
Wheel Loaders	0	Zero
Component Parts	8	Weak
3. Haulage Vehicles		
Off-Highway Trucks	1	Weak
Articulated Trucks	0	Zero
4. Ancillary Vehicles		
Crawlers		Zero
Graders	0	Zero
Utility Vehicles	0	Weak
IV MINERAL PROCESSING		
1. Metallurgical Engineering		
Plant Design	6 +	Good
Process Design	7 +	Good
2. Crushers (all types)	4 +	Good
3. Feeders	3	OK
4. Filtration & Thickening Equipment	2 ?	
5. Grinders (all types)	5	Reasonable
Accessories and Parts	5	OK

Sources: *CAMESE Compendium of Canadian Mining Suppliers, 2000/2001*.

Marland and Boart-Longyear) as well as many smaller firms. (See Appendix Table 2.) A wide variety of utility vehicles with drilling, blasting, shot-crete and other applications is also produced.

Canada is particularly weak in surface mining equipment. While some heavy surface mining equipment was produced in the 1980s, by 2000, virtually all of it was imported. Large-scale off-road haulage trucks, large front-end loaders, crawlers, and even much of the blasting equipment seems to now be imported. This is unfortunate given the trend away from underground mining and towards surface open-pit mining, both in Canada and internationally. Indeed, even within Canada, over 64% of prospective mine projects, namely in the coal and petroleum bearing “oil sands,” are surface mine projects, rather than underground

On the other hand, Canada is strong in most lines of underground equipment. Canadian-based firms are prominent in underground drilling rigs and ore transport and in the production of mine hoists and shaft equipment. They have a presence in continuous hardrock mining systems, provide a broad variety of utility vehicles, and have a reasonable place in shaft, hoisting, electrical, ventilation, dust removal, water removal, and communications subsystems required for underground mining, together with computerized mining process control systems and instrumentation. There are a number of Canadian manufacturers of underground LHDs (load-haul-dump) vehicles as well, namely Tamrock of Finland, (formerly Eimco Jarvis-Clark) in Burlington Ontario, Dux Machinery Corporation in Repentigny Quebec, and Mining Technology International in Sudbury Ontario.

The production of mineral processing equipment in Canada appears to be reasonabe. Crushers of various sorts, grinding mills, vibrating screens and ore separators, flotation cells, launders and mixers, filtration equipment, pumps, and furnaces/roasters/dryers are all produced by firms in Canada, although with varying degrees of domestic content ranging from 70-75% (for vibrating screens & sorters) to 100% (crushers) (DITC, 1982, pp.39-40). For smelting and refining processes developed by Canadian mineral companies (e.g. Inco's flash copper smelting process and nickel refining processes), Canadian manufacturers have expertise and experience in providing much of the relevant equipment.

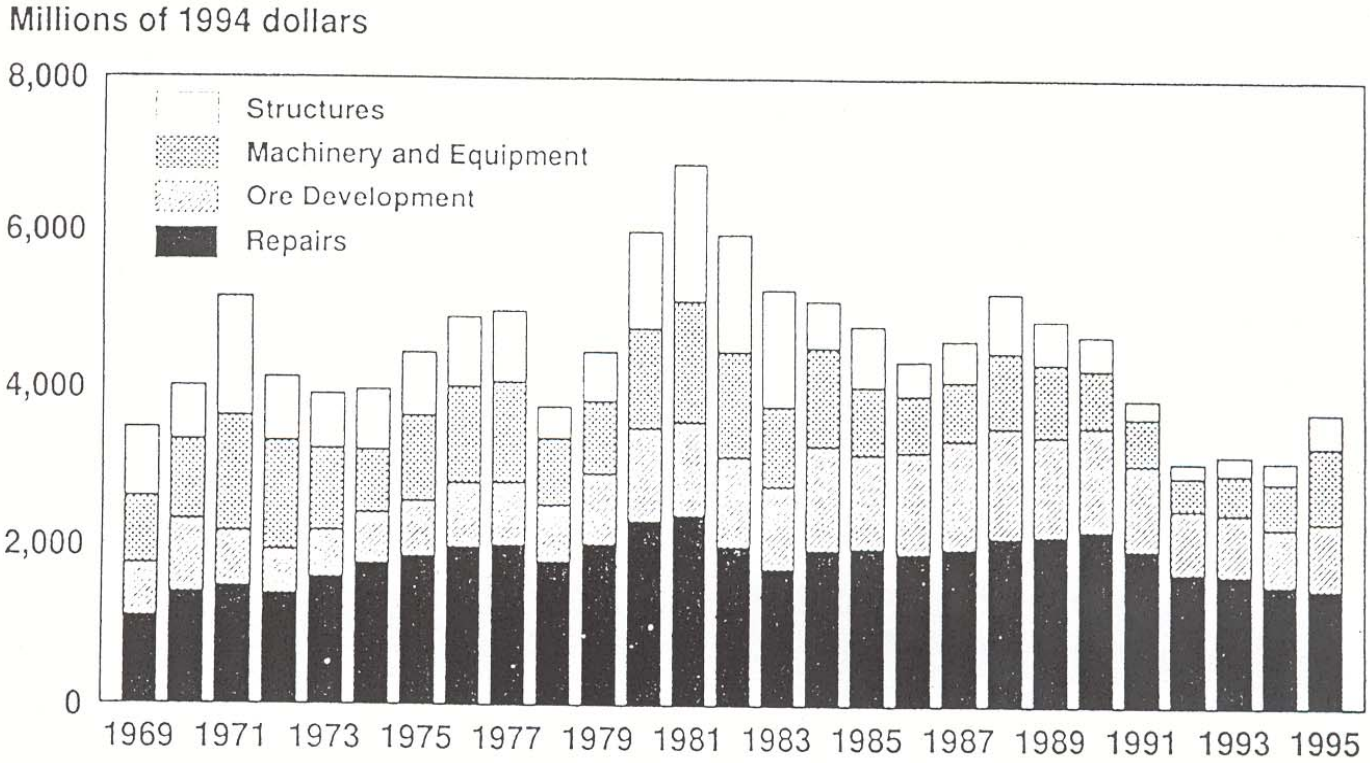
One can obtain an indication of the value of mine machinery and equipment produced for

domestic Canadian use from information on investment expenditures by mine enterprises. The pattern of investment expenditures in mineral extraction on structures, machinery and equipment, ore development and repairs is illustrated in Figure 4. The large amount of investment on repairs and ore development is surprising. It overwhelms expenditures on structures and machinery and equipment significantly. In 1998, for example, investment on capital and repairs in mining but excluding oil sands and petroleum amounted to $CDN 5.093 billion, with about 65% devoted to repairs. These numbers provide some idea of the magnitude of the Canadian market for market for mine machinery and equipment as well as structures. However, the investment figures also include labour and other non-machinery inputs into mine construction such as electrical energy and fuel, for example.

It is difficult to piece together an accurate picture of trade patterns and trends for MMEI. This is because much equipment of general industrial application is used in the sector and is not recorded or measured according to its mining-type end-use. An older and incomplete estimate of the size of the market is presented in Appendix Table 4. In this table, the first categories show the value of trade in machinery and equipment that is used only in mining (with the partial exception of "earth drilling and related machinery and parts".) The second set shows related machinery and equipment, only some of which would be used in mining. The figures for MME, defined narrowly in the Table would appear to be incomplete. For example, exports of general industrial equipment (e.g. pumps, compressors, computers, ventilation systems, electrical systems, motors or parts) are likely recorded under other categories despite their minerals sector destination. The values of exports of many types of machinery and equipment were probably a good deal higher in the 1990s than in those for the 1980s would suggest. Unfortunately data in a useful format for current trading patterns is not available at this time.

Figure 4

Mine Investment in Canada, 1969 - 95 by Investment Category



1994 data are preliminary, 1995 data are intentions.
Source: NRCan, based on Statistics Canada data.

IV. MINERAL SECTOR SERVICE ACTIVITIES

1. Exploration Services

A wide range of service activities surrounds the mineral exploration companies and the exploration activities of the larger integrated mining enterprises. Again, it is difficult to know the magnitude of this part of the mineral cluster, mainly because there does not seem to comprehensive information available on the international activities of Canadian exploration firms.

Within Canada, however, we know that there were 609 firms, including129 of the larger "seniors," 480 smaller "junior" exploration firms and numerous independent prospectors. These enterprises spent almost $CDN 600 million in 1998. However, the planned budgets of the larger Canadian based companies – mainly the larger "seniors" - for exploration outside of Canada amounted to $967 million in 1998 (Canadian Intergovernmental Working Group, 2000, p.110.) The magnitude of the exploration activities of Canadian firms can be understood with a glance at Figure 3 above, which provides information on exploration budgets in different countries and the numbers of exploration properties in different parts of the world. In each case, the relative magnitude of foreign relative to domestic exploration activity is evident.

The size of the exploration budgets provides an impressionistic idea of the size of the activities that provide goods and services to mineral exploration projects. Included in such goods and services would be geo-scientific consultants of all sorts, (geologists, geophysicists, geochemists, and others,) geological surveying, aerial cartographic services, satellite imaging and remote sensing, data management, assaying enterprises, contract drilling, aircraft surveying, air transportation, expedition outfitting, exploration software, due diligence investigation, auditing and community relations specialists.

Large numbers of Canadian enterprises provide these services. A full count for the domestic market appears almost impossible to determine, because so many are involved in the general as well as mineral specific support activities. Some idea of their relative significance can be gained by considering the number of such enterprises which are involved in export to a significant degree. For example, of the enterprises included in the CAMESE Compendium of

exporters, 103 were in fact providing exploration services, out of the total 222 suppliers of goods and services to the mineral sector generally. Many such suppliers were not members of CAMESE, so that its membership is a substantial understatement of the international presence of such firms.

The specialized exploration services are a crucial part of the mineral cluster. They lower exploration costs and increase the effectiveness of exploration activities. The expertise they have acquired over the years, and particularly in the last decade are of tremendous value to the mineral cluster generally because they find the new ore bodies and convert speculative deposits into actual mine projects. They contribute to this process globally but also specifically in the context of the Canadian mineral cluster.

Analytical laboratories are also an important part of the services to exploration. They determine the quantities and values of the minerals in the raw ores samples. This information is of course crucial in the determination of whether a potential mineral deposit can be converted into and active and viable mine.

2. Contract Drilling

One important type of service is contract drilling, for exploration purposes as well as mine development and mineral extraction. This activity has become specialized so that some exploration firms contract out the drilling function. These enterprises undertake both the initial exploration drilling and the more intense “proving up” of ore bodies in order to determine the size, quality and lay-out of ore bodies prior to the decision to invest in a new mine and for the design of a mine operation. Production drilling and mine development, both underground and surface mining may also be contracted out to these specialist firms. There are numerous such contract drilling enterprises, as well as special suppliers of equipment and drill consumables, special training programs for drill personnel, and also manufacturers of drill rigs and consumables of various sorts. These firms have their industrial association, the Canadian Diamond Drilling Association, which is discussed below.

The drilling contractors provide special advantages for the mineral sector. They have become specialist firms, and lower the costs and improve the quality of these services to the

firms that employ them, and to the mining sector generally.

3. **Consultants Services**

Specialized personnel in all areas, from exploration to mineral smelting and refining, work as consultants, usually in consulting companies but also individually. Those involved in exploration have been mentioned already. Specialized consultants are active in all areas of mineral activity, including:

- Exploration
- Mine construction
- Mine operations, management and trouble-shooting
- Mineral processing
- Smelting, refining and further processing
- Environmental protection
- Mine closure and rehabilitation
- Community relations
- Training programs
- Marketing and export services

Such consultants services also invaluable as they lower the costs of crucial expertise and make it available to the mineral sector broadly on a “fee for service” basis. This is far less costly than attempting to maintain the relevant expertise “in-house”, which would be costly for large enterprises and perhaps impossible for smaller firms. The gains from specialization for the whole mining sector of Canada and the world through use of the services of such enterprises and individuals are likely very significant.

4. Engineering, Construction and Procurement (EPC) Firms, Engineering Firms, and Mine Construction

The specialist engineering, construction and procurement (EPC) enterprises that have evolved to design, build, and procure the inputs and building materials for new mines and processing facilities are also of obvious significance to the sector. These firms are of great importance not simply because they design and build the new mine and processing installations, which is significant enough. Such enterprises need engineering expertise in a number of areas,

including geology, mining, mineral processing, hydro-metallurgy, pyro-metallurgy, by-product recovery, bulk materials handling, environmental engineering and protection, and procurement. In the process of designing a mineral extraction and processing operation, they also influence the choice of the machinery and equipment to be used in the operation. They undertake the procurement and arrange the timely delivery of the various component parts, machinery and equipment. They also sub-contract the various specialist services needed for the construction of the facility.

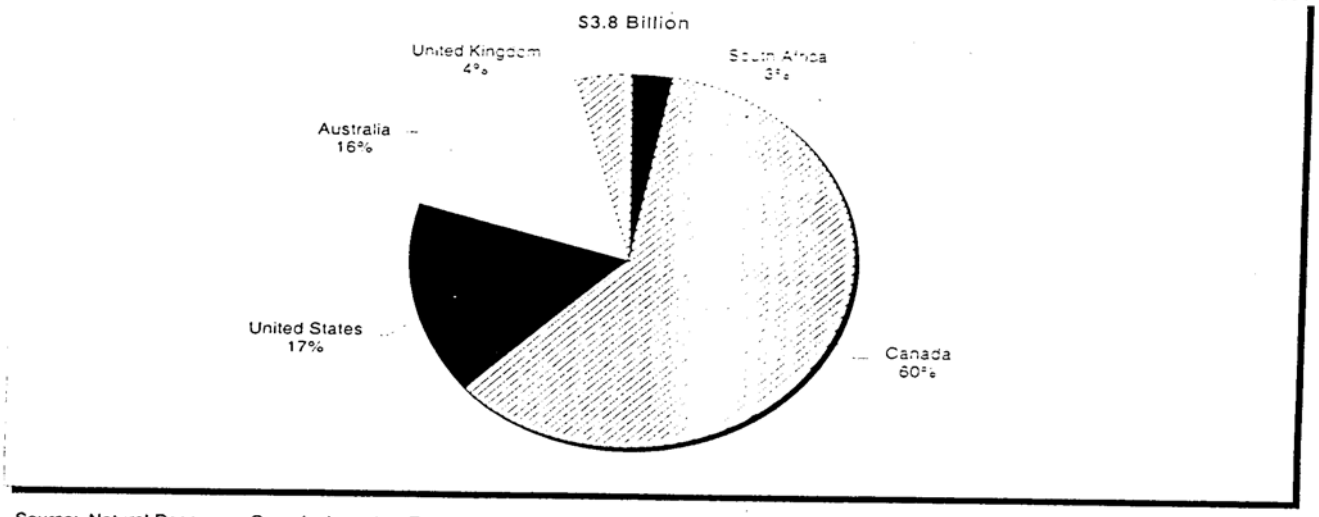
There is probably a normal tendency for EPC enterprises to sub-contract with the specialist enterprises with which they have worked for long periods of time and with which relationships of trust and confidence have been established. This means that an EPC firm from one country probably has a tendency to purchase machinery and equipment and arrange sub-contraction with enterprises from the home country.

How strong are Canadian engineering and construction enterprises? There are a number of firms with outstanding international experience and a range of other enterprises. Among the largest and best-known are SNC-Lavalin, which has recently amalgamated with a number of middle sized firms in the mining area. A second is Redpath-Mackintosh. There are numerous Canadian engineering firms, which design processes as well. These firms are active internationally. However, some of the biggest and best known EPC firms are still from the United States and Europe, and are involved in many of the biggest new mining projects.

Many other engineering enterprises specialize in specific aspects of mine construction and mine site development. All of the various dimensions and stages of construction on mines and mineral facilities have specialist firms: electrical systems, shaft boring and construction of lifting systems, underground ore development, ventilation systems, bulk management systems, water removal systems, environmental protection, processing facilities, smelters, etc. etc. The significance of all of these for the evolution of Canada's mineral sector and increasingly the international mining economy can not be underestimated.

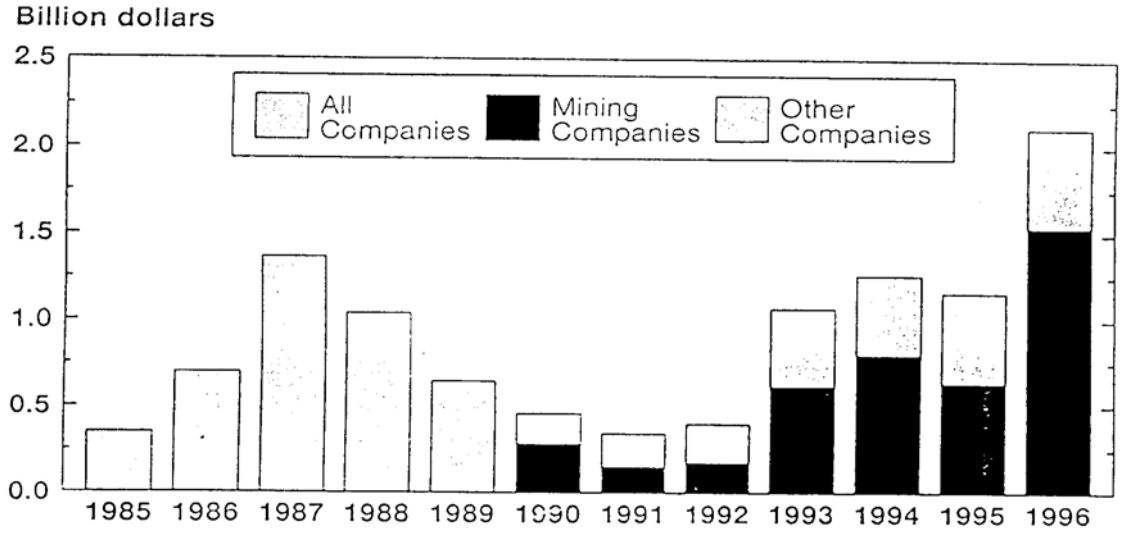
Figure 5

Sources of Equity Financing for the World's Mining Companies, 1998



Source: Natural Resources Canada, based on Toronto Stock Exchange, Securities Data Company, Financial Post DATAGROUP and Gamah International.

Figure 6: Funds Raised on the Vancouver Stock Exchange, 1985-1996



Source: Natural Resources Canada, based on the VSE Statistics Book.
Note: Data for mining companies for 1985 through 1989 are not available.

V. SERVICES RELATED TO THE MINERAL SECTOR

There are a number of ancillary services which are deeply involved with the mining sector in Canada, and which are important elements in the mineral cluster. A few of the more important of these are discussed briefly in this section.

1. Financial Services

One crucial component in the emergence of the Canadian mineral cluster has been the financial sector. Institutions have emerged which have permitted funds to be raised for investment in new mine projects, and in the highly speculative attempts to locate new and commercially viable mineral deposits in Canada and the rest of the world. These institutions include the Toronto Stock Exchange, the Vancouver Stock Exchange (now CDNX,) the banks, which have special expertise on the mineral sector, and the whole network of financial analysts, mining analysts, stock promoters, and due diligence lawyers and legal firms.

The role of Canadian stock markets in supporting and promoting the mineral cluster is most impressive. Apparently about 75% of the world's mining enterprises – 1447 in all - are listed on Canadian markets, while on the other four important mining sector stock exchanges combined, (the Australian Stock Exchange, the NYSE, the LSE and the JSE) a total of 481 mining firms were listed (Ibid. p.41.) Reflecting this is the fact that more mining enterprise home offices are located in Canada than any other country. Many of these of course are the smaller "junior" mining enterprises involved in exploration.

Market capitalization of mining stocks accounted for about 20% of the total in Canadian stock exchanges (Ibid. p. 30.) Banks also have specific expertise on the mineral sector and are active financiers of mineral projects. Related to the stock exchanges as well are the financial and mining sector analysts who advise on investing in the sector together with various types of stock promoters. These individuals play an important role in marketing stock issues for new exploration and mining ventures.

These institutions are responsible, in large part, for the financing of a large proportion of

mineral exploration as well as a significant part of the development of new mineral projects both in Canada and around the world. In 1998, 60 % of the total $CDN 3.8 billion in equity financing in the world for mining companies was raised in Canada. This compared with 17% in the United States, 16% in Australia, 4% in United Kingdom, and 3% in the Republic of South Africa, as indicated in Figure 5. It might be noted that the total equity financing for 1998 was far below the quantity of funds raised in 1996, which reached at least $CDN 10.5 billion, again with 60% raised in Canada. (Ibid. p. 43.)1 The reason for this reduction was due mainly to the decline in mineral prices reflecting the Asian financial crisis and the reduced demand for minerals, perhaps aggravated by the Bre-X scandal in Canada.

The Vancouver Stock Exchange, now the Canadian Venture Exchange (CDNX) has been particularly active in the mining area. Prior to 1997, most of the funds raised on that exchange were destined for the mineral sector, as indicated in Figure 6.

It was basically through these institutions through which the exploration projects undertaken by Canadian firms in many parts of the globe were financed.

2. The Specialized Minerals-Oriented Press and the Press in General

Communications and diffusion of information within the mineral cluster are vital to its existence and functioning. Constant scrutiny of the activities of the numerous companies and incessant criticism of all the actors are vital for maintaining as much transparency and efficiency in the cluster as possible. For these purposes, an active press and a specialised and knowledgeable cohort of reporters and analysts are crucial.

A specialised mineral press has emerged in Canada together with a significant fraternity of specialised reporters who work in both the specialised and the general press. Pride of place in the mineral oriented press probably goes to the weekly newspaper, *The Northern Miner*, established in 1915, which bills itself, probably correctly, as North America's Mining Newspaper. This publication focuses on general mineral sector news, Canadian and International, exploration throughout the world, and mineral sector financing. It includes

1 It is interesting that despite a reputation for caution in a number of areas, Canadian citizens have been the world's foremost gamblers in the mineral exploration business, which is in effect a giant lottery where the chances of striking it rich exist but seem to be small. It is commonly estimated that less than 1% of mineral occurrences discovered are

information on input suppliers, a professional directory, supplier's advertisements, and employment advertisements. It is a key source of information on the sector for all participants and actual or potential investors. A second newspaper is the *Canadian Miner*, "Canada's Global Mining Business Newspaper." Other mineral newspapers and numerous periodicals play important roles in the mineral area. A major national publication is the monthly *Canadian Mining Journal*, established in 1879. It covers major mining issues and projects, in Canada and internationally. Numerous other publications for some of the professional associations involved in mining or for various subgroups of the sector are also produced. The Canadian Diamond Drilliing Association has its own publication, for example. The Canadian Institute of Mining, Metallurgy and Petroleum has its own journal and bulletin. The general press and general business press also have some specific expertise on mining with specialist reporters.

3. Business and Professional Associations

A vital component of the mineral cluster consists of the associations of businesses related to mining, professional associations, and labour unions. There are a total of 61 business associations, which are involved with the mineral sector (NRC 2000, p.32.) Of these, 16 are associations of prospectors and developers. Fourteen are *Chambers of Mines*, that is, Provincial, Territorial and National associations of mine enterprises. There are at least 14 associations of producers of specific minerals.

A number of associations might be mentioned specifically. The first might be the national *Prospectors and Developers Association of Canada (PDAC.)* This organisation consists of about 5,000 individual members who are engaged in mineral prospecting and about 200 corporate members who are similarly engaged. The membership includes a range of individuals involved in the processes of mineral exploration and mine development, including prospectors, geologists and geoscientists, exploration managers, consultants, mining executives, geological survey and government representatives, and junior and large-scale mining company personnel. The PDAC provides a framework for dense net-working and information diffusion in all parts of the mineral exploration cluster.

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worth evaluating, and about 10% of the latter eventually become active mines.

The *Canadian Mining Association*, established in 1935, is the national organisation of Canadian mining enterprises. Its core membership consists of 31 mining enterprises, which account for a large proportion of mineral output in Canada. There are also 22 associate member enterprises in various areas linked to the mineral sector, such as transportation, banking, mine machinery, engineering and consulting. The central objective of this association is to promote the development of the sector "for the good of all Canadians," and to promote the sector's interests at the national level and internationally as well. This organisation has been instrumental in maintaining a harmonious and constructive relationship with the federal government.

The *Canadian Association of Mining Equipment and Services for Export*, as its name suggests, is a trade association designed to help promote the international marketing of goods and services for the mineral sector produced by Canadian enterprises. Established in 1981 and consisting by 2000 of 230 member enterprises, it has been instrumental in supporting both Canadian enterprises supplying the mineral sector in their shift towards international markets, and mining enterprises abroad who benefit from Canadian exports of mineral sector equipment and services. It has made a major contribution to the promotion of and "identity" and a "culture" for the broad mineral cluster in the international arena.

The *Canadian Diamond Drilling Association* includes about 74 enterprises involved in contract drilling, the production of goods and services for drilling for exploration, mine development, underground ore extraction and surface mine extraction. Its membership is spread across Canada and has a significant presence in Latin America, the United States and other countries. The Association promotes its common interests, serves as the voice of the industry, and makes recommendations to governments.

Another association of interest is *the Machinery and Equipment Manufacturers Association of Canada.* This is an organization of the larger capital goods producing industries in Canada. It includes divisions for the major user sectors of the economy and has a section for mine machinery and equipment. Its focus on mining is diluted with its broader concerns for the machinery and equipment producers' sector in general.

Noteworthy as well is the *Canadian Aboriginal Minerals Association*. This association is

indicative of the greater role being undertaken by Canada's First Nations in mineral sector development. It also highlights the attempts by local communities to increase the net benefits from mineral development accruing to them through the establishment of enterprises to supply goods and services to the growing number of mines in the northern parts of Canada.

An additional important component of the cluster is the large number of associations of professionals involved in various aspects of mining. Of the total 39 associations listed by NRC (2000, p.33) some 20 associations involve geo-scientists of various sorts, another 16 are for professional engineers (with a number of associations including both geo-scientists and engineers,) and four concerned safety and accident prevention. There were also specific associations for Resource Law and Mineral Analysts. Two umbrella organizations should be noted, namely the Canadian Institute for Mining Metallurgy and Petroleum and the Geological Association of Canada.

4. Mineral Sector Trade Fairs

The Canadian mineral cluster is on display every year through various trade fairs at home and abroad. Of particular importance is the annual meeting of the PDAC, ***the International Convention, Trade Show and Investors Exchange*** held each March in Canada. These meetings include three component parts. First, is an academic type of conference with presentations on various themes regarding not only exploration but also the international mineral economy generally. The themes for 2001, for example, include "new discoveries and developments world-wide," commodity trends and forecasts, social issues and the role of local communities in mine projects, geophysical practice, "diamonds: Canada's new best friend," and financing issues.

The second component, the Trade Show permits producers of all sorts of instruments, machinery, or services for use in exploration to exhibit their products. Governmental jurisdictions with mineral prospects with which they wish to interest investors, or with cartographic services to market also participate. In the 2000 Meetings, 20 national governments participated, including most of the major mineral producing countries. Twenty-four provinces, states and territories participated, including 12 from Canada, four major mineral states from the US, and five from Australia. Two cities – Sudbury and Yellowknife – had booths as well.

The third component of the Meetings is the Investors Exchange, which permits prospectors, small exploration companies, as well as some larger firms to display their projects in hopes of interesting major investors who might buy the property in whole or in part and bring it into production. There were some 171 exhibits were at the 2000 Conference.

The Annual 2000 Meeting entitled "Mining Millennium 2000" was held sequentially with the Annual Meeting of the Canadian Institute for Mining Metallurgy and Petroleum, *"MM 2000 CIM Tradex,"* which also included an academic component and a major trade show. The trade show was mainly for suppliers of mine machinery and equipment and related services. It included major producing enterprises for machinery and equipment, some Government sponsored exhibits, and some cities and northern territories wishing to publicize their mineral supply capabilities (Sudbury, Labrador City, and the Yukon.) Five universities with mining engineering and metallurgical programs, as well as the Sudbury-based Northern Centre for Advanced Technology, "Norcat," were also represented.

These annual conferences appear to be the central venue for the "gathering of the clans" involved in all aspects of the mining world and culture. Their value for information diffusion as well as networking and deal making must be enormous.

Canadian enterprises have also participated in mineral trade fairs in other parts of the world, including the United States, Mexico, Chile, Argentina Peru, and elsewhere. The Canadian Embassies provide organizational support for Canadian exhibitors at the more distant locations.

5. Education and Training

The public educational system performs a vital role in the mineral cluster. Every Canadian University has a Geology Department, which produce the exploration professionals in the country as well as numerous other types of geoscientist. A substantial number of Universities also have Departments of Mining Engineering or Mining and Metallurgy. (Queen's, McGill, University of Toronto, Universite de Montreal, University of British Columbia, and Laurentian University are some well known Departments.) The Departments of Civil Engineering, Mechanical Engineering and Environmental Engineering also produce professionals for the sector. Computer Science Departments generate the specialists involved in the development of

software for exploration and mine operation.

Middle level training is also provided for specialist mine and processing facility personnel. Haileybury in Northern Ontario specializes on mine personnel, and numerous Community Colleges train relevant tradesmen for the sector. Private firms also offer training in a variety of mining areas such as heavy equipment operation, blasting, etc.

The Universities have also been involved in fundamental and applied research for the mining cluster. Sudbury's Laurentian University in particular has made special efforts to link itself to the mining sector through research activities, as discussed in Section VIII below.

The long history of the educational programs has been vital to the evolution of exploration, mine development, mineral processing, and many of the ancillary activities in the cluster surrounding mining.

6. Transportation

The importance of transportation services serving the mineral sector is obvious. Mineral ores often require transport to processing plants usually by road. Mineral concentrates are shipped to smelters and refiners again often by road or by rail. The smelted or refined products are then shipped to ports or continental destinations by rail. And from East Coast, West Coast and St. Lawrence Ports, mineral products are shipped to distant destinations.

A large portion of the freight carried by Canadian railroads and transhipped at the ports consists of minerals at various stages of production. In 1997, for example, 147.3 million tonnes of revenue earning freight were shipped on Canadian railways, constituting 55.0% of the total freight shipped by weight. The impact of mining on employment in rail transport, road transport and water transport services was estimated by Dungan at 1438; 3209; and 7118 persons respectively in 1992 (See Table 6 above.) A similar estimate for employment in air transport services was 781 persons (Ibid.)

Transportation of mineral product at crude and refined stages is an important component of the demand for transcontinental rail services and port services, and helps cover the overhead costs of maintaining the system. Without such mineral traffic, the overhead costs of the system would have to be borne by other users in other economic sectors.

Personnel are transported increasingly by air. Most new mine sites in the Canadian North are not accompanied by the construction of mining towns. Instead, workers are flown in and then flown out to established towns in the region. Indeed, “fly in – fly out” mining appears to be the wave of the future, mainly because it eliminates the expenses of constructing mining towns which have a limited life span. “Long Distance Commuting by air also strengthens the existing home communities of the workers. Reliance on air transport for this purpose can only increase in future in Canada..

In the exploration phase as well, air transport has been used since the early part of the last century in order to gain quick access to distant exploration sites.

VI. EXPLAINING THE EMERGENCE AND ARTICULATION OF THE “CLUSTER”

1. The Mineral Endowment, Size and Location;

The foundation of the Canada’s mineral cluster is obviously its generous endowment of mineral wealth resources. Without this, Canada would clearly not have developed much of a mining industry or the range of activities surrounding it. An idea of the strength the mineral sector was provided in Section II.1 above and need not be repeated here.

The large size of Canada is also a factor of relevance in explaining the emergence of the successful exploration “sub-cluster.” Public pre-occupation with exploring and mapping the Canadian territory began in 1841, and governments have had an interest in exploration, cartography and geological exploration and mapping ever since. The interest in terrestrial and geological mapping has continued to this day and been a major stimulus to the development of improved surveying and cartographic technologies. This has been an important factor explaining the emergence of the highly successful mineral exploration “sub-cluster.”

2. Technological Evolution and the Mineral Cluster

The character of Canada’s mineral cluster has been shaped by the evolution of

technology in mining and mineral processing and by the process of technological innovation and diffusion. Very important in this process have been the unique geological features of part of Canadian mining as well as proximity to the United States and openness to international trade in machinery and equipment.

Before proceeding with an analysis of the technological forces that have influenced the evolution of the mineral cluster, it is useful to describe briefly the nature of technology in the mine machinery, equipment and instrumentation areas. This can be done most quickly with the assistance of the categorisation summarised in Box 2 below. (This is an elaboration of a set of classes used by the Department of Energy, Mines and Resources now Natural Resources Canada, (1982, p.115) and is just one of a number of possible classifications.) As illustrated in Box 2, the machinery and equipment industry for the mineral sector covers a broad range in terms of its technological complexity and sophistication. The categories are based first on whether the machinery and equipment is specific to the mineral sector (Categories I: A, B and C) or is of general industrial applicability (Category II: D, E, and F) and second, on the sophistication and/or complexity of the machinery. Some types of both specialized and general machinery and equipment are less technically complex, and as can be seen from the examples in the table, some of it is also “high-bulk”, and “high-weight” but “low-value.” Enterprises producing this type of machinery and equipment tend to locate close to intense mining areas due to transportation costs, and because it is technically possible. On the other hand, it is more difficult for countries to move into the “high tech” production lines, both those specialized for mining, and those general industries with mining applications.

The necessity to establish close, enduring and fruitful interaction with customers, component producers, and engineering firms means that the process of entering the capital goods industry is not easy. Large established enterprises usually based in the high income countries, have often cultivated these linkages over long periods of time. They have achieved a sufficient scale and have accumulated a sufficient number and mix of design and production engineers to maintain the effective functioning of these networks.

It also should be emphasized that modern mining and mineral processing almost always occur in sophisticated and complex systems involving many types of equipment linked together for

continuous production. But while modern mining and processing are complex, some of the

Box 2. A TECHNICAL CATEGORIZATION OF MINE MACHINERY AND EQUIPMENT

CATEGORY; DESCRIPTION	EXAMPLES
I. Specialized Machinery for the Mineral Sector Only	
A1 Specialized sophisticated MME where scale economies are important	Drill systems and vehicles; UG+OP loading & hauling vehicle's;, engines, transmissions and hydraulic systems;
A2 Specialized sophisticated MME with limited scale economies	Airborne geophysical instrumentation; raise, shaft and tunnel borers; road-headers
B Specialized engineered mid-tech" MME where scale economies are less possible	Winches, hoists and related; shaft furniture; head frames; crushers; some process equipment; special purpose UG or OP carriers and vehicles
C Specialized "low-tech" MME often high-bulk or weight vis-à-vis their value	Sheet-metal fabrications (bins, hoppers, vats, tanks) "custom castings", conveyor components; drill steel and bits; rock bolts; grinding media; track mounted vehicles; mine supports.
II General Industrial MME also used in mining	
D "High-Tech"	Process control systems; communications systems; instruments; some vehicles; exploration aircraft; laboratory equipment
E "Medium-Tech"	Diesel engines; compressors; electric motors; general purpose pumps; ventilation and dust collection systems; some bulk materials handling; some vehicle components
F "Lower-Tech"	Structural steel and construction materials; track; hose, liners and rubber products; piping; air ducts; some vehicle components (e.g. batteries); some hand tools

types of equipment are less so, as indicated in Box 2 with categories C, the specialized but

“lower-tech” equipment and F, the general “lower-tech” equipment. It is interesting to note that even very complex mineral processing (crushing, grinding, concentrating) involve certain types of equipment that are relatively simple (e.g. bins, tanks, hoppers, feeders, screens).

In Canada’s case, the volume of mining, together with the general level of industrial development

has meant that the “lower-tech” equipment is produced and indeed much of it has been produced for a long time. Canada has also steadily moved into the “medium-tech” areas for both the specialized and general-application machinery and equipment. For the production of specialized “high-tech” equipment focusing in part on the hard-rock underground Central Canadian mining area, there has been considerable success. Much of this machinery and equipment is to some degree “customized” to fit the idiosyncrasies of hard rock underground mining, and does not lead to major economies of large scale production for broader international markets. On the other hand, there is some types of high-tech machinery such as LHDs, that have the potential to be produced for larger international markets thereby yielding major economies of scale.

Some firms have developed specialized lines of products which are competitive in international markets. Usually such success in foreign markets has been built on a base of a reasonably strong domestic market. The Tamrock LHD for example, was developed for the relatively large Canadian market and now is marketed effectively.

An important element in the continuing development of the mine machinery industry is the relationship between the mine enterprise users and the producers. In the Canadian case, some mines had relationships with foreign firms, so that new types of machinery have been suggested, modified and proven by Canadian mines but with the foreign enterprises. One exception to this appears to be Inco which has had a long-standing and close relationship with some Canadian-based machinery firms, many in the Sudbury region, and of developing new lines of machinery and processing systems in conjunction with them. More recently, INCO established the firm Continuous Mining Systems with which it developed a number of new product lines. (This enterprise has since been “spun off,” and is now known as Mining Technologies International.)

The evolution of the Canadian mining machinery sector has been shaped also by its

proximity to the United States. This has meant that Canadian mine enterprises and Canadian machinery and equipment firms have continuously been exposed to leading edge technologies. The mine companies purchased imported machinery when it was desirable for them to do so. The Canadian machinery enterprises thus had to compete with the US suppliers, or learn from them quickly if they were to remain competitive and in business.

Most of the machinery and equipment used in Canada for surface mining is imported mainly from the United States but also from Japan and elsewhere. As indicated in Section III Table 7 above, Canada is exceedingly weak in large-scale off-road ore trucks, articulated trucks, blasting equipment, wheeled loaders, hydraulic excavators, hydraulic rope excavators, drag-lines, crawler-dozers, and other equipment for surface mining. The production of these lines of machinery is now undertaken by a small number of large international conglomerate enterprises that produce broad product lines of earth-moving, construction and mining equipment. After amalgamations, mergers and take-overs, the few major companies remaining in surface mining equipment include Caterpillar, Komatsu, Hitachi, Liebherr (Austria and US,) and Terex (US, which bought out Payhauler, Unit Rig, and Orenstein-Koppel,) and Bucyrus International (US.) As noted earlier, the absence of a significant Canadian role in surface mining machinery is unfortunate in view of the steady shift towards open-pit mining from underground mining in Canada and the world.

3. Public Policy and the Mineral Sectors and Cluster

Canadian governments have played a major role in the provision of public goods and services for the mineral sector. These include geological surveying and cartography, the provision of some infrastructure, international marketing support, education and scientific and technological research. This section outlines briefly the contributions made by these roles of the public sector in the development of the mineral cluster.

a. *Geological Mapping and Mineral Exploration*

Canada's public program in geological surveying and mapping began in 1842, when the Geological Survey of Canada (GSC) was established and its first director, William E. Logan set

out to search for coal in the “Province of Canada,” now Ontario and Quebec. This began a continuing effort to survey the resource endowment. In 1863, the first book on Canada’s mineral resources was published, a 983page book summarising all that was known on the subject at the time. A geological map of Canada followed in 1869.

The GSC undertook annual field surveys and indeed explored and mapped much of the country as well as its mineral wealth. This tradition continues up to the present, as the GSC deepens its mapping of the country using the most recent cartographic and geo-scientific technologies plus instrumentation and computer systems. An important spin-off from the mapping effort is the Canada Centre for Remote Sensing which provides mapping and geo-scientific cartography to users in many sectors, for many purposes, and in all parts of the world.

An initiative to consolidate and harmonize geo-scientific research in Canada has been put forward by the GSC and the Committees of Provincial Geologists. They have proposed the establishment of a Canadian Geo-scientific Knowledge Network, which would link the federal

Box 3 Geological Survey of Canada

In operation since 1842, the GSC's central objectives are to provide a comprehensive inventory and understanding of Canada's geology , in order to support mineral and hydrocarbon exploration assessment and development, to help government in the formulation of policies for the rational use of mineral resources, and to address environmental health and safety issues related to the Canada's geology.

To meet its objectives, it focuses on:

- Ascertaining the nation's energy and mineral resources;
- Identifying and assessing natural hazards;
- Analyzing geological features and processes affecting the environment
- Disseminating geological information to other government agencies; industries; and citizens.

The divisions of the organization, largely self-explanatory, are as follows:

- Cordilleran Geology Division (Vancouver, British Columbia)
- Sedimentary and Petroleum Geology (Calgary, Alberta)
- Precambrian Geology Centre (for Central Canada)
- Atlantic Geoscience Centre (Dartmouth, Nova Scotia)
- Resource Geophysics and Geochemistry Division
- Economic geology Division
- Terrain Sciences Division
- Central Laboratories and Technical Services Division
- Geological Information Division.

and provincial geological surveys and would perhaps include academic and private sector participants. It would provide "single window" access to Canadian geo-scientific knowledge for national and international users (National Geological Surveys Committee, 1998.)
A brief summary of the structure of the GSC is presented in Box 2.

b. The Provision of Infrastructure

Major mining projects have often located far from the well-populated areas of the country far from established communities, transportation systems, electric power, etc. In these

circumstances, mining projects have required significant investment in complementary infrastructure. (This of course has not always been the case, as some new mines have been located in established mining areas or well populated regions where adequate infrastructure already exists.) The infrastructure which may be required for a new mine and perhaps a new town-site can include road and/or rail transport, airport facilities, water systems, electric power, natural gas, town site development, streets, sewers and sidewalks, and waste disposal systems. The infrastructural investment requirements can sometimes be larger than the mine investment sector itself.

The federal government and provincial governments have supported mining activities in newly opening areas of the country, when there are likely to be broader social benefits from the provision of such supportive infrastructure, and not solely private benefits for the owners of the mine. Because the infrastructure investments are usually in the public sector and because the benefits of such investment may be disproportionately private as well as "social," the division of the financial responsibilities between private and public sector and in the Canadian case between levels of government as well, is controversial. However, governments are able to charge the main private sector beneficiaries "user fees" for such infrastructure thereby covering or defraying their costs.

The Canadian government has financed general regional infrastructure in a variety of areas such as the Quebec-Labrador iron ore region, the Great Slave Lake area in the North West Territories, the north-eastern region of British Columbia, and the Lynn Lake - Thompson area of Manitoba (Energy, Mines and Resources Canada, p.73.) This type of public involvement has been important in opening up new mining areas, and has been a significant support for the mineral sector generally.

c. International Marketing Support

The central responsibility for the marketing of the mineral products - concentrates, refined or semi-fabricated - rests of course with the mineral enterprises themselves. However, on some occasions and some circumstances, the federal government has played a supportive role to the private sector mining enterprises and the mineral cluster activities more broadly. Among

the public sector contributions to the international marketing of minerals and related machinery and services are the following:

(i) Negotiating improved access to foreign markets, especially for fabricated and semi-fabricated products, bilaterally, regionally and multilaterally;

(ii) Providing "intelligence" regarding foreign markets through the "trade commissioner service" and export promotion services. The Department of International Relations and Foreign Trade (DFAIT) maintains mineral sector experts in a number of its Embassies in key mineral producing countries such as Mexico and Chile to support Canadian activities there. The Department also produces market analyses for key mining countries. (www.infoexport.gc.ca and DFAIT, 2000.)

(iii) Organisational and financial support for Canadian private sector participants at trade fairs held outside of Canada.

(iv) A broad range of information services on various aspects of international marketing, market opportunities, trade legislation, export marketing training; (See for example, www.exportsource.gc.ca; www.infoexport.gc.ca; www.nrc.gc.ca/mms.)

(v) Export financing and insurance through the Export Development Corporation. The Canadian Commercial Corporation also provides market information, support in contract design and negotiations, and export financing.

(vi) Support for CAMESE, the Canadian Association of Mining Equipment and Services for Export, the lead promoter of the export thrust for the machinery, equipment and services producers.

d) Education

The importance of education for the development of the mineral cluster was emphasized earlier, and needs little additional comment. In Canada, all University and Community College education has been in the public sector – at the Provincial level since the early 1950s. Public financing of education in geology, mining and metallurgical engineering, and all other relevant types of engineering, as well as computer science and geo-science, has been of inestimable value in promoting the flourishing of the mineral cluster. Likewise public education in specialized and general trades as well as mining techniques, and heavy equipment operation are all crucial for mining activities.

4. Public Support for the Cluster

The Federal Government has been aware of the importance of the "mineral cluster" for at least 25 years. Indeed, many analysts emphasized the importance of many of the activities surrounding mining for the comprehensive development of the mineral economy long before Michael Porter coined the term "cluster." The Geological Survey of Canada and the emphasis placed on mining and metallurgical research at the federal level provide some evidence of this.

Public interest has also been focused on designing policies to strengthen the linkages between mining and the capital goods industry since the late 1970s. For example, *Mineral Policy: A Discussion Paper* produced by Energy Mines and Resources Canada (December 1981) includes a chapter on "Mineral Machinery and Equipment." This report emphasized procurement by mineral enterprises as an appropriate policy area and stressed the importance of improving communication between the mining industry and the equipment industry. Further policy measures mentioned in the Mineral Policy Discussion Paper of 1982 included:

- inducements to mining companies to integrate into the equipment industry, presumably to facilitate the process of innovation and product development for both the mining firm and the equipment producer;
- explicit use of government R&D (in CANMET for example) and government funded R&D in the private sector to stimulate expansion of Canadian mine equipment production;
- further strengthening of export financing;
- strengthening the linkages between Canadian EPC enterprises and machinery firms.

A major Task Force also produced a report in 1981 on large scale resource sector projects (including mining) and the opportunities they provided for the stimulation of the capital goods industry in Canada (Major Projects Task Force, June 1981.) In this report, the Task Force proposed a variety of recommendations, the central thrust of which was to use procurement policy more directly in order to capture the prospective benefits from "mega-project spin-offs." Indeed the Federal Government in its November 1981 document Economic Development for Canada in the 1980s also emphasized the industrial potential from prospective mineral (and petroleum, tars ands and transport) projects. These suggested initiatives floundered in 1982, as the recession took hold, and as many mega-projects appeared unviable and/or receded into the future. These policy initiatives seem to have more or less disappeared.

However, a variety of public policies have lent general and sometimes indirect support to the "mineral cluster." One could cite the following types of policies as examples of this:

(i) All of the types of support mentioned in Section VI. 3 above:
- education
- infrastructure
- international marketing
- geological mapping

(ii) Support for research and development in mining and metallurgy through CANMET

(iii) General institutional support for the various organizations and associations of the "cluster;"

(iv) Generous tax treatment of mineral exploration;

(v) The promotion of trade liberalization and market access for Canadian produced mineral-oriented goods and services, though all within a more intense free trade environment, with the phasing out of protective tariffs for the sector in Canada.

VI. THE MINERAL EXPLORATION CLUSTER

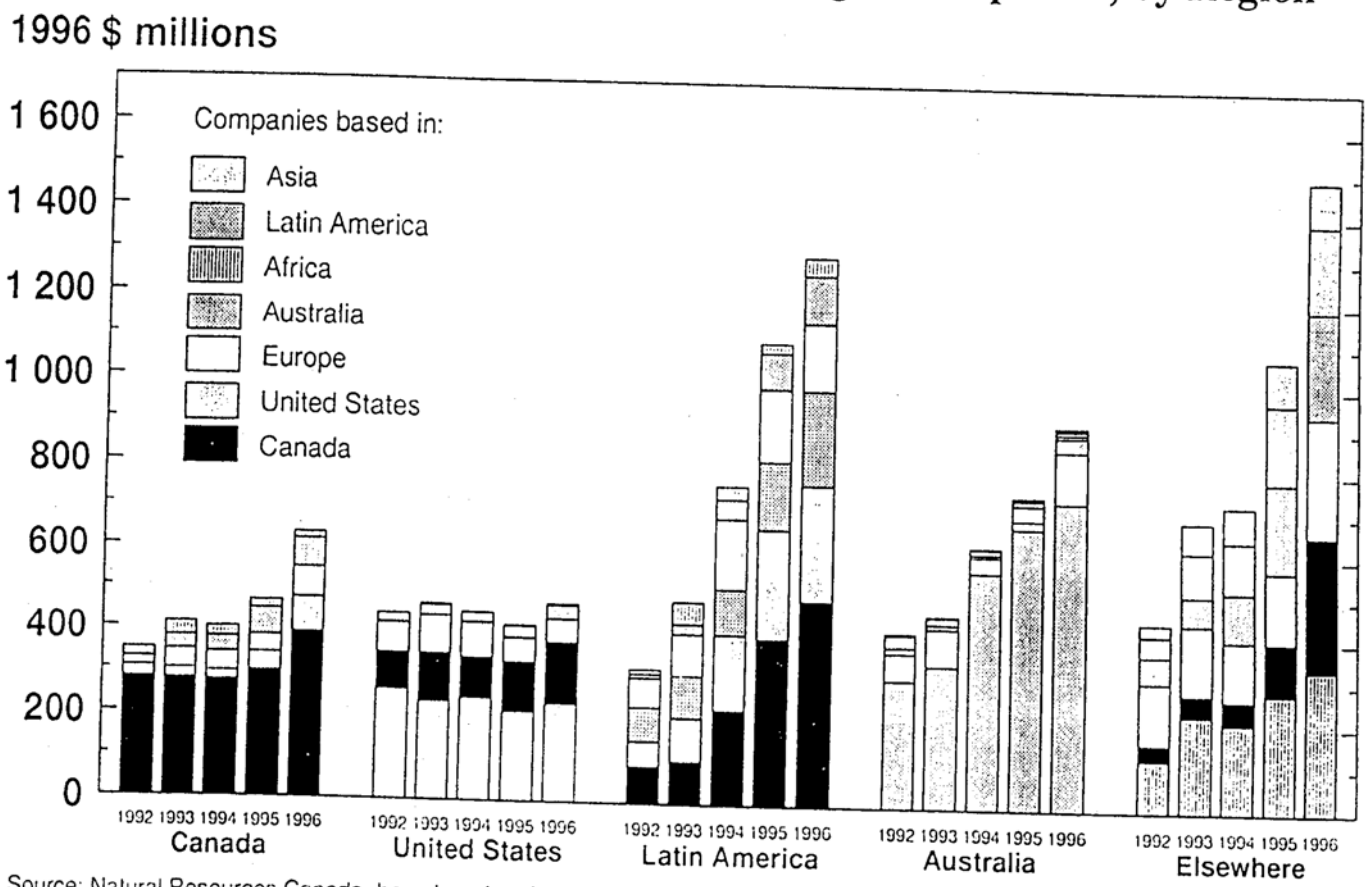
The "exploration sub-cluster" is perhaps one of the strongest parts of the general mineral cluster. In this section, the causal factors underlying the emergence of this sub-cluster of mineral area activity are brought together in order to explain its rather remarkable success.

As outlined earlier, Canadian exploration enterprises ventured out into the world in a major way, especially in the 1990s. By 1996, they were dominating exploration efforts in Latin America as well as Canada and had a significant presence in other continents with the exception of Australia (where Australian firms predominated.) Their relative place in international mineral exploration is illustrated in Figure 7. They had built such a strong base in Canada that they were able to enter the international arena surprisingly quickly. How had they been able to build such a strong base? And why did they extend their activities to the world exploration scene so quickly?

The strength of the Canadian exploration sub-cluster emerged from a variety of fortuitous circumstances and as a result of a good deal of individual effort and co-operative endeavour. Individuals, enterprises, associations and various branches of government all played

Figure 7
Figure 7

Exploration Budgets of the World's Larger Companies, by Region



Source: Natural Resources Canada, based on data from Metals Economics Group, Halifax.
Note: "Larger companies" are defined as those planning to spend $4 million ($US 3 million) or more per year on exploration.

important roles.

1. The Mineral Resource Base

The ultimate source of strength for the exploration sub-cluster was of course Canada's mineral endowment which was there waiting to be explored.

2. Public Sector Action: The Geological Survey of Canada

The mineral potential of Canada's land mass was recognized by the Colonial Government when it established the Canadian Geological Survey (GSC) in 1842. The immediate strategic objective was to locate coal, the basis of early industrial revolutions. But it soon embarked on the major task of exploring, and then surveying and mapping the country. Canada was fortunate that even at the beginning of this endeavour, it was able to use the "leading edge" geological and geographic science of the time, a result of being a British colony, as Britain was one of the countries at the forefront in these areas at that time. Britain was still in high exploration mode in the 1800s, which also lent legitimacy and support to the colonial exploration effort. The GSC has continued its surveying and mapping activities ever since, and has remained at the forefront of the relevant geological sciences. This geological project has served as a foundation for much of the exploration activity in Canada.

The demand on the part of the GSC for top-of-the line techniques, equipment and instrumentation for its activities has also been a stimulus to the development of the producers of such equipment and knowledge, as well as to the enterprises which were able to use such "leading edge" techniques. This likely has made an important contribution to the development of the sub-cluster as well.

3. Prospecting and Exploration Enterprises

Over the years, various mineral discoveries, some of which seem to have been accidental, (such as the Sudbury nickel discoveries,) awakened the popular interest in the mineral sector and in prospecting for gold in particular. Over the years, numerous exploration enterprises emerged to apply scientific methods somewhat more rigorously to exploration than could be done by an individual prospector. The larger mining enterprises also invested in

exploration, usually considerably more than the smaller exploration-only enterprises, or "juniors."

4. Exploration Machinery, Equipment, Instrumentation and Services

To support the intensifying exploration at home and abroad, a variety of Canadian enterprises evolved to provide the various types of machinery, equipment and instrumentation required by the exploration enterprises. As noted in Section III above, this crucial component of the sub-cluster has become surprisingly strong and comprehensive in its product range. It produces aerial equipment and instrumentation together with ground based exploration machinery and equipment. The various specialized suppliers of services to the exploration firms have also developed vigorously.

5. Developing Human Resources: Public Education

The importance of education for the various types of specialists involved in the exploration sub-culture has been emphasized already. While "learning by doing" is always vital in activities such as mineral exploration, formal education in geoscience of various sorts is also vital. Since the financing and management of higher education was taken over by the Provincial Governments, they have been responsible for geoscientific education. This is also the case at the Community College level and special mining school at Haileybury.

6. Openness to the World

The exploration sub-culture has always had to compete openly in the international environment and in close proximity to the United States. This has meant that it continuously and quickly had to learn and acquire the best technologies and methods of exploration. In view of the strength of United States enterprises in these areas and in the context of direct competition from US mining houses and exploration firms, the Canadian exploration sector had to meet the US challenge. At the same time, it was possible to acquire some of the latest technologies from US sources.

7. The Financing of Exploration

The emergence of the Toronto Stock Exchange, the Montreal Stock Exchange and the Vancouver Stock Exchange as centres for financing new exploration companies or raising funds for new projects has been a vital part of the sub-clusters' success. It has been possible for

Canadian exploration entrepreneurs to raise equity capital quickly and effectively, spreading the risk of their exploration ventures over large numbers of Canadian investors who have been willing to take on such risks.

These stock exchanges together with the whole system of stock promoters, exploration entrepreneurs, geologists with good ideas, and mining analysts have been instrumental in making speculative exploration activities possible.

8. *The Mineral Exploration "Character" or "Culture"*

Since the beginnings of mineral exploration in Canada, there has emerged a definite prospecting and mineral exploration "culture" which may be quite unique to this endeavour and to its practice in Canada. Mineral exploration by its very nature requires that its practitioners travel to difficult and typically mountainous locations over difficult terrain in difficult circumstances. The successful mineral prospector must be willing and able to put up with severe personal discomfort, endure any hardship, and do a difficult job. Moreover, the exploration task has not been getting any easier as it is pushed steadily into more and more hostile and difficult environments.

The Canadian mineral exploration geologists have had a long learning process in surviving and thriving in any environment to which their profession has led them. This is undoubtedly an important asset to the Canadian exploration sub-cluster. Canadian geologists enter this culture when they undertake their field excursions in University if not before.

***Why Did Canadian Exploration Investment Shift to Outside Canada*?**

The mineral prospecting sub-cluster seems to have shifted its sights, at least in part, to the international arena and in particular to Latin America for a number of reasons. One important reason is that Latin America became an attractive area for exploration and prospective mineral development. This was because of the return to democracy in most of the region in the 1980s, to the establishment of macro-economic stability in most countries in the region, and to the shift

towards *apertura*, or a more open policy towards trade and foreign investment. A second factor was the perception, right or wrong, that environmental regulations among others were leading to long delays in gaining project approval, thereby stalling otherwise viable projects. But perhaps most important was the perception that Canada and the United States, not to mention Europe, had already been intensively explored. In contrast, Latin America and Africa had not. Thus the chances of making the big discovery appeared to be greater in Latin America than elsewhere. And if the political and economic *ambiente* was now congenial, it made sense to shift a substantial portion of exploration investment to that region. As can be seen clearly in Figure 5, this is exactly what happened.

VII. SUDBURY: THE EMERGENCE OF A "MINING METROPOLIS/"

Over the last 120 years, Sudbury Ontario has gradually evolved from a frontier mining town to a significant "mining metropolis." Gradually, from its humble beginnings as a railway and mining town, it has become an important regional economic centre in Northern Ontario. It has developed both a substantial degree of economic diversification around a mineral-extraction base as well as a broad range of economic activities of a governmental, business service, health and educational character. It has built a significant overall population foundation. Sudbury's development as a major mining centre, and its diversification around mining has occurred slowly and painfully. However, it may now have reached a stage where it is as sustainable as a mining community could expect to be, given its dependence upon difficult and volatile international mineral markets. It may also be poised to participate more effectively in the broader arena of the international minerals economy.

This chapter focuses on the evolution of mining and mineral-related activities in the Sudbury region. The objective is to explore the factors that have permitted the emergence of a significant cluster of economic activities around mining which in turn have converted Sudbury from a mine town to a large and complex regional centre servicing the mining industry. The chapter also explores the possibilities of the city's future evolution in the context of the mining economy. (Other issues of

particular concern in other chapters, such as relations with First Nations' peoples and the social impacts of mining, are not examined here.

1. Historical Development of the Sudbury Mineral Economy and Region

The Sudbury Basin is a unique geological formation measuring about 60 by 27 kilometres in an oval or elliptical shape. The foundation of the basin is about 10 kilometres deep. It is likely that the basin is the result of the impact of an asteroid or huge meteor that collided with the earth and caused a deep fracture in the earth's crust, permitting the magma or molten rock from deep inside the planet to rise to the surface.

Nickel mineralization was first detected by surveyors in 1856. But it was not until the construction of the transcontinental Canadian Pacific Railway in 1883 that an outcropping of copper was revealed in construction blasting and in the ballast used for the rail bed, Which sparked a prospecting rush. In time, with the development of processing technologies for extraction and for separation of nickel from copper, both extraction and smelting expanded. By 1902, the International Nickel company of Canada, INCO, had been created from a merger of two earlier companies, and by 1918, INCO had become an integrated mining, smelting and refining firm, with a refinery in Port Colbourne.

The historical development of the Sudbury region might be divided into four eras, approximately following Saarinen (1992. p. 165):

1. Evolution from a railway town-site and frontier mining town to major mining city (1883-1945);
2. Development into a regional central-place (1945-1970);
3. Relative stagnation as a mining city, (1970-1980); and
4. Evolution towards self-sustainability, as a mining metropolis (1980-2000)

The description of Sudbury's evolution will follow this schema.

Sudbury began as a Canadian Pacific Railways company town, with the construction of the Canadian Pacific Railway in the 1880s. The early development of mining in the region then made Sudbury a significant mining community. By World War I, the area manifested many features of what could be called the "colonial-frontier" town, including resource dependency, environmental pollution, external control, an uncertain future, a low quality of life and a corporate

paternalism in the form of a company town.

During this period, the major mine enterprises operating in the area - INCO and Falconbridge - developed their own company towns at the mine-sites. Sudbury then emerged as a type of fringe of settlement for the whole area. Its development was stunted, because most of the managerial and labour personnel from the mines lived in the company towns, while only those who were less integrated into the main mining economy settled in Sudbury.

Moreover, the mine enterprises, unlike other industrial enterprises, did not pay local property taxes until after 1945. Even in 1945, the companies did not pay local taxes; instead, the Provincial Government provided a compensating revenue, though this amounted only to about one-half of the business revenues received in other non-mining communities (Saarinen, 167.) This lack of an effective tax base undoubtedly limited community action for infrastructure investment, urban development and beautification, and contributed to the much-publicized low physical quality of life in Sudbury.

In this era, Sudbury was not only famous for its the nickel industry. It was also infamous for the environmental destruction caused by the sulphur emissions from the metal smelters, which killed much of the vegetation. The area bore an uncanny resemblance to the lunar landscape.

After World War II Sudbury expanded, as nickel demand grew in response to military and consumer demands. The population in the area increased from about 115,000 in 1951 to around 170,000 in 1971. This population expansion, based ultimately on mineral exports from the region, was caused and, in turn, contributed to, a continuing process of economic diversification mainly of business, educational, health, and government services. Of particular note was the establishment of Laurentian University in 1960, which began to play a steadily more important role in the intellectual life and, in time, the technological leadership in the region.

The Sudbury economy was further strengthened with the establishment of Elliot Lake, which fell within Sudbury’s sphere of influence. The construction of a direct highway link with Southern Ontario via Parry Sound and Gravenhurst gave Sudbury a "gateway" location which

allowed it to evolve as the major transportation centre of Northern Ontario, in competition with North Bay. Trans-Canada Airlines flights were introduced in 1952-54, further consolidating Sudbury's status as a central transportation node.

The growth and maturation of the area was reflected in the acceptance of regional planning, with notable improvements in the better co-ordinated design of infrastructure and urbanization patterns. In this period, there was also a steady expansion and diversification of the population, with the addition of growing populations of professional and "white-collar" workers.

During the 1970s, the Sudbury economy went into a process of contraction caused in large part by reduced mining employment as a result of lower prices in real terms in international nickel markets and reduced nickel production volumes. Paradoxically, however, the groundwork for a subsequent turnaround was also laid in this period.

Competitive pressures on nickel production in the area led INCO and Falconbridge to rationalize their production and initiate major processes of technological improvement designed to lower production costs, to maintain productivity, and to sustain international competitiveness. The upshot of this was that employment in mining in the Sudbury region declined from a high of 25,7000 in 1971, to 17,700 in 1981 and to 9,146 in 1991. One result was population loss for the region, from 170,000 in 1971 to 152,440 in 1986 (Regional Development Corporation).

However, the positive feature of this era was that mining and mineral processing became steadily more technologically sophisticated and capital intensive. The Sudbury basin maintained its competitiveness in an ever-tougher international nickel market. The Sudbury area became a technological leader in high productivity and environmentally friendly technologies. A host of new enterprises producing the newer equipment, machinery and parts, or providing a wide variety of services to mining emerged while some existing enterprises expanded.

At the same time, the municipal government of the region was reorganized on January 1, 1973, so that the whole of the Sudbury Basin became part of the Regional Municipality of Sudbury, an area of 2,600 square kilometres, or about four times the size of Toronto. This has meant that the effectiveness of regional planning for infrastructure and the promotion of economic development have improved. In 1974, a Sudbury Regional Development Corporation was established to promote economic development of the area.

Further improvements in transportation enhanced the "central-place" functions of the city. The new highway north to Timmins and on to Cochrane expanded Sudbury's commercial sphere of influence. This has been of growing importance to the mining-related enterprises in Sudbury as they try to promote and market their products over a broadened area, and in competition with North Bay and Toronto.

During the decade of the 1990s, the Sudbury area appears to have reversed the decline of the previous decade and indeed seems to have consolidated its position as the major mining metropolitan centre of the region. This strengthening of its position is the result of a variety of factors:

1. The major mining enterprises, INCO and Falconbridge have maintained and improved their competitive position in the Sudbury Basin, and which provided a strong foundation for expansion, despite the reductions in direct employment in mining and processing.

2. The commercial sphere of influence of Sudbury expanded due in part to transportation infrastructure projects. This also has a bearing on the diversification and expansion of mine-related goods and services production, which now have access to approximately 90 mines within a 300-mile radius.

3. Effective civic leadership was of central importance in improving the natural environment, beautifying the region, promoting economic development, supporting technological diversification, and promoting the location of regional health, educational, and governmental functions in the region.

4. Support from government at the Provincial and Federal levels was also important as they relocated some of their administrative apparatuses to Sudbury: the Ministry of Northern Development and Mines (with 250 jobs) from Toronto, and the Sudbury Taxation Centre from Ottawa (with 750 full-time and 1500 part-time jobs).

5. Strengthening of the roles of Laurentian University and Cambrian College in their research and training generally, and specifically for the mineral core of the economy

5. The dynamism of the newly emerging enterprises surrounding mining is a final factor of significance.

Sudbury now has established a process of economic diversification around the minerals base which may continue to bear fruit and to improve its role as a major mining metropolis.

2. Sudbury as a Mining Metropolis

By the year 2000, Sudbury had become an attractive and reasonably dynamic city. The key mining enterprises in the Sudbury Basin, INCO and Falconbridge, of course have very successfully "gone global," with investments in most other parts of the world. The Sudbury area has begun to establish itself as a centre for technological innovation in hard-rock mining with a consolidating range of minerals-oriented enterprises. The economy has become more dynamic with a series of other positive impulses. The landscape is returning to its natural state, and the city has become attractive in its healthy natural setting, as a result of the diminution of the sulphur emissions.

Could Sudbury as a major mining metropolis also participate more successfully in a hemispheric and global arena and beyond its regional base?

a. Technological Innovation and the Future of the Mineral Cluster

One of the more encouraging features of the Sudbury economy at this time is the emphasis being placed on innovation. Most important is the civic leadership that is implementing a number of institutional innovations that may be crucial for Sudbury's future. The Sudbury Regional Development Corporation, with financial support from the Provincial Government, has taken the lead.

The roles of Laurentian University Cambrian College in research and training in geological and mining areas is of special significance in the future promotion of a stronger mineral cluster. Laurentian University has offered full programs in mining engineering and Extractive Metallurgical Engineering since 1978, as well as general Civil, Mechanical and Chemical Engineering which are also of relevance to mining and mineral processing. Laurentian also has a strong Earth Sciences Department and Program. There are a number of research centres such as the Laurentian University Mining Automation Laboratory (LUMAL) and the Mineral Exploration Research Centre (MERC). LUMAL focuses on areas such as the analysis and system architecture of tele-remote/automated mining systems, 3-D animation and simulation of mining operations and control systems for vehicle-based transport systems. MERC focuses on support for mineral exploration not only in the Sudbury region but also in Canada and the world more broadly, collaborative research on mineral deposits and Pre-Cambrian geology, and

training of geologists in exploration techniques.

It is important to note also that the offices of the Ontario Geological Survey and the Ontario Geoscience Laboratories are also located at Laurentian University, and undoubtedly provide an important support for the scientific infrastructure which strengthens the mineral cluster in the Sudbury area.

An institutional innovation of great long-term potential is the establishment of NORCAT, the Northern Centre for Advanced Technology Inc. This Centre is a co-operative venture between Cambrian College of Applied Arts and Technology and private businesses. Its objective is to support enterprises with product development, technological transfer and training in resource industries generally, as well in as construction. In 1997, it acquired its own mine from Falconbridge for testing and training purposes. It apparently has already been involved in the development of 43 prototype in mining and construction, and has programs in ten countries.

A second institutional innovation is the creation of a Centre of Excellence in Mines and Mineral Research at Laurentian University. This $75 million centre is a multi-partner co-operative including private and public participation. A commercial applied research park is also in process of development by Laurentian University in collaboration with the Government of Ontario and the Sudbury Regional Development Corporation. The Centre is designed to link researchers for the provision of "analytical and consulting services to the resource industries to offer incubation services for start-up commercial ventures arising from the research activities...(and) will provide education, training, and programs aimed at private sector spin-offs of exportable goods and services." (SRDC, 1999). These research and training centres may be of great importance in strengthening the position of the mineral cluster in the Sudbury area.

b. The Cluster of Enterprises Surrounding Mining

A wide range of enterprises related to mining, have become established in the Sudbury area. These include enterprises in manufacturing, business services such as geological and management consulting, export consulting and services, mine automation and communication, equipment maintenance and repair, machine shops, electrical, plumbing and ventilation contractors, and manufacturers of various sorts. By 1999, some 20 of these

enterprises had joined CAMESE, the Canadian Association of Mining Equipment and Services for Export, indicating that they considered themselves ready for competition in a global market. (There are probably other firms ready for international markets, which are not yet members of CAMESE.) Surprisingly, these enterprises have become more self-conscious and well-organized in their efforts to take collective action in support of their activities. This is reflected in their co-operation in trade fairs and their self-identification as part of the Sudbury area cluster of mineral related activities.

c. Environmental and Social Dimensions

Since 1978, Sudbury has made a major effort to restore and rejuvenate its environment. About 17,400 hectares of land were barren and required re-vegetation and reforestation. A co-operative community effort restored some 3,200 hectares by 1997, planting some 3,500,000 trees in the area. This included the public sector (federal, provincial, and municipal governments), the Nickel Belt Conservation Authority, the private sector (INCO, TransCanada Pipeline, and the Caisse Populaire) and the voluntary sector (YMCA Employment Services, the Lions Club, Tree Canada Foundation, and the Sudbury Social Services Administration Board). There appeared to still be a long way to go. But the region was once again an area of great natural beauty.

This environmental restoration is also important if Sudbury is to be an attractive place to live for the skilled personnel who constitute the basic human foundation for a thriving and self-sustaining urban centre.

By 2000, Sudbury had established a diversified service economy providing for the population in its region. It is a major educational centre for its region, as noted earlier, with some 2,300 persons employed in Laurentian University, Cambrian College and Boreal College. It is a regional health centre with about 2,700 employed in the Sudbury hospital system. It is a thriving transportation and wholesaling hub for its region, with strong transport links to the national economy. Finally, its manufacturing sector generally employed almost 5,000 persons in 1996.

With this degree of economic diversification around the central economic activities related to mining, the economy of the Sudbury region should be self-sustaining to a significant degree, as long as the fundamental mining and transportation activities remain vibrant.

3. Future Risks and Vulnerabilities

As with any region in a larger national or globalized economy, there are risks and vulnerabilities, which will have to be faced in the future. There are factors which may present future challenges to the on-going diversification and expansion of the region.

One such challenge relates to the fundamental health and competitiveness of nickel mining and processing. If some new or expansion projects (such as Voisey's Bay, Australia, or Cuba) come on stream in the future and increase supplies well ahead of demand, and if they are lower-cost producers than those of the Sudbury Basin, there could be a contraction of nickel mining in the region. Obviously this would weaken the primary foundation of the regional economy unless there were new mines opening up. The dilemma for the Sudbury region is that for the mines to remain competitive even further reductions in the labour force may be required, as automation and remote-controlled mining techniques are extended. But it is also imperative that the mines themselves remain competitive in the global nickel economy.

A second challenge relates to the relationship of the region to INCO and Falconbridge, the two mining pillars of the regional economy. These companies have successfully gone Global many years ago, and now have prosperous mining activities in many other parts of the world. They are certainly not headquartered in Sudbury, but instead in Toronto. They do not necessarily have any primordial loyalty to the Sudbury region simply because that was the initial source of their existence and expansion. This means that they would leave the region if it became attractive to do so. It is doubtful that they have a permanent commitment to the local and regional community.

A third vulnerability of the region arises from the fact that open-pit mining is steadily increasing its relative role in the global mining economy, largely because it is much simpler and therefore lower-cost than underground mining which is technologically and logistically complex and therefore relatively costly. The machinery and equipment producers of the Sudbury region specifically and Central Canada generally are geared to produce highly specialized products for underground hard-rock mining rather than the quite distinct machinery and equipment designed for open-pit mining. This means that the international market for the products of Central

Canadian manufacturers on mining machinery and equipment may not be particularly expansive in future.

In sum, a transition from a successful mineral cluster for the regional mining economy to one, which participates effectively in the international economy may not be particularly easy.

One suggestion would be for the clusters centred in Sudbury, North Bay, and the Toronto areas to organize themselves as a "cluster of mineral clusters," (or a "super-cluster.") This would be useful in view of the very important range of mining related activities in the Toronto area (mine company headquarters, machinery and equipment producers, mine finance, geological, mining, and metallurgical consultants, and geophysical surveying, among other things.) North Bay also possesses a range of mine-related activities and is also a regional transportation hub.

IX CONCLUSIONS

Canada's mineral cluster has generated a number of important benefits for Canada. One could say that Canada's fortunate endowment of mineral wealth and the wide range of activities, which have evolved to utilize mineral resources, have been a fundamental building block for Canada's material well-being and human development.

The benefits flowing from the mineral sector have been alluded to in various parts of this study and can be summarized quickly.

1. Employment and Income Generation

The amount of employment generated in the mineral cluster (in full-time job-equivalents in 1998) is significant:

a. Stage I, Extraction and Processing	48,024
b. Stage II, Smelting and Refining	59,588
c. Stage III, Semi-Fabrication	94,134
d. Stage IV, Metal Manufacturing	107,612
e. Suppliers of Goods and Services ("Backward Linked" for Domestic Mining Activities Only, in 1992)	149,284
f. Plus Canadians Involved Directly in All Mining Activities Abroad	Not Known
g. Plus Employees in Supplier Firms for Canadian Mineral Activities Abroad	Not Known

g. Plus Employees in Governmental and Educational Support Activities	Not Known

The total employment in the sector obviously depends on the precise definition of the mineral cluster. If it included Stages I and II, total employment appears rather low. If Stage III were to be added, the total increases. If the broad cluster from “a” to “g” is included, the total amount of employment would increase significantly.

2. Foreign Exchange Earnings

The total foreign exchange earnings from the export of mineral products were significant. However, the export of goods and services for mining activities abroad were also large but not well known or available. The following indicates the components of the foreign exchange earned by the mineral cluster generally:

Mineral Exports (Excluding petroleum and natural gas)	$CDN 45,434 million
Exports of Mine Machinery	Not Available
Exports of Services to Mining Activity Abroad	Not Known
Repatriated Profits from Cdn. Enterprise Abroad	Not Known

Once again, the total earnings from the mineral cluster far exceed those for minerals alone, but lack of information prevents a clear estimation.

One interesting observation is that the (net) value added in the mineral sector, or the contribution of the sector to Gross Domestic Product, falls far short of the foreign exchange earnings from the sector. This is because when mineral products are exported, the value of all of the inputs are exported as well, i.e. the mineral products incorporate all of the inputs of goods and services purchased from outside the mining enterprises. Mineral exports are in fact exports of electricity, petroleum, contractors’ services, machinery and equipment etc. etc.

3. Tax Revenues

The mineral cluster generates tax revenues for all levels of government in Canada.

The Federal Government receives a share of the Corporate Income Tax paid by all businesses in the cluster, a share of the Personal Income Taxes paid by workers in the cluster and

a share of the Sales Tax (Goods and Services Tax.)

The Provincial Governments receive Mineral Royalties, shares of the Corporate Income Tax and Personal Income Tax, and the Provincial Sales Tax.

The Municipal Government level receives property taxes paid by the mining enterprises and workers on their properties.

Increasingly as well, a share of Royalty payments will be directed to the First Nations communities in which some new mine operations will locate.

Such tax revenues are of course the foundation for the social programs undertaken by governments in areas such as education, health, housing, social security, support for the judicial system, policing, physical infrastructure, etc.

4. Support for Infrastructure

Mineral enterprises are major users of some of the public infrastructure, especially the railroads, ports, electrical systems and roads. Their fees for service contribute to the overhead expenses which otherwise would have to be covered by other users. This is a valuable contribution to the general up-keep and maintenance of the country.

This assumes of course that the user fees are adequate to cover operating costs and an appropriate share of overhead costs.

5. Support for Local Communities.

Mining enterprises also usually support local communities through their employment of local personnel, their purchases of some contractors' services from local people, purchases of goods and services from the local community, and the property taxes they and their employees may pay. This support for local communities can be very significant and positive especially when a mine is opened in an established and populated region. An example of such a mine is the Potash Corporation of Saskatchewan mine in Sussex New Brunswick (Ritter, March 2000.)

Such positive implications for local communities are of course not guaranteed. The cases where there are negative environmental and socio-economic impacts are often serious and usually better publicized.

"Fly-In Fly Out" mining or long distance commuting to some more isolated mine sites mainly in the northern part of Canada, will also support established local communities. This is because the workers (and their families) basically will remain at their original communities except while "on the job." This will likely be an increasingly important means of supporting communities and community life in many or the First Nations communities in the North as they will constitute the labour force in mining for that vast region.

6. Support for Frontier and Regional Development

The mining sector has been vital in opening up frontier areas and supporting some of the out-lying regions of Canada. The northern regions of most provinces were opened up and linked to the southern more densely populated regions principally through mining.

This process is continuing with the shift of mineral activity, especially in diamond mining, into the North West Territories, Nunavut, Labrador, and the Yukon as well as the northern reaches of some of the provinces.

7. Support for First Nations (or Aboriginal) Development

As mineral activity moves increasingly into the Canadian North, attempts are being made to ensure that significant socio-economic benefits accrue to the inhabitants of the region, namely the Inuit and Indian Peoples. Mining enterprises wishing to operate in the region now must negotiate Socio-economic and Environmental Agreements with the indigenous peoples of the area to ensure that

- there are significant economic benefits for local people,
- that there is no environmental damage in the region,
- that there is no disruption of traditional economic activities of the local people,
- that compensation is paid if there are costs for the local people, and
- that under some circumstances, local communities receive some sort of royalty payments.

(See for example, the reports of the Canadian Environmental Assessment Agency for the Diavik diamond project and Voisey's Bay nickel project, both published in 1999.)

8. Support for Other Cluster of Economic Activity

The success of the mineral cluster should also be of benefit to other linked clusters of economic activity. For example, the innovations in aerial surveying undertaken principally with the mineral sector in mind should have relevance and related uses for other types of geographic and geological information systems. Similarly, the needs of geo-scientific surveying and mapping can stimulate related parts of the geo-information complex to come up with adaptations and innovative modifications of known techniques to meet the needs of geological surveying. Or, a successful industry producing equipment for underground mining and processing plants will be of benefit to the suppliers of the component parts of the equipment.

Needless to add, there may be significant costs imposed by mining on the rest of society in environmental and socio-economic terms if it is not managed effectively. This is a topic for another study.

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