

## Chapter 9

# The Human Face of Economic Geology: Education, Careers, and Innovation

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### Abstract

On this 100th anniversary of the journal *Economic Geology*, we focus on the economic geologists themselves; specifically, how to maximize and fully realize their human and commercial potential, both on an individual and corporate scale, in the context of a profession undergoing significant change.

All geologists, regardless of career position, have competencies to greater or lesser degrees in three main areas: technical, business, and social. Where the industry overwhelmingly falls short is with respect to social competencies; the mining industry appears out of step with society at large and needs to realign itself, or at least make its message better heard and understood. This challenge underlies many of the sustainability and social issues that are currently the focus of much industry attention.

With respect to education, minerals programs worldwide are shrinking; there will clearly be a diminished supply of potential future explorationists. The social contract between universities and the mining industry, whereby society, through subsidy with tax dollars, provided de facto job training by the universities in order to enjoy the benefits of mining, has been broken. Industry will need to incur significantly more of the costs and provide significantly more funds and training in order to obtain the graduates it needs.

Extensive career data suggest that a typical career in exploration geology involves three basic tracks: technical, general management, and executive. The separation of the technical and management-executive tracks occurs at approximately year 10 of an individual's career; separation of the executive from the management track occurs at approximately year 15. The difference between the three tracks lies mainly in the acquisition, development, and recognition of social competencies, in addition to some business competencies. An individual's position on these tracks is relatively fixed unless significant new competencies can be acquired, utilized, and recognized. In addition, the mining industry is extremely cyclic, generally due to slumps in commodity prices; practitioners within it are periodically subject to severe change and are buffeted by the disruptive winds of job loss, relocations, family issues and/or lifestyle choices, all in the context of varying degrees of opportunity. It is no longer the exception, but now the norm, that industry explorationists will undergo periods of disruption, including sector shifts, layoffs, retraining, and certainly increased stress and uncertainty. This has implications for the supply of future practitioners and their expectations.

Attempts to develop a metric to categorize and measure social competency skills led to a classification and analysis system of underlying personality types, similar to that initially proposed by Carl Jung. Specially, a modified Myers-Briggs test was used here. Results from these tests show that people joining the minerals industry do not reflect the full range of personality types present in the general population. Further, the personality traits of senior minerals personnel increasingly diverge from the overall population; there is a kind of distillation process, whereby industry executives are increasingly thinking as opposed to feeling, extroverted as opposed to introverted. The net result is that the cohort comprising industry's management and executive class comprises a personality type distinctly different from that of society at large; this gap is suspected to be a major reason for the disconnect between the mining industry and society. Simply put, the way industry approaches, views, and communicates about issues is very different from the way society at large thinks and communicates about the same issues. Education and training in social competencies, perhaps similar in aspect to the leadership training currently practiced by the military, may be one approach to bridging this gap. There is a distinct correlation between certain personality types and position on the corporate ladder within the mining industry. As the emphasis on multidisciplinary and multipersonality teams in exploration increases, individuals with the social competencies to lead these teams will thrive. Breakthrough innovations are increasingly seen as the application of technologies or processes developed

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in other industries to problems facing the mining industry. Individuals and companies that can appreciate and implement concepts from other disciplines will generate the new revolutionary technologies, and they and their companies will profit accordingly.

### Introduction

If the necessity of entering mines often involves vexing delays and loss of time, it brings the geologist into contact with men of many types and teaches him that a knowledge of human nature may in some cases be quite as useful an instrument of investigation as petrography.

—Ransome, 1905, p. 10

THIS QUOTATION, taken from the very first article in *Economic Geology* by Fredrick Leslie Ransome (1905), addresses our present theme: the knowledge of human nature and how it affects the minerals industry and our careers within it. At the same time, we attempt to look forward to see what the future holds for us and our industry.

The papers in the *Economic Geology 100th Anniversary Volume* testify that the science of economic geology is alive and vibrant. But what of the practitioners? Will there be exploration jobs? Will the job be the same? What can the industry (and its members) expect in the years to come? The global and historical forces affecting the mining industry in the recent past have been well documented and discussed by Snow and Juhas (2002). In contrast to these authors, our focus is centered on the scale of the individual rather than the industry as a whole. First, we turn to questions of overall supply and demand. Will there be enough minerals professionals in the future? Will they be able to achieve decent jobs or careers? We do this first by looking at the supply pipeline, university programs in economic geology and mining engineering worldwide. We then compare the estimated supply of minerals professionals to the predicted demand. This gives us a big picture view of the industry as whole at this one instant in time, and helps constrain the expectations of the practitioners within it.

We then examine the careers of explorationists. What can an explorationist expect from his/her career? What are the career paths within the industry? What are the tracks on a career ladder and their timing? What skill sets will be required for these career tracks? How do these skill sets compare with what was required to do the job in the past?

Finally, we close with brief looks at what we consider to be three significant trends for future explorationists: interdisciplinary teams, social responsibility, and managing for innovation. How the geologists and mining companies of the future address these themes will, we believe, dictate in large part how successful they will be.

### Education: The Starting Point

Most professional careers in the minerals business start with university training but this training is in jeopardy at many institutions throughout the world. The following sections, which review the status of minerals education in several coun-

tries with strong traditions in the field, show a significant loss of educational capacity. This decline can be attributed most easily to economic pressures on the industry and universities, but it also has important social and cultural aspects.

There are three major reasons for the decline in support for minerals education:

1. Student numbers in minerals education are falling, and many universities worldwide are questioning the need to maintain their economic geology, mining engineering, and metallurgy programs. The very small job market in the minerals industry partly explains the low student numbers, but they also reflect students' perceptions of the industry and its activities. The minerals industry does not have the cachet it once had.

2. Universities are increasingly being run as businesses, and not as a public good (see for example, Strauss and Howe, 2005). In this context, minerals education is a very small, and rather expensive, niche in the education market; it is not a lucrative market for universities. It is much cheaper to teach large lecture courses in the arts than to run small-group laboratory and field classes in geology and mining engineering.

3. The social contract between the universities and the minerals industry has broken down. Universities have been, in effect, subsidizing industry by providing tax-supported job training in return for anticipated social benefits. As society sees less mutual benefit from this arrangement, social and political support for minerals programs is waning and, when this is compounded with economic pressures, university-based minerals programs are being eliminated.

Although much weaker than in the past, the minerals education sector can still be revived and, indeed, it may benefit from a thorough review and reconfiguration. Any such review should recognize that minerals education does not occur in a vacuum. It is one more element in the complex social, economic, and political environment in which the minerals industry operates.

### *Minerals education: The United States and Canada*

The geosciences, economic geology, and mining engineering are minority interests in North America. The geosciences accounted for approximately 1 percent of all bachelor's and master's degrees in science granted in the United States in 1998 to 2000 (American Geological Institute, 2002; NSF, 2004). Enrollment in the geosciences has fluctuated greatly over the past 50 years, but it is currently at its lowest level in the United States since 1968 (American Geological Institute, 2002). More than 25 U.S. geoscience departments have announced closure since 1998, and many remaining departments have merged with other disciplines (Rossbacher and Rhodes, 2004). Student numbers in Canadian geoscience departments, however, have recovered significantly after a drastic decline in the late 1980s and early 1990s (Michael Doggett, pers. commun., 2005).

The statistics on economic geology are somber: there was an overall halving of the number of North American economic geology graduate students in the decade 1984 to 1994 (Einaudi, 1994), fewer than 2 percent of North American geoscience faculty list economic geology as their primary interest (Dilles et al., 2003), and the proportion of economic geology faculty relative to all geoscience faculty in North America has halved over the past 25 years (American Geological Institute, 1975, 2004). Long-standing and prestigious endowed chairs in economic geology at Harvard and Stanford universities were not filled by economic geologists when the incumbents retired in the past few years. The drop in student numbers and the likelihood that retiring economic geology faculty will not be replaced by economic geologists have led to the prediction that there may be fewer than 10 U.S. universities with any geoscience faculty studying mineral deposits in less than two decades (U.S. House Committee on Energy and Commerce, in press).

Mining engineers constitute less than 0.2 percent of all engineering graduates in the United States (NSF, 2004; U.S. House Committee on Energy and Commerce, in press). Enrollment in mining engineering in the United States halved between 1984 and 1994 (U.S. House Committee on Energy and Commerce, in press), but the number of bachelor's degrees awarded declined by nearly 75 percent. At least 12 mining engineering programs have closed in the United States since 1985. There are now 12 accredited mining engineering programs in the United States and nine in Canada, graduating a total of about 150 to 250 mining engineers annually. Enrollment in Canadian mining schools increased dramatically in 2003, with incoming classes up 237 to 412 percent at three universities (O'Hara, 2003). The increased numbers, however, still do not match 2000 enrollment figures (O'Hara, 2003), and it is unclear if the growth will be sustained. Almost 30 percent of U.S. mining engineering faculty may retire by 2010 (U.S. House Committee on Energy and Commerce, in press), and their replacement is far from certain.

Minerals programs in North America are highly fragmented. Dilles et al. (2003) show that those few universities with an economic geology program typically have only one economic geologist on faculty. Testimony presented by Mary Poulton to the U.S. House Committee on Energy and Commerce (in press) suggests that two to five faculty members per existing mining engineering program would be appropriate. Such small departments make it difficult to teach the full spectrum of economic geology or mining engineering, collaborative research becomes more challenging, and students do not benefit from the synergy of a team approach.

*Composition of the U.S. student body:* A major decline in the number of male geoscience students is causing a significant change in the gender distribution of U.S. geoscience graduates. The actual number of women students has remained relatively constant but, with the drop in male numbers, the percentage of women enrolled in geoscience has risen consistently from 18.5 percent in 1974 to 38 percent in 2000 (American Geological Institute, 2002). Women now obtain 40 percent of undergraduate degrees and 38 percent of master's

degrees in geoscience in the United States (Holmes et al., 2003). In Canada, 25 percent of the 2003 graduates in mining engineering were women (O'Hara, 2003). Although this still does not match the proportion of women in the general population, it does present a stark contrast to the percentage of women now in the minerals industry. Women made up 15 percent of the total mining industry workforce in the United States in 2003 (U.S. Department of Labor, 2004), fewer than 11 percent of the mining engineers in the United States in 2001 (U.S. Department of Labor, 2002), between 2 and 14 percent of various professional occupations in mining in Australia in 2000 (Horsley, 2000), and 8 percent of the total mining workforce in Queensland in 2001-2002 (Australian Bureau of Statistics, 2004, <http://www.abs.gov.au/Ausstats/>). There is likely to be an increase in the percentage of women in the minerals industry, and this may bring changes to the industry and its practices.

The number of ethnic-minority students studying geoscience in the United States is very low. In 1999-2000, only 55 African Americans and 125 Hispanic Americans earned bachelor's degrees in any of the geosciences (Czujko and Henly, 2003).

No other field has a lower participation among either African Americans or Hispanic Americans than do the geosciences. ... Among geoscience bachelor's [degrees] awarded [in 2000], African Americans and Hispanic Americans earned a mere 1.3 percent and 3.1 percent, respectively. (Czujko and Henly, 2003)

The number of foreign undergraduate and graduate students studying geoscience in the United States also fell significantly during the 1990s, from more than 8 percent of all students in 1990 to just over 2 percent in 2001 (American Geological Institute, 2002). The percentage of foreign students in minerals education may not be as low as for the geosciences overall, but exact figures are not available.

Nearly one-fifth of the adult population in the United States comprises people with disabilities, but there is insufficient information to draw any conclusions on their participation in the geosciences (Karsten, 2003). This could be significant for employers under the Americans with Disabilities Act of 1990, which prohibits discrimination on the basis of disability.

Creating a multi-ethnic or multinational workforce from the U.S. student pool will be increasingly difficult if current trends continue.

#### *Minerals education: Chile*

Student numbers in Chile have remained constant for the past several years. Approximately 40 to 80 mining and metallurgical engineers graduate yearly, with similar numbers of geoscientists. The mining industry employs approximately 75 to 80 percent of graduate geologists (Reinaldo Charrier, pers. commun., 2004).

The major centers for minerals education in Chile are the Universidad de Chile, in Santiago, Universidad Católica del



Norte, in Antofagasta, and Universidad de Concepción. The geology departments in these universities were founded in 1956, 1971, and 1972, respectively, and by 1997, had a total of 829 geoscience graduates, more than 60 percent of whom came from the Universidad de Chile (Aguirre et al., 2000). The Universidad Católica del Norte started a master's degree program in economic geology with a specialization in exploration in 1996. By 2000, there were 23 graduates of the program, nine of whom were non-Chilean (Aguirre et al., 2000). Some minerals or mining courses are also offered at Universidad de Santiago, Universidad de Atacama, Copiapó, and Universidad de Tarapacá, Iquique.

#### *Minerals education: Australia*

Minerals education in Australia is in decline. A major report by the Minerals Council of Australia (1998) showed the minerals education sector to be fragmented, unstable, and fragile; a further study in 2003 states that the situation has deteriorated considerably and that few Australian tertiary minerals education programs are viable under existing circumstances (Galvin and Carter, 2003a). Some 14 minerals programs closed, were likely to close, or had been modified between 1998 and 2003. The number of mining engineering graduates fell 30 percent, earth science graduates fell by 60 percent; the number of metallurgists, however, rose by 150 percent from 2001 to 2004 (Galvin and Carter, 2003b). Nevertheless, Galvin and Carter (2003a) note the dire state of metallurgy programs, but they suggest that mining engineering and earth sciences are holding ground in spite of the closure of several programs.

Following the 1998 report, the Minerals Council of Australia set up the Minerals Tertiary Education Council (MTEC) to work with universities and industry to secure minerals education in Australia. The MTEC program is still in its first five-year phase, and it has not yet achieved its goals.

#### *Minerals education: Western Europe*

Minerals education is weak in Western Europe. Some universities, such as Freiberg, Cracow, and Leeds, do maintain independent programs. In addition, two cooperative programs, the European Mining Course and the European Mineral Engineering Course, were created in 1996 and 1998, respectively, to maintain skills in mining engineering and minerals engineering. Six universities—Aachen; TU Delft; Helsinki; Imperial College, London (Royal School of Mines); Exeter (Camborne); and Leeds—teach the courses cooperatively. For eight months, the students move as a group among universities studying specific areas of expertise, they then complete M.Sc. thesis work at the most appropriate campus for their specialty. Total enrollment in the Mining course was 131 from 1996 to 2004; the Mining Engineering course had 73 enrollees between 1998 and 2004 (European Mining Course, 2004, <http://www.emc-edu.org>).

#### *Minerals education: Rest of the world*

Some parts of the world have not seen the drastic decline in student numbers and minerals programs that is apparent in much of the developed world. Many developing coun-

tries have thriving undergraduate programs in mining engineering, and there are large minerals programs in China and Eastern Europe (McDivitt, 2002). Graduates from developing countries often move to North America, Australia, or Western Europe for graduate training, thus helping to sustain graduate programs in the countries to which they move (McDivitt, 2002).

#### *Supply of graduates*

Student numbers respond strongly to employment opportunities: "The key influence [on cyclicity in student numbers] seems to be the industry's demand for graduates" (Minerals Council of Australia, 1998). Data from the University of Arizona over a 20-year period show that general undergraduate enrollment in mining engineering falls in tandem with a drop in copper prices, but lags a rise in copper prices (U.S. House Committee on Energy and Commerce, in press). Australian data show that the number of mining engineering graduates similarly tracks investment in the minerals industry (Minerals Council of Australia, 1998).

Students commit to a specialty two to four years before graduation and a downward business cycle may have changed into an upward cycle before the students become available for employment. This time lag probably means that there will never be perfect equilibrium between industry's demand for students and the supply of students from universities. The challenge is for industry and universities to work constructively around this known problem.

The traditional university system is not designed to respond rapidly to changes in demand. Student numbers may rise and fall cyclically, but any loss of educational capacity is likely to be permanent. If minerals programs are abolished during a downturn in student numbers, the university system will not be able to deal with increasing student demand during an industry boom. The tenure system, by which faculty are guaranteed a job until retirement, builds stability and has allowed many minerals programs to survive even with low enrollments, but it also works against rapid change. If tenured positions in minerals are lost to other specialties, those positions may not become available again for 20 or 30 years.

#### *Initial employment of graduates*

Producing graduates in geoscience, economic geology, or mining engineering is only part of the requirement for developing and maintaining a skilled workforce. Graduates must find employment if they are to enter or stay in the field. During the 1990s, the primary problem for people wishing to join the minerals industry was not obtaining a minerals education, it was obtaining and maintaining employment. The statistics indicate an oversupply of minerals graduates during the 1990s. For example:

1. Only 25 percent of Colorado School of Mines graduate students in economic geology and mining engineering, with U.S. citizenship, found employment in the minerals industry in the period 1993 to 2002 (M.W. Hitzman, pers. commun., 2004).

2. Ten years after graduation, 50 percent of Canadian mining engineers are no longer involved with the mining industry (O'Hara, 2003).

3. Between 30 and 50 percent of students in Canadian mining engineering programs do not even seek employment in mining (Archibald et al., 2002).

4. More than half the graduates of many mining engineering schools worldwide find work in fields not related to minerals (McDivitt, 2002).

5. Industry information indicates that approximately 30 percent of entry-level practitioners leave the field within the first five years of employment.

This wastage of graduate- and entry-level talent has not presented a problem for the industry in the past, though it is often a problem for the individuals involved. Since the early part of the 20th century, the mining industry has been conditioned to expect an oversupply of graduates and potential workers (Ochs, 1992). Industry has expected to cherry-pick the very best graduates to use in its workforce, but now that the forces of supply and demand appear to be changing, the minerals industry may need to focus more attention on attracting, recruiting, and retaining suitable employees.

#### *Future demand for graduates*

There is little information on worldwide demand for explorationists, but the situation may be similar to that for mining engineers where, at first glance, there now appears to be a crude equilibrium between industry requirements as a whole and the total number of available graduates. In 2004, approximately 500 bachelor and 190 master of science degree mining engineers will graduate from universities in Australia, Canada, Chile, South Africa, the United States, and the United Kingdom; this represents the lowest number since the early 1990s and is approaching the lowest number since surveys of these data began in the mid-1970s (Davidson, 2004). The estimated average demand for graduate mining engineers is between 500 to 800 mining engineers per year (Davidson, 2004). This estimate assumes normal rates of retirement (4–5% per year for the next 10 years) in the United States and Canada. If the rate of retirement rises in these two countries, then demand for mining engineering graduates is estimated to increase to 700 to 900 per year (Davidson, 2004). The apparent balance in supply and demand for mining engineers worldwide, however, takes no account of the fact that up to half of all mining engineering graduates do not enter the minerals industry (Archibald et al., 2002; McDivitt, 2002). There may actually be a shortfall of up to one-half in the numbers of mining engineers likely to be needed by industry in the coming years.

On closer inspection, there appears to be a significant disparity between the number of available graduates and industry's needs within the United States and Canada, and this situation could get much worse in the years ahead. One recent study shows that 300 mining engineers will be required annually for the next 12 years simply to replace

those who will be retiring in the United States; currently, approximately 80 to 100 mining engineers graduate annually in the United States (U.S. House Committee on Energy and Commerce, in press). The U.S. and Canadian mining industry workforce is aging. In Canada, the proportion of people over 40 in exploration is higher than would be expected based on national demographics (Michael Doggett, pers. commun., 2005); estimates suggest that 40 percent of Canada's mining engineers will retire before 2018 (O'Hara, 2003), and that 50 to 75 percent of the overall Canadian mining workforce will retire by 2015 (Silver, 2004). The problem appears not to be the retirement rate per se, but the lack of younger workers in the industry who can be promoted to replace the soon-to-be-retired, and the lack of entry-level workers at the beginning of the employment pipeline.

Mining represents an extremely small employment market: the 100 managers, 1,000 scientists, 1,500 engineers, and 1,600 technicians employed in metal mining in the United States in 1998 represent fewer than 0.1 percent of all scientists, engineers, and technicians employed in the United States (NSF, 2001), and the 2,400 mining engineers in Canada form only about 1 to 2 percent of the country's professional engineers (O'Hara, 2003). Nevertheless, within this niche market in North America, there will be an increased level of demand for graduates, particularly those perceived to be potential stars. Recruitment and procurement costs for these individuals will increase; one can expect signing bonuses and significantly higher starting salaries, and there may be an influx of foreign workers into the North American sector. It is going to be a good time to be a future graduate in the mining industry.

#### *Implications for industry and universities*

Industry has relied on universities to provide initial training for the professional workforce, and there has been relatively little need for interaction between educators and employers. This situation is changing. It is our contention that with the breaking of the traditional social contract and the general withdrawal of government support for minerals education and research a new model of university-industry partnership will be required to guarantee the survival of both large- and small-scale minerals programs. Without a long-term, sincere commitment by universities and industry to sustain a mutually beneficial system of minerals education, the outcome could be the collapse of the current structure, with no viable replacement in sight. If industry values university training for its workforce, it will have to provide strong support to ensure its survival (Hitzman, 2005).

The time may have come for a comprehensive review of the educational needs of the minerals industry. Are universities vital to maintaining professional expertise in the industry? What other sources of education are available or appropriate? What skills are needed by individuals, and by the workforce as a whole? At what point in an individual career path are certain skills most needed, and how are they best acquired? Who should pay for an adequate minerals-education system?



Most minerals education programs in the developed world are too fragmented and too small to be viable. While there is a place for small programs, it may be necessary to develop centers of excellence offering an integrated, cross-disciplinary, comprehensive education in all aspects of the minerals system, including exploration, mining, and metallurgy; economics; cultural, legal, and social studies; and environmental studies. The synergies from co-locating all facets of the study of the minerals business should be attractive to students and faculty, and such centers should have enough critical investment mass and economies of scale to survive the immediate pressures of university budgets and cyclic downturns in the metals markets. They should also be capable of producing the types of graduates required by industry.

Universities will not be willing to commit resources, however, unless there are clear indications of demand, backed by substantial financial support, from industry. Developing such university-industry partnerships will place burdens on both partners. Universities are accustomed to partnering with government; working with industry provides a different set of challenges. Both sides of the partnership must strive to understand each other's cultures and constraints, and to share the responsibilities of meeting each other's expectations, if a collaborative effort to maintain minerals education within the university environment is to succeed.

Universities currently provide highly specialized (and expensive) graduates "just in case" industry needs them; it may be more efficient for industry and universities to cooperate in ensuring an adequate supply of "just in time" specialized graduates, together with a wider pool of adaptive and skilled graduates. These general graduates will need further training and mentoring in order to operate independently in the minerals business. The whole area of continuing education is ripe for collaboration between industry, academia, and the professional societies. Professionals need to constantly update and add to their skill sets, and the trend toward professional registration and accreditation demands constant learning. There is probably a strong business case for developing coordinated programs, at strategic locations around the world, that focus on continuing professional development. Additional training could be provided through on-the-job training, postgraduate specialist courses, a work-study combination of internships and professional development, or by formal mentoring within a company.

Companies may choose to deal with universities on an individual basis, or they could form consortia to support specific programs or research. AMIRA (previously Australian Mineral Industries Research Association Limited) International and CAMIRO (Canadian Mining Industry Research Organization) currently operate on the second model. Most mining industry consortia only support short-term projects; AMIRA International projects, for example, typically last approximately three years (J. Cucuzza, 1999, unpub. rept.). This is in contrast to some research and development consortia within the computer industry such as MCC (Microelectronics and Computer Technology Corporation) and SEMATECH (SEmiconductor MANufacturing TECHNOlogy) which tend to have a longer-term com-

mitment to specific research efforts (Smilor and Gibson, 1991; Gibson and Rogers, 1994). Mining industry consortia have not yet focused on the long-term agreements needed to guarantee educational capacity for the future. A further constraint is that most mining research projects developed through consortia originate with university researchers (Cucuzza, 1999, unpub. rept.); industry only indirectly controls the research direction, first by choosing which proposals to support and then helping to refine some of the objectives. New collaborative models may be needed to allow more active participation by industry, in terms of funding, idea generation, and research management.

While most of these suggestions relate to operational and economic matters, industry and universities will also need to pay attention to the social and cultural aspects of maintaining minerals programs. The public image of the industry is important in attracting students and in promoting acceptance of minerals programs in a university's portfolio of discipline specialties. Educational issues are closely related to all the other social challenges that currently face the minerals industry, and should be treated as part of that whole.

### **Career Paths, Personality Types, and Climbing the Career Ladder**

This section examines many aspects of a career in the minerals industry, including the competencies required for success, the distinctive personality traits of people in the industry, and the resulting varied career paths and related compensation. The minerals industry is here considered to include metals, aggregates, coal, industrial minerals, and oil sands. The primary source of data for these analyses is derived from an extensive, ongoing study by one of the authors (LF) whose professional firm specializes in sourcing people for the natural resources sector. This study, comprising approximately two person-years worth of effort, examines the careers of more than 170 managers, engineers, geoscientists, finance professionals, and human resources personnel in the minerals industry, including an account of each participant's formal education, career positions and responsibilities, compensation history, a personality profile based on a Myers-Briggs Type Indicator (MBTI) test, and an in-depth behavioral-based interview. Job descriptions, performance expectations, and compensation packages for more than 1,000 individual positions in more than 200 companies were also analyzed. Additional information is drawn from a database of more than 20,000 resumes from professionals on seven continents, and interviews of varying completeness with more than 1,000 professionals. The data vary from information on entry-level practitioners to senior-level professionals on the cusp of retirement, but are centered on those with 10 to 30 years' experience, earning a base compensation of US\$75,000 to \$150,000 annually. A separate study of the employment history of 42 individuals, combined with a more general study of 230 geological careers, is also discussed.

#### *Personal competencies and the career ladder*

Table 1 summarizes the typical career ladder from entry-level geologist to chief executive officer in the mining/explo-

TABLE 1. The Career Ladder Defined in Terms of Seniority Levels, Typical Job Titles, and Competencies

Seniority level	Role - description and/or title	Example titles - major company	Example titles - midsize-junior companies	Supervision or influence (1)	Relative competencies																	Compensation (2)		
					Technical				General management				Executive				Total Competencies	Nominal units	Base compensation \$US ± 20% midpoint major company	Bonus				
					T	B	SI	SE	T	B	SI	SE	T	B	SI	SE								
1	Graduates or no supervision	Junior geologist		nil	2	0	0	0										2	1	\$50k				
2	Supervisors or engineers with a few years experience	Project geologist		0 to 5	3	0	1	0										4	1.2	\$60k				
3	Project managers, senior engineers or accountants, superintendents	Senior geologist, chief mine geologist, project manager		2 to 20	3	1	1	0	2	1	2	0						5	1.6	\$80k				
4	Division or department managers and project directors and resident managers	Senior proj manager, Senior = Geologist (corp)		5 to 100	4	1	1	1	2	2	2	1						7	2.4	\$120k	+			
4.5		Chief geologist (corp)		10 to 200	4	1	2	1	2	2	2	2	2	2	2	2		8	3.2	\$160k	++			
5	General manager		COO, Sn VP, VP GM	20 to 500	4	2	2	1	2	2	3	2	2	2	3	2		9	3.6	\$180k	+++			
5.5		EVP, COO, CFO, Senior VP							2	3	3	2	2	2	3	3		10	6.0	\$200k - \$400k	++++			
6	Managing director	Chairman, CEO	CEO, EVP	50 to + 500									2	3	3	4		12	11.0	\$300k - \$800k	+++++			

Note: The compensation figures given are within approximately 20 percent of 2004 compensation levels in the United States, but are not based on a comprehensive salary survey; relative compensation levels for different seniority levels are probably a more reliable indicator than the actual dollar amounts

1 = Includes direct supervision in hierarchical organizations, informal relationships in matrix organizations, as well as responsibility to influence stakeholders

2 = To this base can be added allowances for international work and hardship; major company base salary

Major company title abbreviations: CEO = chief executive officer, COO = chief operating officer, EVP = executive vice president, GM = general management track, Sn VP = senior vice president

Competency levels: 0 = low, 1 = medium, 2 = high, 3 = very high, 4 = unique expertise

Relative competencies:

B = Business competency: application of technical competency to the business of the company

SE = Social competency applied externally, i.e., without some measure of authority

SI = Social competency applied internally, i.e., with some measure of authority

T = Technical competency: applies to primary discipline, i.e., mining, geology, finance or human resources

+ = Nominal unit of bonus, might represent 10 or 20% of base compensation, or stock options



ration business; it correlates seniority with the competencies needed for each position. Six general seniority levels, with some half steps, are used to categorize professionals in a simple system: seniority is calculated from a combination of job responsibilities, the competencies needed for the job, the number of people supervised, and the level of compensation.

Competencies are the skill sets needed to fulfill the functions of the job effectively; there are three broad categories of competencies—technical, business, and social. The latter is subdivided into internally directed and externally directed social competency.

*Technical competency*, as defined here, applies to the knowledge and utilization of a specific discipline of formal study, such as geology, mining, finance, accounting, or human resources. In the case of economic geologists, it includes physical geology, stratigraphy, alteration, economic geology, field mapping, and can include parallel studies such as physical chemistry or engineering. The foundation of technical competency is usually education and aptitude, but the level of competency increases significantly with mentoring and/or experience.

*Business competency* refers to the understanding and utilization of business concepts to realize commercial value from technical competency. It embraces a broad range of topics from the time value of money, to accounting and business management topics, organizational structures, and the application of technologies and their commercial consequences. The foundation of business competency is usually education and aptitude, but it increases significantly with mentoring and/or experience. Most minerals professionals develop a significant component of business competency without the benefit of formal training, and there may be scope for considerable improvement in this area.

*Social competency* defines a person's ability to sell ideas, provide leadership, and to influence and motivate others. It includes empathy, listening, understanding, salesmanship, intervention, leadership, change management, and the realization of strategic plans. Social competency allows the creation of value through others, thereby multiplying an individual's technical and business competencies. Social competency is applied internally and externally to the company—persuading and leading people within the company structure where there is a level of authority associated with the action, and persuading and communicating with people outside the company structure where there is no associated authority. Social competence appears to be particularly dependent on personality type and preferences; it can, however, be taught and learned.

Competencies are a key to success. The ability to create value is directly related to an individual's combination of technical, business, and social competencies, and the range of competencies required increases with increasing seniority. At the start of a career, technical ability is most crucial, but even the best technical idea is worth little if it is not accepted by others and applied, so social competency is also required to realize value from technical knowledge. Further up the career ladder, greater management and business skills are required; this brings into play a different

set of competencies (Table 1). Individual opportunities and personal choices multiply in proportion to the level and breadth of competencies. A balance of competencies can be deliberately developed and acquired at critical points along a career path; Table 1 highlights the competencies and the level of proficiency that are needed to progress from one level of seniority to the next. Individuals and companies can plan strategically to cultivate relevant competencies in a timely fashion.

#### *The importance of social competency*

Social competencies are critical to the business of mining because social competency leverages technical and business competencies to realize commercial success. Two trends, the increasing use of multidisciplinary teams and the increasing influence of stakeholders in corporate affairs, reinforce the strong business case for cultivating internal and external social competency. Social competency is also vital for the individual hoping to climb the corporate ladder. For the highest common position on the technical track (seniority level 4.5), social competencies constitute over a third of the total competencies (Table 1). For general managers and executives (seniority levels 5 and 6), social competencies exceed half of the total competencies.

At present, universities provide the foundation for the development of technical and business competencies but they do not teach social skills. The development of courses in leadership, which is one component of social competency, may provide a useful analogy. For many years, leadership was considered innate; there were born leaders. However, the U.S. military and others, following extensive study and analysis, developed leadership training programs that help develop and expand natural leadership tendencies. It should be possible to create similar programs for all aspects of social competency.

It is personality types, however, and not course work, that provide the foundation upon which to develop social competencies. Is the industry recruiting graduates with this in mind? Do students and employees realize the unique career opportunities for those who develop strong social competencies? Is industry providing mentoring programs to develop social competencies in concert with technical and business competencies?

#### *Compensation and social competency*

Compensation increases rapidly with increasing seniority (Table 1). The compensation figures given in Table 1 are within approximately 20 percent of current compensation levels in the United States, but they are not based on a comprehensive salary survey. The relative compensation levels for the different seniority levels are probably a more reliable indicator than the actual dollar amounts. The figures show the high value of individuals with broad and deep technical, business, and social competencies, and the corresponding lesser compensation for those with more restricted skill sets. The higher compensation for managers and executives is justified by the multiplier effect that is introduced as the number of people supervised or influ-



enced increases. A chief geologist, for example, can propagate his or her technical and business ideas by promoting them throughout the company where they can be used by others to create value.

Each unit of competency within Table 1 is estimated to be worth approximately US\$15,000 to \$20,000 in annual base salary for seniority levels 2 through 5. Level 1 starts out relatively high (\$25,000 per unit) as new graduates are paid a premium for potential. At executive levels (5.5 and 6), compensation increases sharply in recognition of the uniqueness of those individuals with the necessary balance of competencies (\$20,000 to \$65,000 per competency unit).

We work in a market economy. To be paid more, an employee must create more value than his/her peers. How is this possible? In most cases, a professional with some balance of technical, business, and social competencies is worth substantially more than one without balance. For example, to realize value in private industry, a technical idea must be used to create commercial value. A technical expert must have sufficient social skills to ensure that his/her idea is accepted and used by others. The ultimate potential value of any particular technical concept is increased at any point in time by its degree of application. Of course, a company or an individual may seek out others with social competencies to help sell technical ideas, but this obvious solution involves all or portions of two salaries to deliver the product. Those professionals capable of efficiently and effectively selling their own technical or business ideas have higher value. Ultimately, it is social competence that provides the opportunity to produce value well beyond that of an individual contributor, because influencing others to adopt one's ideas provides a multiplier effect.

*The three-track model:* Figure 1 shows the career trajectories of individuals believed typical for their relative seniority positions: executives, middle managers, and technical experts. Note that all the individuals depicted in Figure 1 stayed within the industry throughout their careers; this is not necessarily the norm for many employees. Some key points in regards to Figure 1:

1. There is nothing particularly unique about career trajectories in the minerals industry. They are believed to be similar to career paths in other industries, at least as shown by this type of diagram.

2. Career trajectories are essentially fully developed in 20 years.

3. Most people reach seniority level 2 in approximately 2 years. A separation between the career trajectories of those on the technical track and the management tracks typically starts 5 years later (approx. year 7) and is distinct in another 5 years (approx. year 12). By that time, individuals are more or less determined to be on the management or the technical track.

4. The executive track typically begins to split out from the general management track in year 12.

5. Advancement to the next seniority level, or to a different career track, is accomplished by acquiring additional functional competencies. It takes about five years to acquire competencies and learn to employ them effectively, and for

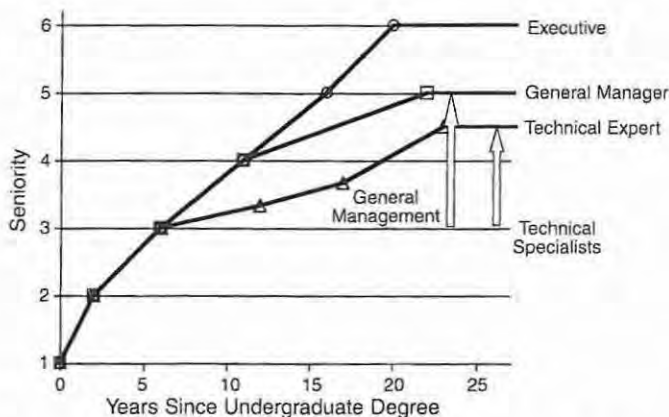


FIG. 1. Advancement on the career ladder, starting from year of undergraduate degree. All tracks start with a two-year apprenticeship period. Subsequent changes tend to occur in 5-year intervals, typically reaching completion in approximately 20 years. The technical track starts at level 1 and proceeds to a maximum of 4.5. The general management track branches off from the technical track at approximately level 3 at about year 7 and advances to a maximum of 5.0, general manager. The executive track branches off from the general management track at approximately level 4 at about year 11 or 12 and continues to levels 5.5 and 6.

employers to recognize and reward the additional competencies through promotion.

*Changes in job sector:* The career paths in Figure 1 follow smooth trajectories. A different analysis of career paths can produce a very different pattern, full of abrupt zigzags. Here we examine the experiences of 42 geoscientists and measure the number of times they changed employment sector (defined as student, academia, federal or state, industry, consulting firm, self-employed or individual consultant, non-profit, and other or nongeologic) during their careers. The study stemmed from the anxiety of some geoscientists that they did not have what is perceived as a traditional career path—one in which they got a steady job that provided a well-defined path to career advancement, a sense of personal and corporate identity, and minimal disruption to other facets of their lives. With so many geoscientists seemingly having nontraditional career experiences, the question became: What is a traditional career path in the geosciences?

Respondents were asked to plot their career paths on a graph with time plotted on the Y-axis, and employment sector on the X-axis. Changes of job within a sector do not show up on this plot but a change of sector, by definition, implies a change of job. The resulting plots were analyzed for the number of sector changes and the average time spent in a sector. All respondents had a minimum of five years' postgraduation experience, the mean being 26 years.

Approximately 30 percent of respondents had a traditional career path, as illustrated in Figure 2. They changed sector 0 to 2 times in careers that average 30 years to the time of the survey. Three-quarters of geoscientists with this career path worked in the federal government, state government, or academic sectors.

The remaining 70 percent of respondents had a nontraditional career path, such as that illustrated in Figure 3.

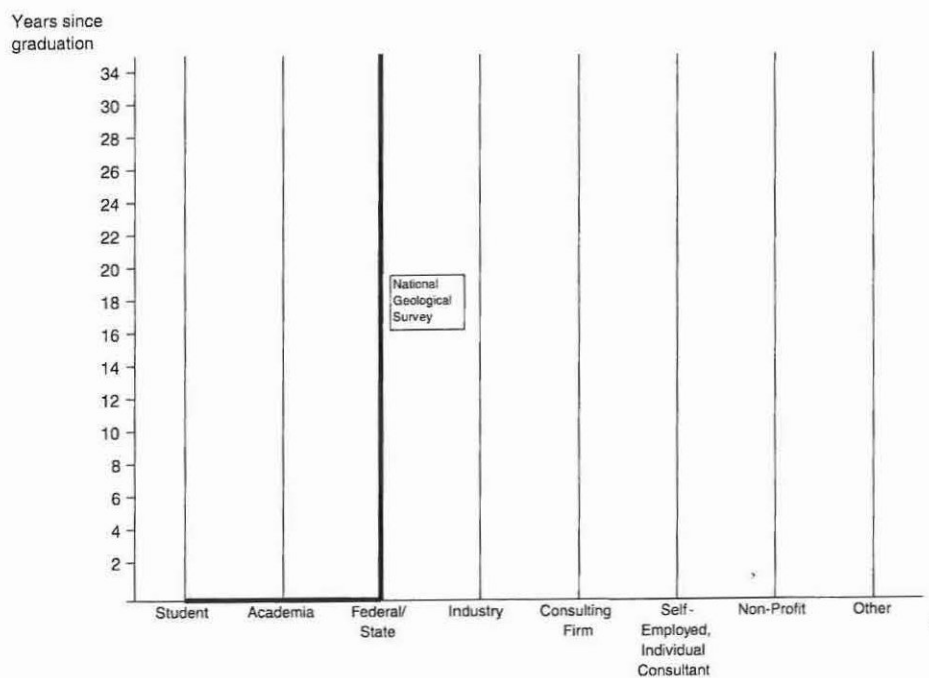


FIG. 2. A traditional career path. Paths such as these are still present in academia and government sectors; they have largely disappeared from industry.

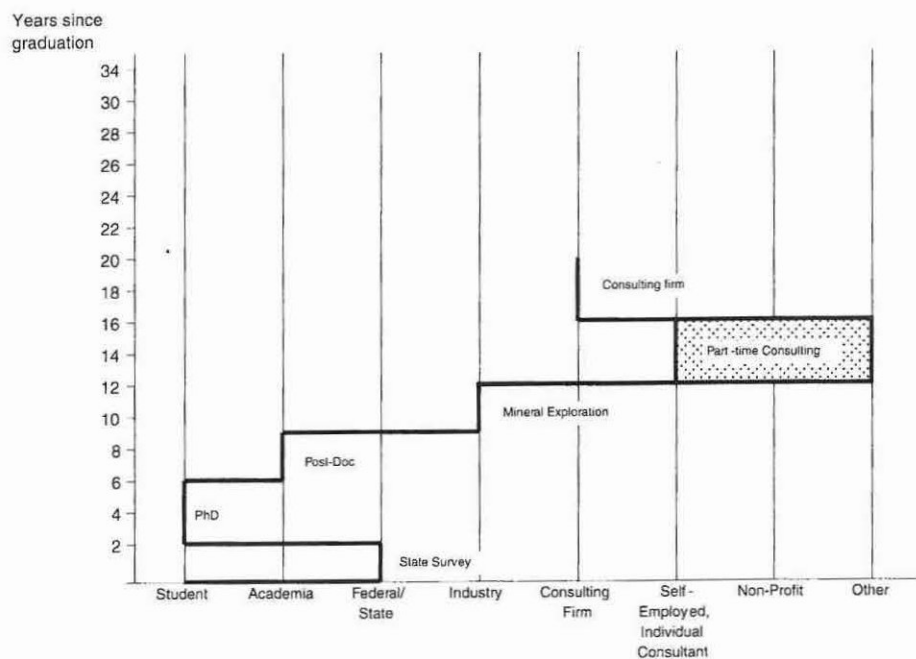


FIG. 3. One person's zig-zag career path. Paths such as these can now be viewed as the norm for industry exploration geologists.



These respondents averaged 25 years of experience each; they changed sectors between 3 and 11 times, with an average of 5 sector changes each. Most respondents changed sector every 5 to 6 years, with men showing a tendency to stay slightly longer in a given sector than women, probably reflecting the greater demands of family on most women. It is noteworthy, however, that almost equal numbers of men and women had nontraditional career paths. This zigzag pattern seems to be a fundamental characteristic of geoscience employment for many people, regardless of gender.

A preliminary study of the careers of Colorado School of Mines (CSM) geology and geologic engineering alumni who graduated in the 3 years from 1965 to 1967 shows the stability of employment in government and academia. Twenty-five percent of the 60 graduates for whom information is available entered government or academic employment and stayed there, the only exceptions being forced terminations resulting from the closure of the U.S. Bureau of Mines. Of the remaining 45 students, 8 percent of graduates never entered geologic employment, and equal numbers (22–23% each) entered the minerals, petroleum, and consulting or indeterminate sectors. A similar longitudinal study was performed on the career paths of CSM geology alumni from the years 1985 to 1987. The results compare well with the 1965 to 1967 data except that the percentage entering the mining industry was markedly lower (8% vs. 22%), and a significant percentage (27%) of the career paths showed major sectoral changes.

The results of these three studies, coupled with an abundance of anecdotal evidence, indicate that the perception of a traditional career path in the geosciences should, perhaps, be turned on its head. If a geoscientist does not gain employment in academia or government, he/she is very likely to have an interrupted career path, complete with layoffs, job shifts, and sectoral changes. The seemingly smooth trajectories in Figure 1 may mask sharper and more traumatic career changes such as those in Figure 3.

Many areas of geoscience employment are subject to cyclical demand, and changing sectors is often an astute adaptation to the prevailing conditions—one that also allows geoscientists to acquire many diverse skills and competencies. But voluntary and enforced changes come at a cost, often involving retraining, relocation, changes in compensation, and great uncertainty and stress. Given that this is the norm, is it any wonder that people in early and midcareer often make lifestyle choices that minimize the risk of such dislocation, frequently by leaving the minerals industry?

Thus we see that the average career of an explorationist is subject to two very real forces. One is the standard "time's arrow" (in the sense of Gould, 1987) as applied to careers—if you have not made the management track within 10 or so years of starting your career, you may never make it unless you deliberately develop additional competencies; and if you have been subjected to one of the many industry-wide purges, this too may remove you from the management track. Thus it can be seen that the pool of future executives within the industry is in fact quite limited.

### *Personality types and their role in the minerals industry*

*Classifying personality types:* Carl Gustav Jung, in his 1921 book, *Psychological Types*, was among the first to classify personalities according to a systematic metric. The fundamental premise of Jung's theory is that much seemingly random variation in behavior is actually quite orderly and consistent, being due to basic differences in how individuals prefer to use their perception and judgment (O'Brien et al., 1998). Thus, a relatively small number of discernable variables can be used to describe personality and to group people with similar personality types who tend to behave in similar, repeatable, and somewhat predictable manners.

The Myers-Briggs Type Indicator (MBTI) test is based on Jung's concepts. MBTI is widely used in many industries, particularly as a career guidance method. It is not without challenge (National Research Council, 1991; Pittenger, 1993); nonetheless, it is still the most commonly accepted tool for categorizing personality types. In a modified version of the MBTI method, two main indices are used to distinguish personality: (1) Extroversion-Introversion (E and I): Extroverts react to people and objects in the external environment; Introverts concentrate on an inner reality of concepts and ideas; (2) Thinking-Feeling (T and F): Thinking people make decisions based on objective, logical reasoning; Feeling people make decisions subjectively based on internal or external value systems and emotions (Pittenger, 1993; O'Brien et al., 1998).

Combining the two main indices generates four basic personality types:

1. IT (introverted thinking)—analytical, systematic, precise;
2. ET (extroverted thinking)—directing, controlling, responsible;
3. EF (extroverted feeling)—inspiring, motivating; and
4. IF (introverted feeling)—supporting, helping.

General tendencies and predicted behaviors for the four personality types are shown in Table 2. Everyone contains within them behavior patterns ascribed to all four personality types, but some are more dominant than others. The dominant type may vary in different situations in response to stress, group dynamics, or the personality preferences of others intimately involved in the situation. Most individuals comfortably use two personality preferences; they are termed classic. Some can use three; these individuals are described as accommodating. Some are more likely to use only one; these individuals are termed focused.

*Distribution of personality types in the minerals industry:* The minerals industry does not contain a representative cross-section of the personality types found in the general population. Minerals professionals favor thinking over feeling to a much greater extent than the general population: 76 percent of all minerals professionals are dominantly thinking types, in contrast to 51 percent of the general population (Table 3). This difference in feeling versus thinking is more marked when those with more than 20 years' experience in

TABLE 2. Classification of Jungian Behaviors and Associated Personality Traits

	Descriptors	Approach to life	Goals	Statements	Interventions	Decision making	Positives	Negatives	Energy
IT	Analytical	High standards and correct	Understanding	Let's do it right	Informative	Formal, detached, correct	Cautious, precise, deliberate, questioning,	Stuffy, Indecisive, Suspicious, cold, reserved	Analytical and distrustful
ET	Directing	Inner certainty, focus on action	Personal achievement, meeting challenges	Let's do it NOW	Confronting	Impersonal, objective, competitive	Competitive, demanding, determined, strong-willed, purposeful	Aggressive, controlling, driving, overbearing, intolerant	Impatient
EF	Inspiring	Fun and interactive	Recognition	Let's do it together	Expansive	Personal, involved, accommodating	Sociable, dynamic, demonstrative, enthusiastic, persuasive	Excitable, frantic, indiscreet, flamboyant, hasty	Disorganized
IF	Supporting	Focus on stability, values, supporting others	Harmony	Let's do it in a caring way	Supportive	Informal, considerate, caring	Caring, encouraging, sharing, patient, relaxed	Docile, bland, plodding, reliant, stubborn	Mild and docile

Note: We utilized the Insights version of the MBTI (Meyers Briggs Type Indicator) assessment tool in order to classify personality types. Abbreviations: EF = Extrovert-Feeling, ET = Extrovert-Thinking, IF = Introvert-Feeling, IT = Introvert-Thinking

TABLE 3. Distribution of Personality Types in the Mining Industry as Compared to the General Population

General population <sup>1</sup>		This study: Minerals industry			
		All, Minerals industry	By years since undergraduate degree		
			<10	10 to 20	>20
IT	15%	35%	30%	33%	37%
ET	36%	41%	31%	39%	46%
EF	36%	15%	26%	16%	10%
IF	13%	9%	13%	12%	7%

Mining professionals have a much higher proportion of thinking (T) personality types; this difference increases over time; differences can give rise to misunderstandings between leaders in the mining industry and the general population unless differences in behaviors are recognized

Abbreviations: EF = Extrovert-Feeling, ET = Extrovert-Thinking, IF = Introvert-Feeling, IT = Introvert-Thinking

<sup>1</sup> Keirsey and Bates (1984)

the industry are compared to the general population. Thinking characteristics dominate to such an extent that there are very few feeling-dominant personalities in the cohort with more than 20 years' experience in the industry who are in management grades (Tables 4 and 5). In addition, the general population is much more extroverted than those in the mining industry: 72 percent of the general population is extroverted versus 56 percent in the mining industry (Keirsey and Bates, 1984).

Executives in the minerals business are even more different from the general population than most members of the industry with respect to their primary personality type, and are significantly different from people with 20 years of industry experience but lower levels of seniority (Tables 4 and 5). People in general management tend to have accommodating personalities (Table 6); they can draw on

three personality types and employ them as appropriate to a situation. This suggests that general managers are more likely to be able to view problems from multiple perspectives and appreciate the perspective of others. They are less likely to be fixed on any one viewpoint. Executives (seniority level 5.5 and 6) and discipline specialists (seniority level 3 to 4.5), on the other hand, tend to be less accommodating and perhaps be more definite in their behavioral styles.

The percentage of professionals with extrovert-thinking characteristics increases consistently with seniority and is the dominant personality type in some 78 percent of the executives studied (Table 5). The most marked difference between lower seniority levels and executives with seniority levels 5.5 and 6 is the higher level of extrovert-feeling characteristics that correspond to the ability to inspire others (Fig. 4). The specific mix of personality types in any one



TABLE 4. Comparison of Roles Filled by Professionals with at Least 20 Years of Experience According to their Primary and Secondary Personality Types

Seniority	IF	IF/IT	IF/EF	IF/ET	EF	EF/IF	EF/IT	EF/ET	IT	IT/IF	IT/EF	IT/ET	ET	ET/IF	ET/IT	ET/EF
3 - 3.5		Sp-T										Sp-T				
		Sp-T										Sp-T				
		Sp-T				Sp-T						Sp-T			Sp-T	
		Sp-HR				Sp-T						Sp-T			Sp-T	
		Sp-HR		Sp-T		Sp-HR		Sp-HR		Sp-T		Sp-T		Sp-T	Sp-HR	Sp-HR
4 - 4.5												GM				
												GM				
												GM				
												GM				
												Sp-F			GM	
												Sp-F			GM	
												Sp-F			GM	Ex
												Sp-T			GM	GM
												Sp-T			GM	GM
												Sp-T			GM	GM
												Sp-T			GM	Sp-T
												Sp-F			GM	Sp-T
					GM	Sp-HR		Sp-HR	GM	Sp-T	Sp-T	Sp-T	Sp-T	Sp-T	Sp-T	
5																Ex
																Ex
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															Sp-T	Ex
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5.5 - 6																
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																Ex
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																Ex

Notes: Bold type denotes an accommodating personality; predictable behaviors associated with these personality preferences are consistent with their responsibilities; human resource specialists tend to have feeling (F) personality types; technical and financial specialist tend to be drawn from the introverted-thinking (IT) population; those in general management (GM) are typically extroverted-thinking (ET), while executives are dominantly ET, corresponding to their need/ability to direct and influence others to meet their responsibilities.

Abbreviations: IT = Introvert-Thinking, ET = Extrovert-Thinking, EF = Extrovert-Feeling, IF = Introvert-Feeling, IT/EF = Primary/secondary personality types, Sp-HR = Specialist-human resources, Sp-F = Specialists-finance, Sp-T = Specialist-technical, GM = General management, Ex = Executive

Individual also varies with seniority. Table 7 shows the percentages of professionals at various seniority levels who report a significant component of each personality type (note that the percentages may exceed 100% because people may utilize more than one personality type).

There are several possible explanations for why personality types of senior managers and executives differ from the characteristics of average employees:

1. Professionals with certain characteristics are more likely to advance to higher levels of seniority.
2. As they advance in seniority, professionals develop or refine certain characteristics to allow them to be effective.
3. Professionals with certain characteristics (introversion, feeling, and extremes of thinking) are more likely to seek other employment, or be forced out of the industry, early in their careers, leaving a population skewed toward certain personality characteristics.
4. Managers tend to hire and promote in their own image. Once a given manager type is established, it tends to persist.

*Team building with different personality types:* Professionals inclined to have particularly high technical or business competencies are most likely to be thinking introverts. Professionals inclined to have particularly high social competencies, including the ability and inclination to manage, inspire, motivate and influence people, are most likely to be thinking extroverts. Seemingly, good science or business and good implementation are mutually exclusive, or at least they do not typically reside within one person. One solution to this dilemma is to form multidisciplinary teams made of participants committed to working together, each with complementary strengths and weaknesses. With knowledge of cognitive processes, teams of professionals can be constructed so that the collective capacity of the team is greater than the sum of the capacities of the individual participants. For a team to operate efficiently there must be sufficient overlap in personality types to ensure communication within the team and to prevent marginalization of some team members. Our data suggest that there are no fundamental differences among the personality types of geologists, mining engineers,

TABLE 5. Comparison of Primary Personality Types, Seniority Levels, and Roles

	Seniority by primary personality type					n
	3-3.5	4-4.5	5	5.5-6		
IT	19%	52%	23%	6%	100%	31
ET	12%	35%	35%	19%	100%	43
EF	57%	29%	0%	14%	100%	7
IF	86%	0%	14%	0%	100%	7
						88
	Primary personality type by seniority					n
	IT	ET	EF	IF		
3-3.5	29%	24%	19%	29%	71%	21
4-4.5	48%	45%	6%	0%	52%	33
5	30%	65%	0%	4%	70%	23
5.5-6	18%	73%	9%	0%	82%	11
						88
	Primary personality type by role					n
	IT	ET	EF	IF		
Sp-HR	13%	25%	38%	25%	100%	8
Sp-T+F	50%	31%	6%	13%	100%	32
GM	37%	57%	3%	3%	100%	30
Exec	17%	78%	6%	0%	100%	18
						88

Personality types: EF = Extrovert-Feeling, ET = Extrovert-Thinking, IF = Introvert-Feeling, IT = Introvert-Thinking

Roles: Exec = executive, GM = general manager, Sp-F = specialist-finance, Sp-HR = specialist-human resources,

SP-T = specialist-technical

and finance personnel (Table 8). This implies that there are no major personality barriers that could prevent these professionals from acquiring and developing similar skill sets. Human resources personnel, however, show very different personality traits from geologists, engineers, and accountants. They typically have a much stronger focus on feeling attributes. Accordingly, companies might look to their human resources department to help build balanced teams, especially when the team is to deal with the general population whose feeling attributes are not reflected in the rest of the minerals industry.

Diversity in today's workplace is an important attribute. It is typically interpreted as comprising women, minorities, those with disabilities, etc. We suggest that companies could benefit from encompassing diverse personality types as well.

*Communication and personality—challenges for the mining industry:* The mismatch between the range of personality types within the mining industry and in the general population highlighted by our studies can lead to problems of understanding and communication. This mismatch may be one of the root causes of the challenges that the industry faces in obtaining a social license to operate or in meeting shareholder expectations.

Communication between individuals with different personality types can be severely limited unless the differences in thinking style are recognized. This starts with recognizing that everyone does not think, learn, or communicate in the same way. Individuals in the mining business may present data that they believe clearly outlines a task and the methods for undertaking it. However, to much of the general population, their presentation would appear suspect.

Understanding personality preferences provides a tool for understanding one's own strengths and weaknesses, and for understanding how to effectively communicate with, manage, and influence other people. It is best to use the language, communication style, and learning style of the person with whom one wishes to communicate.

#### *Implications for industry*

More than 50 years ago, Wallace Pratt pointed out, "Where oil [and ore] fields are really found, in the final analysis, is in the minds of men [and women]" (Pratt, 1952, p. 2231), yet people are one of the least valued assets in the mining industry. The skills and accumulated experience of the minerals workforce have largely been taken for granted. Now, however, industry cannot assume a constant (over)supply of either minerals graduates or experienced geologists. The situation calls for a strategic approach to managing the dwindling human capital in the industry.

Instead of an ad hoc policy of hiring anyone available in a boom, and firing just about everyone in a bust—a pattern well illustrated by many individual career paths—companies need to take a longer-term approach to developing a skilled workforce, maintaining a stable corporate knowledge base, and using that knowledge and experience to maximum advantage. The workforce represents a considerable investment by the individuals, companies, and society, and like any other asset it should be managed as efficiently as possible.

The human resources component of the minerals business is amenable to systematic analysis. The preliminary data presented above show the importance of personal competencies and personality traits to the minerals business, and the impact of job instability and the three-track



TABLE 6. Comparison of Role and Personality Types with Degree of Personality Type

	By role—general			n
	F	C	A	
Sp-HR	13%	75%	13%	8
Sp-T + F	3%	59%	38%	32
GM	0%	37%	63%	30
Exec	0%	61%	39%	18
				88

Technical specialists	By role and personality type			n
	F	C	A	
IF	0%	0%	100%	4
EF	0%	50%	50%	2
IT	0%	69%	31%	16
ET	10%	70%	20%	10
				32

General managers				n
	F	C	A	
IF	0%	0%	100%	1
EF	0%	0%	100%	1
IT	0%	45%	55%	11
ET	0%	41%	59%	17
				30

Executives				n
	F	C	A	
IF				0
EF	0%	0%	100%	1
IT	0%	0%	100%	3
ET	0%	79%	21%	14
				18

All individuals in the data set have 20 or more years experience; the principal use of one dominant personality is termed "focused"; use of two personality types (the norm) is termed "classic"; use of three personality types is termed "accommodating"; use of number of personality types varies by role

Primary personality types: EF = Extrovert-Feeling, ET = Extrovert-Thinking, IF = Introvert-Feeling, IT = Introvert-Thinking

Role: Exec = executive, GM = general manager, SP-F = specialist-finance, Sp-HR = specialist-human resources, SP-T = specialist-technical  
A = Accommodating-three significant personality types, C = Classic-two significant personality types, F = Focused-one significant personality type

career model on the personnel profile of the industry. These findings, coupled with additional in-depth analysis, could form the basis of targeted human resources plans at the company level, and professional development plans for individuals. With the assessment tools currently available, companies can deliberately cultivate and reward a range and balance of competencies and personality types within the company in order to achieve technical, business, and social goals. Broadening the range of personality types in the industry may cause stress when different communication styles meet within the industry, but it may alleviate some of the difficulties in communicating with those outside the industry. Understanding the various elements involved in human interactions should also help in cultivating social capital—the reciprocal bonds of trust, shared experiences, interdependencies, and networks that are an

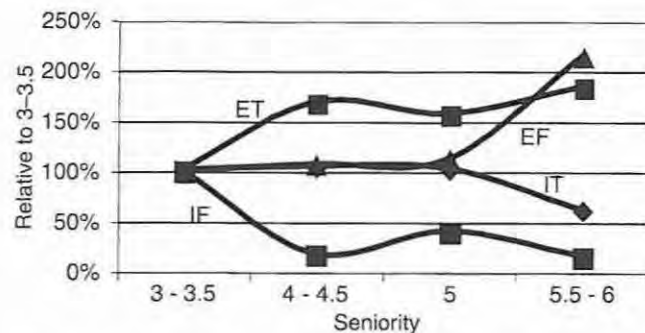


FIG. 4. Comparison of significant personality types normalized using the overall average of personality types for level 3 to 3.5. This figure presents changes in behaviors (as evidenced by personality types) with respect to increasing seniority. The first step sees ET (Extroverted Thinking, i.e., controlling/directing, internal social competency) increase at the potential expense of IF (Introverted Feeling, i.e., harmony). This is consistent with supervision roles. The final step, to executive, sees a marked increase in EF (Extroverted Feeling, i.e., inspiring, external social competency) consistent with the responsibilities of executives.

intangible, yet invaluable and essential, product of the appropriate management of human capital.

### Three Management Trends: Multidisciplinary Teams, Social Responsibility, Fostering Innovation

#### Multidisciplinary teams

Exploration success, measured in dollar value of ore found versus annual exploration expenditures, has been decreasing at a fairly constant rate since the mid-1960s (Enders and Leveille, 2004). Despite increasing overall exploration budgets, total discovered tons of copper per year have been decreasing; this trend has been occurring since the early 1980s (Enders and Leveille, 2004). Similar circumstances of diminishing exploration success in the face of overall increasing expenditures were found in the petroleum industry in the mid- to late 1980s. One of the responses by the petroleum industry to this situation was to implement multidisciplinary teams.

These teams have been widely adopted in the oil industry, but not significantly to date by the minerals industry (although Woodall, 1993, offers an exception), to bring a range of skills to focus on a specific exploration problem. Multidisciplinary teams are integrated technological teams operating in fluid, flexible structures, insulated from the old hierarchical command structures. The teams typically are ephemeral and coordinated by a team leader, commonly a geologist. These teams are assembled on the basis of need, after value ordering the needs of the company. The teams are commonly on a fixed timetable and after concluding a project, the team dissolves, with members moving on to other vital projects (Downey, 1993).

The multidisciplinary team concept hit the petroleum industry in the early 1990s (Ching et al., 1993; Schneider, 1996); it now appears to be a standard mode of operation. There have been certain well-documented success stories associated with multidisciplinary teams (e.g., Alqassar et al.,

TABLE 7. Comparison of Significant Personality Types with Seniority

Seniority	n	IT	n	ET	n	EF	n	IF	n
3-3.3-5%	22	68%	15	50%	11	27%	6	55%	12
4-4.5%	31	71%	22	84%	26	29%	9	10%	3
5	23	70%	16	78%	18	30%	7	22%	5
5.5-6%	12	42%	5	92%	11	58%	7	8%	1
Total	88								

Most professionals utilize two or three personality types; accordingly, the columns and rows in this table total well in excess of 100 percent; the relatively high proportion of the introvert-feeling (IF) personality type distinguishes the lowest seniority level whereas extrovert-feeling (EF) distinguishes the highest level; relative change in personality types is shown graphically in Figure 4 (ET = extrovert-thinking, IT = introvert-thinking)

TABLE 8. Distribution of Personality Types from Geology, Mining Engineering, and Finance, and Human Resources

	Geology	Mining engineering	Finance	Human resources
IT	33%	40%	46%	21%
ET	50%	45%	38%	21%
EF	10%	10%	8%	21%
IF	7%	5%	8%	37%

People with technical backgrounds are dominantly thinking (T), whereas human resources professionals are dominantly feeling (F); behaviors of the first group are likely to be similar; human resource professionals are likely to be quite different, an aspect that can be used to build teams representing a broader mix of behavior types and thinking styles. Abbreviations: EF = Extrovert-Feeling, ET = Extrovert-Thinking, IF = Introvert-Feeling, IT = Introvert-Thinking

1991; Schneider, 1991; Ching, 1993). The common thread in these success stories is the apparent synergy gained through the combined efforts of highly qualified individuals focused on a common goal or path (Girgis et al., 1995).

Do these teams actually work? Or is this just another management fad? Schneider (1991) outlines one of the few quantitative experiments utilizing multidisciplinary teams. In this experiment, a large oil and gas company formed a small multidisciplinary exploration and production company that directly competed on an equal basis with one of the parent company's exploration and production divisions. In this test, both entities competed in the same geographic area, had similar budgets, technical databases, and economic and risk criteria for projects. The age distribution and experience of the staff of the two entities were approximately the same. The principal differences lay in how the two entities were organized, as well as in the number of individuals associated with each entity (34 for the multidisciplinary team vs. 178 for the traditional). The multidisciplinary teams were organized around specific plays or prospects. They had a flat reporting structure with only two management layers (team leader, company president). The more traditional entity was organized around activities, such as the acquisitions group; its organization was much more hierarchical with four layers of management (project leader, district supervisor, division head, general manager).

What were the results? After a five-year period, the multidisciplinary team found nearly three times the reserves at a finding cost of approximately half that of the traditional company. These results so impressed the parent organization that two layers of management in the parent organiza-

tion's exploration and production division were eventually removed. In addition, much more financial responsibility was pushed down the hierarchical chain.

Multidisciplinary teams as presented here are an accountant's dream: they find significantly more reserves with much lower personnel costs (and fewer higher paid managers as well!). But is it as simple as only removing some management layers? What are the factors that lead to successful multidisciplinary teams? What are the challenges and threats that cause these teams to fail? (Certainly not all teams succeed.)

In a study based on 10-year operating experiences of multidisciplinary teams in Indonesia, Girgis et al. (1995) outline what they view as successful factors:

1. The problem must be such that several highly technical disciplines are needed to address it (i.e., it must be truly multidisciplinary). This allows the team to form an "artificial brain" (in the sense of Masters, 1993), where the sum of the whole is greater than the various parts.
2. There must be strong management support—both in words and actions. If team recommendations are constantly changed after the fact by management, then the implied message is clear: management either does not trust the team or is not committed to the team concept.
3. Teams must include at least one highly talented, experienced member for each discipline for direct input. This appears to be the critical factor for successful multidisciplinary teams. It is one thing to remove layers of management as a cost-saving mechanism. However, those layers existed in the first place to provide experience and oversight. If the team lacks sufficient expertise, then it will most likely fail.



(and more importantly, the organization will not catch the error until much later in the process when significant expenditures have already been made). There are numerous horror stories of organizations that overly flattened their organizations, losing too much institutional knowledge and wisdom; this appears to be a potentially serious problem in the mining industry today.

4. The objective must be clear. Roles (team leader, team member, manager) must be clearly defined.

5. Teams typically require time to develop trust and synergy (3 to 6 months is common). Results are not instantaneous.

6. Individuals should only be on one team for the duration of that team's life. This is the key distinction between teams and work groups, which are comprised of individuals assigned to more than one project. Work groups typically do not achieve the synergy one sees in the best teams (Lane, 1990); simply put, there isn't as much commitment among the work group members, who are usually responsible for multiple projects at the same time, as there is within a team.

7. Cross-functional training is considered a strong plus in forming better team decisions and breaking down traditional barriers. This last point has been taken to heart by the major oil companies; early rotation among the various operating divisions is considered standard procedure for new hires in the larger oil companies.

Threats to team building typically fall within three areas: control, credit, and compensation. Control issues typically arise from resistance or conflict from various outside functional departments potentially impacted by the team. In many cases, the loss of primary decision-making capacity is resented by the impacted functional department; lack of appropriate credit (i.e., the department gets the work, the interdisciplinary team gets the glory) is a commonly perceived factor. Further, those managers with an autocratic top-down style commonly have problems with the egalitarian style of teams.

Who gets the credit for generating outstanding ideas—and presumably the associated compensation that should accompany the idea generation—is a considerable issue in the functionality of teams. If individuals are not recognized for their unique contributions, incentives to work harder and go the extra mile vanish. The multidisciplinary team concept significantly flattens the company's organization chart; how then is the individual to be rewarded or promoted (Greene, 1993; Warren, 1994)? How can he/she advance? Conflict and a detrimental lack of innovation can result. Companies can attempt to mitigate this by internal team review and active involvement of management (Downey, 1993); this is clearly a critical component in maintaining satisfaction within a team environment.

The mix of personality types in a team has a significant impact on the team's success. Teams must contain a compatible group of personality types, in addition to the required mix of technical competencies, in order to succeed. In an ideal situation, a team would contain members

with diverse but overlapping personality preferences; this provides the benefits of diverse cognitive processes with enough overlap to enable efficient communication and understanding, while providing support for team members.

The multidisciplinary team approach appears here to stay, certainly within the petroleum industry. If the mining industry adopts the practice, what is the role of the exploration geologist in these teams? As envisioned by Masters (1993), the geologist is the general developer of concepts and then integrator of the data, and usually the critical team leader. Thus, in addition to the technical excellence in geologic skills assumed to reside in the explorationists, superior business and management skills will be needed.

One caveat: Exploration in the petroleum industry may not always be the best analog for exploration in the mining business. The petroleum industry operates on a much larger scale than the mining business, generates much larger profits, and is able to bring far more resources to bear on problems than even the largest mining house. Geologists in the petroleum sector are also much further removed from the outcrop than minerals geologists. In minerals exploration, the geologist still does hammer on the rock and there is a much greater place for personal experience and intuition in interpreting the raw data. The lone prospector still does have a place in mineral exploration, but there increasingly may be circumstances where a team approach would be more beneficial. Certainly, the shift to more under-cover and deeper exploration (with significantly greater costs and higher risks) suggests that a broader skill base will be required for success; this will almost certainly necessitate a team approach.

#### *Managing for social responsibility*

It is no longer acceptable to view mining projects exclusively in terms of profit and loss, or tonnage, grade, and recovery. Companies need a social license to operate and this must be factored into every equation concerning mining. These constraints are summarized in the concept of the triple bottom line, based on the metrics for the Dow Jones Sustainability Group Index, which incorporates financial, technical, and environmental elements in calculating the viability of a project (James, 2000). Mining managers are familiar with assessing the technical and economic components of a project, but managing for social acceptance and sustainable development is still a challenge.

The concept of sustainability was introduced in 1980 by the International Union for the Conservation of Nature, but the World Council on Environment and Development in 1987 formulated the best-known definition: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (International Institute for Environmental Development, and World Business Council for Sustainable Development, 2002). Within the mining industry, sustainable development was a relatively little known concept as late as 1998 (James, 2000), but it is now widely recognized within the industry, particularly by the larger mining houses.

In response to a growing awareness of the challenges of socially responsible management, the Global Mining Initiative, a group of 10 major mining companies, in collaboration with the World Business Council for Sustainable Development, established the Mining, Minerals, and Sustainable Development (MMSD) project. This was designed to understand the societal implications of mining, specifically the relationships between mining and sustainable development. Beginning in April 2000, the independent MMSD project team conducted and commissioned extensive research, and they consulted with more than 700 stakeholders including industry, governments, nongovernmental organizations, artisanal miners, labor groups, the financial sector, and indigenous groups in 23 workshops held around the world. From this work, the team identified nine key challenges facing the minerals industry: viability of the minerals industry; the control, use, and management of land; minerals and economic development; local communities and mines; mining, minerals, and the environment; an integrated approach to using minerals; access to information; artisanal and small-scale mining; and the roles, responsibilities, and instruments for change in sector governance. They then proposed an agenda for change in the mining and minerals sector that calls for participation and engagement by all stakeholders in order to achieve sustainable development at global, national, regional, and local levels (International Institute for Environment and Development, and World Business Council for Sustainable Development, 2002).

The broad-ranging MMSD recommendations touch on many of the critical social issues facing the minerals industry and its managers. The report offers a set of general principles that could form a framework for developing socially responsible corporate and community policies, but these policies would have to be adapted to the site-specific conditions of individual exploration and mining projects. One possibility is that companies could create and implement a Code of Conduct with respect to sustainable development. Socially responsible management involves more than having a corporate policy, however. It is an ethos that must permeate the whole company, from the junior exploration geologist who is likely to have the first encounters with the local population, to corporate lawyers who negotiate with governments, to the entire management culture. Critically, a Code of Conduct must be truly accepted by upper management because, typically, the "way of doing business" in an organization is a function of the level of importance demonstrated by the behavior of the CEO and executive management. If a company makes a sincere commitment to a Code of Conduct (as opposed to lip service so as to appease attorneys or provide public relations), then this could go a long way toward the translation of sustainable development principles into everyday work practices.

Just as managing the human capital of a company involves building social capital within a company, socially responsible management involves building social capital across a larger community. One of the major challenges facing all workers in the mining industry is how to translate the principles of

sustainable development into everyday work practices, while maintaining a positive triple bottom line.

A variety of resource industries such as forestry and the agri-pharmaceutical industry have been dealing with antagonistic opponents, new environmental regulations, and the increasing use of technology; there may be valuable lessons to be learned from their experiences in sustainable forestry development and the introduction of genetically modified organisms. Studies in the social sciences, offering insights from communication science, anthropology, and political science, for example, may also be relevant. The necessity for much greater social competencies underlies all of these various approaches to socially responsible management.

#### *Managing for innovation—The GE example*

How does the mining industry innovate? Is it innovating today? Approximately 100 years ago, mining was considered the cutting-edge innovative industry in the United States. Society looked toward mining to help solve its pressing problems, to lead the way to a better standard of living and quality of life. Many of the famous U.S. mining institutions, such as the Colorado School of Mines and Mackay School of Mines, Nevada, were founded at about this time, with this implicit ideal. So what happened? Has the industry stopped innovating? Or is it just innovating at a much slower rate? How can we encourage greater innovation on the part of the mining industry?

Most of the literature on innovation deals with the so-called high-tech industries, particularly semiconductors and computing. Similar emphasis has not, to the authors' knowledge, been placed on the mining industry. A look at how one high-tech innovative firm, General Electric Corporation, addresses the issue of innovation may prove useful as a comparison to the exploration industry.

General Electric (GE) Corporation, under CEO Jeffrey Immelt, is being reorganized and restructured in order to emphasize technological innovation (Schonfeld, 2004). GE had been viewed by some as becoming technologically stale (see comments by J. Brown, Xerox's director of research, in Glasser, 1999); this reorganization is explicitly designed to jumpstart innovation. As espoused by Immelt in a keynote speech at the Emerging Technologies Conference (Ewalt, 2003), the vision for GE is to be more entrepreneurial and more science based, with growth derived from internal operations. Immelt's strategy is essentially two pronged: grab the scientific lead on the far technical frontiers of specific markets, and create more highly developed marketing to exploit this scientific edge.

How is Immelt doing this? He significantly increased the engineering staff, adding more than 5,000 since 2001, he also promoted more engineers to top management positions. Prior to Immelt's tenure as CEO, there were only seven top managers (out of 175) with an engineering background; this has now been tripled. He applied a similar strategy to marketing: he has greatly increased his sales staff (adding more than 5,000) and created a chief marketing officer for each major business. Many of these new officers have engineering backgrounds; there appears to be an



explicit attempt to break down the traditional wall that existed between marketing and engineering.

So far, this is just throwing money and bodies at a problem, even though the scale at which GE can operate is much, much larger than most. But what specifically is GE doing to foster innovation? Immelt convened a series of major marketing brainstorm meetings in which each significant business division was given two months to generate five new imaginative breakthrough businesses, each with a potential to generate annual revenues of \$100 M in three years (Schonfeld, 2004). The tight deadline led many managers to look for promising but sidetracked technologies, or to dream up ways to refashion existing technologies for new markets.

Clearly Immelt is searching for those disruptive revolutionary technologies (in the sense of Utterback, 1994) that transform industries and generate large profits to those who become the standard bearer. This approach does not appear to favor incremental-change technologies, i.e., those are perceived to evolve naturally.

There is some empirical support for Immelt's approach. Preliminary studies by Morone (summarized in Glasser, 1999) suggest that many breakthrough technologies gestate for periods of 20 years or more; the breakthrough occurs when the technology is applied to new and different uses as opposed to its original application. A good example of this occurred in the mining industry with the development of solvent extraction electro-winning (SX-EW) (Bartos, 2002). Organic solvents that were designed for dissolution of uranium during the Manhattan project in World War II were applied to oxide copper mineralization some 20 years later. This breakthrough created the SX-EW process that has transformed copper mining. GE's brainstorm meetings appear to be an explicit attempt to utilize this mental process and focus the company's energies on application.

The other major effort by GE is to cycle marketing managers through the research laboratories, again with the idea of trying to familiarize as many people in the company with available or newly developing technologies, in the hope of developing those lateral leaps where the technology can be applied in new and different ways, thus revolutionizing an industry (Sutton, 2004). In addition, GE is focusing its research on a few key areas as opposed to broad-brush basic research. At one time, GE ran over 1,000 laboratory-based projects; these have now been pruned to approximately 100 highly focused projects (Schonfeld, 2004). To quote Scott Donnelly, head of GE global research, "To manage the kind of innovation we're looking for—first you have to have a strategy of where you want your company to be, where you can be a big player and where technology can make a difference" (Schonfeld, 2004, p. 85).

What are the applications to the mining industry? Innovation, particularly radical innovation, appears to be a process of cross-fertilization, of taking ideas from one field and applying them to another. Those ideas may relate to technology, economics, social practices, organizational theory, or to any other facet of the business. By the very nature of innovation, they are likely to relate to some aspect that has previously been ignored or overlooked. Overall, one

could argue that the best way to innovate is to expose people to multiple ideas and viewpoints. To quote Robert Sutton, co-leader of Stanford University's Center for Work, Technology and Organization: "If you want innovation, you should reward people for sharing ideas and punish them if they don't ... If you want fast innovation, you need to take as many ideas as you can from outside your group and company and add some of your own" (Sutton, 2004).

### The Future

Assessing the current state of the business is a good starting point for addressing the future. How would we rank the minerals industry today with respect to the three main competencies?

1. **Technical Competency:** The industry has more than a hundred-year history of supplying society with necessary natural resources at ever decreasing costs (in inflation adjusted dollars). This is in the face of exponential growth in consumption. As explorers, we are collectively very good at what we do. Overall grade: high.

2. **Business Competency:** Virtually all companies in the industry do not return an adequate and sustainable return on shareholder equity. This has also been true on a historical basis (Snow and Juhas, 2002). This is not to say that there have not been individual companies that have been very successful, but the industry as a whole has not had a sustainable return on investment. Certainly, there is room for improvement in the overall business skills of the industry. Overall grade: medium to low.

3a. **Internal Social Competency:** In most companies, exploration geologists are or feel marginalized, outside the main flow of the business. This is despite the fact that outstanding mines start with the discovery of outstanding ore reserves. Some of the marginalization may well be our own fault. Simply put, geoscientists typically do not do a good enough job of selling and deploying their skills within their organizations in order to be understood, recognized, and appreciated. Overall grade: low.

3b. **External Social Competency:** The industry as a whole is in conflict virtually everywhere it goes. This is in spite of the fact that the mining industry provides the natural resources upon which the foundation of society depends. Even in places where mining has been long established, opposition to the industry appears to be growing (Jensen, 2005; Northern Miner, 2005). One senses that the bulk of the overall population wishes simply that the industry would just go away. Overall grade: extremely low.

At a minimum, the industry should maintain the current level of technical competency, increase its business competency, and fundamentally overhaul its social competency. This needs to be done at the level of each individual professional, each multidisciplinary team, each company, and the industry as a whole.

What will the future bring? Some aspects are clear:

1. The rate of change in technology, the business environment, and social needs and demands is increasing.



2. The use of multidisciplinary teams will increase.
3. Outside stakeholders will become more involved in the business of minerals companies.
4. The triple bottom line principle is increasingly being applied to all exploration and mining projects.
5. There will be an increased need for innovative solutions to technical, business, and social challenges.

The common thread in these trends is the importance of people as social beings, not just as technical or business automatons. The personal traits and experiences of exploration geologists, mining engineers, business managers—everyone at all levels of the industry—affect the career of each individual, but they also affect the well-being of the industry. The social sciences have much to teach us. Recognizing and learning to manage the human and social aspects of the business, we predict, will be one of the greatest sources of innovation and improvement in the industry. New paradigms need to be developed for minerals education, paradigms that reflect the demand for social skills in even the freshest graduate. We envision a day when explorationists graduate not only well trained in field mapping, alteration, and ore-deposits models, but with business courses, and most importantly, with training in social competency. New educational models will recognize the business reality facing the tertiary-level minerals education sector, and will ensure adequate funding to maintain educational capacity.

Companies should become active in developing social competency. As an example of how this may be achieved, Placer Dome (to name just one company) introduced a type of social competency training for supervisors and management staff in the late 1970s in response to widespread, severe labor problems in their Canadian operations. As a result of this program, Placer Dome is considered by the authors to have one of the best career development and succession planning programs in the industry, and its labor problems have diminished significantly. This type of program needs to be expanded to encompass all aspect of social competency, particularly in dealing with sustainability and triple bottom line issues.

The future of our industry will be determined by our ability to realize the full potential of each individual economic geologist, and through teams of individual professionals working together, to collectively create value well beyond our individual capacities. Our ability to embrace the future lies in the development and fully integrated use of our technical, business, and social competencies for the commercial benefit of the companies we serve.

### Summary

A review of university economic geology and mining programs worldwide strongly suggests that they are contracting. It is not yet clear that there will be an actual shortage of entry-level explorationists. Rather, one could argue that the available supply of entry-level explorationists will be more in line with available demand.

More importantly, the social contract between the mining industry and universities appears to have been irrevoca-

bly broken. No longer does society at large appear to value mining, and the procurement of natural resources in general, sufficiently to subsidize the industry by providing de facto job training at universities. Rather, industry will have to contribute significantly more, either by subsidizing training and coursework at those universities that continue to have minerals programs, or by providing its own specific job training for general geoscience graduates. As a result, industry's costs in obtaining entry-level workers are predicted to increase significantly. Indeed this already appears to be happening.

The career path of most professionals in the mining industry has changed. Our data indicate that a majority of explorationists can expect a career path full of starts and stops, with sector shifts, returns for retraining and periods of overall uncertainty, layoffs, and stress. This situation is no longer restricted to some unfortunate few; this has become the norm for the practicing industry exploration geologist. Those who find employment in government or academic sectors tend to have traditional job stability—so far, although this, too, seems to be changing.

An extensive personality study on the nature of explorationists shows what many of us have long suspected: our modes of thought, our very ways of expression, and how we approach and solve problems differ considerably from the general population; these differences becomes sharper and more distinct when those with long experience in the industry, including senior industry managers, are compared to the general population. Is it any wonder that our industry seems out of step with society as whole?

The career path of minerals professionals typically contain three tracks with a clear boundary between technical specialists and those on the management/executive track; this division starts within the first 10 years of a career. The executive track splits from the middle management track at approximately year 15. With 20 years' experience, you have achieved your destiny; thereafter, changing career tracks appears quite unlikely. Many geologists may not want to actually leave the technical track; however, the other tracks are where higher financial rewards and recognition lie. This three-track system, coupled with the vagaries of widespread layoffs, retraining, etc., produces a very small (too small?) pool of future leaders for the industry.

The skill set that an explorationist will need in order to practice his/her trade (and the percentage of women explorationists will significantly increase; this too will change the nature of the job) will be significantly different from what it was just a few years ago. No longer is it sufficient to be a first-rate field geologist, well versed in the latest exploration models and able to recognize subtle indications of alteration and mineralization. Now, social and political skills are needed at all levels of the industry. Given the advent and acceptance of such concepts as the triple bottom line, it is becoming clear that the explorationist is the first contact that some isolated societies may have with a large industry such as mining. Failure to handle the first contact correctly can jeopardize the entire future project, whether or not a potential mineable deposit is identified.

No longer will the explorationists be the modern equivalent of the lonely prospector armed with only a rock pick, hand lens, and well-worn field boots. Instead, they will be expected and required to be ambassadors from the company to culturally different people, many of whom may be deeply suspicious of the company's intentions.

Strong teamwork and team-building skills will also be needed. Analogies from petroleum exploration indicate that some of the exploration of tomorrow will be handled by multidisciplinary teams, composed of specialists in individual functions, who come together for a limited time to solve specific exploration problems. The geologist usually heads or guides these teams; management skills are absolutely required.

Cross-linking with other disciplines and fields will be vital. Studies from high-tech industries show that most revolutionary innovations actually come from the application of existing technologies to different fields; this finding has significant implications for future exploration and for the mining industry as a whole. Unfortunately, the mining industry's ability to adopt new technology has diminished considerably, as those who previously performed this function have either retired, been laid off, or are swamped in day-to-day duties as a result of relentless cost-cutting and understaffing. The industry may have a developing innovation gap.

This then is our vision for the explorationists of tomorrow. There will always be those who wish to explore the remote corners of the globe for natural resources. How these explorers go about practicing their trade will be different from the way it is undertaken today, the degree to which is still uncertain. Some aspects of the future are difficult to predict; for other aspects, the future seems quite clear. We foresee a period of great change, great challenges, and possibly, great opportunity, but one where understanding and managing the many facets of human nature will be recognized as essential to personal and corporate success.

### Closing Statement

This paper opened with a quotation written 100 years ago on the necessity of knowledge of human nature in order to be an effective economic geologist. We close with the last words of Frederick Leslie Ransome in his inaugural *Economic Geology* paper (1905, p. 10), as true now as then:

The problems connected with economic geology are many and varied and their solution calls for scientific ability of as high an order as is demanded in any other branch of earth science. If the fact that proficiency in economic work is coming to have a high market value be regarded as inimical to the spirit of science, the danger is one that most men can face, if not with confidence, at least with serenity.

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