Document generated on 09/25/2024 10:26 a.m.

Geoscience Canada

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Volume 29, Number 1, March 2002

URI: https://id.erudit.org/iderudit/geocan29_1art02

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Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Heath, C. P. M. (2002). Technical, Non-technical, and Other Skills Needed by Canadian Mining, Petroleum and Public Sector Organizations. *Geoscience Canada*, *29*(1), 21–34.

Article abstract

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Geoscience skills comprise about 50% of the entire skill profile. Computer skills (16%) are highly transferable to alternative careers. Non-technical and softskills (34%) are also essential. The teaching-learning process develops some non-technical and soft skills although many of them seem to be innate. Although students and alumni wanted more language education at university, executives seemed lukewarm to language skills. Most respondents wanted some business education to be included in curricula: sodid alumni and students. New external forces now influence education and recruiting. These include a more sophisticated and global recruiting process and an expectation that recruits have higher qualifications and industry-related work experience. The need for all geoscience stakeholders to work together in the preparation of young geoscientists has become essential.

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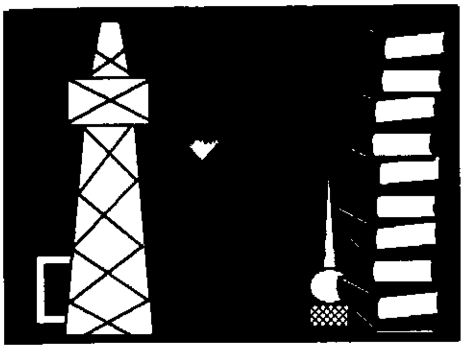

Technical, Non-technical, and Other Skills Needed by Canadian Mining, Petroleum and Public Sector Organizations

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SUMMARY
Events of the last decade have forced Canada's geoscience community to restructure, refocus on core businesses, and devise new strategies. These require new technologies to replace the old. Using 1996-1997 data collected from 21 large mining and oil companies and five public sector organizations, the author identifies, assesses, and ranks about 150 geoscience sub-disciplines, computer skills, non-technical and soft skills, and also evaluates mathematics, language, and business requirements.

Geoscience skills comprise about 50% of the entire skill profile. Computer skills (16%) are highly transferable to alternative careers. Non-technical and soft skills (34%) are also essential. The teaching-learning process develops some non-technical and soft skills although many of them seem to be innate. Although students and alumni wanted more language education at university, executives seemed lukewarm to language skills. Most respondents wanted some business education to be included in curricula: so did alumni and students. New external forces now influence education and recruiting. These include a more sophisticated and global recruiting process and an expectation that recruits have higher qualifications and industry-related work experience. The need for all geoscience stakeholders to work together in the preparation of young geoscientists has become essential.

RÉSUMÉ
Les événements de la dernière décennie ont forcé la communauté géoscientifique à se redéfinir et à recentrer son attention sur les activités essentielles ainsi qu'à convenir de nouvelles stratégies. Cela nécessite la mise au point de nouvelles technologies qui remplacent les anciennes. À partir des données recueillies de 1996 à 1997 auprès de 21 grandes sociétés minières ou pétrolières et de cinq organismes du secteur public, l'auteur définit, évalue et classe environ 150 sous-disciplines, compétences informatiques, connaissances générales et non-techniques, et évalue l'importance relative des exigences en mathématiques, en langue et en commerce.

Les compétences géoscientifiques constituent environ 50 % du profil complet des compétences requises. Les compétences informatiques (16 %) sont directement applicables en cas de réorientations de carrière. Les compétences générales et non techniques sont également jugées essentielles. L'apprentissage formel permet d'acquérir certaines compétences générales et non-techniques, mais nombre d'entres-elles semblent être innées. Alors que les étudiants actuels et les anciens considèrent qu'il faudrait augmenter la formation en langue à l'université, les dirigeants d'entreprise semblaient plus réservés en la matière. La majorité des répondants considéraient que le programme d'enseignement devrait être constitué d'une certaine proportion de connaissances commerciales, et les étudiants actuels et anciens étaient d'accord. De nos jours, des forces nouvelles influent sur l'éducation et le recrutement. Ainsi, le recrutement est maintenant un processus plus élaboré et plus global, et l'on s'attend à ce que les recrues soient plus qualifiées et qu'elles possèdent une expérience pertinente. Il est maintenant évident que tous les parties intéressées devront travailler de concert afin de mieux préparer les jeunes géoscientifiques.

INTRODUCTION
Changing domestic and international politics, increased global competition, and fluctuating commodity prices have had a major impact on Canada's geoscience community. In response to these trends, many organizations have been forced to restructure in order to survive. Private companies have refocussed on key businesses, abandoned peripheral activities, and developed new and effective business strategies. Many private companies have moved overseas where better opportunities exist. To accommodate these changes companies have had to develop new skills and abandon others. Consequently, some geoscientists have been released as companies reduced staff and cut costs. Other geoscientists, either unable to adapt or lacking the skill mix required for these new and reinvigorated businesses, have moved into other businesses requiring different geoscientific and other skills. Some have abandoned geology and geophysics altogether.

Public geoscience sectors have been similarly affected. Not only have their budgets been severely cut as governments were forced to balance their books, they have been also been asked to take on new responsibilities. Many of the latter may require different geoscientific skills as well as new technical skills in other fields. Consequently, they too have had to develop new strategies and new competencies.

University geoscience departments may have difficulty in responding to these evolving requirements unless they know what geological, geophysical, and other skills geoscience-based employers now expect their geoscientists to have. Likewise, unless university students in these fields obtain the requisite skills, their chances of obtaining jobs in their chosen careers may be sharply reduced. To address these issues the author, upon his retirement from the international oil industry, spent seven months at Edinburgh University evaluating geoscience education trends and the needs of geoscience-based organizations in Britain (Heath, 1999). Later, he spent two years (1996-1998) at the University of British Columbia studying the Canadian geoscience community. Here, the focus was on the mining and oil industries and governmental geoscience agencies, traditionally the principal employers of geoscientists. However, because the fields of hydrology, hydrogeology (hereinafter collectively called "geo/hydrology") and environmental geosciences have become important in Canada, the author also evaluated these fields as well, although to a lesser extent.

Five aspects were of particular interest:

1. The key geological and geophysical sub-disciplines now needed by these organizations.
2. The level of computer competency now required.
3. Other skills or disciplines that could be important.
4. The role and importance of "non-technical" and "soft" skills in these sectors.
5. Other factors that might affect geoscience education and graduate recruitment.

In the context of this paper, the sub-disciplines that are the components of the disciplines of geology and geophysics constitute "geoscientific" skills while a "geoscientist" is an individual with knowledge in either or both disciplines. In this paper, the term "skill" is used to define abilities acquired through education (principally through course work) and practice, and can cover a very wide range of knowledge sets such as geochemistry, spreadsheets, or initiative. The terms "non-technical" and "soft" also require some explanation. Soft skills comprise a broad range of abilities and attributes that appear to be innate to the individual. These include such behaviours as creativity, initiative, self-motivation, and the like. Also included in this group are certain other behavioural skills that are developed as the individual proceeds through the education process. Time management, co-operation and coping with stress come to mind. Some of these may also be rooted in one's psychological make-up, although this is unclear to a non-psychologist.

The non-technical skills comprise a mix of competencies that play an overt role in the workplace. Some, such as communication and languages, are taught formally at every university. Others are honed or developed by students under the guidance of instructors as part of the teaching-learning process, irrespective of the principle discipline being taught. Problem solving, analytical skills, and logical argument (reasoning) fall into this category. Whether some of these could be innate as well is not at all clear to the writer, although it is possible. Consequently, the boundary between these two groups is somewhat indistinct. Also, the one- or two-word descriptions that have had to be used in this paper to describe these skills, attributes, and abilities do not reflect the complicated inter-relationships that must exist among them. Be that as it may, the combination and degree of development of these skills probably form part of the ultimate psychological and behavioural makeup of individuals. These may not only have an impact upon their subsequent careers, but also influence the success, or otherwise, of the company that employs a geoscientist. Yet, it seems that employers only recently have realized the importance of these skills and have started to evaluate them when assessing job applicants or employees.

METHODOLOGY

The Survey Process

A 15-page questionnaire was distributed to about 200 private companies throughout Canada in 1996-1997. Five public sector organizations located in the Maritimes, Eastern Canada, Western Canada, and a territory were also contacted. These comprised local provincial or federal geological surveys or mineral resources offices. The survey asked respondents to assess the relative importance of a wide range of topics in their particular sector. The text comprised a number of preferential ranking box-filling exercises covering approximately 150 topics. The format used and the methodology employed to convert these data into scores are shown in Table 1. The scores generated were used first to assess the relative importance of each skill, and then for ranking and comparing skills, competencies, and abilities. Of the box-filling questions, 73 were related to sub-disciplines of geology and geophysics. These had been extracted from curricula of eight geoscience departments offering graduate degrees from universities located in the Maritimes, and Eastern and Western Canada. Excluded from the survey were introductory courses and some courses only offered by one or two departments. Ten of the sub-disciplines thought to be directly associated with geological engineering, geo/hydrology, and environmental geoscience have been omitted from this study. Sub-disciplines such as groundwater contamination, and both soil and rock mechanics, fell into this category. Both geo/hydrology and environmental science were found to be relatively unimportant to the mining, oil, or public sector groups (see Heath 2000a). Surveyed in a similar manner were computer competencies, non-technical and soft skills, mathematics, language training, and business education. Open-ended questions were also included, seeking not only opinions and ideas, but also exploring such issues as employments practices, employment qualifications, and the potential for industry-departmental co-operation.

Sixty companies, including the five public sector entities, provided useable data: mostly compiled by senior executives (Table 2). As can be seen, 26 organizations comprising the 14 large mining companies, seven oil companies, and the five public sector groups predominate: employing 367,651 people worldwide including 6154 geoscientists, well over 90% of all those covered by the survey. Almost half of the large mining and oil companies were foreign owned: principally by American or British interests, but also by Swedish, Australian, and French firms, demonstrating the global nature of today's mining and oil activities. One company only worked in Canada, while the rest pursued overseas interests or activities as well. Together, these large companies tended to dominate their respective industries through their size (capitalization and manpower), range of interests, market share, and technical leadership. They also had strong connections with universities through recruiting and other activities, and consequently were in a position to provide useful insights for this review. The same applies to governmental geoscience agencies, although they are considerably smaller and have different objectives. While data from these 26 entities provided the foundation for this project, information supplied by other respondents has been incorporated into this paper where appropriate. Data from 32 other contributors comprising 12 small mining firms, four coal companies, contractors, and consultants may be found elsewhere (Heath, 2000a). Also included among the 60 respondents were a geotechnical (geo/hydrology) company and an environmental firm. Both proved to be engineering companies. Their input is discussed separately.

Limitations of this Study

Past experience has shown that short surveys are more likely to elicit replies than long ones. Since this study covered such a wide range of topics, it was almost inevitable that the survey would be long: 15 sides of paper, in fact. It was therefore gratifying to discover that so many companies and government agencies were prepared to complete such an extensive survey and offer comments on a wide range of issues. This may reflect their interest in the subject being investigated. While the main core of the survey proved quite robust, it became apparent that the computer and mathematics education components of the survey needed to be expanded. This was done in subsequent surveys (Heath 2000b, and studies in progress).

The mining, oil, and public sector organizations are not the only fields that offer career opportunities to geoscience graduates, instructors, and researchers. Of particular interest have been the environmental and geo/hydrological industries. The author has carried out studies of both sectors but the surveys were very limited and therefore the findings described here have to be considered as being very provisional.

Table 1 Background data.

Calculation for Skill Tables:

The skill tables reflect the relative importance of each topic according to companies or organizations within each business sector.

Step1: The 14 mining companies were asked to assess the relative importance of terrain analysis (remote sensing, air photography, *etc.*) in their business by marking the appropriate box. This produced the results shown below:

	Critical	Very Important	Useful	Somewhat Useful	Not Important
Terrain Analysis	2 votes	4	6	2	0

Step2: Critical votes were assigned scores of 4 points each, with **Very Important**, **Useful**, **Somewhat Useful**, and not important scoring 3, 2, 1, and 0 respectively, so that:

Critical	Very Important	Useful	Somewhat Useful	Not Important
2 x 4 = 8	4 x 3 = 12	6 x 2 = 12	2 x 1 = 2	0 x 0 = 0

Step 3: Sum of scores is 8 + 12 + 12 + 2 + 0 = 34, out of a maximum of 14 x 4 or 56.
34/56 = .6071 or 60.71 rounded to a score of 61.

Legend for Skill Tables:

61• Represents the relative importance of terrain analysis to the mining companies. However, this score may be obtainable through a different mix of votes.

• All companies considered the skill to be Critical, Very Important or Useful in their business.

Table 2 Employment information for companies providing data.

	Geoscientists Employed Worldwide	Employees Worldwide
Business Sector Mining Community		
26 Mining Companies		
14 Large Companies	2,825	191,411
12 Small	59	741
4 Coal Companies	28	4,520
6 Geological Consultants – Mining Only	47	145
7 Geophysical Contractors – Mining Only	241	735
Subtotal	**3,200**	**197,552**
Other Business Sectors		
7 Oil Companies	2,735	174,880
5 Public Sector Organizations	594	1,360
Subtotal	**3,329**	**176,240**
Additional Data Received From:		
1 Geological Engineering Consultant (Geo/Hydrology)	100	600
1 Environmental Consultant	60	100
3 Computer Applications Companies – Mining	~ 40	~ 70
Subtotal	**200**	**770**
TOTALS	6,729	374,562

Notes:
- Geoscientist totals are included in the worldwide employee data set. Not all companies surveyed provided complete sets of usable data.
- Small mining companies employ less than 25 geoscientists.

Data from more companies would have improved the overall reliability and quality of the information gathered. Despite these shortcomings, it is believed that the data presented will provide departments and students with new insights into the needs of these sectors that will not only help them in their endeavours, but also will help generate a more open discussion amongst geoscience stakeholders.

The Skill Profile

The skills that geoscience-based organizations want their geoscientists to possess comprise packages of knowledge, abilities, and behaviours that will aid employers in their various activities. Thus, when a respondent reports that, say, stratigraphy is very important in their business, it implies that they want both current employees and potential recruits to have considerable knowledge in this sub-discipline. Should young job applicants not possess the required level of knowledge in key sub-disciplines, companies may not hire them. Therefore, the onus is on the geoscience students to acquire the right "mix" of knowledge and expertise by attending the appropriate courses offered by their geoscience departments.

Companies now realize that, to compete successfully in the global arena, their geoscience employees must be not only competent in their core discipline, but also in computer manipulation of data and a wide range of non-technical and soft skills. While government geoscience agencies may not have to face global competition, they too need their geoscience employees to have the appropriate mix of skills necessary to do their jobs effectively. For purposes of this study, the total skill profile for geoscientists was broken down into three groups: geological and geophysical skills, computer competency, and non-technical and soft skills. Respondents were asked what they thought the ideal mix of these three components should be, as seen in Table 3. Why mining companies placed somewhat less emphasis on geoscientific skills than did the other sectors is unclear. These three components are discussed below, followed by comments on less critical issues.

GEOLOGICAL AND GEOPHYSICAL TECHNICAL SKILL REQUIREMENTS

Industry input shown in Tables 4a, 4b, and 4c covers the 63 sub-disciplines that comprise the geoscience component of the skill set. They are ranked in descending order of importance according to the Total Score figure shown in the column next to the topic names. The Total Score is the sum of the scores for the mining and oil companies and the public sector organizations. Table 4a contains 15 topics having Total Scores of 200 or more. Although this figure is an arbitrary cutoff, all of the technical skills listed received strong support from employers. Therefore, acquisition of most of these critical skills will provide students with maximum flexibility should they be undecided as to which of these career paths, if any, they wish to pursue. The under-representation of geophysics in Table 4a is somewhat deceptive. This is a consequence of the relative lack of interest in this discipline by the public geoscience agencies and the differences in the specific geophysical skills or knowledge needed by the mining *versus* oil industries [see also Heath, 2000b and geophysical contractors (Heath, 2000a)].

Traditionally, a bachelors degree was meant to be completed after four years of university education. However, increased scientific and non-scientific prerequisites and requirements have made it increasingly difficult for geoscience undergraduates to take a sufficient number of the essential geoscience courses listed in Table 4a within the four-year time frame. Consequently, students may be forced take five-year degree programs or attend graduate schools. As is shown below, this may prove to be a worthwhile investment.

Table 4b lists sub-disciplines having Total Scores ranging between 150 and 199. Some are important in specific industries, such as geophysics in the oil sector, while others are of only intermediate importance to the sectors surveyed. Some of these sub-disciplines may be found in graduate or specialist programs. On the other hand, while some topics such as general paleontology and geomorphology appear to play less important roles in any of these sectors, they are important components of traditional geological education. They may also comprise essential building blocks for other sub-disciplines, disciplines, degrees, and careers.

Table 4c comprises the 21 remaining topics. More than half of these had Total Scores of less than 120 or individual sector scores of no more than 50. Few of these topics interested the 26 main respondents (see above under The Survey Process). From the viewpoint of the three sectors, most of the environmental and engineering related sub-disciplines would appear on this table had they been included (see Heath, 2000a for mining data). While the excluded topics may not enhance the chances of young graduates getting positions in mining, oil, or the public sector they are important sub-disciplines in other fields, most notably in environmental science and geo/hydrology. In addition, these and other less common topics enhance the general education process. Some will also broaden a student's geoscientific outlook and may encourage them to pursue graduate research in these areas. Clearly such geoscience diversity is essential if we are to advance our understanding of the discipline of geoscience as a whole.

Table 5 identifies the most important sub-disciplines for each sector. The seven topics common to all three groups are capitalized and in bold face. This may not only aid students wanting to focus on a career in a specific industry, but also help those departments considering development of semi-specialist programs. In general, each sector has its own set of skill requirements, although there is often some overlap with another sector. Mining requirements seem to comprise mainly mono-disciplinary subjects, whereas the oil industry list includes several multi- or inter-disciplinary topics and more geophysics sub-disciplines.

Few topics cited by public sector organizations have high scores, presumably reflecting their historic focus on near-surface geology. Most are core topics. However, government geoscience agencies report that the range of technical skills now needed is both changing and expanding as they take on an ever-widening range of scientific projects initiated by provincial or federal governments (*e.g.*, Swinden, 2001; also personal communications). Should these new initiatives prove long term, one can expect these agencies to change their technical requirements. Therefore, the need for near-surface geological skills may decline to be replaced by other geoscience needs or new technologies in other fields.

Table 3 Composition of geoscience skill profile by industry (expressed in percentages of the entire skill profile).

Skill	Average	13 Mining Companies	6 Oil & Gas Companies	5 Public Sector Organizations
Geoscience	55	51	57	58
Non-technical and soft skills	29	36	25	26
Computer	16	13	18	16
Range of non-technical and soft skill scores		20 –70	10 – 50	5 – 60

Such changes might even reduce the call for geologists.

The idea of grouping sub-disciplines into families under such headings as "Paleontology" or "Sedimentary rocks" was considered but abandoned. The idea of pigeonholing a particular skill contravened the linkages already suggested and the trend for many sub-disciplines and skills becoming interdisciplinary. An example of this might be sequence stratigraphy, a sub-discipline that applies geophysical acquisition and interpretation techniques to stratigraphy. The structure of these groupings may also be influenced by the sub-discipline being considered. The design adopted herein should allow interested readers to compile groups to meet their own needs and interests.

A number of students and alumni surveyed by the author complained that some courses they had taken lacked relevance, whereas others were too theoretical. Both issues are of considerable concern in light of today's economic imperative because many students are anxious to acquire those skills that would help them get jobs upon graduation. Some alumni also regretted not having taken some outside courses while at university, particularly business courses and languages.

The Environment and Geo/hydrology

Although it was not intended that this study should include the environmental science or geo/hydrology sectors, one company from each industry did complete the questionnaire. While the data collected were insufficient for a meaningful analysis to be carried out, it did appear that both companies had needs that differed from those of either the mining and oil industries or the government geoscience agencies. This came as no surprise to the author, who had surveyed both industries in Britain while at the University of Edinburgh (Heath, 1999).

The 1996 British Survey

In the British study (Heath, 1999), the objective was to evaluate the University of Edinburgh's geoscience curricula that included an environmental geoscience degree program, and to determine if the University of Edinburgh could introduce a geo/hydrology program as well. The survey format used was different from

Table 4a Geoscientific skills needed by the mining, oil and gas industries and the public sector. Top 15 geoscience skills for a first degree (total score 200-300).

		Top Quartile 76 – 100			2nd Quartile 51 – 75			3rd Quartile 26 – 50			Bottom Quartile 0 – 25		
	Total Score (out of 300)	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.
Fieldwork and Mapping	277 •	95 •	82 •	100 •									
Stratigraphy	262 •	77 •	100 •	85 •									
Sedimentology	260 •	79 •	96 •	85 •									
Introductory Struct. Geol. (Principles & Defs.)	251 •		96 •	80 •	75 •								
Sedimentary Structures	238 •		82 •	85 •	71 •								
Advanced Struct. Geology	237 •		89 •	80 •	68 •								
General Geochemistry	225 •	82 •				68 •	75 •						
Reg.Geol.-Basin Systems	220		96 •		59		65						
Magnetics (G)	220 •	86 •				64 •	70 •						
Economic Geology	214	98 •		80					36				
Reg.Geol.-Cordillera*	207		79 •		68		60						
Sedimentary Petrology	203		86 •		52		65						
Global Geology	203				73 •	75	55						
Rec., Quat., or Surficial Geology	201		79 •		52		70						
PlateTectonics/ Geodynamics	200				64 •	71	65						

Notes: Total Score for Fieldwork = Mining 95 + Oil 82 + Public Sector 100 = 277
- • All companies in the business sector considered the skill to be Critical, Very Important or Useful in their business.
- * Several respondents were from eastern Canada, otherwise scores would have been higher.

(G) Geophysics

Table 4b Geoscientific skills needed by the mining, oil and gas industries, and the public sector. Middle 27 geoscience skills for a first degree (total score 150-199).

		Top Quartile 76 – 100			2nd Quartile 51 – 75			3rd Quartile 26 – 50			Bottom Quartile 0 – 25		
	Total Score (out of 300)	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.
Basin Analysis	196		93 •				55	48					
Sequence Stratigraphy	196		93 •				55	48					
Electrical/Electromagnetics (G)	194	91 •					60		43				
Geoph. Acquisition and Methods (G)	192		79		68					45			
Reg. Geol-Basement Complexes (Shield, *etc.*)	191	77				64				50			
Log/Core Analysis (Petrophysics, *etc.*)	187		93 •					44		50			
Gravity (G)	187				68	64 •	55						
Mineral Dep. Assessment (Reserve Est., *etc.*)	184	88 •					75					21	
Terrain Analysis (R.S., Air Photo, *etc.*)	182				61	61	60 •						
Mineralogy	180	79 •					65 •		36				
Geoph. – Interpretation (G)	179		93 •					41		45			
Geostatistics	177				59	68				50			
Igneous and Metamorphic Rocks	175	82 •					75 •					28	
General Paleontology	172					64 •	60	48					
Geomorphology	172				54	53	65						
Reflection Geophysics (G)	172		93 •					34		45			
Rock: Fluid Interaction	170				52	68 •				50			
Reservoir Geology	167		100 •					27		40			
Mineral Economics	167	80 •					55		32				
Radiometrics, (IP, *etc.*) (G)	164	80 •					55		29				
Special Rock Studies (*e.g.*, carbonites, granites)	158		82 •					46		30			
Time : Series Analysis (G)	156					75		41		40			
Mineral Exploration Geochemistry	155	84 •					60 •					11	
Inorganic Chemistry	153				57		60 •		36				
Petroleum Geology	152		96 •							40	16		
Environmental Geology	152					54	55	43					
Gen. Hydrology Geohydrology	150				52		55		43				

Notes: • All companies in the business sector considered the skill to be Critical, Very Important or Useful in their business.
(G) Geophysics

Table 4c Geoscientific skills needed by the mining, oil and gas industries, and the public sector. Bottom 21 skills for a first degree (total score <150).

	Total Score (out of 300)	Top Quartile 76 – 100			2nd Quartile 51 – 75			3rd Quartile 26 – 50			Bottom Quartile 0 – 25		
		14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.	14 Mining Cos.	7 Oil & Gas Cos.	5 Public Sector Orgs.
Geochronology	148				55				43	50			
Geophysics Inversion (G)	146					75		41		40			
Volcanology	144				75 •		55 •					14	
Groundwater Hydrology	144						60	38	50				
Invert. Paleontology	139					64		30		45			
Soil Chemistry	136				66					45		25	
Organic Chemistry	134					61		38		35			
Refraction Geophysics (G)	126					57		29		40			
Clay Mineralogy	124							39	50	35			
Surveying	119							43	36	40			
Neotectonics	116							41	42	30			
Micropaleontology	110					61				35	14		
Palynology	102								50	40	12		
Crystallography	92							43		35		14	
Macropaleontology	86								43		23		20
Shallow Geophysics (G)	87								36	30	21		
Vertebrate Paleontology	79								43		11		25
Oceanography (Various)	77								43		14		20
Paleobotany	65								36		9		20
Earthquake Seismology (G)	60									35	11	14	
Planetary Geology	50										23	7	20

Notes: Total score for geochronology = Mining 55 + Oil 43 + Public Sector = 148.

• = all companies in the business sector considered the skill to be Critical, Very Important, or Useful in their business.

that employed subsequently in this study. There were fewer geoscience topics evaluated and less emphasis was placed on computer skills. However, more specialist skills were included. Non-technical and soft skills were evaluated in a manner not used later in Canada.

The geoscience section for both the environmental geoscience and the geo/hydrology surveys contained 27 identical geoscience sub-disciplines as well as hydrogeology and soil and rock mechanics (see Heath, 1999). Both surveys also contained an additional page of sub-disciplines pertinent to that particular field. Not all were engineering linked. The specialist topics used in the environmental survey comprised 30 subjects that had been extracted from curricula of 19 of British departments who offered environmental geoscience degrees. The list for geo/hydrology specializations was markedly different and had also been taken from the few curricula available. It had a slightly stronger engineering component. Six companies from each industry responded. It was discovered that all of them were, in fact, engineering firms. The most significant geoscience scores collected from both sectors are shown in Table 6. Few geoscience skills received high scores from either environmental or geo/hydrological firms, although the latter was more enthusiastic. The ranking orders were different as were the mix of critical skills required. Data not presented here also showed that environmental companies placed somewhat more value on the specialist skills, particularly in the areas of environmental science and engineering. The same applied for the geo/hydrological firms where the differences between geoscience scores and specialist scores were considerably greater and the specialist scores generally higher. It was interesting to note that only one of 20 British environmental geoscience departments contacted had sought advice from potential employers concerning the design of the curricula. There also appears to have been little or no market research carried out to determine if there were employment opportunities for graduates in environmental geoscience.

The 1998 Canadian Test Survey

Having received survey input from

Table 5 Most important geoscience skills, by business sector.

MINING COMPANIES (14)	OIL AND GAS COMPANIES (7)	PUBLIC SECTOR ORGANIZATIONS (5)
Geology	*Geology*	*Geology*
Economic Geology (98•)	STRATIGRAPHY (100•)	FIELD WORK and MAPPING (100•)
FIELD WORK and MAPPING (95•)	Reservoir Geology (100•)	STRATIGRAPHY (85•)
Mineral Deposit Assessment (88•)	SEDIMENTOLOGY (96•)	SEDIMENTOLOGY (85•)
Mineral Exploration Geochemistry (84•)	INTRODUCTORY STRUCT. GEOL. (96•)	SEDIMENTARY STRUCTURES (85•)
General Geochemistry (82•)	Reg. Geology-Basin Systems (96•)	INTRO. STRUCTURAL GEOLOGY (80•)
Igneous and Metamorphic Rocks (82•)	Petroleum Geology (96•)	ADVANCED STRUCT. GEOLOGY (80•)
Mineral Economics (80•)	Basin Analysis (93•)	Economic Geology (80)
Mineralogy (79•)	Log/Core Analysis (Fm. Eval., *etc.*) (93•)	General Geochemistry (75•)
SEDIMENTOLOGY (79•)	ADVANCED STRUCT. GEOLOGY (89•)	Mineral Deposit Assessment (75)
STRATIGRAPHY (77•)	Sedimentary Petrography (86•)	Igneous and Metamorphic Rocks (75•)
Reg. Geol.–Basement Complexes (77)	FIELD WORK & MAPPING (82•)	Rec., Quat. and Surf. Geol. (70)
INTRODUCTORY STRUCT. GEOL. (75•)	SEDIMENTARY STRUCTURES (82•)	Reg. Geology–Basin Systems (65)
Volcanology (75•)	Special Rock Studies (Carbs and Clast.) (82•)	Sedimentary Petrology (65)
Global Geology/Geology of the World (73•)	REGIONAL GEOL.–CORDILLERA (79•)	Plate Tectonics/Geodynamics (65)
SEDIMENTARY STRUCTURES (71•)	Rec., Quat. and Surf. Geol. (79•)	Mineralogy (65•)
ADVANCED STRUCTURAL GEOL. (68•)	Global Geology/Geology of the World (79)	Geomorphology (65)
REG. GEOLOGY–CORDILLERA (68)	Plate Tectonics/Geodynamics (71)	REG. GEOL.–CORDILLERA (60)
Soil Chemistry (66)		General Paleontology (60)
	Geophysics	Mineral Exploration Geochem. (60•)
Geophysics	Interpretation and Mapping (93•)	Inorganic Chemistry (60•)
Electrical/Electro-magnetics (91•)	Reflection Seismic (93•)	Groundwater Hydrology (60)
Magnetics (86•)	Sequence Stratigraphy (93•)	Terrain Analysis (R.S., *etc.*) (60•)
Radiometrics (80•)	Acquisition Methods (79)	
Acquisition Methods (68)	Time : Series Analysis (75)	*Geophysics*
Gravity (68)	Inversion (75)	Magnetics (70•)
		Electrical/Electromagnetics (60)

Table 6 Geological and geophysical skills required by environmental and geo/hydrological companies. (Based on 1995-1996 unpublished and published British survey data; Heath, 1999).

Topic	Total Score	Environmental Companies (6)	Geo/Hydrological Companies (6)
Hydrology	200	100	100
Environmental Geology	175	75	100
Recent Sediments	160	80	80
Sedimentology	158	75	83
Surveying/Mapping	150	83	67
Electrical/El-magnetic	143	60	83
Geomorphology	142	75	67
Inorganic Geochemistry	141	58	83
Organic Geochemistry	125	58	67
Shallow Geophysics	125	58	67
Stratigraphy	117	50	67
Remote Sensing	110	20	90
Mineralogy	108	58	50
Potential Fields	107	40	67
Structural Geology	92	25	67
Sedimentary Petrography	90	40	50
Mineral Resources	83	50	33
Igneous Petrology	80	30	50

Notes: 83 = Critical skills are scores that exceed 80
- Clay mineralogy was scored 67 by environmental firms.
- Other topics assessed received low scores. These were: hydrocarbon and coal, macropaleontology, metamorphic rocks, geodesy, micropaleontology

geotechnical (geo/hydrology) and environmental companies and heard that these sectors have become increasingly important in Canada, the writer developed a test survey covering both disciplines to determine the feasibility of embarking on additional surveys. The technical skills used in the survey comprised 50 geoscience, environmental, engineering-oriented, and other related topics selected from the 1996-1997 Canadian survey used for this paper. The list was augmented by data collected from pertinent curricula found at the University of British Columbia's career office, those skills that had received high scores from the companies participating in the British survey, and the input obtained from the two Canadian companies involved in these industries. The sections on computer skills and mathematics education were expanded. The overall format was similar to that used in the mining, oil, and public sector study described in this paper. The test survey was distributed in 1998 to three firms working in either the geo/hydrological or environmental businesses. All of them returned completed surveys. The merged results of the highest scoring skills are shown in Table 7. Twelve geoscientific sub-disciplines had scores exceeding 50, while 13 non-geoscience scores (Engineering and Other Skills) exceeded 75. This suggests that engineering knowledge may be considerably more important than geoscientific skills in these industries.

Comparing these scores and rankings with those displayed in Table 5 demonstrates the diversity of the basic skill requirements between sectors, thus emphasizing the teaching dilemma now faced by geoscience departments. Although it is difficult to draw any meaningful conclusions from either study, it appears that engineering competencies may be paramount in both sectors, and the role that geoscience may play seems somewhat limited. The American experience has been that enrolment in environmental geoscience has declined over recent years as business activity has shifted from the identification and measurement phases toward remediation, which is mainly engineering driven. Whether this applies to Canada is unclear. However, the results presented here are very preliminary, and further investigation is required to determine the true role geoscience plays in both fields within the Canadian context.

Field and Mapping Training

Tables 4a and 5 demonstrate the importance employers in all three sectors place on their geoscientists having field and mapping skills. Since the delivery of field training is expensive, the author looked at the topic in greater detail to look for potential savings in instruction effort (Table 8). The data suggest that field and mapping skills are less important to oil companies than to other sectors (see also Heath, 2000b). However, all agreed that skills in rock description, structural geology, and mapping are essential. Equally important are some of the non-technical skills developed through fieldwork, particularly data integration, analysis and interpretation, oral and written communications, and time management (See also Heath, 2000a).

Computer Skills

Table 3 suggests that, on average, computer skills comprise about 16% of the total geoscientist skill profile for the three sectors evaluated. This may not seem to be a significant component of the entire geoscience profile but of all the skills taught at university, computer knowledge is probably the most transferable to alternative careers: geoscientific or otherwise. This is important because career switching is an increasingly common phenomenon in today's business environment. In geosciences, one might have assumed that it would be almost impossible for graduates to get meaningful jobs if they lacked computer training. Yet, as Table 9 indicates, two companies, a large mining firm and a smaller oil company, thought computer skills were unnecessary for their geoscientists. Almost

Table 7 Top 35 geoscientific and other skills required by Canadian environmental and geo/hydrology companies (based on unpublished 1998 Canadian survey data from five companies).

Geology and Geophysics Skills	Score	Engineering and Other Skills	Score
Log and Core Analysis	100	Groundwater Contamination and Remediation	100 † xx
Geohydrology	92 †	Groundwater and Subsurface Hydrology	100 †
Environmental/Hydrology Lab and Field Methods	83	Groundwater Assessment	100xx
Terrain Analysis (Remote Sensing, Air Photo)	75 †	General Hydrology	92 † xx
Recent, Quat. and Surficial Geology	75	Site Investigations and Case Histories	92
Field Skills (Mapping, *etc.*)	67 † xx	Fluid/Aquifer Dynamics and Modelling	92 †
Geomorphology	67 †	Environmental/Hydrological Modelling	92
Environmental Geology	67 † xx	Conservation	92
General Geochemistry	67	Principles of Geological Engineering	83
Aqueous Geochemistry	67	Environmental / Hydrology Lab and Field Methods	83 † xx
Environmental/Hydrology Risk Analysis	67	Environmental Assessments and Impact Statements	83
Environmental Geochemistry	67	Instrument and Analytical Methods	75
Stratigraphy	50 †	Rock : Fluid Interaction	75
Shallow Geophysics	42	Soil Chemistry	75
Reflection and Refraction Seismic	42	Environmental/Hydrology Risk Analysis	67
Electrical/El-Magnetics	42	Rock/Soil Mechanics	50 † xx
Potential Fields	42	Laws and Regulations	50 †
Geohazards and Earthquakes	42 †		

Data from the 1996-1997 Canadian Survey:
Environmental Company: xx skills considered to be Critical or Very Important, other Critical or Very Important skills were surveying and clay mineralogy
Geotechnical Company: † skills considered to be Critical or Very Important; other Critical or Very Important were advanced structural geology, reservoir geology, surveying, and sedimentary structures.

Notes:
- 1998 test survey evaluated 50 geoscience and other topics.
- The 1996-1997 survey covered 63 geoscience sub-disciplines and 10 skills related closely to environmental or geotechnical sub-disciplines (Heath, 2000a).

all undergraduates today will know how to use computers by the time they arrive at university. Therefore, while geoscience departments won't need to teach basic computer operations, it seems likely that they will have to provide training on GIS, spreadsheets, and databases as well as providing exposure to interpretation systems (Heath, 2000b).

Limitations of Data, Tables 1-7

The data in Tables 1-7 assess the importance of numerous geology and geophysics sub-disciplines in the mining and oil industries and public sector geoscience organizations. They do not assess the needs of other geoscience-based activities. Nor do the rankings presented take into account the teaching sequences usually followed by departments.

NON-TECHNICAL AND SOFT SKILLS

Although geological, geophysical, and computational disciplines are important components of the earth science education process, it is now clear that the possession of non-technical and soft skills is almost as essential in today's workplace. Because of the inter-connectivity that must exist among some of the 31 attributes evaluated, it would seem foolhardy for a non-psychologist to try to group these attributes them into a number of subsets. Besides, few would be likely to agree with any groupings proposed. Nevertheless, to the untrained eye, the skills evaluated can be divided into two broad groups: those that might be acquired or enhanced by the teaching process, and those that may not. In the context of this paper, most of the former would be considered to be non-technical skills. These are not geoscientific sub-disciplines *per se* but they are skills that are developed or enhanced by instructors of geology, geophysics, and teachers elsewhere in universities. The author's assessment of what skills might fall into this category are listed and ranked in Table 10a. Scores exceeding 80 are highlighted in bold face to emphasize their importance in each sector.

Table 10b lists other skills assessed that have been evaluated by the author. Most seem to be entirely behavioural or innate and perhaps are only marginally influenced by the teaching-learning process. Others are probably innate but are honed through education. The origin of the innate skills is unclear to this writer, although heritage, culture, genetics, and other factors must play their part. In the context of this paper, however, it is not the classification or origin or cause of these skills that is important, it is the need for students to recognize that these non-technical and soft skills are extremely important in today's workplace. While

Table 8 Field and mapping education. Importance of field and mapping training in the undergraduate curriculum.

Days Preferred – Duration of Training	Total	Mining Companies (14)	Oil & Gas Companies (7)	Public Sector (5)
101 days or more	9	6	3	
80 – 100 days	2	1	1	
51 – 80 days	7	2	3	2
31 – 50 days	4	2	2	
30 days or less	4	3	1	
Approximate Average	**70**	**70**	**60**	**80**
TECHNICAL SKILLS INVOLVED				
Outcrop – Examination, Sampling and Recording	98	98•	100•	100•
Regional Mapping	92	84•	93•	100•
Detailed Mapping	91	93•	86•	95•
Structural Geology	86	86•	86•	85•
Drilling and Coring	66	66	71	60
Surveying	65	57	68•	70
Average	–	**81**	**84**	**85**
NON-TECHNICAL SKILLS INVOLVED				
Data Integration, Analysis and Interpretation	91	91•	93•	90•
Oral Presentation/ Communication	85	89•	86•	80•
Report Writing	85	73•	93•	90•
Time Management	80	79•	86•	75•
Teamwork Skills	79	80•	71•	85•
Planning	78	73•	82•	80•
Project Management	78	73•	82•	80•
Average	–	**80**	**85**	**83**

Table 9 Computer skills

General Skills	Average Scores	Mining Companies (14)	Oil & Gas Companies (7)	Public Sector (5)
Work station skills	74	59•	93•	70•
Data management	71	73•	75•	65
Basic Operations				
No skills needed	7	7 (1 co.)	14 (1 co.)	–
Spreadsheets (*e.g.*, Excel)	88	93	71	100
Word processing, E-mail, Internet	81	93	71	80
Web	51	50	43	60
Statistical Packages (*e.g.*, SAS)	44	43	29	60
Data Bases				
Introduction (*e.g.*, FoxPro, Paradox)	62	64	42	80
Advanced (*e.g.*, Oracle)	14	14	29	–
Other Skills				
GIS (*e.g.*, Map Info)	79	79	57	100
Graphics (*e.g.*, CorelDraw, Autocad)	71	43	71	100
Program Writing	2	7 (1 co.)	–	–
Operations Geoscience				
Geoscience Computer Modelling	66	61	82	55

instructors can do their best to develop some of the skill listed on Table 10a in the teaching process, ultimately it is the responsibility of the student to develop these skills to the maximum.

A number of points are of interest:

- The high scores reflect the importance of these skills in the workplaces of the three sectors surveyed.
- It was intriguing to discover that scores exceeding 80 were more common among the innate soft skills than in the other group (Table 10b). This was found to be essentially true in other surveys as well. This characteristic might have considerable implications in the recruit assessment process.
- For reasons that are unclear, both the scores and rankings for each sector vary. Rankings and scores are also known to differ between other industries and nations (Heath, 1999, 2000a, b).
- Written and oral communication skills are highly valued by employers whereas summarization/abstracting and listening skills seem to be of only intermediate importance.
- Both ethics and teamwork are highly valued by all employers surveyed. The degree to which teamwork and practical ethics, rather than academic ethics, are incorporated in Canadian geoscience curricula seems to vary in both content and depth (personal communications with departments). However, most young geoscientists now have to pass ethics exams when seeking provincially based professional accreditation.
- Certain attributes thought to be important to academics such as inquiry/research skills and intellect, appear to be less valued by employers. While a low score for inquiry/research did not surprise the author, the low score for intellect did to some degree. It seems very unlikely that recruiters would not consider such factors as grades and intelligence as part of their recruit assessment process. On the other hand, once hired, it is employees' performance on the job that is important and not their academic grades.
- Several skills one might expect companies to appreciate, such as risk taking and entrepreneurial flair, also scored poorly. While the scores for both skills tended to be somewhat higher for smaller oil and mining companies (Heath, 2000a, b), other businesses within the mining industry such as coal firms, software companies, contractors, and consultants also produced low scores (Heath, 2000a). Preliminary results from an ongoing study of the North American oil industry indicate similar characteristics.

Table 10a Non-technical and soft skills needed in the workplace. Non-technical and soft skills that the teaching process may develop or enhance: ranked in descending order of average scores; 81 = critical skills are scores exceeding 80.

Non-Technical or Soft Skill	Average Scores	Mining Companies (12)	Oil & Gas Companies (7)	Public Sector (5)
Teamwork	88	81	89	95
Written communication	84	83	82	85
Oral communication	84	75	96	80
Ethics	81	83	82	80
Problem solving	81	73	89	80
Analytical ability	79	81	82	75
Summarizing/abstracting	78	67	93	75
Inquiry/Research	71	63	71	80
Intellect (*e.g.*, good grades)	71	63	86	65
Logical argument/Reasoning	67	71	71	60
Numeracy	62	56	61	70
Language	53	61	57	40
Average	–	71	**80**	74

Notes: · dot system (•) not used for this table.
· two mining companies did not complete this section

Table 10b Non-technical and soft skills needed in the workplace. Soft skills that appear to be innate: ranked in descending order or averaged scores. 81= Critical Skills are scores exceeding 80.

Non-Technical or Soft Skill	Average Scores	Mining Companies (12)	Oil & Gas Companies (7)	Public Sector (5)
Willingness to learn	87	83	93	85
Dependability/Reliability	85	79	86	90
Drive/Enthusiasm	84	81	86	85
Commitment	84	85	86	80
Self-motivation	83	83	86	80
Adaptability (Org. and Intellectual)	83	79	89	80
Initiative	83	79	89	80
Desire to achieve	83	77	86	85
Co-operation	80	79	86	75
Flexibility	80	73	82	85
Creativity/ Out-of-box thinking	76	65	93	70
Listening	74	69	79	75
Can cope with stress	72	63	82	70
Time management	71	67	75	70
Self-confidence	71	67	75	70
Rapid conceptualization of issues	67	63	82	55
Leadership	64	65	61	65
Risk taker	55	52	68	45
Entrepreneurial flair	53	48	71	40
Average	–	71	**82**	73

Notes: · dot system (•) not used for this table
· two mining companies did not complete this section

MATHEMATICS, LANGUAGE, AND BUSINESS EDUCATION

The skills, abilities, and knowledge sets discussed above are not the only competencies required by geoscientists in today's work environment. Previous studies and comments made by survey participants suggest that three additional disciplines may also be important: mathematics, languages, and business skills. Therefore respondents were also asked to evaluate these as well. Most Canadian mining companies and public sector organizations favored at least two years of mathematics education although a few thought one year was sufficient. No oil company wanted their geoscientists to have only one year of mathematics, and it was clear from data submitted by geophysical contractors that geophysicists needed closer to three years of mathematics education (Heath, 2000a). Subsequent studies of the oil industry (Heath, 2000b) indicated that oil firms preferred their geologists to have exposure to applied mathematics or geostatistics rather than a second year of calculus.

With the expansion of international business, the author expected companies to value language skills among their employees. An ability to speak non-native languages would not only enhance international relationships, but also enable a company to understand local cultural attitudes and business practices. Having worked extensively overseas, the author was disappointed to find that, while most companies regarded language skills to be useful, only four of the large commercial companies thought that some language education at university should be mandatory. Many alumni surveyed separately said that they wished they had taken a language course while at university.

Both British and Canadian media have commented upon the poor business skills possessed by many young people. Wade (1997) has pointed out that this weakness had made it difficult for some British geology graduates to obtain geological employment. Table 11a shows that Canadian companies responded enthusiastically to the suggestion that some form of business education be incorporated into the undergraduate geoscience curriculum, although the mining companies were somewhat less supportive. Table 11b ranks their opinions on a number of topics that the author suggested might be included in a business module. Apart from ethics, the key business skills favoured were project management (also supported in alumni and student surveys), planning, and economic analysis (Heath, 2000a). The British-based oil companies tended to agree (Heath, 2000b). Other research revealed that smaller companies tended to place more importance on business skills than did their larger colleagues (Heath, 2000a,b).

DEPARTMENTAL–INDUSTRY CO-OPERATION

Over the past decade or more, most Canadian universities have faced budget cuts almost annually as provincial and federal governments struggled to get their finances under control. These cutbacks have come at a bad time for geoscience departments. While some companies still need well-trained specialists, corporate and government restructuring have reduced the need for traditionally educated geologists and geophysicists but increased the need for geologists having some knowledge of geophysics, and *vice versa*. In addition, these geoscientists may need other skills as well, notably some business knowledge. This is particularly true for mining and oil companies and is becoming important for government agencies as well (personal communications). While departments struggle to accommodate these changes, new geoscience-linked fields have emerged, notably environmental science and geo/hydrology. These and other emerging geoscience-based career possibilities may have further fragmented the discipline, making it more difficult for geoscience departments to respond.

The plight of the geoscience departments has been well described by Barnes *et al.* (1996) and Church (1998). They pointed out that the increased complexity of demands and expectations has put a great strain on every department's instructors and facilities. Money will be needed to review and redesign curricula, retrain existing faculty, and hire new staff. New teaching and research strategies will have to be devised and additional research equipment purchased. Although there was little indication in either paper that employers had been consulted or their concerns addressed, Heath found that many British and Canadian companies appeared ready to help departments if approached (1999, 2000a).

This help included support for research programs, both basic and applied. The research may take the form of either company- funded contracts for specific research projects or the establishment of strategic research partnerships. Closer relationships could create a win-win environment for those involved. Departmental researchers would be able to pursue frontier research on complex problems and get paid for it. Students at

Table 11a Business education. Company reaction to the introduction of business education in geoscience undergraduate curriculum.

Business Sector	Score
Large Mining Companies (14)	71
Oil Companies (7)	86 •
Public Sector Organizations (5)	90 •

Table 11b Assessment of possible subjects.

Topic	Large Mining Companies (14)	Oil Companies (7)	Public Sector Organizations (5)	Average Score
Ethics	84	68	90	84
Project Management x xx	73	82	80	78
Planning	68	75	80	72
Economic Assessment xx	40	82	80	67
General Business Knowledge	57	75	70	67
Finance/Budgeting	55	57	75	62
Strategy Development	54	64	60	59
Total	62	72	76	

Notes: x = extracted from the non-technical skills taught in field training.
xx = identified as an important skill by both alumni and students surveyed

all levels would become involved and be able to work on either applied or basic research topics, thereby developing their research and problem solving skills. Employers would have access to first-class minds to help them solve problems that they could not or chose not to solve themselves. There are caveats, however. Companies must finance the research and the necessary equipment. They must also allow researchers to publish non-confidential findings. At the same time departments must ensure that these joint projects are effectively managed, schedules are maintained, reporting is timely, and accountability is clearly defined (Heath, 1999, 2000a). It is important to recognize that corporate help is unlikely to be all-embracing or indiscriminate, particularly in the area of non-applied or basic research. Issues of university-mining industry collaboration on research projects are discussed further by Galley *et al.* (2001).

EXTERNAL INFLUENCES ON UNIVERSITY EARTH SCIENCE CURRICULUM DESIGN AND RECRUITING

Current Recruiting Practices

Over the past few years there have been a number of changes in the external environment that will affect both geoscience departments and their students. Among these are new recruiting practices, possible escalation of minimum qualifications requirements for employment, and the increased importance of pre-hiring work experience in the recruit selection process. In a drive to reduce costs, save on time spent on recruiting, and improve efficiency, companies have introduced much more sophisticated recruit assessment methods. Most companies now visit or recruit from fewer university departments than in the past. As part of the selection/de-selection process, some companies have ranked departments according to such factors as corporate requirements, the quality and content of curriculum, and reputations of both departments and universities. Such assessments may go beyond national boundaries because recruiting has become more global as companies look far and wide for top-quality graduates. This has been made easier by the use of the Internet. In addition, overseas contracts often contain clauses committing companies to hire local staff rather than expatriates (Heath, 2000a). This practice may reduce the opportunities for Canadian nationals, but not for Canadian-trained geoscientists from elsewhere.

Minimum Qualifications

The study of the British-based geoscience industries (Heath, 1999) revealed that there was an even split between those agreeing that a Master's degree was becoming the minimum degree required for employment and those who disagreed. Yet, by about 2000 the swing toward the Masters degree minimum has become widespread, at least for Britain's oil industry (Heath, 2000b). In the Canadian, study most of the 60 respondents still found the possession of a good Bachelor's degree to be sufficient (Heath, 2000a). However, 16 of the large mining and oil companies and the public sector agencies that commented on this topic were evenly split on the issue at 8:8. Should the British trend become established throughout Canada, geoscience departments may need to expand their Master's programs so that students wanting to pursue long-term careers in any of these sectors can obtain additional instruction or advanced qualifications.

Table 12 Relative importance of pre-hiring work experience in the recruiting process.

Experience	Large Mining Companies (14)	Oil Companies (7)	Public Sector Organizations (5)	Average Score
Industry related work	75•	86•	65•	75
Government or University Labs/Research	39	50	55•	48
Unpaid work (*e.g.*, Volunteer, Social)	30	29	25	28
Non-Industry Related (*e.g.*, Waiter, Cashier)	20	18	25	21
Present or past responsibilities	57	57•	65•	60
International travel or living	41	43	30	36

Pre-hiring Experience

Pre-hiring work experience inevitably plays a part in the recruit evaluation process but perhaps other factors play a part as well. Respondents were asked to evaluate six options. Their input is shown in Table 12. Clearly, industry-related work experience was far more important to potential employers than research experience, voluntary, or non-industry related work. Fortunately, the more promising students in Canada can gain the necessary industrial experience through summer internships and co-op programs. Other students may not be so lucky. Evidence of job applicants having present or past responsibilities was also found to be important. Even international experience was more important than several forms of work experience.

CONCLUSIONS

Although the organizations participating in this study comprise a limited portion of Canada's geoscience community, survey participants seem to be fairly typical of the sectors they represent. All employ many geologists and geophysicists and are familiar with Canada's education process. Consequently, their opinions are worth considering. In the context of the mining, oil industry and public geoscience sector, several findings seem significant:

- That less than 60 % of the skill profile for any sector was related to geoscientific skills demonstrates the importance of other skills, abilities and behaviours in the workplace.
- Field and mapping training and experience remains a critical component of geoscience education.
- Besides introductory subjects, seven key sub-disciplines are critical to the three sectors evaluated. These are: field work and mapping, sedimentology, stratigraphy, introductory structural geology, advanced structural geology, sedimentary structures, and regional geology (of some sort).
- Beyond these key sub-disciplines the mining companies, oil companies, and government agencies have their own special technical requirements, unique business cultures, and value systems.

- Should Canada's public geoscience surveys and resource agencies shift away from their historical emphasis on geoscience in response to changing political mandates, it is possible that the need for geoscientists by these organizations may either change in focus or even decline.
- All sectors would like their geoscientists to be knowledgeable of both geology and geophysics, particularly in the oil industry. This expectation has to be incorporated into the way these disciplines are taught.
- Computer competency in both operations and systems use is important. Such skills are particularly valuable because they can be easily transferred to alternative careers.
- The importance of non-technical and soft skills in the workplace cannot be overemphasized. Many are developed or enhanced by university instructors.
- Most major companies want recruits to have at least two years of mathematics education. For geologists applied mathematics and geostatistics may be more important than a second year of calculus. Geophysicists were expected to have more mathematics education than geologists.
- Support for some business education being included in undergraduate curricula was widespread. In addition to ethics, project management, planning, and economic analysis are favoured topics.
- New business trends and practices are also important to both departments and students. These include: 1)Higher-degree qualifications may be required soon (as is already the case for some large companies). 2) Job applicants are now expected to have pre-hiring industry-related work experience. 3) The recruiting process has become very sophisticated and global. Consequently there will be increased competition for geoscience jobs, particularly those overseas.
- Certain geoscience sub-disciplines are essential in the workplace, whereas others are less valued. In the sectors studied, paleontology and geomorphology fall into this category. Both departments and students need to be aware of this. However, some of the less-valued skills may be important in sectors not covered by this review and may be foundation courses for other important sub-disciplines, disciplines, and careers.
- Information concerning both environmental geoscience and geo/hydrology sectors is incomplete. However, there is some indication that geoscience is probably not as important in these fields as other disciplines such as engineering. More research is required to evaluate both sectors.

Geoscience has become increasingly subdivided as the interests of traditional employers change, new technologies develop, and new provincial and federal policies are put in place. These changes are generating new and exciting employment opportunities for geoscience graduates and for university departments in terms of teaching and research. However, these changes are not without cost for employers, geoscience departments, and students. Particularly pressing for the departments has been the lack of money, staff, and facilities to cater for such a wide range of disciplines and career options. Faculty overload and increasingly complex curricula requirements have meant the delivery of the necessary courses within a four-year (or even five-year) degree time frame has become increasingly difficult to achieve. This will not only increase student debt, but also delay entry into the job market.

The intent of this paper has been to provide information that may help the geoscience community in its efforts to overcome the challenges it faces. It is not a document telling geoscience departments what they need to do. However, it seems essential that departments and professional bodies become more open to suggestions put forward by employers than seems to have been the case in the past. This applies principally to curriculum design and professional registration requirements. Three factors need to be taken into account in any reforms considered. Firstly, all stakeholders need to be consulted to ensure buy-in and support. Secondly, for several career options, geoscientists now need to have knowledge of both geology and geophysics. Departments and professional bodies need to accommodate this development. Finally, while some traditional geology and geophysics courses remain essential, technical advances and changes in business practices over the past decade have resulted in mining, oil, and public sector organizations now needing a new range of scientific and non-scientific skills to augment or replace those that went before. Students need to be aware of these evolving requirements so that they are properly prepared for meaningful careers. Adapting to change throughout the geoscience community is a stressful process but adjustment is essential. Everybody in the community loses should the needed changes not be accomplished in a timely manner. To ensure that change creates a win-win environment, it is imperative that departments, professional societies, and industry work together to achieve this goal.

ACKNOWLEDGMENTS

I would like to thank journal reviewers Michael Church, Jeremy Hall, and Alan Morgan, also *Geoscience Canada* editor Roger Macqueen, all of whom made valuable and helpful suggestions used in revising the manuscript. This study would not have been possible without the co-operation of the companies that submitted data.

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Accepted as revised 10 December 2001