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The Canadian Federation of Earth Sciences / Fédération Canadienne des Sciences de la Terre: 2008 Highlights

The Cenozoic Arctic Ocean Climate

Rapid Carbon Injection and Transient Global Warming During the Paleocene – Eocene Thermal Maximum

Utilizing Paleosols in Quaternary Climate Change Studies

Ice Cores, Greenhouse Gases and Climate Change

Applications of Seafloor Mapping on the Canadian Atlantic Continental Shelf

Review

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Cover. Photograph illustrating the loess–paleosol sequence, near Xian, southern Chinese Loess Plateau, about 200 km east of Baoji. See article, by Nat Rutter, beginning on page 65.

SERIES

ISSUES in CANADIAN GEOSCIENCE The Canadian Federation of Earth Sciences / Fédération Canadienne des Sciences de la Terre: 2008 Highlights

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SUMMARY
The Canadian Geoscience Council (CGC) was reorganized into the Canadian Federation of Earth Sciences/ Fédération Canadienne des Sciences de la Terre (CFES/FCST) in the fall of 2006. This article highlights the activities of the new organization in 2008, the first year that real progress and renewal could be demonstrated. The organization aims to be the unified voice of earth science in Canada, using a multi-pronged approach along three lines: defragmentation of the Earth Science sector, outreach (to K-12 and the general public) and lobbying (to decision makers). We also published a Human Resources snapshot of our sector and are making progress toward creating one Canadian Geoscience Literature database.

RÉSUMÉ
La Fédération canadienne des sciences de la Terre (FCST), jadis le *Canadian Geoscience Council* en anglais a été réorganisé à l'automne 2006 et se présente dorénavant sous les appellations de *Canadian Federation of Earth Sciences* / Fédération canadienne des Sciences de la Terre (CFES/FCST). L'article qui suit souligne les principales activités du nouvel organisme en 2008, une première année de véritable progrès et de renouvellement de la participation. Cet organisme entend être « la » voix des géosciences au Canada en concentrant ses efforts en trois directions, soit : la défragmentation du secteur sciences de la Terre, la sensibilisation (niveau fin secondaire et grand public), le lobbyism (influence auprès des instances décisionnelles). Nous avons aussi publié un instantané des ressources humaines du secteur et progressons dans l'établissement d'une base de données de la littérature géoscientifique canadienne.

INTRODUCTION
The Canadian Federation of Earth Sciences/Fédération canadienne des sciences de la Terre [CFES/FCST; www.geoscience.ca] is the new constellation of earth science organizations that replaced the Canadian Geoscience Council (CGC) in the fall of 2006. A short summary for those of you who are not aware of this history: the CGC was created in 1971 as an umbrella organization for Canadian Geoscience. Despite considerable effort and success, CGC's effectiveness decreased over the last decade. Several member societies withdrew from CGC, causing different sectors of our profession to become increasingly isolated from each other.

The 21st century demanded renewal, and this realization resulted in reorganizing and renaming CGC in 2006. The new organization, CFES/FCST, charges its constituent associations an annual fee of $2 per member (minimum of $500 total) and has a professional managing director rather than a volunteer, whereas most CGC finances were covered by generous grants from Natural Resources Canada. Fortunately, member organizations[1] have expressed a lot of trust in this renewed venture and have joined CFES/FCST without hesitation. There are now twelve paying member organizations and we thank them for their continued support, both financially and otherwise.

The mandate and vision of CFES/FCST is to be the unified voice

[1] Canadian Quaternary Association (CanQua), Council of Chairs of Canadian Earth Science Departments (CCCESD), Canadian Institute of Mining, Metallurgy and Petroleum (CIM), Canadian Geomorphological Research Group (CGRG) of the Canadian Association of Geographers (CAG), Canadian Geotechnical Society (CGS), Canadian National Chapter of the International Association of Hydrogeologists (CNC-IAH), Canadian Society of Exploration Geophysicists (CSEG), Canadian Society of Petroleum Geologists (CSPG), Canadian Well Logging Society (CWLS), Geological Association of Canada (GAC), Mineralogical Association of Canada (MAC), and Prospectors and Developers Association of Canada (PDAC).

for earth science in Canada through initiation and support of activities that supersede those of individual member societies. Activities roughly divide along three lines:

i) Lobbying;
ii) 'Defragmentation' of Canadian earth science; and
iii) Geoscience outreach.

PEOPLE

The CFES/FCST has a seven-person Board of Directors. The CFES/FCST president serves 2 years, and 2008 was Ian Young's last year as the first president of the new organization. Ian (Encana, Calgary) brought in fresh ideas and an immense amount of energy, and this was certainly key to making the (re)start of CFES/FCST successful. Ian stays on as past-president through 2009. In October 2008, he was succeeded by Bill Mercer of Toronto, who is an independent mineral exploration geologist and a past-president of PDAC. Bill brings a very different background to CFES/FCST, and his long experience in the Arctic gives us many new and needed insights from which the organization will benefit.

Also in 2008, we said goodbye to our dedicated international director Bryan Schreiner and welcomed in his place Peter Bobrowsky, who is with the GSC in Ottawa. Peter is also the Secretary General of the International Union of Geosciences (IUGS), one of 30 unions under the UN umbrella of the International Council of Science (ICSU), and is therefore very valuable to Canada and to CFES/FCST. Our treasurer, James Burns, stepped down and we were happy to find a replacement for this important, but difficult, and hence unpopular task in the person of Pat Ryall, who is at Dalhousie University's Earth Science Department in Halifax.

Fran Haidl remained our outreach director in 2008, but has recently been replaced by Godfrey Nowlan, the incoming president of the Canadian Geoscience Education Network. With 300 members and growing Fran works for the Saskatchewan provincial government in Regina and has immense experience in outreach. She also serves as president of the Canadian Geoscience Education Network (CGEN); with 270 members and growing, CGEN is a subcommittee of CFES/FCST, and its president serves as a CFES/FCST director. The remaining directors are Jeff Packard, CFES/FCST's communication director, and Steve Holysh. Jeff, who works for Talisman Energy Inc. in Calgary, is a past-president of CSPG, serves on GAC Council and is one of those who were instrumental in transforming the CGC into CFES/FCST. Steve Holysh is Senior Hydrogeologist at the Conservation Authorities Moraine Coalition, based in Downsview, ON, and is a past-president of the National Chapter of the International Association of Hydrogeologists (CNCIAH).

Although CFES/FCST is formally based in Calgary, the actual hub is in Wolfville, Nova Scotia, where Elisabeth Kosters does the day-to-day management from her home office on the Minas Basin. Elisabeth brings 25 years of international earth science experience in government and academia to the job and enjoys all aspects of the CFES/FCST managing directorship. Administrative assistant Catherine Barrett, based in Calgary, played a key role in the collection and manipulation of data from the Human Resources Survey (see following section) and otherwise provides invaluable back-up help.

HUMAN RESOURCES SURVEY

A project that does not concern the three main issues listed in the Introduction, but was likely one of the most important in 2008, was a human resources survey, *Human Resources Needs in Earth Science in Canada* [http://www.geoscience.ca/CFES_HR_requirements_Canadian_earth_sciences.pdf]. By the time this article is published, some of you will have seen discussions of this subject in *The Reservoir, The Recorder* or the *AAPG Explorer*. The survey, the first of its kind in Canada, warned of impending, across-the-board labour shortages in the earth science professions. We are greying fast everywhere except in the environmental/geotechnical sectors. This is worrisome, as most sectors expect to grow significantly in the next 5 years (although we note here that the survey was done prior to the start of the economic downturn). The survey also examined work conditions and educational requirements. In addition to publication in Canadian trade magazines, an article discussing the results of the survey will be published in the AAPG Explorer. Some of the important data collected during the survey are illustrated in Figures 1 to 4.

LOBBYING

Canada has more landmass than any other country except Russia (and more coastline than any other country) and it has amazingly rich resources and stunningly pristine environments. It has the world's largest reserves of fresh water and six UNESCO World (Geo)Heritage Sites [http://whc.unesco.org/en/statesparties/ca]. Yet decision makers are largely unaware of these facts and of what this means for our national identity and well-being. Of course, every Member of Parliament will be able to quote something that resembles the first sentence of this paragraph, but it more or less stops there. Confronted with a natural hydrocarbon seep in an outcrop close to his home, one MP asked anxiously "but it isn't dangerous, is it?" Many readers will have similar experiences. Earth science literacy is poor, at best, and this meagre level of understanding does not benefit policy and decision making. Clearly, there is work to do here, but how can it be done in a concise and convincing manner? A daunting task, and one that we are just beginning to address. The CFES/FCST uses a multi-pronged approach. To get the word out, you must have media attention, but you must also have something intelligent to say. The human resources survey generated important information, and we issued a media release following its completion. When the Prime Minister announced that $100m would be spent on geological mapping to stimulate mineral exploration and economic development in northern communities, we sent him an open letter congratulating him on the wise decision, but also warned him that we may not have enough professional people power to carry out the task [http://www.geoscience.ca/Open_Letter_Prime_Minister_Sept_2008.pdf].

Earth Science Advisory and Advocacy Panel: 'The Celebrity Approach'

Within our wider earth science professional environment are accomplished individuals who have earned wide recognition for their achievements. These achievements vary widely in character, but together such people can have a formidable impact on the public perception of earth science. The CFES/FCST has invited up to six individuals from across our profession (representing heritage, hydrocarbons, earth resources, environment and research and education) to form a panel that will advocate the earth sciences at every possible opportunity. At the time of writing this overview, we are in the final stages of formalizing the panel, and have had great success in attracting our first choice candidates. Watch for an announcement shortly!

Position Papers

The two most contentious issues currently facing earth scientists on a regular basis are Climate Change and Creationism/Intelligent Design. CFES/FCST published 2 position papers on these issues [http://www.geoscience.ca/pospapers.html] and some web surfing has taught us that they have both been quoted in various locations.

DEFRAGMENTATION

All sectors of the Canadian earth science community face common challenges, and member societies have addressed many of these individually over the years. The CFES/FCST is working to facilitate finding nationwide solutions to some of these challenges. Two issues that we worked on last year were Insurance and Student Chapters. In addition, we are working hard, in conjunction with our American counterpart, the American Geological Institute (AGI), to create a Canadian Earth Science Literature Database, CanGeoRef.

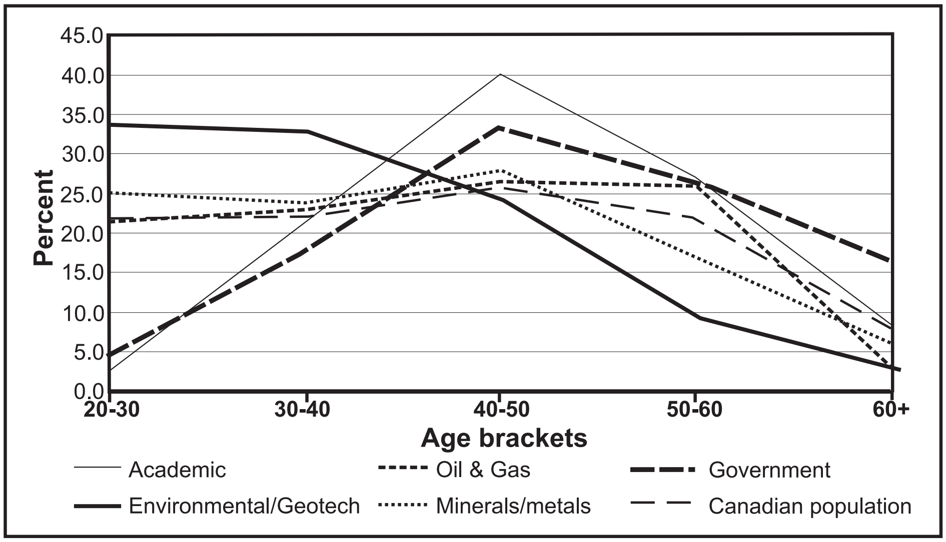

Figure 1. Age distribution of professionals practicing in different earth science sectors.

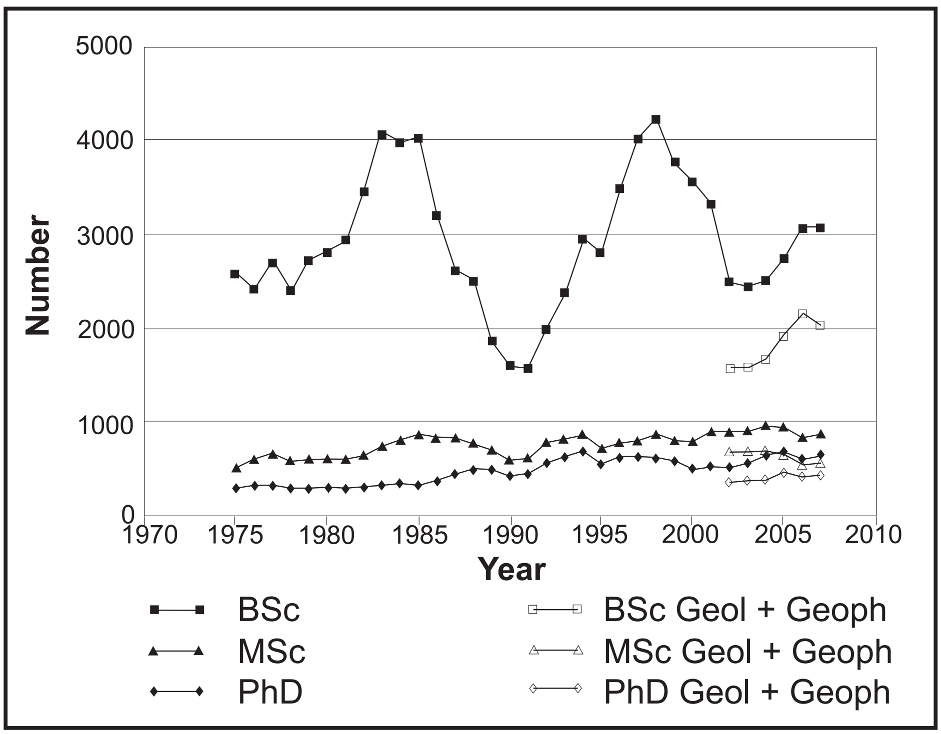

Figure 2. Number of B.Sc. (> year 1), M.Sc. and Ph.D. program registrants in Canadian university earth science departments from 1975 to 2006. Source: Council of Chairs of Canadian Earth Science Departments (CCCESD).

CanGeoRef

The AGI launched GeoRef in 1966, and more than 40 years later, it is the world's best and most complete Earth Science Database [http://www.agiweb.org/georef/]. Over the years, GeoRef has expanded from containing mostly American and English language earth science literature to more global references, and it contains not only peer-reviewed articles, but also government reports and university theses. There are presently over 3 million references in GeoRef.

Around 2002, AGI initiated a cooperative venture with Geoscience Australia (the equivalent of the GSC) to create AusGeoRef, a subset of GeoRef. The customized AusGeoRef is now available at a lower price than the larger GeoRef, thus making it more attractive for smaller companies to buy a license.

The GeoRef currently contains about 150 000 Canadian earth science references. These include all literature produced by NRCan, a few provincial references, some Canadian

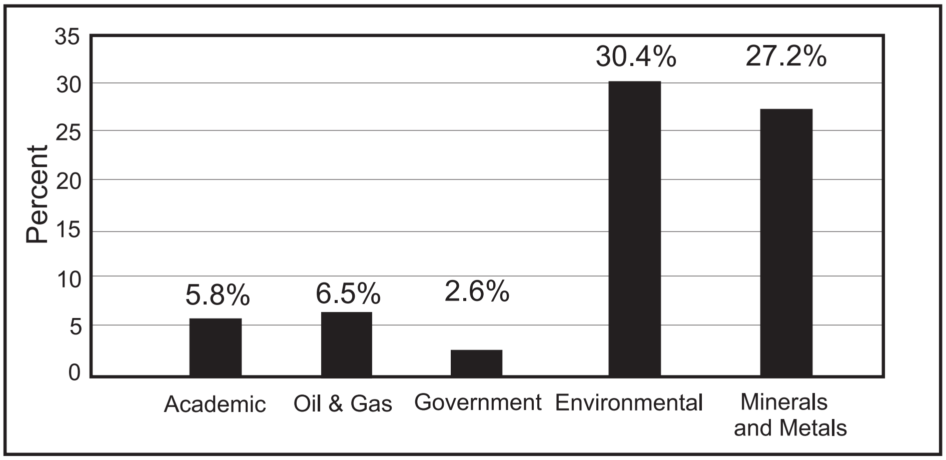

Figure 3. Expected net change in employment over the next five years among various earth science sectors. It should be noted that the survey was completed in the late spring of 2008, before the present economic downturn.

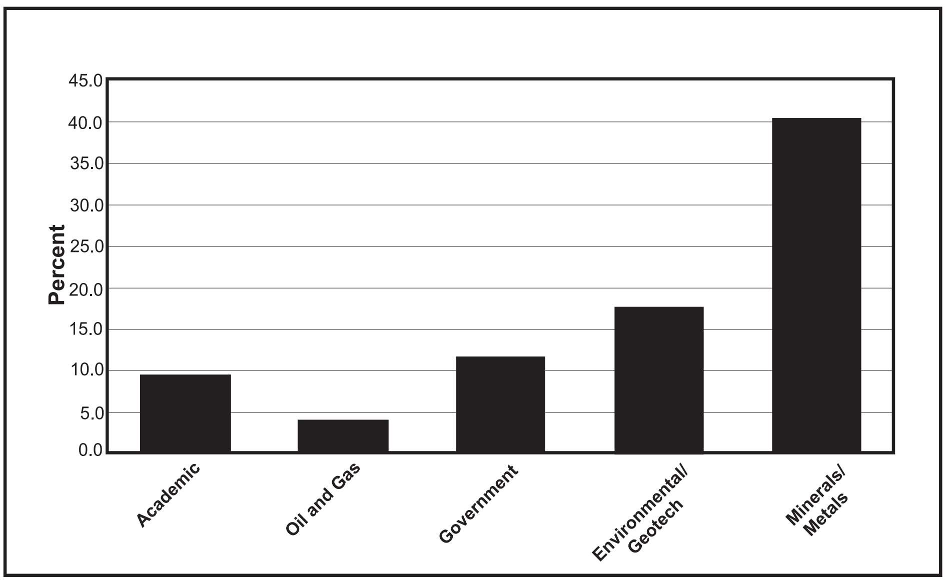

Figure 4. Percentage of temporary staff in various earth science sectors.

university theses, and a fairly complete set of articles published in peer-reviewed journals. It is estimated that an additional 150 000 references, many of them from provincial publications, are missing from GeoRef, and that at least 3000 new references can be added annually.

The AGI has asked CFES/FCST to partner with them in developing CanGeoRef, a Canadian earth science literature subset. New entries will be part of GeoRef, but CanGeoRef itself will be available as a separate subset at a much lower price than GeoRef, thus making it attractive to a much larger market that includes smaller companies and other user groups seeking only Canadian geoscience literature. Hence, more Canadian earth science literature would be easily accessible to everyone. At the time of writing this article, CFES/FCST is still researching the issue together with the provincial geological surveys and AGI, but we believe that the chances are very good that we can offer this high-quality product to the Canadian earth science community at a competitive price in the near future.

Insurance

In 2007 and 2008, the PDAC negotiated a very competitive insurance package for independent consultants and small consultancies in the minerals industry. In 2008, CFES/FCST brought together representatives from member societies together with the insurance broker to explore the possibility of opening this opportunity up to sectors. These meetings were very constructive and the discussion expanded to explore better insurance packages for member societies themselves. The result is positive and the final touches are being worked on; look for an announcement on the website of your member society! This is where it pays off to be a member of a CFES/FCST constituent society, because the policies will be available only to those members.

Student Chapters

Canada has more than 20 degree-granting university programs in earth sciences, and technical societies are all eager to reach out to these students. A few years ago, GAC and PDAC merged their student chapters into the Logan Student Chapters [http://www.gac.ca/students/], a big step forward because it is challenging for student clubs of smaller university departments to manage affiliation with more than one technical or professional society. Among other member societies, CSPG also has a sizeable student chapter program [http://www.cspg.org/students/students-outreach-chapters.cfm]. During 2008, CFES/FCST facilitated discussions between GAC, PDAC and CSPG to explore the possibility of merging the CSPG student chapters with the Logan student chapters. While this merger has as yet not been completed, the issue is close to being resolved and all parties hope that the academic year 2009-2010 will see a merger of the respective chapters. Once the newly merged chapters have functioned for a year or two, we plan to invite other societies to join, so that eventually, we will have one national student chapter program, representative of all technical societies. However, individual societies will continue to offer their own student awards and other student programs, such as CSPG's Student–Industry Field Trip and PDAC's Student–Industry Mineral Exploration Workshop. Joining forces in this way is especially important because both the American Association of Petroleum Geologists and the Society of Economic Geologists are opening offices in Canada and are approaching students with attractive student chapters. While we welcome the interest of other societies in the Canadian earth science community, we think that it is of paramount importance not to lose students to non-Canadian student chapters.

Gussow–Nuna Conference

The CFES/FCST was one of the driving forces behind, and co-sponsor of, the *Geoscience of Climate Change* Gussow–Nuna Conference, held last October at the Banff Centre in Alberta. The conference was organized by member societies CSPG and GAC as a combined Gussow–Nuna Conference, and chaired by Dr. Andrew Miall of the University of Toronto. Andrew convened a stellar international group of speakers around a well-balanced program that addressed the fundamental scientific questions of long- and short-term climate change, mankind as a geologic factor, and the relationship between climate change and declining global hydrocarbon reserves. Those who missed the conference can view the presentations at [http://www.cspg.org/conventions/abstracts/2008abstracts_gussow.htm].

OUTREACH

During 2008, the central year of the three-year International Year of Planet Earth (IYPE), outreach was of foremost importance to the CFES/FCST. The website of the Canadian National Committee (CNC) for IYPE introduces the viewer to the three main Canadian IYPE activities: i) the WHERE Challenge; ii) the upcoming book on the geology of Canada, *Four Billion Years and Counting*; and iii) the Careers in Earth Sciences website. Although the CFES/FCST was not the main driver for these activities, we were sufficiently involved to warrant a short overview of each of these initiatives. Soon after its formation, the CNC of IYPE decided to focus its activities on outreach, under the thematic acronym WHERE (Water, Hazards, Energy, Resources, Environment). Ian Young, as CFES/FCST president, serves on the CNC-IYPE, as does Godfrey Nowlan, in his role as as president of CGEN. The CNC-IYPE website [www.earthsciencescanada.com] will eventually become the website of the CFES/FCST, hence close cooperation is necessary.

Careers in Earth Sciences Website

The 'Earth Science Careers' website [www.earthsciencescanada.com/careers/] was launched in the fall of 2008. It was initiated by CGEN and has been incubating for a few years, as ideas developed for a site to educate, excite and encourage youth to consider a career in the earth sciences. The site is designed as a treasure map and takes students through the questions 'What is it?', 'What do I need?', 'What can I be?' (answers appear in the form of an exhaustive alphabetical list of careers), 'Where can I learn?', 'How much can I make?' and 'What is it like?' component. Many Canadian earth scientists volunteered their experiences as content for the what is it like component. Check out this site – you may find one of your colleagues or friends there!

'WHERE' Challenge

What on Earth is in your Stuff and Where on Earth does it come from? Even many professionals are not consciously aware of the answer to that question for much of our 'stuff'. From cell phones to LCD screens, the cooling element in the fridge, the light but strong frame of that new bicycle, and of course the chips in the now ubiquitous ipod, Earth materials are, well... elemental. And yet society takes these things for granted. The 'Where Challenge' [www.earthsciencescanada.com/where/] aims to inform youth up to the age of 14, and fill in this knowledge gap. The contest deadline was in early March; prizes will be awarded regionally as well as nationally and were made possible thanks to generous donations. CFES/FCST hopes to entice enough sponsors to be able to make this an annual contest under the leadership of CGEN. One year is obviously not enough for such an important issue.

Four Billion Years and Counting: Canada's Geological Heritage

In 2001, the Atlantic Geoscience Society published *The Last Billion Years, a Geological History of the Maritime Provinces of Canada*. The book became a Canadian non-fiction bestseller in that same year and is now entering its fourth printing. Inspired by this success, its editors, Rob Fensome and Graham Williams of GSC Atlantic, set out to produce a book modelled along similar lines but with a much-expanded focus – the *Geology of Canada* [http://cfes-fcst.ca/fby/]. This project has become one of the CNC-IYPE outreach projects, thus enabling it to attract sponsorship. The CFES/FCST will be the copyright holder for this book, which is expected to be published in late 2009.

Outreach Liaison Committee

As with student chapters, all technical societies are active in outreach to the general public. Outreach directors generally have considerable experience and brim with creative ideas; however, they usually do not have time to communicate extensively with each other. The CFES/FCST therefore created the 'outreach liaison' committee, in which the outreach directors of its member societies participate via teleconference every three months; we sometimes have as many as 15 people on the phone. The goal is to share ideas, and the lively discussions and positive feedback tell us that we are providing a welcome service.

OTHER

And last but not least, we were approached with a very well conceived proposal to generate a mentorship award. After lively discussions, we concluded that this is an extremely important, and often overlooked, aspect of everyone's working life, independent of sector or level of education of mentor or mentee. A subcommittee was formed and the first mentorship award was presented during the 2009 Joint Assembly in Toronto. The first recipient will be Dr. Paul Williams, Emeritus Professor of Structural Geology at the University of New Brunswick in Fredericton (Fig. 5).

CONCLUSION

If you did not know what CFES/FCST is or does, we hope that you have found this article informative. Most of the work is carried out by volunteers, either by our directors or by

Figure 5. The first CFES/FCST Mentorship Medal, created in honour of and awarded to Dr. Paul Williams, professor emeritus of the University of New Brunswick.

people who are generously donating their time on subcommittees. We also benefit immensely, twice a year, from round table discussions with representatives from our member societies and from our observer organizations: the Canadian Council of Professional Geologists, Natural Resources Canada, the Committee of Provincial Geologists, the Alliance of Natural History Museums of Canada, and the Canadian Association of Science Centres. This year, we will also welcome the Canadian Geological Foundation and the Partnership Group for Science and Engineering as observer organizations. We can only serve as the unified voice of Canadian Earth Science by communicating intensively with our constituents so that our actions are truly a joint effort. There is much work to be done, but we feel that we are moving in the right direction. Please join us and be part of the future of Geoscience in Canada!

SERIES

The Geoscience of Climate and Energy 3. The Cenozoic Arctic Ocean Climate

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INTRODUCTION

Throughout the Cenozoic, over the past 65 million years, Earth's climate system has experienced sometimes rapid and sometimes gradual change. This long-term climate change has induced a transition from a planet with no ice caps, glaciers or sea-ice, dubbed the 'greenhouse world' to today's 'icehouse world' of glacial and interglacial cycles.

It is well known that the climate is primarily forced by regular and predictable changes in Earth's orbital geometry and secondarily by long-term tectonic rearrangements of the continents, yet an explanation for the shift from the warm to the cold world is not yet known. What is clear is that the polar regions are critical cogs in the climate wheel, so they must have played a role in the switch from the 'greenhouse' to 'icehouse' world. For example, Earth's albedo (the percent of reflected solar radiation) can be classified as a major climate feedback mechanism, and polar ice has the highest albedo of any part of the planet. So, the establishment or destruction of ice at the poles can 'tip' the planet to a cooler or hotter place. Today, we are witnessing such a shift – the Arctic's permanent sea-ice rapidly melting.

The greenhouse/icehouse transition took millions of years, but a prominent overprint on the long-term cooling trend are extreme climate events, called hyperthermals, e.g. the Paleocene–Eocene Thermal Maximum (PETM) at ~55 Ma. Hyperthermals have been identified and studied with the purpose of advancing our knowledge of how the Earth system responds to large atmospheric, oceanographic, and/or external perturbations. Both the gradual paleoclimate evolution and the extreme events are captured in various archives located around the globe in ocean and lake sediments, ice sheets, caves, and reefs. The Earth is currently undergoing a climatic warming of unprecedented rapidity, and the understanding of the Earth's long-term climate trends and its response to past climatic extreme events has become increasingly important.

Zachos et al. (2001) reviewed the current state of knowledge of Cenozoic climate in a landmark paper that assembled the known (at that time) extreme events and integrated them with a robust compilation of proxy data from equatorial and mid-latitudes that describe the long-term changes throughout this era. This review has formed the framework upon which much of the recent Cenozoic paleoceanographic research has been based.

SERIES

Geoscience of Climate and Energy 4. Rapid Carbon Injection and Transient Global Warming during the Paleocene–Eocene Thermal Maximum

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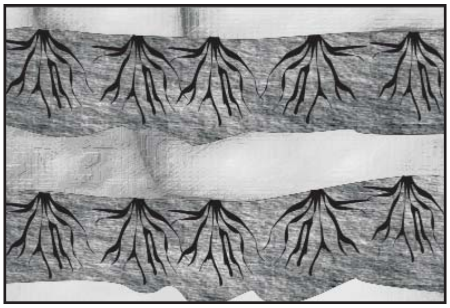
INTRODUCTION

The Paleocene–Eocene Thermal Maximum (PETM), ~55.5 My ago, was a geologically brief (~170 ky) episode of globally elevated temperature that was superimposed on the long-term Late Paleocene and Early Eocene warming trend (Fig. 1). It was marked by a 5-8°C warming in both low and high-latitude regions, a perturbation of the hydrological cycle and major biotic response on land and in the oceans, including radiations, extinctions and migrations (see overviews in Bowen et al. 2006 and Sluijs et al. 2007a). In addition, the PETM is associated with a pronounced negative carbon-isotope excursion (CIE), recorded as a >2.5‰ decrease in the stable carbon isotope composition ($\delta^{13}C$) of sedimentary components (e.g. Kennett and Stott 1991; Koch et al. 1992; Fig. 1). The CIE can only be explained by a carbon 'burp' – a massive (at least 1.5×10^{18} g or 1500 Gt) injection of ^{13}C-depleted carbon into the ocean-atmosphere system (Dickens et al. 1995).

Recent work has focused on elucidating the injection mechanism(s) and the quantity of carbon that caused the CIE, but has also addressed the question of whether the ^{13}C-depleted carbon caused the warming or acted as a positive feedback in an already warming world. Was the PETM a unique event in the early Paleogene greenhouse world, and what is the relevance of the PETM for current carbon injection from fossil fuel burning?

SERIES



International Year of Planet Earth 4. Utilizing Paleosols in Quaternary Climate Change Studies

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SUMMARY
Paleosols are an important tool in interpreting Quaternary stratigraphic sequences. Buried, exhumed, and relict soils delineate ancient surfaces that may have undergone weathering processes for long periods. Soils, including many buried soils, sometimes manifest complex histories characterized by polygenetic or superimposed profiles. Identification of the type of paleosol, or at least a diagnostic horizon, can provide valuable insight into past climates, which in turn assists in determining past vegetation. Interpreting a paleosol may be hindered by eroded or partially preserved horizons, complex climatic and environmental histories, and in the case of buried paleosols, alteration of one or more soil horizons by infiltration of material from overlying units. Soil thickness allows the minimum time of the weathering interval to be estimated and various methods are available for estimating the age of a paleosol. Probably the most accurate dating technique involves bracketing the age of the paleosol using datable material in sedimentary units above and below. Buried soils are found throughout the world, and are common in eolian deposits, such as loess and sand dunes, and alluvial deposits. In Canada, and other glaciated regions, they are interbedded with glacial deposits and have been most useful in determining periods of sedimentary nondeposition, and interpreting interglacial climates. The loess–paleosol sequences of the Chinese Loess Plateau, where over 37 major climatic cycles have been identified in the past 2.6 Ma, are presented as an outstanding example of the usefulness of buried soils. The Chinese paleosols are similar to Canadian chernozems and Luvisols, indicating steppe–forest to dense forest or steppe–forest vegetation. The cycles are best explained by Milankovitch forcing.

RÉSUMÉ
Les paléosols constituent un outil important dans l'interprétation des séquences stratigraphiques quaternaires. Les sols enfouis, exhumés et reliques constituent des surfaces anciennes qui peuvent avoir été soumises à l'altération pendant de longues périodes. Les sols, notamment les sols enfouis, révèlent parfois des histoires complexes caractérisées par des profils polygéniques ou superposés. L'identification du type de paléosol, ou d'un horizon diagnostique du moins, peut nous dire beaucoup sur les climats anciens, ce qui nous aide ensuite à connaître la végétation ancienne. L'interprétation des paléosols peut être compliquée du fait d'horizons érodés ou partiellement préservés, de la complexité des histoires climatiques et environnementales, et dans le cas de sols enfouis, par l'altération d'un ou de plusieurs horizons par infiltration provenant des couches sus-jacentes. L'épaisseur des sols permet d'estimer la durée d'altération minimum alors que des méthodes variées permettent d'en estimer l'âge. La technique de datation la plus juste probablement, consiste à délimiter une fourchette d'âge d'un paléosol à partir de matériel approprié des unités sédimentaires sus-jacents et sous-jacents. Il existe des sols enfouis partout dans le monde, et ils sont fréquents dans les dépôts éoliens, tel ceux des lœss et des dunes de sables, et les dépôts alluviaux. Au Canada et dans d'autres régions jadis glaciaires, les paléosols sont intercalés dans des dépôts glaciaires ont été très utiles pour déterminer les périodes d'absence de dépôts, et pour interpréter les climats interglaciaires. Les séquences lœss-paléosol du Plateau de lœss de Chine, où 37 cycles climatiques majeurs ont été circonscrits au cours des derniers 2,6 Ma, sont décrits à titre d'exemple remarquable de l'utilité des sols enfouis. Les paléosols de Chine sont semblables aux tchernozioms et luvisols canadiens, et représentent une végétation allant de la forêt de steppe à la forêt dense. Les cycles s'expliquent le mieux par l'hypothèse du forçage de Milankovitch.

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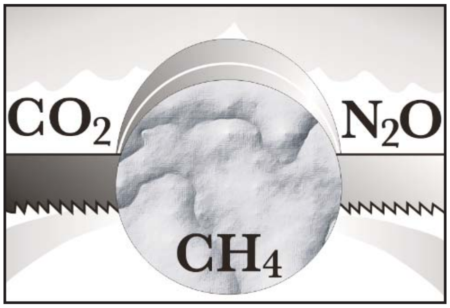

Geoscience of Climate and Energy 5. Ice Cores, Greenhouse Gases and Climate Change

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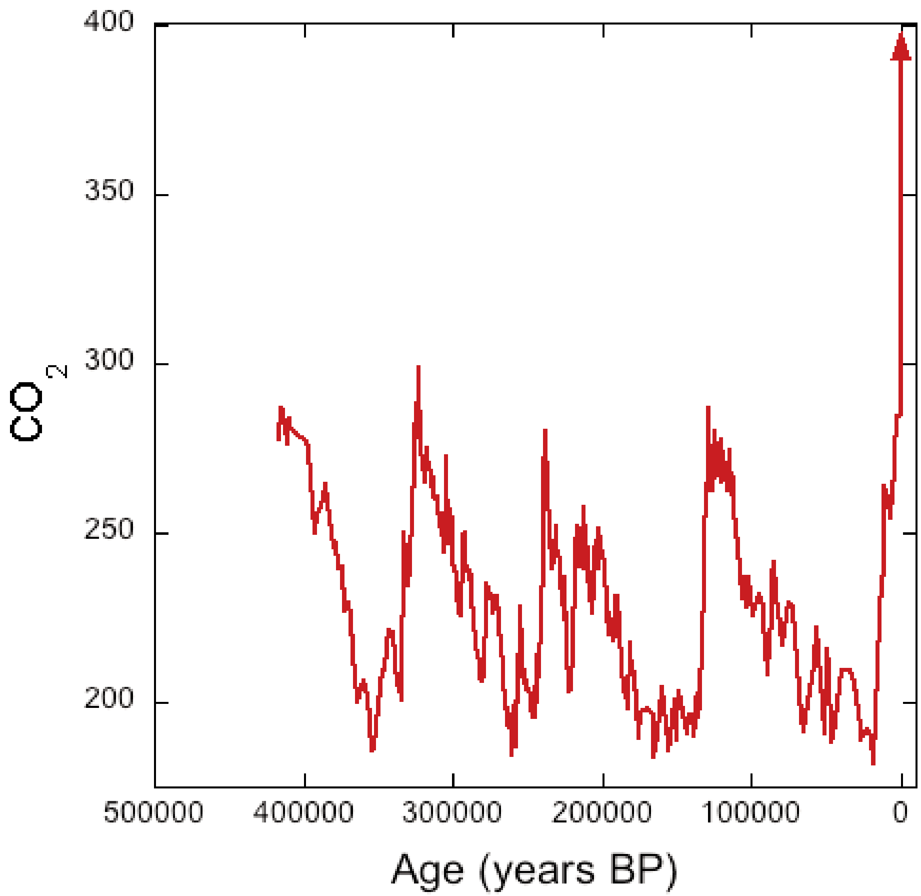

Figure 1. The CO_2 levels in the atmosphere, over the past 400 000 years, as measured in the Vostok ice core.

Ice cores are unique in that they contain not only a record of past environments, but also trap small volumes of atmosphere that directly record the levels of past greenhouse gases. Ice cores trade off temporal resolution for age via the amount of snow that falls at a given location. In places where snowfall rates are high, ice cores yield detailed temporal resolution but represent a limited time span. Annually resolved records of dust, chemical composition, accumulation and temperature via stable isotope ratios are possible in such locations along with gas records that have temporal resolutions of a few years. In places where snowfall rates are low, the temporal resolution of isotope records, for example, can be decades, and that of gases, centuries. Such records reach far back in time; currently, the longest records (from Antarctica) span more than 800 000 years (Siegenthaler et al. 2005; Lüthi et al. 2008).

In ice cores that cover the widest age ranges, records of greenhouse gases show variability on both orbital (Milankovitch) and sub-orbital time scales. Carbon dioxide (CO_2) varies by about 50% relative to its lowest glacial levels, methane (CH_4) by 100%, and nitrous oxide (N_2O) by about 40%. Carbon dioxide is readily correlated with temperature estimates from stable isotope ratios and shows little sub-orbital variability compared with CH_4 and N_2O, both of which have clear orbital variability but also vary significantly during abrupt climate changes (Loulergue et al. 2008). The strong relationship between greenhouse gases and temperature helps to scale the impact of greenhouse gases on climate, and confirms what simple radiation-balance models of the planet tell us; that greenhouse gases are a key determinant in setting global temperature. Also, they help to quickly and simply scale for the non-scientist the impacts of humans on the energy

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International Year of Planet Earth 5. Applications of Seafloor Mapping on the Canadian Atlantic Continental Shelf

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SUMMARY
Canada's final mapping frontier is its offshore territory. Compared to Canada's landmass, only a limited portion of Canada's seafloor has been mapped using the modern technology of multibeam sonar. Where this high-resolution mapping technique has been applied on Canada's Atlantic continental margin, insight has been gained into the studies of seafloor habitat mapping, Quaternary history and sea-level change, sediment bedforms and dynamics, and seafloor conditions for in-stream tidal power. Seafloor habitat mapping in Canada provides the knowledge base to effectively manage offshore fisheries, evaluate marine protected areas, minimize the environmental impact of offshore development, and resolve seafloor-use conflicts. Multibeam sonar mapping has revealed a complex glacial landsystem developed on the Canadian Atlantic continental shelf and supports the concept of the late glacial maximum reaching the shelf edge. The application of multibeam sonar technology offers unprecedented images of bedform geomorphology and this knowledge is crucial to understanding sediment mobility and its effect on seafloor habitat, engineering, and infrastructure. To minimize the risk to engineering infrastructure on the seabed, planning of tidal-energy developments in regions of large tidal range requires detailed information about the water depth, seafloor substrate and sediment mobility, and long-term seabed change garnered using multibeam sonar mapping techniques.

RÉSUMÉ
L'ultime frontière de la cartographie du Canada est son territoire extracôtier. Par rapport à son territoire continental, seule une faible portion du territoire extracôtier canadien a été cartographié par la technique moderne d'imagerie sonar multifaisceaux. Là où cette technique de cartographie de haute résolution a été utilisée sur la marge continentale canadienne atlantique, on a pu faire des progrès dans l'étude de cartographie d'habitat du fond marin, de l'histoire quaternaire des fluctuations du niveau de la mer, de la morphologie des couches et de la dynamique sédimentaires, ainsi que des caractéristiques du fond marin en vue de l'installation de centrales marémotrices. La cartographie d'habitat du fond marin permet de constituer une base de connaissances nécessaires pour gérer efficacement la pêche hauturière, établir la valeur des zones marines protégées, minimiser les incidences environnementales des activités de mise en valeur extracôtières, et résoudre les conflits d'utilisation des fonds marins. La cartographie par imagerie sonar multifaisceaux a montré qu'un système complexe de terres émergées s'est développé sur le plateau continental atlantique du Canada et qui correspond au concept d'un maximum glaciaire ayant atteint la limite du plateau continental. L'utilisation de la technologie sonar multifaisceaux permet d'obtenir des images sans précédents de la morphologie des dépôts, et ces connaissances sont cruciales pour comprendre la mobilité des sédiments et les répercussions sur l'habitat du fond marin, les aménagements et les infrastructures. Dans le but de minimiser les risques sur les infrastructures installées sur le fond marin, la planification d'installations marémotrices en zones de marées à grandes variations exige des informations détaillées sur la profondeur d'eau, la nature du fond marin et la mobilité des sédiments, ainsi que sur les changements à longs termes obtenues par l'utilisation de technique de cartographie sonar multifaisceaux.

REVIEWS

Cores and Core Logging for Geoscientists, 2nd edition

By Graham A. Blackbourn
Whittles Publishing, 2009
distributed by CRC Press
ISBN-10: 978-1904445395
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US $79.95, hardcover, 152 p.

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This book is an expanded and updated version of *Cores and Core Logging for Geologists* (ISBN-13: 978-1870325257), which was originally published in 1999 as a 120 page paperback (US $39.95). The author is a sedimentologist and his Scotland-based company, Blackbourn Geoconsulting, caters to the petroleum industry; consequently, the emphasis is on cores and core logging practices from oil and gas wells. Upon learning this, my first reaction was that this book will be of little use to me as a hardrock geologist who looks at mineral industry drill cores. To my surprise, I was wrong, as my wife delights in telling me at every opportunity.

The book is laid out in seven chapters and three appendices, including chapters on drilling and coring methods (2), core handling (3), core logging (4), core analysis and testing (5), interpretation and preparation of final logs (6), and core preservation and storage (7). Each of these chapters contains nuggets of useful information and a few practical tips for any geologist who works with drill cores or drilling projects. This book should be mandatory reading for geology students, although North Americans need to keep in mind that a 'conductor pipe' is called a drill casing and a 'torch' is a flashlight on this continent.

Overall, it is well written and well illustrated apart from the odd editorial oversight, e.g. 'But although' and 'one-off studies', and the handling of the colour figures. These figures are all placed in the centre of the book, obviously to reduce printing costs, and are assigned chapter-specific figure numbers, which are referred to in the text. When reading along in the text, however, it is not obvious where to find each missing colour figure, especially if one misses the 'Key to colour section' at the beginning of the book. It would have been less confusing for this reader if these colour images were labelled with plate numbers, rather than chapter-specific figure numbers.

What is most surprising is that there is no comparable book with a minerals-industry perspective on cores and core logging, given the increased emphasis in recent years on reporting standards by regulatory agencies, e.g. Canadian National Instrument 43-101. The book, *Geoscience Reporting Guidelines* (ISBN-10: 0-968769314), by Brian Grant has seven pages (out of a total of 346) devoted to the preparation of 'Drillcore Logs', which is more than can be found in the 'Exploration Best Practice Guidelines', to which NI 43-101 refers. In my opinion, there is a real need for a 'best practices' book on core logging for minerals industry geologists, in order to ensure consistent reporting. However, until such a book is published, I am going to keep a copy of Graham Blackbourn's second edition on my shelf for handy reference.

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Underground Gas Storage: Worldwide Experiences and Future Development in the UK and Europe

Edited By D. J. Evans and R. A. Chadwick

The UK became a net importer of natural gas in 2004 and by 2020 will import up to 90% of its requirements, leaving it vulnerable to increasing energy bills and risk of disruption to supply. New pipelines to Europe and improvements to interconnectors will meet some demand, but Government recognises the need for increased gas storage capacity: best met by the construction of underground storage facilities. Energy security has also raised the likelihood of a new generation of coal-fired power-stations, which to be environmentally viable, will require clean-coal technologies with near-zero greenhouse gas emissions. A key element of this strategy will be underground CO2 storage. This volume reviews the technologies and issues involved in the underground storage of natural gas and CO2, with examples from the UK and overseas. The potential for underground storage of other gases such as hydrogen, or compressed air linked to renewable sources is also reviewed.

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