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Trends in the earth science education in the schools

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Several general trends in the teaching of science have developed in the past several years and are now underway in this province. The first relates to presenting science in a broader context and stressing the interrelationship of science, technology and society (the STS approach). Second, educators are being encouraged to draw upon a broader range of resources including individuals (e.g., earth scientists) with specialized skills or knowledge to contribute. These trends are illustrated in the following examples.

- A Science-Technology-Society course for the high school level is currently being developed by the Department of Education, which is drawing strongly upon the resources of the local community. The course includes a natural resources module focused on mineral exploration and mining.
- Teacher inservice and training benefits tremendously from contact with "real live" geologists, especially in the field, and there is a growing trend toward participation from the university and Department of Mines and Energy personnel.
- Several earth scientists from industry, the university and government have joined the "Scientists in the Schools" speakers program. This is intended to put individuals who work in science into the classroom to bring science alive in individual courses and provide a wider range of role models for students.

Earth science remains an excellent vehicle for introducing students to the discovery and inquiry approach in all of the basic sciences that it embodies and has gained renewed relevance through the resurgence of interest in environmental issues. These aspects will be reflected in the revision of the high school Earth Science course.

Computer reconstructions of trilobites: a practical example

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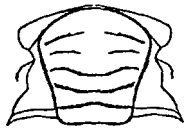
Poulsen and Anderson (1975; plate 1, figs. 4-10) illustrated the trilobite *Paradoxides* sp. from the Manuels River Formation. They suggested that it was possibly synonymous with *Paradoxides forchhammeri* Angelin, 1851, but considered their material insufficient for a specific assignment. A computer-assisted reconstruction (Fig. 1) of their largest cranidium (Poulsen and Anderson, 1975; plate 1, fig. 4) indicates that they were overly cautious in their taxonomic assessment; their material can confidently be assigned to *Paradoxides forchhammeri* Angelin, 1851 (Fig. 2).



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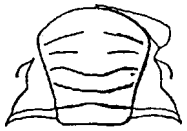

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Fig. 1. Three-stage computer assisted reconstruction of *Paradoxides* sp. cranidium of Poulsen and Anderson (1975; plate 1, fig. 4).

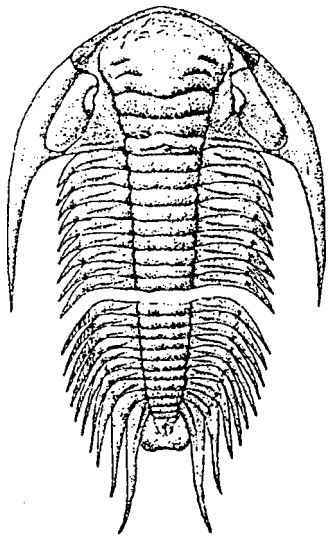

Fig. 2. Reconstruction of *Paradoxides forchhammeri* Angelin, 1851 (from Bergstrom and LeviSetti, 1978, page 20, fig. 7D).

A field study using the stable isotopes of oxygen and hydrogen to calculate evaporation

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Evaporation from a large tundra watershed (850 km^2) was examined in central District of Keewatin, N.W.T. (64°41'N; 97°03'W), as part of a pioneer water balance study at this arctic site. The ^{18}O and ^{2}H compositions of precipitation, surface waters, and groundwaters were monitored during the summers of 1988 and 1989 to trace their movement, mixing, and evaporation within the flow system. This work was conducted in conjunction with an evaporation-pan study. An isotope mass-balance technique was applied to the combined data set in order that the annual vapour losses could be calculated for the study area.

The importance of evaporation in this part of the arctic is readily discerned from the ^{18}O and ^{2}H contents of the lakes and ponds. The effects of this process are qualitatively identified on a $\delta^{18}O$ versus $\delta^{2}H$ diagram, with respect to the Global Meteoric Water Line (GMWL; $\delta^{2}H = 8\delta^{18}O + 10$). The enrichment signals that are preserved in these surface waters characterize a well-defined evaporation line described by the relation $\delta^{2}H = 5.5\delta^{18}O - 49$.

To calculate evaporation (E) from the isotopic data, the bulk composition of the derived moisture, δ_e, must be determined. The theoretical values of δ_e were computed for both isotopes through analysis of their slopes of isotopic enrichments in the evaporating-pan water, with respect to the fraction of water that remained. These estimates were refined by relating them to the evaporation line, which describes the true behaviour of these isotopes during evaporation in the natural environment. E is then calculated from a water balance equation and its related isotopic expressions.

The calculations indicate that evaporation is of variable importance at different levels in the drainage system. Small tundra ponds with limited surface inflow or outflow are strongly enriched in both ^{18}O and ^{2}H (up to -12 ‰ $\delta^{18}O$ and -113 ‰ $\delta^{2}H$), relative to mean annual precipitation ($\delta^{18}O$ = -22.7 ‰, $\delta^{2}H$ = -174 ‰), and as much as half of their water output can be lost to evaporation. Conversely large and well-drained lake ($\delta^{81}O$ = -20.6 ‰, $\delta^{2}H$ = -158 ‰), loses only 10% or less of its annual water budget as vapour.

Results obtained from this project demonstrate the viability of gauging evaporation and studying water balance with the stable isotopes. Techniques developed in this study can also be applied to a variety of hydrological problems associated with mining and tailings management. This work would be particularly useful for defining the long-term water balances of mine sites, permitting assessments of the long-term capacities of tailings ponds and evaluations of water inflow problems.

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Quaternary and environmental geology of the proposed Site C hydroelectric dam Peace River region, British Columbia

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The Site C hydroelectric dam project represents the third stage of B.C. Hydro's development of the Peace River. Construction of the dam will result in the flooding of approximately 80 km of the valley between Hudson Hope and Fort St. John. Concerns about the environmental impact of dam construction led the Geological Survey Branch of British Columbia to support study of the Quaternary and environmental geology of the region.

Weakly consolidated Cretaceous shales and sandstones underlie the Peace River region. The Quaternary stratigraphy consists of a succession of preglacial braided stream gravels, basal melt-out tills, other diamicton types, and minor amounts of coarse glaciofluvial sediment derived from both the Laurentide Inlands is to the east and Cordilleran glaciers to the west, and thick sequences of glaciolacustrine silt and clay. The region was completely glaciated on at least one occasion during the Quaternary, but the eastern and western ice masses did not coalesce during the Late Wisconsinan. Glacial lake development is the major influence on the region's physiography. Holocene fluvial and colluvial deposits are present along the Peace River and its major tributaries. Minor mid-Holocene aeolian deposits present in the northeast represent the Hypsithermal, a dry climatic episode.

Aggregate exploitation in the region is confined to the glaciofluvial deposits, and to terraces of coarse fluvial sediments along the Peace River. The scarcity of aggregate poses a potential problem for construction. Peat resources in the region are also limited, and economic exploitation is not feasible at present.

The major environmental geological hazard in the region is slope failure. Valley slopes throughout the region are highly subject to slumping, mass flow, creep, and other forms

of colluviation. Most failures are centred in the Cretaceous shale, especially in bentonitic units. ^{14}C dating of palaeo-failures has revealed that mass movement processes have been vigorously active since deglaciation. Failure rates and extents are greatly enhanced by lubrication of the strata. Construction of the Site C dam could induce extensive slope failure along the entire reach of the Peace River, unless proper engineering precautions are taken.

Geology - applications in engineering and the environment in Newfoundland and Labrador

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There is a natural tendency to think of a geologist practising in Newfoundland and Labrador as a "hard rock" specialist conducting exploration work for the mining and petroleum industries and government agencies. Most geologists in the province undoubtedly are involved in this type of work but there are many other important areas where geology skills are applied particularly in the fields of engineering and, increasingly, the environment. The general public and the geological community will be familiar with the examples cited where this is the case: Hibernia, the decommissioning of the Long Harbour phosphorous plant, and the jet fuel spill in 1988 in Goose Bay. Other examples will not be so familiar: the North Warning System short range radar network in Labrador and off the tip of Baffin Island, individual studies to identify armour stone sources for marine projects, and rock slope stability assessments such as that carried out in Western Brook Pond, Gros Morne National Park. These projects collectively demonstrate the wide range in areas of specialization that exists for geologists in the province.

Case histories of applied structural geology, hydrogeology in engineering and environmental sectors (e.g., design implications of groundwater flow, the behaviour of contaminants in the subsurface) and terrain analysis are discussed. The diversity of geological assignments in the province is demonstrated in an ironic way. At the very time that a team of geotechnical engineers and geologists were investigating the Hibernia GBS site on the Grand Banks, from which crude oil has not yet begun to flow, another group was applying hydrogeological expertise to delineate the extent of refined petroleum, in this case gasoline, which had been released to the subsurface and eventually led to building evacuations in downtown St. John's.

The move towards environmental geochemistry

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In Europe and the Soviet Union the legacy of chemical pollution from poorly controlled mining and industrial development is considered so severe that many geoscientists are now focusing their efforts on the geochemistry of the environment. Fortunately, the Canadian environment is still relatively clean, and so it is timely to establish databases of the natural distribution of chemical elements, and the processes which modify these distributions, to permit future evaluation of environmental change. GSC programs are establishing geochemical databases, with new emphasis on 'toxic' elements in sediments, waters and coals.

Rocks form the bottom end of the food chain. The composition of rocks and their comminuted derivatives (glacial deposits, soils, sediments) governs the chemistry of ground waters and crops, and ultimately, therefore, the quality of human health. Geochemists and health specialists are seeking links between natural metal enrichment and diseases. Other GSC activities include production of natural radioactivity maps; 'forensic' investigations of hydrocarbon traces; research on acid mine drainage and acid rain; and the use of natural brines to capture CO_2 emissions.

EM survey of suspected farm groundwater contamination

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Over the last decade, electrical geophysical techniques have been gaining acceptance for investigating geotechnical problems, particularly in the area of detecting and monitoring groundwater contamination.

A terrain conductivity survey using a Geonics EM-31D terrain conductivity meter was conducted at a local farm site last year. The purpose of this survey was to determine if an in-ground manure lagoon constructed two years previously,

without a floor, was impairing groundwater quality in the area. The concrete lagoon measures 17.4 by 33.5 m (57 by 110 feet), and contains the manure and waste water generated from the daily use of a dairy barn.

Leachates, emanating from a sub-surface site tend to contaminate the groundwater beneath and downgrade from it. If a manure lagoon such as the one described is leaching contaminants into the groundwater, then increased concentrations of nitrates, nitrites, chlorides, and ammonia should be found in the groundwater. These constituents will increase the specific conductance of the groundwater and consequently the apparent terrain conductivity measurements. Groundwater contaminated with dissolved salts usually has a higher conductivity value than uncontaminated groundwater. If one is able to detect the plume of higher conductive groundwater near a contamination site, then it can be mapped to determine its extent.

Eleven parallel survey lines were established at the farm to give a grid spacing of 30.5 x 30.5 m (100 x 100 feet) between survey stations. The area up gradient, to the south of the lagoon, was used to give a background or control measurement. The instrument was read at each station and the results contoured.

A high is evident over the manure lagoon. The lagoon conductivity is about thirteen times higher than background. The area around the lagoon has higher ground conductivity values than elsewhere on the farm except for the extreme northeast corner of the survey area. Conductivity values drop off quickly away from the farm and lagoon to background levels as was confirmed by near background chemical results from the furthest monitoring well. It appears that groundwater contamination is presently confined to the farm site.

Lithoprobe east: 650 km of deep seismic reflection profile across the Appalachians, onshore Newfoundland

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Six hundred fifty kilometres of land Vibroseis seismic reflection data were collected during 1989 on three profiles across parts of the Appalachian mobile belt in Newfoundland. Data were collected 60 fold on an asymmetrical split spread with CMP spacing of 25 m with 4 ms sampling to 18 s record length; four vibrators were used, sweeping from 8 to 56 Hz, for a total effort of 112 s per v.p. Special experiments were conducted at some locations to record extra long and/or broadside offsets, for superior structural and velocity control. Fifteen kilometres of high resolution data, with 10 m CMP spacing, and 2 ms sampling, were recorded together with the regional data across a mineralized zone at Buchans in central Newfoundland. An overview of the data shows that (i) there is much more reflectivity in the upper crust than was apparent from earlier adjacent marine profiles, (ii) dipping reflectors can be traced to within less than 1 km of the surface and sometimes can be correlated with known geological boundaries, though the major terrane boundaries are not always clearly imaged as either reflectors or boundaries of reflection character, (iii) the polarity of dip reflectors, previously interpreted as shear zones, is similar to that observed offshore, so that interpolation of the major deep structures across Newfoundland is now possible, and (iv) the high resolution data has successfully imaged lithological units and deformation zones in the near surface mineralized zone.

Late Jurassic carbonates of the Grand Banks of Newfoundland

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From eastern Nova Scotia and the Grand Banks of Newfoundland to the Atlas Mountains of Morocco, to the Western Desert of Egypt, to the north Sinai, and on to the basins of Saudi Arabia, basinal and platform carbonates accumulated during the late Jurassic. Platform carbonates throughout the region were deposited in a general transgressive sequence with many associated minor sea level changes. Many intrashelf basins developed in this setting accumulated organically rich carbonates under euxinic conditions. Such carbonates are the identified source of oils accumulating in the huge Jurassic reservoirs of Saudi Arabia. Similar Jurassic sourced oils have been reported in the Western Desert of Egypt. Aeromagnetic data have revealed many deep basins in the north Sinai. Basins having developed under similar geologic conditions to those in the Western Desert and in Saudi Arabia, are expected to similarly generate petroleum. Throughout the region the carbonates are characterized as oolitic limestones and bioclastic peloidal packstones and wackestones with isolated biohermal buildups. Steep platform or ramp margins are transitional to basinal sediments. Canadian

equivalents of these shallow carbonates reflect the strong influence of terrigenous siliciclastic influx. Saudi Arabian carbonates have significant coeval evaporite sediments.

Two periods of rifting in the Jeanne D'Arc Basin of the Grand Banks were separated by middle-late Jurassic passive margin sedimentation, at which time were deposited basinal Downing Formation fine clastics and shelf Rankin Formation limestone. Within the Rankin are source rocks of the Egret shale which, like their eastern counterparts, are interpreted to have accumulated in shallow neritic and brackish lagoons. The coeval Downing Formation is dominated by a sequence of siltstones of deep marine limestone, with interbedded South Tempest sandstones of deep marine turbidite origin. On-going and beginning studies by the Global Petroleum Resource Evaluation Group will attempt to determine the depositional model and to evaluate the petroleum potential of these Jurassic units of the Grand Banks using the knowledge available from the Newfoundland and regional geologic setting.

In-situ trace element and isotope ratio determinations in rock-forming minerals using Laser Ablation Microprobe (LAM)-ICP-MS

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A laser ablation solid sample introduction system, designed for microsampling of minerals in petrographic sections, has been coupled to a SCIEX ELAN ICP-MS to produce a microprobe with trace element and isotope ratio determining capabilities. The system consists of a Q-switched Nd-YAG laser, laser energy attenuation optics, beam steering mirrors, petrographic microscope, sample cell and television observation system.

The response of minerals to the ablation process is strongly dependent upon their structure, tenacity and composition (and consequent absorbtivity). However, ablation pit diameters as low as 30 μm have been achieved in many minerals, allowing studies of chemical zoning in some cases. Simultaneous determination of up to 20 elements in 15 seconds is possible with detection limits as low as 1 ppm. LAM- and solution-ICP-MS analyses of a variety of mineral separates indicate that good accuracy (Fig. 1) and precision (r.s.d. < 10% at > 50 ppm) can be achieved. In addition, the technique has the potential to perform analyses of individual fluid inclusions.

LAM-ICP-MS can also provide rapid isotope ratio determinations of single grains with precision sufficient for application to more radiogenic isotopic systems; e.g., direct dating of U-rich phases such as uraninite (Fig. 2). Preliminary work on zircons suggests that it may rival competing techniques for provenance studies.

With its trace element and isotopic analytical capabilities and low capital costs compared to competing techniques, LAM-ICP-MS has profound potential in igneous, metamorphic and sedimentary petrogenetic research as well as in ore genesis studies and mineral processing.

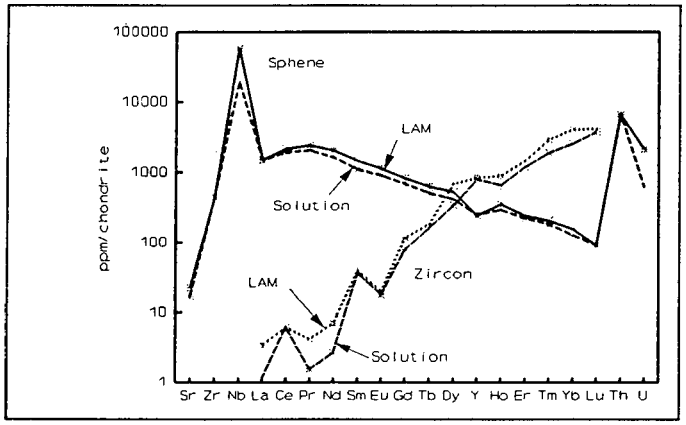

Figure 1

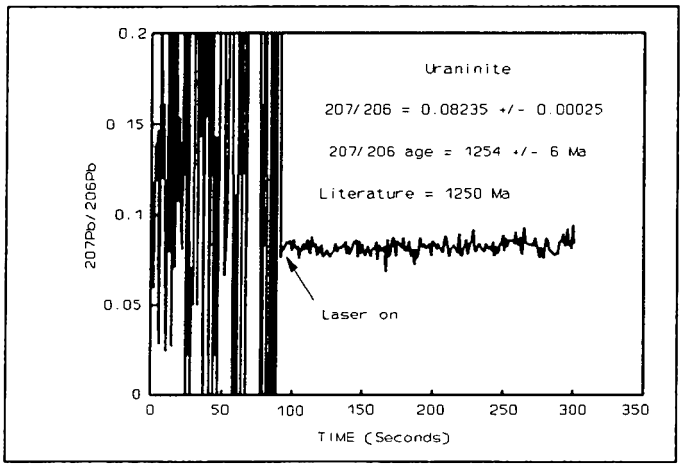

Figure 2

Environmental monitoring at remote Arctic sites for local area studies

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Environmental studies in the Arctic often have a local or mesoscale focus and involve locations that are remote from permanent settlements. For many kinds of research into Quaternary paleoenvironments and environmental change, there is a need for current data, particularly on climate. Gathering of such data once required field seasons under difficult conditions, but recent innovations now make it possible to operate unattended observing stations at such locations on a continuous basis. A network of such stations is being operated in Baffin Island by the author, with the support of the Canadian Climate Centre. The main purpose is to obtain climatic data to supplement the sparse permanent meteorological station network, but these stations can support other kinds of environmental studies. The remote station data are especially useful for assessing the paleobotanical record from lake sediments. They also provide opportunities for special measurements relating, for example, to the permafrost thermal regime and to glacial mass balance. A proposal has been put forward to install such stations in Labrador in support of a developing program of long-term environmental studies.

Neodymium isotopic evidence for interaction of mantle and crustal components in the genesis of A-type granite suites in Labrador

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Petrogenetic models for so-called "A-type" or "within-plate" or "anorogenic" granite suites include derivation from enriched mantle sources, metasomatism of "normal" granites, and anatexis of lower-crustal rocks that may have been depleted via previous melt extraction. Nd isotopic data from a much wider population of granitoid rocks have been interpreted by some to reflect mixing of new, mantle-derived material and sialic crust; however, very few Nd isotopic data have to date been reported from A-type suites.

In this contribution, we report Nd isotopic data from two post-orogenic, A-type, granite suites in the Early Proterozoic Makkovik Province of north-central Labrador. εNd values (relative to CHUR) for the ca. 1720 Ma old Strawberry Intrusive Suite lie between values expected for depleted mantle and calculated for local basement rocks at this time. This relationship holds for an array of intrusions that crosses the inferred boundary between a ca. 3000 Ma old Archean Craton and adjoining Early Proterozoic crust that is no older than 2000 Ma. The εNd of granite plutons changes from -7 to +5 across this fundamental boundary, but there is no discernable shift in their elemental geochemistry. The ca. 1800 Ma (or 1720 Ma?) old Lanceground Intrusive Suite, located at the eastern edge of the Archean block, shows similar behaviour, and has εNd of 0 to -3.

The Nd isotopic data from both crustal blocks are consistent with mixing of mantle-derived magmas and local crustal rocks to produce A-type parental magmas. Calculations suggest that, in some cases, "new" material may actually have dominated over recycled older crust. The data argue against the prevalent "residual source" model, and suggest that A-type suites are part of a continuum, rather than discrete grouping indicative of a specific source material.

Elemental analysis at Memorial

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Elemental analysis of rocks, soils, and natural water samples is of increasing importance in earth science, for investigations ranging from the environment, to petrogenesis, and exploration. Most of these studies require multi elemental capabilities. The complimentary nature of various techniques will be compared, as no single instrumental method of elemental analysis is a panacea for all purposes. In choosing a method of elemental analysis, users of analytical results must consider the elemental concentration range to be determined, the nature of the sample material, and cost.

We will review the procedures currently in place at Memorial University, using Inductively Coupled Plasma-

Mass Spectrometry (ICP-MS) for elemental determinations. For rocks and minerals, analysis follows dissolution using mixed acids or sintering with sodium peroxide. Procedures are also available for elemental analysis of fresh waters and digested biological samples. Capabilities for studies of the environment will be presented.

Major advances have recently been obtained in solid sample analysis with the installation, in early 1990, of a modern sequential, ARL X-Ray Fluorescence (XRF). This new instrument demonstrates greatly improved stability and sensitivity, and is producing the low limits of detection for Rb, Y and Nb, crucial for lithogeochemical studies. Pressed pellet determinations of 30 elements, including semi-quantitative majors, are available and their quality is constantly being improved as better matrix correction procedures are brought on line. Major element determinations using glass bead fusions are also being developed.

A hydrogeological interpretation of trace metal concentrations in lake sediment in the Holyrood granite

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A regional lake/pond sediment survey over the Avalon Peninsula in 1976, by the Newfoundland Department of Mines, showed a number of lakes with anomalous concentrations of uranium and other metals in the area of the Holyrood Pluton. These anomalies apparently have no association with the host granite rock geochemistry. The hydrogeological framework, including detailed analysis of the fracture systems as major groundwater conduits, has been studied in an attempt to determine the role of groundwaters in transporting and localizing concentrations of trace metals in lake sediment in four lakes in the area.

Groundwater discharge into the lakes was estimated to range from 20 to 35 percent of their water balances, based on characteristic differences between groundwater and surface waters. Detailed sampling, on a grid pattern, of lake sediment showed a non-uniform areal distribution of metals over these lakes. This sampling also showed that peak concentrations were not restricted to the centre or deepest point in the lake. The maximum concentration of uranium found in these lakes ranged from 69 to 309 ppm, which were higher than those recorded in the regional survey. In some cases the elongated shape of the anomalous area aligned with the orientation of one the major fracture sets in the study area. Sampling of vertical sections of sediment, through both anomalous and background areas showed a considerable variation of metals in the sediment column. However there appeared to be no direct relationship between surface sediment concentration and peak concentrations at depth. Although concentrations of most metals in the sediment are at about detrital levels anomalous concentrations of uranium in the cores appear to be associated with a sharp decline in LOI or organic content. A mechanism is proposed where mobile uranium in oxidizing groundwaters is reduced to its tetravalent state when it encounters organic rich muds as it discharges into a lake. Seepage flux values along with uranium concentrations found in deep groundwaters in the granite suggest that groundwaters are a possible mechanism of transport and metal concentration in lake sediment.

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Rare metals and rare earths in Labrador

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The discovery of the world class Strange Lake Zr-Y-Nb-Be-REE Deposit on the Quebec-Labrador border has focused attention on Labrador as a potential source of other rare metal - rare earth deposits. Areas of high potential in Labrador contain the following rare-metal - rare-earth showings, most of which have not been thoroughly evaluated: the Mann showings (Be-Nb±Y), the Two Tom Lake showing (Be-Nb±Y), and the Red Wine showings (Zr-Y), in the Letitia Lake area, and showings within the Flowers River Igneous Suite (Zr-Y-Nb-REE). Presently, only the Strange Lake property is staked, whereas all other rare-metal - rare-earth showings and areas with high potential are open for staking.

Recent petrological work on the Strange Lake Deposit and Letitia Lake area showings indicate that rare-metal - rare-earth mineralization is spatially and genetically associated with early Neohelikian peralkaline and felsic intrusive - volcanic rocks related to crustal uplift or extension. This mineralization is hosted by peralkaline granites (Strange Lake and Flowers River), peralkaline quartz syenites and trachytes (Mann and Two Tom Lake showings), and undersaturated peralkaline syenites (Red Wine Intrusive Suite nepheline syenite). The mineralization occurs within these felsic settings as aplite-pegmatite veins and lenses (Strange Lake, Flowers River), near-vent - late-stage flows (Mann

showings, Two Tom Lake), and other late-stage veins (Mann and Two Tom Lake showings) or satellite intrusions within an igneous suite (Strange Lake and Flowers River).

The development of a rare-metal - rare-earth exploration model from showings and deposits in Labrador has made it easier to identify specific exploration targets in Labrador. Prime targets for rare-metal - rare-earth mineralization include: the vicinity of the Strange Lake deposit, the Letitia Lake area and the Flowers River area. These target areas are currently being evaluated by the Newfoundland Geological Survey and the preliminary rare-metal - rare-earth results are encouraging. Companies wishing to obtain positions in the high-growth high-tech metals market should seriously consider exploration in Labrador.

Geoscience education and the GAC

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Education has always been a concern of the GAC Newfoundland Section. The Education Committee has been active since it was formed and has promoted education in the schools in various ways. These include: essay contests, career days, workshops, scholarships, field trips and, of course, the Newfoundland Journal of Geological Education.

The Journal was first published in the fall of 1975 and has been a very successful project. In 1979 the Northern Miner characterized the Journal as "one of the more successful projects taken on by any branch of the Geological Association of Canada".

In the promotion of earth science education, the members of the GAC Newfoundland Section have benefitted greatly from the co-operation of the university, government and industry. In many cases, requests from schools are made to one of these groups and GAC members are asked to respond.

The most recent endeavour of the Association has been setting up the St. John's -88 fund for the purposes of educational development. Recently, a proposal was made to the GAC Newfoundland Section to provide a two-day geological workshop for teachers on the Burin Peninsula through the St. John's - 88 fund. Two geologists from the Department of Mines and Energy were asked by the GAC executive to run this workshop; this turned out to be a very satisfying and worthwhile experience. The main part of the workshop was field oriented and provided teachers in various schools with knowledge of geological features in their area. The field trip was video-taped by one of the participants. This will enable teachers to refer back to the tape or the field guide and pass on the knowledge to students for many years to come. The key to reaching as many students as possible is through workshops and local field trips for teachers in many parts of Newfoundland and Labrador.

Education committees exist in various organizations. The Canadian Institute of Mining and Metallurgy, the Prospectors and Developers Association and the Geological Association of Canada provide funds for educational purposes. If all these organizations combined their funding, a more serious effort could be made to promote education in the earth sciences. This would allow students to gain an appreciation of our Province's resources and resource potential as well as a fuller understanding of our natural environment.

Study of soil plugging beneath a manure lagoon

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A study was undertaken to verify the existence of a biological seal beneath a liquid manure, storage lagoon. Piezometers were used to delineate the water table configuration which was, in turn, used to locate 4 sampling wells. One well was constructed up-gradient of the lagoon to establish the background conditions and 3 wells were installed in a line directly down-gradient of the lagoon to determine the extent of groundwater contamination in this area. The groundwater chemistry of the water in the lagoon and the background water quality were compared to that detected from the wells. Slug tests were performed on the sampling wells to determine the hydraulic conductivity of the upper portions of the aquifer. Permeability tests were conducted, in the laboratory, on disturbed soil samples obtained from a test pit excavated to bedrock in the study area.

The study has shown that the concentration of most chemical constituents from all sampling wells was elevated above background levels. The concentration of most parameters also decreased with distance from the lagoon. Most constituents were near background concentrations in the well farthest from the lagoon. The concentration of chloride in the groundwater was not substantially different from the other ions and in addition, it decreased with distance, at a similar rate. Thus it appeared that dilution, not adsorption, was the major cause of the decrease in concentration. The concentration of manganese provided evidence of a halo effect which indicated that the plume front was probably straddled by the sampling wells.

Although the lagoon had caused some down-gradient groundwater contamination the level of contamination was

less than expected. Assuming that dilution was the dominant process, and that the values determined for hydraulic conductivity were correct, the concentration of a conservative ion, such as chloride, should have been much higher. It was evident, therefore, that there is some sealing of the soils beneath the lagoon. Further work of a more controlled nature was recommended to confirm and quantify this conclusion.

Environmental and economic impacts of future shallow placer mining in Newfoundland: a pilot study

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This paper reports on the first year of a test program to determine the environmental and economic impact of offshore placer mining on the fishery in Newfoundland. The area chosen for the study is the North-East coast of the island where there is felt to be potential for placer gold deposits.

The first part of the program is devoted to establishing a suitable test site for the work. In the first year, regional mapping was undertaken by the Atlantic Geoscience Centre, with input from C-CORE, off part of the northeast coast. A preliminary cruise was carried out in late June, and a more detailed study in August. The work included geophysical surveys to determine sediment volumes and types, and collection of bottom samples. Samples from both cruises have been submitted for assay, and results from the preliminary cruise have been released as an open file. No results have yet been released for the second visit. Further regional mapping is expected for the area in this coming summer.

Once the regional work is complete, detailed sampling in areas of greatest promise will be used to decide on the test site. At the same time background data will be compiled on benthic organisms present in the area.

Once an appropriate site is identified, a one-month mining operation will be undertaken. During the mining a very intensive monitoring program will be carried out, to monitor sediment suspension and fallout, plume generation and dissipation, water chemistry and impact on the biota of the area. After a month mining will cease, and the recovery of the site will be monitored for two years. If necessary, a second mining experiment may be undertaken, with mining techniques modified in the light of the first test. Finally both sites will be monitored to assess the longer-term impact of the mining activities on the seabed and on the biological species.

The program will have the advice of an advisory committee, which includes government representatives responsible for monitoring environmental impact of marine operations. Because a full yearly report will be published, this program will provide a basis of fact in the public domain. From this basis it is expected that regulations can be formulated to govern future marine mining operations. An unbiased pilot study of this stature will provide sufficient information to permit rational public discussion of the potentially contentious issue of marine mining in an area of rich fisheries.

Regional analysis of iceberg scours: an application for GIS

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Iceberg scour information are usually stored on separate databases or maps. GIS provide the capability of integrating, scaling and manipulating spatially distributed data, overcoming the limitations of traditional media. For example, iceberg scour depth can be integrated with surficial geology and bathymetric data to examine the relationships between scour depth, bathymetry and seabed sediments. Strategies required to develop a GIS that will enable scientists to examine multivariate spatial relationships between marine phenomena (e.g., water body and sea bottom data recorded on Canada's eastern continental shelf areas) are presented. To demonstrate the methodology required to develop such a GIS, a spatial model for mapping iceberg scours is developed. This modelling process synthesizes iceberg scour data, surficial geology, bathymetric data (e.g., slope, aspect, etc.) and complementary environmental data. A prototype of this unique, non-land based GIS is presented.

Aquatic environmental monitoring

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Compliance and environmental effects monitoring programs are often required by government regulatory agencies for various industrial operations which release effluent into the aquatic environment and as part of a component study for an Environmental Impact Statement. LeDrew, Fudge and Associates Limited (LFA) is a Newfoundland-based environmental consulting firm able to design and implement land-based and aquatic environmental monitoring programs which ensure compliance with the appropriate regulations.

The focus of this presentation will be a discussion of the different collection techniques and equipment used in marine and freshwater monitoring programs. An aquatic monitoring program may incorporate qualitative and quantitative sampling of the water column, sediments and resident flora and fauna; qualitatively by underwater photography, Remotely Operated Vehicle (ROV) surveys and SCUBA surveys, and quantitatively using plankton nets, Niskin water sampling bottles, grab samplers, coring devices, electrofishing techniques, gill netting and Fyke netting. The sampling capabilities of the grab and core samplers used by LFA will be discussed.

Collected samples are chemically analyzed for parameters such as total oil and grease, PCBs, metals, PAHs and phenols depending upon the regulatory requirements which need to be addressed for each program.

Compliance with existing regulations and reviews of all industrial operations by regulatory authorities will facilitate and promote protection of our aquatic resources.

The proposed wilderness research centre of the Labrador Institute of Northern Studies, Memorial University

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A Task Force created by the Governing Board of the Labrador Institute of Northern Studies (LINS) of the Memorial University of Newfoundland (MUN) has recently examined the feasibility of establishing a wildlife and resources research centre in Labrador. It was the unanimous conclusion of the Task Force that establishment of such a centre would have positive scientific and educational impacts on MUN and the province. Labrador is the site of some remarkable and relatively unperturbed terrestrial, aquatic and marine ecosystems. The proposed centre would execute, broker and encourage basic scientific research in Labrador to provide baseline scientific knowledge on a wilderness ecosystem. The centre would build upon the personnel, analytical expertise, and laboratory facilities at MUN to establish a programme in wildlife ecology and resources research that integrates all facets of research in Labrador into a system science approach. The centre could provide graduate training, continuing professional development, research internships, and adjunct research linkages. The centre could provide an impetus for the development of a school of environmental - earth system science research at MUN. The centre could act as an environmental and resource survey organization which would provide the continuous and long-term scientific data needed to resolve conflicting and fundamental land use questions. Linkages will be achieved by the innovative use of geographic information systems (GIS) and the integration of research facilities, logistics and documentation.

ICP-MS trace element analyses of surface waters from fault zones in the eastern and western margins of the Dunnage tectonostratigraphic zones of the Newfoundland Appalachians

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Fifty-three surface water samples were collected from standing bodies of water located in the vicinity of major regional fault systems and/or mineral occurrences on both the eastern and western margins of the Dunnage Zone. The samples were 50 or 100 ml specimens which were collected with disposable syringes, filtered through 0.45 μm disposable filters and acidified with 1 to 2 ml distilled 8M nitric acid to make ≈ 0.2M nitric acid solutions; all in the field. The

samples were run a the ICP-MS laboratory, Department of Earth Sciences, MUN, using a modified biological waters analytical program. Concentrations of 29 elements were analyzed in each sample. Detection levels for 26 elements (all except Cl, Ca and Fe) were < 1 ppb, and < 0.1 ppb for 17 elements. Hg and Tl were not detected in any samples.

There were distinct geochemical differences in the waters from the different margins of the Dunnage Zone. The western Dunnage samples contained generally higher concentrations (in terms of mean values) of Ag, B, Ba, Ca, Ce, Cl, Cu, Mg, Ni, Se, Sr, V and Zn. The eastern Dunnage samples had relatively higher values of As, Cd, Fe, Li, Mo, Sb, Rb and U. These elemental distinctions are logically linked to the differences in lithologies associated with the different regions sampled, *viz.*: the western Dunnage samples were collected from the Baie Verte Peninsula and Carboniferous Deer Lake basin area and hence have abundant oceanic crust in the vicinity; the eastern Dunnage samples came from areas underlain by granitoids and felsic volcanic rocks in the St. Albans area and by shales and siltstones of the Davidsville Group, Gander area. The most elevated Cu, Mg, Mo, Ni and Se contents were in a water sample from Winsor Lake, Tilt Cove.

The ICP-MS water analysis technique offers an inexpensive and relatively simple means of deriving geochemical data at very low detection levels for exploration and/or environmental monitoring. The method involves sampling a medium which is essentially a focus and locus for regional geochemical inputs.

Ice scour in the geological record and its applicability to offshore oil and gas development

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Interaction between the keels of floating ice masses and seabed or lakebed sediments results in the formation of linear or curved scours in the substrate. A typical iceberg scour is 1.4 m deep and 45 m wide, and a typical scour formed by sea ice pressure ridge keels is 0.5 m deep and 26 m wide. Scour length in both cases may range from several hundreds of metres to several tens of kilometres.

Examinations of relict Pleistocene scours exposed above water level, and of modern, small scale tidal flat scours developed in clays and silts provide subsurface information which cannot be easily obtained from submerged features. Sediments are displaced by the penetrating, moving keel. In the general case material in front of the keel is pushed forward into a surcharge and is displaced laterally to either side forming linear piles, or berms, of typically disaggregated sediment which form the outer berm margins. Sediments beneath the keel are displaced downward, and sediment at the free surfaces on either side of the keel respond to this compression by upwarping to form the inner berms of typically cohesive material with prominent fractures. Localized faults with large displacements (3.5 m) may develop beneath the scour trough and berms.

Small scale modelling of the scour process has been undertaken in sand and silt at 1 gravity, and in clay at 100 gravities. Among the most important findings of these physical models are: that sub-scour deformations are not negligible, that the attack angle of the keel's leading edge makes a significant difference to the sub-scour deformations, and that soil density and type are major controllers of seabed response to scouring.

The combination of field observations and small scale modelling has allowed the development of more accurate conceptual models of the scour process. These models will lead to codes of practice for burying submarine pipelines in sediments affected by scour, because well defined zones of scour-related perturbations may be delineated. This could lead to savings of millions of dollars in development regions such as the Canadian east coast and Beaufort Sea.