Articles

A Renaissance for Canadian Geoscience

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Every aspect of our present and future prosperity depends directly on the supply of mineral and energy resources and, hence, on the geosciences. No other group of disciplines will be so vitally important in the 25 years remaining in this century.

These opening lines of the Canadian *Geoscience Council Report on the* Geosciences in Canada - 1974 (Available to GAC members at no charge from the Director, Geological Survey of Canada, as GSC Paper 75-6) were designed to awaken Canadian geoscientists to the opportunities that have recently opened up to them. The statement could be rightfully challenged by those in some other scientific disciplines. In an era of population, food, energy and environmental crises we can *forgive biologists, food chemists,* agricultural and medical scientists and some kinds of engineers for feeling that they too might contribute something to the solution of these problems. But we *have little patience with the sceptics in* our own profession who deplore the statement as a completely unwarranted exaggeration and who are content with the present rather subordinate role and status of the geosciences. These are the same people who quite happily rely on the culls from other disciplines to fill their classes. They are also the ones who consider it part of the ordained nature of things that so few students of geoscience have the grades and other attributes to qualify for NRC Centennial Scholarships and other top awards.

If geoscientists are to meet their challenges of the next quarter of a century, they must work vigorously to rectify present imbalances in the support and direction of science in this country. At present nongovernmental geoscience is funded at a relatively low *level and there are few geoscientists in* the top decision making posts of universities, governments or the major granting and advisory councils. Less obvious but even more important is the *general dearth of good geoscience* teaching in pre-university education programs. There are several reasons for the present humble status of the geosciences but the main fault probably lies with its practitioners - with those of us who too readily accepted the slogan "Physics is Good for You" and with those who placidly advised NRC officials that geoscientists required only small grants to do their thing.

The remedy must come from awareness and action by the geoscience community. Awareness of our rapidly changing national obligations and priorities, awareness of current strength compared to relevance of both *our own and sister sciences. Together* with biology, medicine, agriculture and other sciences we must then gird ourselves to fight what the Director of the Geological Survey of Canada has referred to as the Third World War - the war against over-population and diminishing resources.

In this paper we briefly review the chain of events that left the geosciences in their present weakened state on the eve of this war. We shall also give our own simple prescriptions to restore them as a viable combative force. But let us start at the beginning . . .

The Good Old Days

Following well established tradition we shall hark back to the days of Logan. Every budding young Canadian geologist knows that William Logan had it tough when he came back to his birthplace and founded the Geological Survey of Canada in 1842. We've all heard about his cramped little office littered with rocks and smelly boots, his *toil by candlelight over his maps and* notes in primitive little tents - spurned by inn keepers because of his shabby clothes, his desperate appeals to parliamentarians for funds. All this misery is reflected in our textbook portrait of a heavily bearded old gentleman who looks tired, worried and constipated (Fig. 1). In our simple masochistic ways most of us have tried to live up to this Logan tradition of doing a lot on a little in the hardest way possible. Geological wags refer to it as the "can of tomatoes syndrome" in derisive reference to a typical end of field season treat awarded to field parties after their summer of feasting on pemmican and burned bannocks.

But another portrait of Logan has recently come to light (Fig. 2): clean shaven, pink-cheeked with bright eyes twinkling behind foppish little pince-nez.

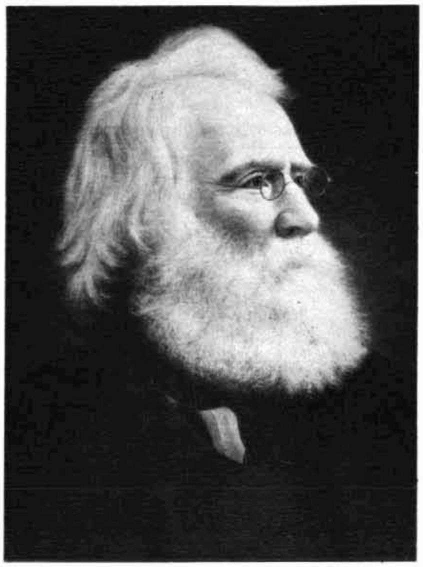
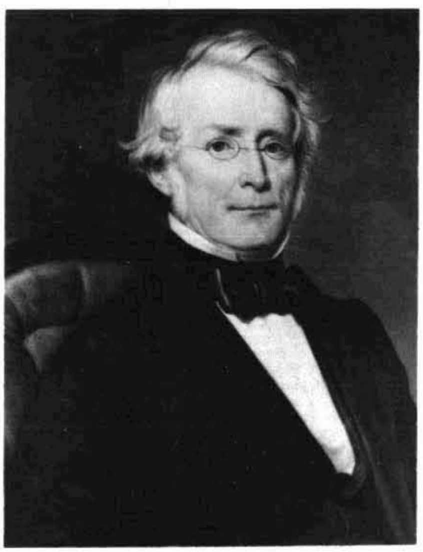


Figure 1
Old constipated Logan.



Photos: The Public Archives of Canada

Figure 2
Young wine-sipping Logan.

It's easy to visualize this chap sipping champagne from his favourite silver fountain while regaling his sophisticated drawing room guests with accounts of his own and his colleagues' accomplishments. Logan had many accomplishments to delight in, not the least of which was the fact that his Geological Survey was Canada's first governmental scientific institute. The work of the Survey won support and respect at home and recognition abroad. Eventually it spawned off a myriad of museums, research and service departments throughout government. Logan himself won a knighthood, fellowship in the Royal Society of London and a chestful of assorted gongs.

One of Logan's colleagues, Sterry Hunt, a grand uncle of modern geochemistry went on to become the first president of M.I.T. This was the first of a series of shifts of Survey personnel to become captains of universities and industries. One of the last of that era was J. B. Tyrrell who died fairly recently at a great age. It was also a period when some of the classic Survey studies were carried out by university people such as Frank D. Adams and Alfred E. Barlow.

Geologists, particularly Sir William Dawson of McGill, played a leading role in establishing our national academy, the Royal Society of Canada in 1882. For many years geoscientists were so large and important a part of that regal body that they formed one of its four sections.

The second image is the one we prefer of Logan and his successors and the productive years between 1842 and 1912 - years of great scientific achievements coupled with relevance to the nation's needs. We believe that we have gone full circle in the intervening period and returned again to a threshold of golden years.

WW I and II Bring Shift in Emphases

The First World War and a little bit of needling from the U.K. challenged our government to extend its involvement with science and technology beyond its preoccupation with the resource-oriented natural sciences. The outcome was an Order-In-Council in 1916 followed by a statute in 1917 that set up the National Research Council of Canada. Its original responsibility was to plan and coordinate scientific and industrial research in Canada. However, in most areas there wasn't a great deal of research to coordinate: only two Canadian universities offered the Ph.D. degree; industry was doing very little and even in those days there was the complaint that foreign-owned companies carried out their R and D abroad; and a country-wide survey led to the conclusion that there were only about 50 "pure research" people extant.

The outcome was that NRC was eventually able to establish its own laboratories which it did in 1932. These laboratories did not initially undertake work in the geosciences, mining, agriculture, forestry and fisheries. This work was already being carried out in government departments whose directors successfully resisted integration or coordination of any segments of their empires. Those who feel that the manipulation and intrigue of top management is largely restricted to business men in grey flannel suits or professors in C.P. Snow novels would have their eyes opened by reading accounts of how the mandarins blocked and frustrated the new research council during these early years (Thistle, 1966; Lamontagne, 1970).

NRC grew to become a very potent force in Canadian science during World War II. Within months after the start of the war its staff had expanded from 300 to 2,000 and its budget had increased sevenfold. It is claimed that it had more buildings at the end of the war than it had scientists in 1939. This boom continued into the postwar years under a dynamic and articulate president, E. W. R. Steacie (1952-1962) who was himself a renowned chemist and former McGill University professor. NRC not only built up an enviable international reputation for the research produced by its own labs but it also built up strong scientific cadres in the universities. From its inception the Council had granted scholarships for post-graduate work in the sciences. Later it established a system of grants to university personnel to cover operating costs and the purchase of equipment. During Steacie's tenure of office these grants increased tenfold. They were awarded on the basis of productive scholarship as determined by peer assessment. NRC involved people from outside its rank in many aspects of decision making. Although a tendency developed for many scientists to spend their entire careers with the Council there was probably a much greater flexibility and exchange of personnel with universities and industry at all levels than was possible with those government science groups which came under the jurisdiction of the Civil Service Commission.

University science, particularly physics and chemistry, flourished under this generous encouragement. Unfortunately the geosciences did not originally come under the NRC umbrella with the exception of the group in Geodesy and Geophysics who benefitted greatly from their inclusion in an Associate Committee. For whatever reason the rest of us were outside of the favoured circle. A well known, chemically-oriented geoscientist who later won world acclaim in his field was told by a high ranking NRC official that he could not be supported because his project represented weak chemistry and poor science. Geoscience departments remained small and ill-equipped, research activity reached a low level as many professors took on remunerative but mundane consulting jobs in their free time. Research-oriented professors and their graduate students carried out rather pedestrian mapping projects for the Survey or for provincial agencies. Many of our best graduates pursued their advanced studies in the U.S.A. or the U.K.

How Much for Your Rock-Collecting Trip?

The National Advisory Committee on Research in the Geological Sciences was formed in 1946 to promote an increased effort in geoscience research. It had difficulty in finding takers for its initial research fund of $10,000 provided by the GSC (Fortier, 1973) - surely an indication of the university research level of that time! This Committee continued to function until 1972 by which time its annual grants amounted to ¼ million (probably the average research budget of a medium-sized geology department today). It also developed a number of subcommittees that reported on progress in the subdisciplines, kept geoscientists in touch with one another and kept at least some people in industry and the universities aware of the plans and activities of the country's major geoscience research institute, the Geological Survey of Canada. It accomplished a lot for very little but in no way did it serve non-governmental geoscience in the manner that NRC served physics, chemistry and some other sciences.

There are probably several reasons for the final mushrooming in size and activity of Canadian geology departments in the early to mid 60s, long after the post-Sputnik boom had been felt in other sectors. The return of many bright young Ph.D.s who had studied and worked abroad, the importing of research-oriented geoscientists (chiefly from the U.K.) into industry and universities certainly contributed, as did the unprecedented growth of all university science departments in the 60s. Another critical factor was undoubtedly NRC's decision to assume a granting function in the geosciences in 1958. That university geoscientists now have sophisticated laboratory equipment at their disposal, that they are able to collect fossils in the Arctic or search for the oldest rocks of the Earth's crust in Labrador in their own way and at their own time, and that graduate studies in geoscience in Canada have developed at last, are directly attributable to NRC assistance. Yet there is still cause for great dissatisfaction with the present level of support. NRC grants in our science are still far below those given to physics and chemistry - this although the greater current relevance of our field is being increasingly acknowledged (Fig. 3). Distribution of NRC grants rests presently with 22 individual committees, one of which is the Earth Science Grant Selection Committee. Table I lists the average operating grants in various disciplines during the current year. Earth

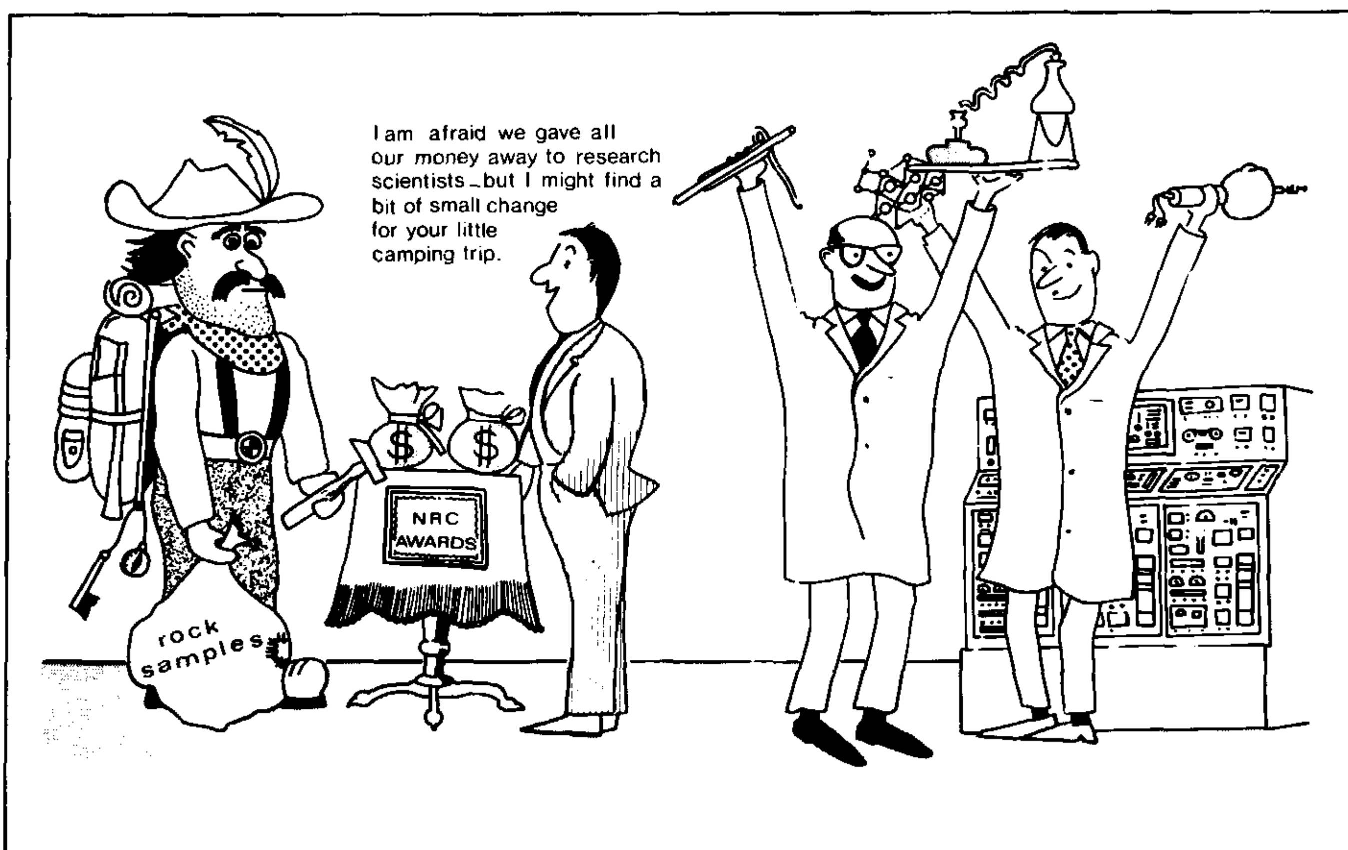


Figure 3
The awarding of grants.

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Table I *NRC Operating Grant Priorities 1975(1)*

"Value" (expressed by average grant)	Physical Sciences	Biological Sciences	Applied Sciences
$21,100(2)	Physics (452:94%)(3)		
$14,300	Chemistry (541:90%)		
$13,000	Space & Astronomy (154:99%)		
$11,700	Average operating grant for all 4413 grantees.		
$11,600		Cell Biology (323:89%)	
$11,000			Mechanical Engineering (257:94%)
$10,800			Chemical and Metalurgical Engineering (317:99%)
$10,600		Plant Biology (241:85%)	
$10,400			Electrical Engineering (302:92%)
$10,100		Psychology (227:86%)	
$ 9,900	Earth Sciences (423:85%)		
$ 9,300		Animal Biology (316:90%)	
$ 8,900			Civil Engineering (248:96%)
$ 8,500			Computing and Information Science (203:85%)
$ 8,300		Population Biology (360:92%)	
$ 8,300			Interdisciplinary (3:100%)
$ 7,100			Industrial Engineering (46:88%)

Not supported as such: Food Science
Agricultural Science and Engineering
Oceanography

(1) From NRC Summary of March 1975 competition.
(2) Includes Nuclear Physics and Physics operating grants, high energy physics grants and NRC and AECB major physics grants shown as a per capita average.
(3) (number of awards; percentage of successful applicants)

science occupies a middle rung, the average grant in chemistry, for example, being 50 per cent higher. The NRC grant budget has not kept up with inflation over the past several years and in order to raise the average for one group it may become necessary to cut back on another, longer established group. The lack of geoscience representation in high places in NRC is also cause for concern. Only two geoscientists have ever had seats on Council in its 60 year history: J. Tuzo Wilson of Toronto and H. D. Bruce Wilson of Winnipeg. There may be other, less visible reasons for the relative size of grants.

Reflections on the Pyramid of Science

A second glance at the NRC list of awards shows that although it is ordered on a decreasing scale of average operating grants it also appears ordered in other ways. For example, it is a fairly accurate index of the scale of study - with sub-atomic and molecular studies near the top of the list and macroscopic, field and applied studies well below them. Even in a single subject like biology we find cell biology is "worth more" than whole animal biology which itself is "worth more" than population biology. Our own field, if broken down, would show geophysics and other instrumental studies worth more than field oriented studies. As we have observed elsewhere (Wynne-Edwards and Neale, 1975), our scale of values seems to be roughly the inverse of the size of material observed, almost as if the ultimate goal of science was to extend the range of human senses rather than to discover fundamental truths and relationships. Nor can we justify the size of these awards by claiming that atomic and molecular science is more expensive than, say, operation of an oceanographic vessel or the logistics of projects in the Canadian Arctic!

There is another peculiarity about this list of average awards: from top to bottom it represents a status rating or intellectual pecking order of the sciences which until recently was accepted in universities and government and possibly by the general public.

Following World War I we came to accept the existence of a basic pyramid of dependent scientific knowledge with pure mathematics at the top, physics and chemistry just beneath it and drawing on the mathematical fundamentals, the plethora of life sciences and earth sciences drawing on these three, and on the bottom tier the applied sciences such as agriculture, medicine and engineering drawing from all those above (Fig. 4). This stacking order was firmly established as a classical hierarchy of scientific endeavour by the triumphs of physical science and mathematics during the second World War. The pyramid is one of increasing "purity" and decreasing directly visible relevance to socio-economic problems from bottom to top.

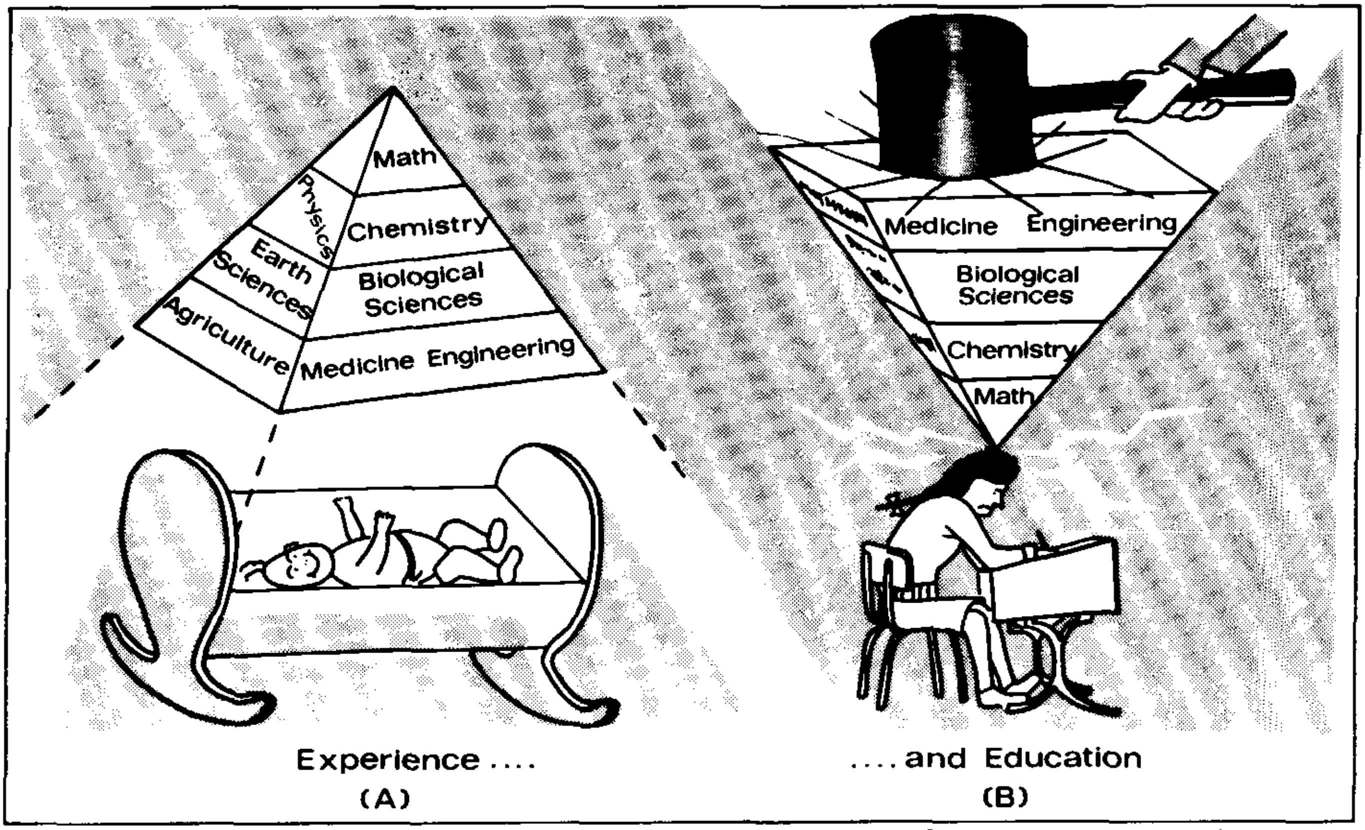

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Figure 4
Experience and education.

For many years the highest intellectual challenges and the greatest recognition have been offered near the apex of this pyramid - if we except medicine which enjoys an unusual special status once reserved for the priesthood. Admirable as this hierarchy may have been in the middle years we submit that it could generate severe problems in the remaining 25 years of this century.

One such problem relates to education. When a child initially encounters our pyramid of science it is from the bottom upwards - from the natural things and human artifacts around it and from its nourishment and well-being. Yet when the time arrives for formal education we attempt to force an inverted pyramid of knowledge into its skull, point first, by insisting on large, undiluted doses of maths, physics and chemistry (Fig. 4). The cry for relevance in education in the mid 60s by a generation seeking to know itself and its surroundings was partly a protest against this method of teaching. The remedy is to ensure that these self-styled "pure" and "basic" or "*fundamental" sciences are fully* integrated with every stage of a much more natural learning process. Those who are seeking to introduce improved earth science teaching in our school system are making useful contributions to this end. So are those who make noises about using the natural, social, engineering, medical and agricultural sciences as major vehicles to introduce students of all levels to the so-called basic sciences. There is nothing immutable about education. The basic principles of science could be equally or better taught in the context of their application. That way, as their learning proceeded, students could gradually seek specialization, but from an *appropriate common awareness of their* natural surroundings.

The Geosciences On the Eve of WW III

The impending confrontation of rising world population with a fragile environment and inadequate or dwindling food, energy and mineral resources can be identified in a sense as World War III. The type of combat is to be *very different from WW I and WW II and* the priorities of science and technology must undergo correspondingly major revision. The list of average grants shown in Table I, like our accepted pyramid of scientific knowledge (Fig. 4) is upside down in terms of 1973 priorities. Faced with a state of emergency *we find that the most* urgently needed disciplines are not on that list or are near its bottom. Geoscience has suddenly become one of the very high priority disciplines. We are needed, just as Logan and his colleagues and successors were in the last century. However, we are unprepared in some spheres to take on the tasks that confront us and rapid remedies are required.

Superficially, of course, things look pretty good to us after 60 lean years. We've developed good reputations as mine finders and oil finders. Everyone has heard at considerable length about the successes of our exploration geophysics industry - its services are in demand all over the world and it currently supplies 75 per cent of the world's mining geophysical equipment. The preceding pages have stated that *geoscience departments in universities* have grown remarkably in size and productivity over the past ten years. Most remarkable of all is our government's recognition of the growing importance of geoscience and kindred disciplines as reflected in the rapid growth in size and prestige of the Department of Energy, Mines and Resources and the Department of Environment. The opulent EMR high-rise office complex on Booth Street in Ottawa is symbolic acknowledgement of the role that resource science must assume in the years ahead.

However, when we closely scrutinize the various segments of geoscience activity we find that government is actually the only one in a relatively healthy state of growth and development.

As the Canadian Geoscience Council Report attests, the current decline in petroleum and mineral exploration is leading to a loss of trained scientists at a time when the country badly needs them. Not only experience but much valuable documentation in private company files is being lost, perhaps permanently. The rate of discovery of Canadian mineral deposits is only a small fraction of the present production rate. Despite the supposed stature of mineral deposits research in this country the single most important public source of geological data is in (mostly unpublished) university theses. Leading industrial geoscientists regret major gaps in university training and research in important fields such as coal geology (Fig. 5), paleontology, petrophysics and organic chemistry.

At a time they are to be most needed, university geoscience departments are no longer growing in staff or facilities, only in student enrollment. Growth was cut off long before they could attain the optimum size to develop excellence. Several relatively new universities, e.g., Trent, Victoria, Winnipeg and Simon Fraser, have apparently relegated their modest geoscience activities, if any, wholly to their geography departments. NRC grants-in-aid have declined steadily in real, dollar value over the past five years and the geosciences still only receive about eight per cent of the total grant budget. Although for several years the geosciences have attracted many more student majors than either physics or chemistry, they commonly remain only a fraction of the size of these departments (Table II). The largest Canadian geology faculty is at the University of British Columbia which for many years has claimed the largest geology student enrollment in North America. Its teaching staff is less than half of chemistry and a third the size of physics at that institution.

Government geoscience has started to flourish because politicians recognize a pressing need. The data base that existed in the 1960s was inadequate for the scientific inventory and base line studies required to understand natural systems and to develop regulations for monitoring their use and modification. Government science, formerly done as a service and incentive to industry and to provide public information now also furnishes an important contribution to the development of government policy. The growth of EMR, DOE, and corresponding provincial agencies has been the result. There has been no parallel growth of the needed disciplines in universities.

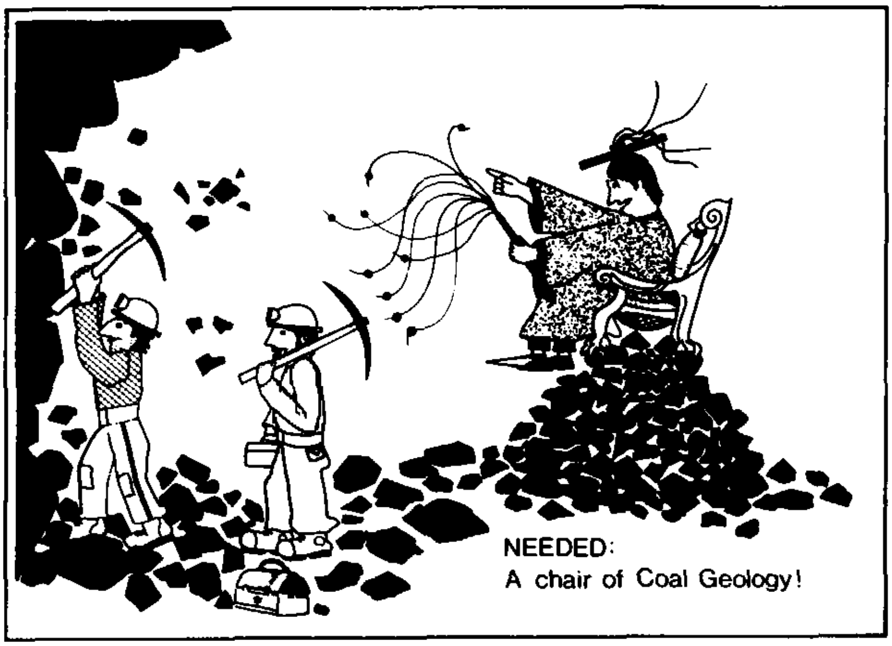

Figure 5
Needed, a chair of coal geology.

Table II *Size of Science Departments in Some Canadian Universities+(data chiefly from 1975 calendars)*

	Science Departments			
University	**Geology**	**Geophysics**	**Chemistry****	**Physics**
Memorial	18		29	35*
Dalhousie	14*		26	20
New Brunswick	16*		17	18
McGill	15*		32	43
Laval	12*		22	39
Toronto	23		49	70*
Queen's	19*		28	34
McMaster	12		32	37
Waterloo	19		33	37*
Western	19	7	34	30
Manitoba	16*		30	29
Saskatchewan	13*		32	23
Alberta	20		38	46*
British Columbia	26	16	62	76

* Includes Geosphysics group
** Does not include biochemistry
+ Includes instructors, lecturers and teaching fellows.

Much of the research now done in government could as readily be done elsewhere, and if more was done in universities it could simultaneously contribute to education, help train new professional manpower, and much more readily act to raise the level of public awareness, provide cultural satisfaction and increase national innovative capacity. Government science by its mandate is concerned with data gathering and data analysis, activities not generally likely to produce new syntheses, new ideas and new models. But within that framework some excellent science is presently being done. Ted Irving's paleomagic and Paul Hoffman's aulacogens have developed in government under enlightened management. But these are exceptions. We must develop pockets of innovative excellence around the country to match the mission-oriented excellence that is growing up in government. We need more J. Tuzo Wilsons and Bill Fyfes, Dick Armstrongs and Dave Strongs, and they are not the type of people who normally find a comfortable home in government labs.

Otherwise, because of our preoccupation with the non-innovative research necessary to provide a minimum inventory of this vast country, and the dominance of government science to accomplish this, our science will continue at its good but pedestrian level. We shall remain "hewers of stone and drawers of maps". As pointed out in the Canadian Geoscience Council report (Neale, *et al.*, 1975), most of Canada's notable geoscience accomplishments have been concerned with the production of geological and geophysical maps, autocartography, data storage and retrieval, stratigraphy of the Devonian and Triassic systems rather than the production of new ideas and hypotheses. The same report points out that in such important fields as petrology, glaciology, geochronology and marine geoscience we have often been parochial, failed to develop new conceptual models and at times have been embarrassingly behind the state-of-the-art.

We enjoy a level of camaraderie and rapport between government, university and industrial geoscientists that we don't find in other countries. Maybe it all started when we shared tents on GSC or provincial field parties. We don't wish to harm or destroy it by plain speaking, but much needs to be done to increase our innovative and creative abilities for the challenging future we face in the preparation for the new kind of world war to come.

A Simple Prescription for Excellence
To prepare ourselves for the demands that must be made upon geoscience in the remaining years of this century we must build up research capability in the universities and industry in the same way that it is being built up in government. We should also increase the size of university geoscience departments and assume a more prominent role in the management of science and of those institutions in which science is an important component. We must challenge the existing hierarchy of learning and introduce elements of geoscience into many parts of the school and more parts of the university curriculum. Here are our recommendations:

1) With the possible demise of the NRC granting function and the instigation of a new granting council we must press for adequate geoscience representation at all levels of decision-making. These are the only grants that are given to professors on the basis of their personal excellence. We need more of this type of person so we need larger individual grants and more than the eight per cent of the total budget that we presently receive. However, we cannot expect great increases from this source. NRC has a tradition in certain fields and its support of some of them, e.g., physics and chemistry, has been very successful in that it has produced widely acknowledged excellence. At a time of diminishing funds and a hardening public attitude for this kind of research, we must work to produce shifts in emphases appropriate for the decades ahead. Only in this way will the needed increases in the support of curiosity oriented university research be forthcoming. A significant part of these funds, at least for the geosciences, should come from Energy, Mines and Resources, Environment Canada and their sister provincial agencies.
2) The Department of Energy, Mines and Resources must introduce a system of *grants to industry and to universities that will enable non-governmental research in the geosciences to grow and flourish on the same scale that governmental research has developed.* Some of this could be at the expense of present governmental activities but we should collectively press for additional charges on the public purse in the light of our urgent new position. The public is aware of the crises that confront society and seems not unwilling to pay the price of remedies. These grants would not be for laissez-faire or curiosity-motivated research, they could be mission-oriented and have rigid specifications, constraints and deadlines. But they should be subject to the excellent peer review system developed over the years by NRC. We would also welcome this system being introduced into internal government research programs in much the same way as some university departments and faculties who invite outside advisory committees to scrutinize and report on their operations at regular intervals. There are very encouraging indications that this will happen soon within at least some segments of Energy, Mines and Resources.
3) We must become more active as individuals and through our professional associations in *efforts to increase the quality and amount of geoscience* taught in our high schools and in university. Geoscience is one of several of the most natural and effective ways to transmit elements of the basic sciences. Competent teaching in the high schools would attract more of the best students to the challenges of our field. At present too many top students are programmed toward the apex of the pyramid of learning early in their careers and continue unswervingly onward, oblivious to the attractions near the base of this pyramid.

At the university, geoscience if properly taught, offers an excellent vehicle for imparting knowledge of the scientific method and the relevance of science to human affairs. We should be obliged to provide courses that offer such an eclectic mix of the sciences. Too many of us sit back complacently while our arts and commerce students are directed into "Physics and Society" or "Chemistry and the World Around Us". We are doing far too little with "The Whole Earth Catalogue" that belongs chiefly to us and the biological sciences.

4) Probably our biggest challenge is to seize more initiatives in interdisciplinary endeavours - to introduce our chemical colleagues to more of the excitements and rewards of geochemical and biogeochemical projects, to involve ourselves with biologists, engineers, social scientists and physical scientists in marine and land-based environmental projects. In this way we can break down the rigid and rather artificial boundaries of the pyramid of knowledge and the departments of universities and re-shape these boundaries to suit the time in which we live.
5) Finally, we must stop doffing our caps to those who are closer to the apex of the entertaining but antiquated pyramid of education (Fig. 4b). We are in the middle of an intellectually exciting scientific revolution in our own field. Our services are needed immediately to provide answers to the current human crisis. This is not the time to step humbly backward when there is a threat to restrict the growth of geoscience departments or to lose the services of experienced exploration personnel. It is our time to lead so don't be hesitant about volunteering yourself or nominating a colleague to one of the positions, boards or committees that govern the size of your research grants, the numbers in your geoscience department or the fate of the geoscience community. We now have to play some part in deciding where we are going instead of complacently being led by the nose or prodded in the rump.

We finish this raucous call to arms with a battle cry: "For Willie Logan (Fig. 2, that is!), justice and a place in the sun". Lace up your high boots and start kicking.

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