Vol 21, April 2006

NEWSLETTER FOR THE

Canadian Antarctic Research Network

Inside

Canadian M.D. Serves as South Pole Station Physician: Report from South Pole

Christian Otto

Drs Christian Otto and Rebecca Comley are emergency physicians living in Kingston, Ontario. On October 22, 2004, the husband and wife team arrived at South Pole Station to assume medical duties for the station. Dr Comley had signed on for the Antarctic summer, while Dr Otto would serve for one year. He had completed a prior one-year tour as the McMurdo Station physician in 2002–03. Dr Comley completed her undergraduate and residency programs at Queen's University and her medical degree at McMaster University. Dr Otto pursued his undergraduate and medical degrees at the University of Ottawa, and his residency at Queen's University. Both physicians have worked in the Canadian high Arctic; in addition, Dr Otto has served as an expedition physician. Dr Otto's research focuses on remote operational medicine. He is also a member of SCAR's Expert Working Group in Human Biology and Medicine. When not in the Antarctic, both physicians practice emergency medicine in the Bay of Quinte region of eastern Ontario.

Science is the primary purpose of South Pole Station. The South Pole is ideally suited to several branches of scientific study due to its unique location at one of the Earth's poles, the cold environment, high altitude, and six months of darkness. The types of science conducted here include projects in the dark sector, which comprise astronomy, astrophysics, cosmology and space physics; the clean-air sector, which includes meteorology and climatology; and the quiet sector, where studies in geophysics and glaciology are performed.

The past year at South Pole was very busy for science, for construction of the new elevated station, and the busiest on record for medical operations. The summer season was hampered initially by the first ever outbreak of Influenza A

Figure 1
Husband and wife team, Drs Rebecca Comley and Christian Otto, South Pole Station physicians 2004–05.

virus at South Pole. From October 23 to November 30, there were 458 patient visits to the South Pole clinic. The mean number of patient visits over the typical three-and-a-half month summer season is 422. Over the 37 day outbreak, 207 visits were for upper respiratory symptoms. The previous year, only 66 persons presented to the medical clinic with cold symptoms during the same period. Sixty-two patients met the case definition for influenza. Given the maximum station population at the time, 26.5% of the station became infected. The relatively low attack rate for this poorly vaccinated population was due to the rapid identification of the outbreak by Dr Comley, aggressive infection control measures, in addition to the use of prophylactic medication to prevent the spread of infection. The operational impact to South Pole was significant: 1034 hours were lost due to influenza. Over the same period in 2003, total sick hours were two-thirds less.

Unseasonably cold temperatures in November also

Figure 2
Workers placing steel for the A4 pod.

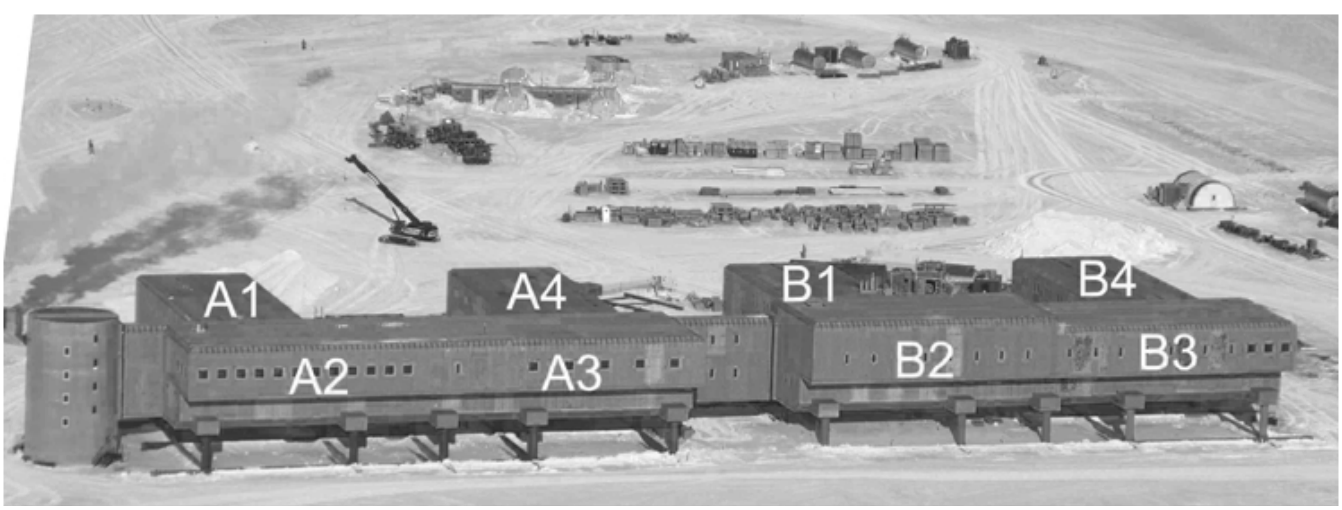
Opposite page:
Figure 4
Completed South Pole Station footprint, February 2005.

slowed the delivery of construction and science materials for three weeks. All personnel and cargo are delivered to the South Pole by C-130 ski-equipped Hercules aircraft. Approximately 300 flights are scheduled each summer to deliver all necessary materials for construction and operation of the station. Unfortunately, the unseasonably cold temperatures prevented the C-130 from idling to allow ground vehicles to unload contents. This was due to clouds of frozen vapour, referred to as contrails, created by the plane's propellers, obscuring visibility behind the aircraft. As a result, only materials that could be "combat off-loaded", while the aircraft was taxiing, could be delivered. The extreme temperatures also affected crane operations, which temporarily delayed erection of the steel structures for the A4 berthing pod and the B4 gymnasium pod. However, by the end of November, temperatures had moderated and normal operations were resumed.

One of the major science events of the summer was the arrival of the materials and staff for the Ice Cube Neutrino detector; a $400M international collaborative project involving construction of the world's largest neutrino telescope built into the polar plateau at South Pole. When completed, the project will consist of 80 detector strings extending 2 km into the ice, spread over a 2 km^2 area. Each string has 60 digital optical modules designed to detect minute light signatures, indicative of neutrino collisions with frozen water molecules.

Figure 3
Ice Cube workers lowering detector string and module.

The entire start-up infrastructure was received and erected. By the close of the summer, the first two strings had been placed in the ice: a major accomplishment.



The construction crews worked tirelessly throughout the summer and were able to complete the outside structures of both the A4 berthing pod and the B4 gymnasium pod. This completed the footprint of the new $240M elevated South Pole Station; a project started in 2001 and scheduled for completion in 2006, the 50th anniversary of the International Geophysical Year as well as the 50th anniversary of continued presence at South Pole Station.

The past summer season also marked the first full summer of operation for the new medical clinic. The modern facility has a large treatment area capable of ambulatory and emergency medical care, a two-bed patient ward, laboratory and medical office. The clinic is equipped as a mini-hospital with a wide variety of diagnostic and treatment capabilities, including a state-of-the-art telehealth diagnostic and communications system that allows medical consultation with tertiary care centres in the United States. This season witnessed the single highest number of patient visits to the clinic in South Pole history. By station close, 967 patients' visits had been recorded. This represents a 266% increase over the average number of visits. Four international medical evacuations were staged from South Pole in the month of January, three of which are described here.

A member of the Russian Antonov Biplane recovery project developed a serious case of high-altitude pulmonary edema requiring admission and treatment in the clinic. Acute mountain sickness is an ever-present threat at South Pole due to its elevation (2835 m a.s.l.) and the combined barometric pressure, which result in an average physiological altitude of 3200 m a.s.l. The patient was evacuated two days later to McMurdo Station.

One week later, a major medical rescue was staged from South Pole. A call was received from a Chinese National expedition that had traversed inland 965 km over three weeks from Zhongshan Station. The expedition had reached Dome Argus, their goal, one of the most inaccessible locations and, at >4000 m a.s.l., the highest point on the Polar Plateau. China hopes to build a station there in the next five years and this was their first foray to survey Dome A. An

Figure 5
Arriving at Dome A to evacuate Chinese expeditioner.

expedition member had been experiencing chest pains and shortness of breath. One of the South Pole scientists spoke Mandarin and acted as an interpreter. After assessing the situation, it was determined that evacuation of the sick expeditioner was necessary. The Chinese government formally requested assistance and permission was granted by the National Science Foundation Office of Polar Programs. Unfortunately, the 1225 km from South Pole to Dome A was just outside the range of the Twin Otter aircraft. However, the Chinese were able to supply four barrels of fuel, allowing for a direct flight to their location. It was a four-hour flight to Dome A and the first time that a Twin Otter had ever landed there. Upon arrival the patient was stable and was transported back to South Pole while undergoing medical monitoring and treatment. He received additional medical care and testing at South Pole where he remained for two days before evacuation to Christchurch, New Zealand.

The next weekend, South Pole Station experienced the worst trauma it had seen in four decades. A member of the Ice Cube Neutrino project drill team, on the night shift, had tried to stop one of the 1000 m cables from injuring a fellow driller when it came unspooled and began flailing about. The driller was struck in the chest and thrown about 5 m. The medical team was alerted and arrived within minutes.

The patient required immediate medical attention and was transported to the clinic. Life-saving procedures were performed as the medical team worked on the patient for the next eight hours. This included activating the walking blood bank for the first time in the Station's history. Dr Comley collected several units of blood from station personnel. A C-130 aircraft was requested from McMurdo station for a priority medical evacuation. Dr Comley and medical personnel from McMurdo Station accompanied the patient to Christchurch, New Zealand, where he underwent additional treatment for his injuries. The patient survived, and will be returning to work at South Pole for the following summer season.

By season's end, in mid-February, outside construction on the two berthing pods had been completed and the footprint of the new elevated station was complete. Unfortunately, the combination of poor weather and a slow start to the season, as well as bad weather at station close, resulted in a shortfall of construction supplies. One of the science projects that had to be delayed was construction of the new 10 m submillimeter radio telescope that will have a ground shield nearly the size of the old Dome station inverted. In addition, winter construction tasking for the new station was reduced and the winter population was decreased to 86 from close to 100 persons. However, the current population remained the highest ever to winter at South Pole. The major construction tasks for the winter season were the berthing areas of the A4 pod, the office space and communications centre in the B3 pod and the B4 gymnasium. The construction team worked steadily throughout the eight month winter and has nearly completed these last sections, which comprise nearly 25000 ft^2 (2320 m^2): the total area of the station being 60000 ft^2 (5575 m^2).

Despite what many people may think, life during the winter at South Pole Station is very busy. Personnel work six days a week, nine hours a day, for the entire winter. As a community, the population pitches in and shares the various duties. Some personnel are members of the fire team while

igure 6
Dr Comley drawing blood from volunteer donor.

Figure 7
Dr Otto performing surgical procedure on trauma patient.

others are on the trauma team. Everyone participates in station chores such as cleaning, helping to bring in the week's food supply, assisting in the galley, or in the station store. Volunteers put on recreational activities, such as craft or exercise classes, and movie nights.

This winter saw the new greenhouse in full production. A joint effort with the University of Arizona, the greenhouse is computer-controlled, adjusting all aspects of plant production from lighting, and water supply to nutrient content for the growing plants. As a result, it has provided a

Figure 8
South Pole greenhouse in winter.

steady supply of various varieties of lettuce, tomatoes, cucumbers and herbs. Some weeks the yield exceeded 25 kg of produce. Consequently, salad was served up to five times a week. In addition, the greenhouse offered a unique refuge for personnel to see and smell growing plants, in a bright and humid environment, a welcome diversion from the extremely dry and relatively sterile polar plateau.

Life as the station physician is a unique and deeply rewarding experience, especially for a Canadian, who normally has little access to such opportunities. The breadth of practice can be daunting for some, but an attraction to others. One must be comfortable working outside one's expertise at times. The physician runs a small hospital; among the various duties are taking X-rays, conducting ultrasounds and providing dental care This winter over 25 dental cases were seen from broken teeth to missing crowns. The construction environment also means that physical therapy is in regular demand, with over 100 physical therapy visits recorded this winter. Whenever lab work is required, the physician is the phlebotomist and the lab technician. Over 150 blood draws were performed through the winter. In addition to standard medical care, the physician serves as counsellor, psychiatrist, and mediator. Although it is impossible for a single individual to be an expert in all areas of medicine, breadth of training, as well as an interest and a desire to learn can provide a successful outcome to almost any challenging case. There were more than 860 visits to the clinic over the course of the winter. As with the summer, the 2005 winter was a record for the number of visits to the South Pole medical clinic.

It is difficult to give a true sense of the austral winter to those who have not experienced it. Far from being dark and featureless, it is constantly changing in its character and beauty. Thousands of stars are visible in the night sky, and the Milky Way can be seen with an unparalleled clarity that defies description. Each month, the brief presence of the moon was welcomed as the added light improved visibility and provided additional motivation to venture outside in the −65°C temperatures for a walk or possibly a ski. The coldest temperature recorded this past winter was −110.4°F (−79.1°C), the likes of which had not been seen in the past eight years.

Throughout the winter, magnificent displays of Aurora Australis or Southern Lights brightened the night sky over the station. The solar wind, interacting with the upper atmosphere, excites oxygen and gives off an incandescent green glow. As we approached sunrise, the increasing ultraviolet light in the upper atmosphere resulted in the excitation of nitrogen, which added deep violet to the mix of aurora colours. Many hands became numb in the cold as South Pole amateur photographers captured these incredible displays of nature.

As is common at most Antarctic stations, several milestones marked the winter: the sundown party, midwinter's day celebration, and finally sunrise. These opportunities are times for celebration and reflection on the unique experience that is wintering over at the most remote location on Earth, and the sacrifices that winter-overs make to be here. The motivations vary from individual to individual; however, all have made significant contributions to construction of the new station and its operation, or to science at the South Pole. The arrival of the Sun above the horizon signals the approach of a new season, and the arrival of a new crew. Many of the winter-overs will be unwinding with travel to warm and sunny locations or returning home. Dr Otto will be returning to Eastern Ontario to see his wife after their nine month separation, and twelve months at the Pole. After a brief break he will be returning to work in the emergency room, and continuing his research in remote medicine.

Dr Otto practices emergency medicine in the Bay of Quinte region, Ontario, and is a member of SCAR's Expert Working Group in Human Biology and Medicine (christianaotto @hotmail.com).

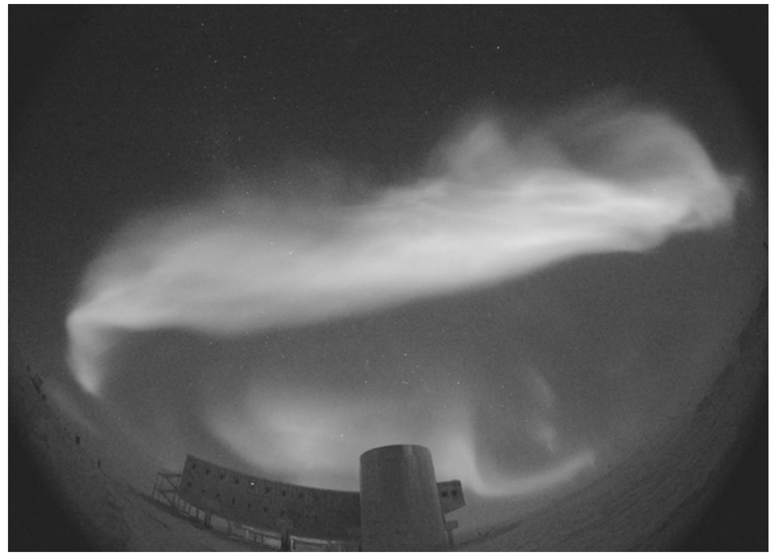


Figure 9
South Pole aurora, July 10.

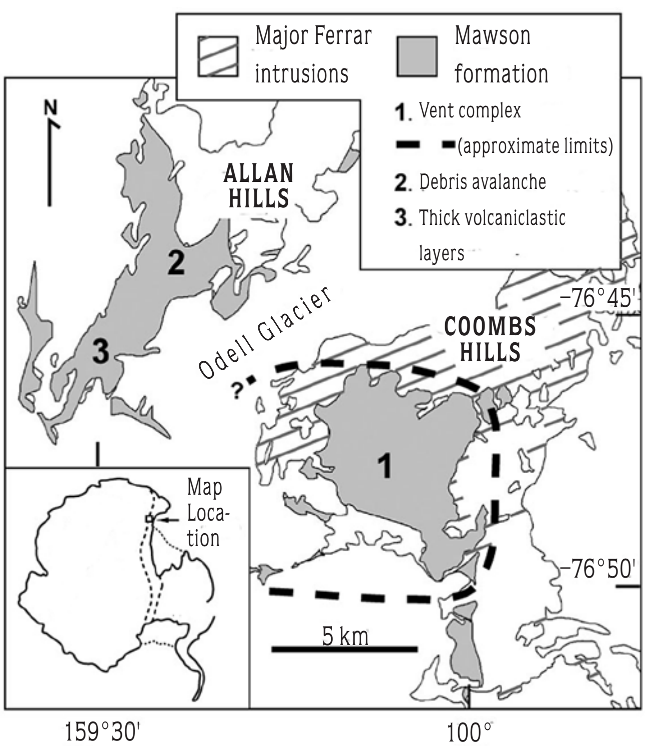
Figure 10
The Sun returns to South Pole.

Ferrar Large Igneous Province Rocks at Allan Hills, South Victoria Land

Pierre-Simon Ross, James D.L. White and Olivier Reubi

Large igneous provinces are characterized by the emplacement of millions of km^3 of magma in a focused area within a few million years. Continental flood basalts represent an important type of mafic large igneous province and include the famous Deccan Traps of India (Cretaceous to Triassic) and the Colombia River Basalts of the northwestern U.S.A. (Miocene). In these relatively young provinces, the lower part of the volcanic stratigraphy and the subvolcanic rocks are not well exposed because the flood lavas can form km-thick piles. In older provinces such as the Ferrar in Antarctica (Jurassic), the lavas have been largely eroded, so the early stages of the eruptions – preserved as mafic volcaniclastic deposits – can be studied.

Figure 1
Location map.



One of the best areas of South Victoria Land (Transantarctic Mountains) to examine the pre-lava mafic volcaniclastic rocks, which belong to the Mawson Formation, is the Coombs–Allan Hills region (Fig. 1). Our 2002/03 Coombs Hills field season results were described in a previous report (Ross and White, 2003). In summary, much of the Mawson Formation there consists of coarse non-bedded rocks interpreted to fill a phreatomagmatic vent complex excavated into the sedimentary Beacon Supergroup (*cf.* Ross and White, 2006). Coarse volcaniclastic rocks are crosscut by tuff dikes, the largest of which represent some of the biggest exposed clastic dikes on Earth (Ross and White, 2005a).

The 2003/04 season revealed rocks of a different origin. At Allan Hills, the Mawson is divided into m_1 and m_2. The former member is exposed only at central Allan Hills, consists essentially of fragmented sedimentary material from the underlying Beacon Supergroup, and is interpreted as a 180 m-thick debris avalanche deposit (Reubi and others, 2005). Most megablocks in m_1 were derived from the late Triassic Lashly Formation, parts of which were probably only weakly consolidated in the Jurassic. Sandstone breccias dominate volumetrically over megablocks within the deposits. This indicates pervasive and relatively uniform fragmentation of the moving mass, and probably reflects the weak and relatively homogeneous nature of the material involved. The avalanche flowed into a pre-existing topographic depression carved into the Beacon sequence, and flow indicators reveal a northeastward movement. Sparse globular basaltic megablocks (Fig. 2) suggest that Ferrar intrusions played a role in triggering the avalanche.

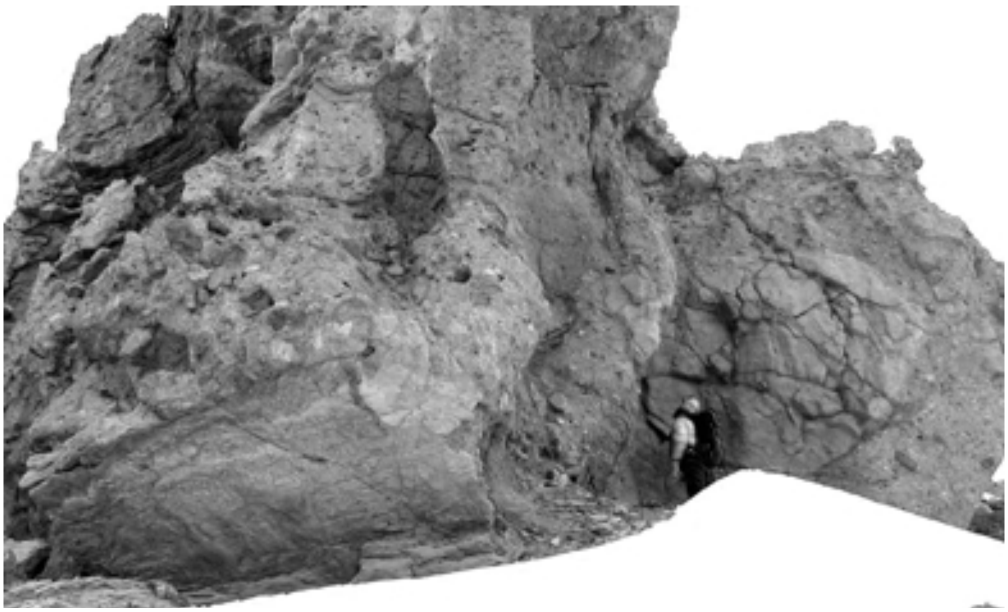


Figure 2
Mawson m_1 rocks interpreted as a lithified debris avalanche deposit at central Allan Hills. The megablock behind the person is basaltic, whereas the one a few metres to the left consists of Beacon Supergroup sandstone. Most of m_1 contains less basaltic material than shown here (photo courtesy of O. Reubi).

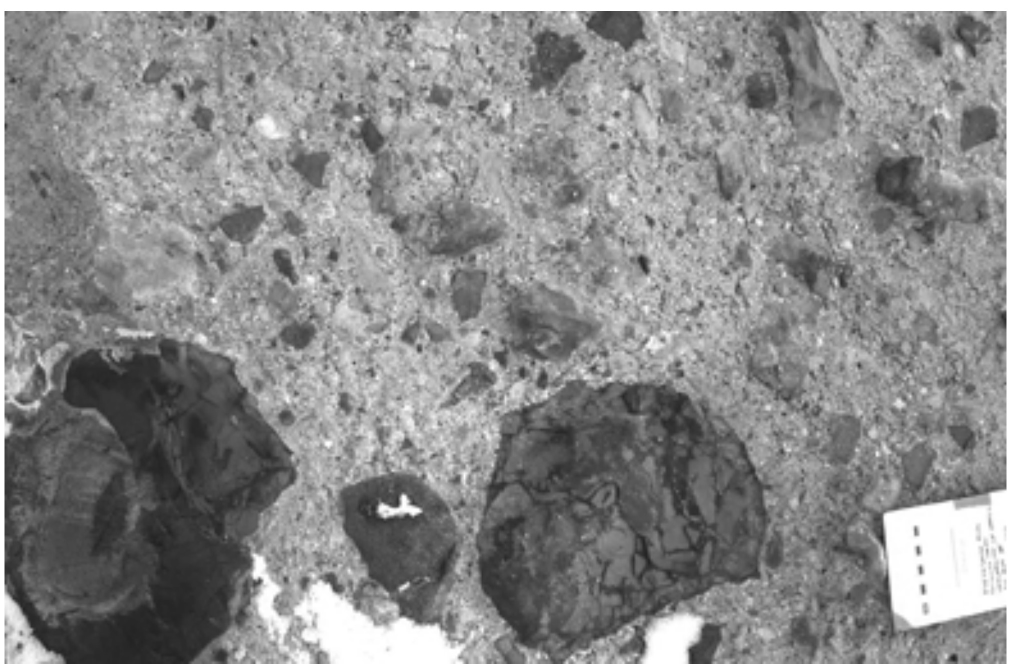


Figure 3
Photo of Mawson m_2 rocks interpreted as lithified pyroclastic flow deposits, from southern Allan Hills. The scale bar on the notebook is graduated in centimetres.

Member m_2, which is exposed at both central and southern Allan Hills, consists predominantly of metre-thick basaltic volcaniclastic layers that fall into three broad categories: (i) poorly sorted, coarse lapilli-tuff and tuff-breccia (Fig. 3); (ii) block-rich layers; (iii) tuff and fine lapilli-tuff. The former type is interpreted as the deposits of high-concentration pyroclastic density currents, probably formed during the collapse of phreatomagmatic eruption plumes (Ross and White, 2005b). Occasional block-rich layers probably were formed by both ballistic fall from local vents and pyroclastic flows, and the finer-grained layers were probably deposited by dilute pyroclastic density currents. Dilute, moist turbulent currents were also likely responsible for the generation and deposition of large (≤4.5 cm) rim-type accretionary lapilli. The thick layers are underlain locally by, or interbedded with, thin tuff ring-style volcaniclastic layers, and all the layers are underlain and invaded by basalt-rich tuff-breccias and lapilli-tuffs.

Acknowledgements
Pierre-Simon Ross received the Sir Robine Irvine Antarctic scholarship from Antarctica New Zealand, and Ph.D. scholarships from the University of Otago and the Fonds québécois de recherche sur la nature et les technologies. Antarctica NZ provided logistical support for the research and associated costs were met by an Otago Research Grant to James D.L. White.

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Dr Pierre-Simon Ross (p_s_ross@hotmail.com) holds a M.Sc. in Earth Sciences from the Université du Québec à Montréal (UQAM) and a Ph.D. in Geology from the University of Otago, New Zealand. Dr James D.L. White is senior lecturer in volcanology and sedimentology at the University of Otago. Dr Olivier Reubi is currently based at the Université de Lausanne in Switzerland and was involved with Antarctic research at Otago as a postdoctoral fellow after completing his Ph.D. at Monash University, Australia.

Tools for Bioremediation of Sub-Antarctic Soils Exposed to Petroleum Hydrocarbons

Daniel Delille[1], Émilien Pelletier[2], Frédéric Coulon[1], George Feller[3] and Bruno Delille[4]

Introduction

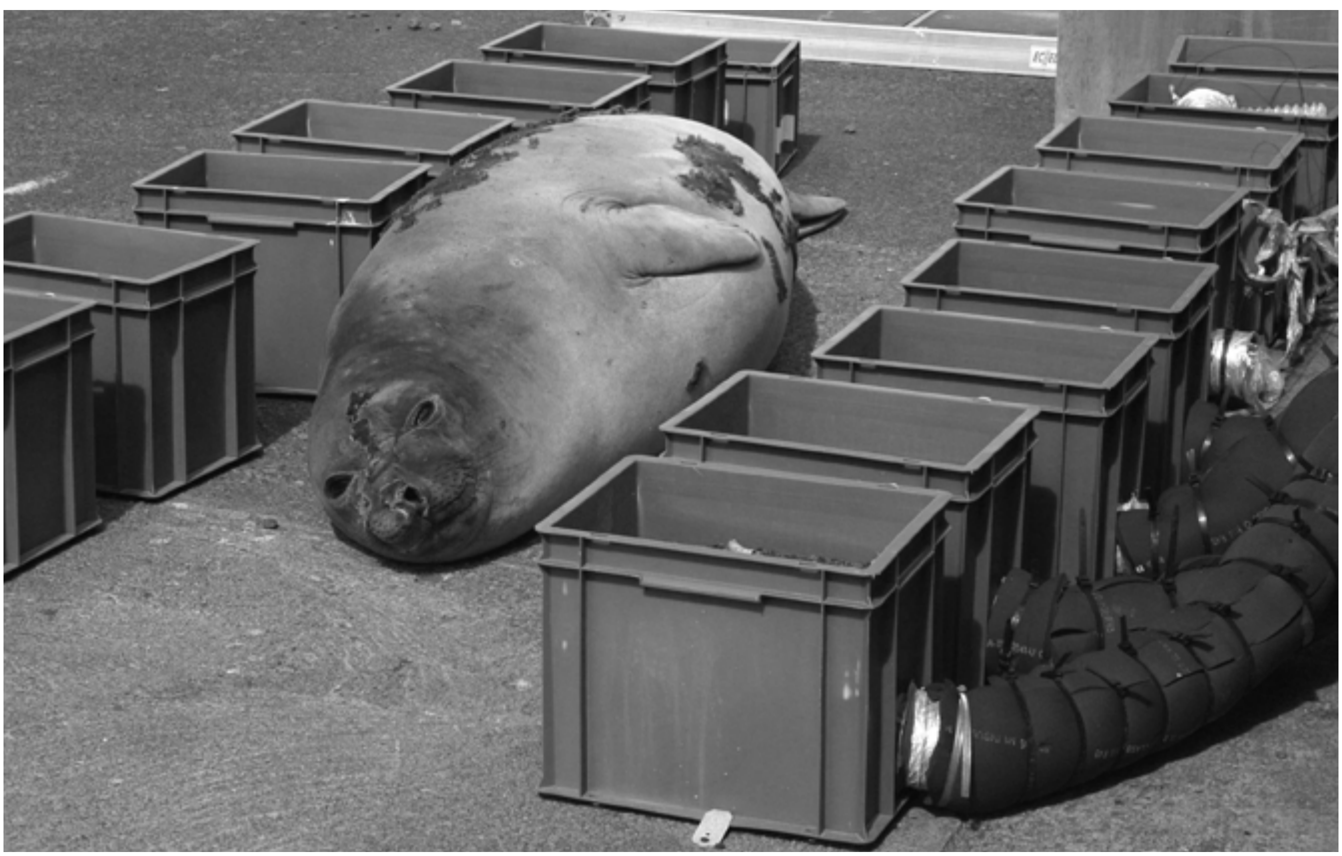
Human activities in high-latitude regions rely heavily on fossil fuels: for transportation; the generation of electricity and heat for research stations; and expanding activities of tourists and wildlife adventurers. Of all the different types of contamination reported so far in the Southern Ocean, on the Antarctic continent itself, and on sub-Antarctic islands, petroleum hydrocarbons have been identified as the most urgent and significant problem. The wreckage of supply ships *Nella Dan* and *Bahia Paraiso*, which ran aground near Macquarie Island and the Antarctic Peninsula, respectively, highlighted the need for research into hydrocarbon contamination of Southern Ocean ecosystems.

Figure 1
Aerial view of the Alfred Faure scientific station (Crozet Island) showing diesel-fuel-contaminated zone (circled) a few weeks after the 1997 spill (Photo: D. Delille).

Bioremediation is a field procedure designed to increase the rate of natural degradation of contaminants. Biodegradation, by naturally occurring microbial populations, is a major mechanism for the removal of petroleum from the environment (bioattenuation). However, in some particularly severe environments, environmental conditions limit the presence or the effectiveness of natural degrading consortia. In these cases, biostimulation or bioaugmentation techniques may be appropriate. The former is the addition of chemicals, such as nutrients (*e.g.*, nitrate, ammonium, phosphate and/or oxygen) and/or surfactants, to stimulate the natural flora, while the latter refers to the addition of exogenous organisms, having oil-degradation capabilities to improve the yield of the natural microflora. Similar procedures may also be applied on-site after excavation and treatment of contaminated soils or sediments (biopiles).

Although bioremediation may be an efficient and economic alternative to physical and chemical treatment of contaminated fields that could be implemented on a large scale in the Antarctic and sub-Antarctic, little is known about hydrocarbon biodegradation processes and remediation rates in cold environments, particularly in sub-Antarctic islands and on the Antarctic continent. The general aim of the cooperative research between Laboratoire Arago in France and ISMER in Canada, initiated in the early 1990s, is the development of new bioremediation tools for soils and sediments contaminated by crude oil, diesel and oil residues, using genuine bacterial assemblages and fertilizers that are harmless in the pristine southern environments.

Figure 2
Experimental biopiles. The visitor is a young southern sea elephant (photo: D. Delille).



A Case Study on Crozet Island

An accidental contamination by >20,000 L of diesel fuel occurred on Crozet Island between July and November 1997 near the "Alfred Faure" scientific station (51°51'E–46°25'S) (Fig. 1). Very high counts of hydrocarbon-degrading micro-organisms were present two years later in the more contaminated zone, clearly revealing bioattenuation activities. After five years, without any human involvement or intrusion, much of the diesel patch still remained (Delille and Pelletier, 2002). In sub-Antarctic soils, air temperatures above 20°C are only attained briefly during the austral summer; generally temperatures between −2°C and 15°C prevail. These conditions greatly influence soil microbial degradation rates and demand a high level of microbial adaptation to cold. There are many questions about the applicability of a bioremediation approach in cold regions. To evaluate the efficiency of the slow ongoing bioattenuation process at Crozet, a field study was initiated in July 2001. The contaminated area is in a transition zone between an arid fell-field (upstream) and a wet vegetated area (downstream). Six experimental plots (0.75 x 0.75 m) were settled firmly into each of the two parts of the contaminated area and some were treated with the slow-release fertilizer Inipol® (Elf Atochem). To increase the temperature, half of them were covered with a plastic sheet. All plots were sampled over two years for total bacteria, hydrocarbon-degrading and heterotrophic bacteria. Soil samples were collected for chemical estimates of hydrocarbon degradation. Heterotrophic and hydrocarbon-degrading microbial counts revealed a significant response of sub-Antarctic microbial soil communities to the diesel-fuel contamination. In contrast, total bacterial abundance was approximately constant under the same conditions. Biological and chemical data suggest that temperature increase and fertilizer addition may both improve the rate of diesel biodegradation. However, there were significant differences between the two different contaminated areas. The stimulating effect of bioremediation was higher in the wet than in the dry area (Delille and others, in press). Further samplings of the studied sites are planned over the next three years to provide additional long-term field data and confirm our initial findings.

In-situ Field Experiment

A field study was initiated in December 2000 in two selected soils of The Grande Terre (Kerguelen Archipelago near Port-aux-Français, 69°42'E–49°19'S) to determine the long-term effects of adding fertilizer on the biodegradation rate and the toxicity of oil residues under severe sub-Antarctic conditions. Two soils were selected: the first supported an abundant vegetated cover, while the second was a desert soil without any plant material and low organic carbon content. Two sets of five experimental enclosures (0.75 x 0.75 m) were set into each of the studied soils. After removal of the superficial vegetation, the soils were contaminated by direct application of crude oil or diesel fuel to the surface of the enclosures. Each plot received 500 mL of diesel or Arabian light crude oil and some were treated with a bioremediation agent Inipol®. In the first set of enclosures, the soil was in direct contact with the atmosphere. In the second one, the soil was protected by a black plastic sheet placed directly on the soil, and a transparent plastic cover placed 10 cm above the soil and nailed to the walls. Periodic sampling allowed a regular survey of total, saprophytic and hydrocarbon-degrading bacteria, hydrocarbon composition and toxicity. All plots were sampled over a four year period. During the experiment, mean soil temperatures ranged from 0°C in winter to 20°C in summer. Temperatures were always warmer in the covered than in the uncovered soils. The annual mean temperature enhancement was +2.2°C. Total bacterial counts did not differ significantly between pristine and contaminated zones, but a significant response of more specific bacterial communities to diesel-fuel contamination was observed. An increase of heterotrophic and hydrocarbon-degrading micro-organisms of two orders of magnitude occurred during the first month of the experiment in all treated enclosures. With values ranging from 5.0×10^5 to

2.0 x 10^6 MPN mL^{-1}, hydrocarbon-degrading bacteria found in pristine soils never represented more than 0.5% of the total bacterial assemblage. After nine months, this proportion exceeded 50% in some cases. The microbial response was improved by bioremediation treatments. However, fertilizer addition had a greater impact on the desert soil than the vegetated one. All chemical indices showed a reduction of alkanes and light aromatics. Degradation rates of total petroleum hydrocarbons (TPH) in amended plots were faster than in non-amended ones. After one year, we observed a strong degradation of hydrocarbons (over 90%) within all plots. The decrease of TPH concentrations was always enhanced in the covered, compared to the uncovered soils. After one year of remediation, the remaining concentrations of TPH were less than half the corresponding values of those in the uncovered soils (Delille and others, 2004). Toxicity results showed a high variability between treatments and environmental conditions. It is clear the microbial response was rapid and efficient despite severe weather conditions, and the rate of degradation was improved by bioremediation treatments. However, after one year of treatment, a relatively high toxicity of oiled residues (determined by a solid phase Microtox test) still remained in both soils. Our results indicated that low temperatures (0–7°C) still allow oil biodegradation by indigenous micro-organisms when adequately stimulated. Soil coverage induced a small but permanent increase of temperature in the surface soil of 2°C (annual mean) and favoured the degradation of alkanes over aromatics. These observations increase the possible scenarios involving controlled-temperature design and effects in bioremediation strategies for sub-Antarctic soils.

Experiments in Mesocosms

In parallel with previous field experiments, mesocosm studies using sub-Antarctic soils artificially contaminated with diesel or crude oil were also made at Port-aux-Français to evaluate the combined effects of temperature, humidity and fertilizer on bioremediation rates. Experiments were undertaken in polyethylene containers (27 x 24 x 13 cm). The soil was artificially contaminated by direct application of crude oil or diesel fuel. For each incubation temperature (4°C, 10°C and 20°C), three conditions were used: control; contaminant alone (100 mL); and contaminant (100 mL) + fertilizer (50 mL). The mesocosms were incubated in the dark under aerobic conditions. They were homogenized twice a month. All mesocosms were sampled regularly over a six-month period. A significant increase of saprophytic and hydrocarbon-degrading bacteria was always observed after contamination. Temperature affected the TPH biodegradation. In all cases, maximum degradation was observed at 10°C. The Inipol® addition stimulated both bacterial growth and the TPH biodegradation rate. Without Inipol®, remaining concentrations of TPH of diesel fuel were 25% at 4°C and only 15% at 10°C. The remaining concentrations of TPH were lower in amended mesocosms (19% at 4°C, 10% at 10°C). Soils responded positively to temperature increases from 4–20°C and to the addition of a commercial oleophilic fertilizer containing N and P. Both increased hydrocarbon-degrading microbial abundance and TPH degradation. In general, alkanes were degraded faster than PAHs (polyaromatic hydrocarbons). After 180 days, total alkane losses of both oils reached 77–95% whereas total PAH degradation never exceeded 80% under optimal conditions at 10°C with fertilizer added. Detailed analysis of naphthalenes, dibenzothiophenes, phenanthrenes, and pyrenes showed a clear decrease of their degradation rate as a function of the size of the PAH molecules. During the experiment, there was only a slight decrease in the toxicity of studied soils, although the concentration of TPH decreased significantly at the same time. The most significant reduction in toxicity occurred at 4°C (Pelletier and others, 2004).

Bioremediation of hydrocarbon-contaminated sub-Antarctic soil appears to be feasible, and engineering strategies, such as heating or amending the soil, can accelerate hydrocarbon degradation. However, the residual toxicity of contaminated soil remained drastically high before the desired clean-up was apparently completed and can represent a limiting factor in the bioremediation of sub-Antarctic soil (Coulon and others, 2005).

Biopile Experiments

Experiments using biopiles (also named biocells or biomounds) were conducted in 12 polyethylene containers (31 x 26 x 36 cm). Soil samples (3.5 kg) were placed in every container, on agricultural sheets fixed 15 cm above the bottom. All the containers were placed in two rows outside the biological laboratory of the Port-aux-Français station (Fig. 2). The water content of all the soils was kept constant by regular addition of sterile water. A first set of three biopiles, containing uncontaminated control soil, contaminated non-amended soil (200 mL of diesel fuel), and contaminated amended soil (200 mL of diesel fuel, 50 mL of Inipol®), received no specific treatment. A second similar set received a "land-farming" treatment (weekly aeration of soil). A third set was submitted to permanent ventilation at ambient temperature. Ventilation pipes were fixed between the soil and the bottom of the containers. A fourth set was submitted to permanent warm ventilation (10°C above ambient temperature). As observed in mesocosm experiments, a significant increase of saprophytic and hydrocarbon-degrading bacteria was always observed after diesel fuel addition. Biostimulation, by addition of fertilizer, always induced a very large increase of both saprophytic and hydrocarbon-degrading bacterial abundance. In contrast, none of the other three bioremediation treatments used (land-farming, cold and warm ventilation) succeeded in increasing saprophytic bacterial abundance. Results are more promising for hydrocarbon-specific bacteria. Land-farming induced significant increases of hydrocarbon-degrading bacterial abundance in both amended and non-amended soils. Warm ventilation had no positive effect in non-amended soil, but induced a spectacular development of hydrocarbon-degrading bacteria in amended soil. These pilot biopile experiments confirmed that constant heating of the soil accelerated bioremediation of diesel-contaminated sub-Antarctic soils. Furthermore, the microbial response was always improved by a complementary fertilizer addition (Delille and others, in press).

Conclusion

Results obtained in the three projects described are in good agreement. The introduction of diesel fuel into a sub-Antarctic soil results in an enrichment of saprophytic and hydrocarbon-degrading micro-organisms in all cases. Despite the low level of contamination in all these bioremediation experiments, hydrocarbon-degrading bacterial abundance observed after bioattenuation was in some cases the same order of magnitude as that observed after heavy diesel-fuel contamination on Crozet Island (>108 MPN mL^{-1}). The observed increase of the hydrocarbon-degrading assemblage after contamination is a clear indication of bioattenuation activities, which is confirmed by the observed decrease of hydrocarbon concentration during the experiments. Our study of sub-Antarctic soil confirmed the efficiency of a fertiliser addition for hydrocarbon biodegradation. Among the other parameters controlling hydrocarbon biodegradation, temperature is generally considered as one of the most important in high-latitude environments. Our in-situ experiments with plastic-sheet-covered soils showed an annual mean increase of temperature of only +2°C, and covering the soil led to a significant reduction in the time necessary to achieve bioremediation objectives. Mesocosm studies and biopile experiments confirmed that a temperature increase can stimulate TPH biodegradation. Indigenous hydrocarbon-degrading micro-organisms in sub-Antarctic soils showed their high potential for bioremediation action when stimulated. However, care must be taken in extrapolating these experimental results to more general environmental conditions. The design of an efficient bioremediation system will require a careful study of local conditions, such as the physical, chemical and microbial properties of the contaminated soil and weather conditions.

Future Work

Our upcoming multi-year research program is the field application of previously acquired knowledge in the field and laboratory. More specifically, we intend to:

- Initiate and develop bioaddition protocols in confined environments using the austral strains already isolated by the Belgian team at the University of Liège;
- Evaluate the yield of these strains from the microbiological (viability and growth rate) and chemical (hydrocarbon biodegradation) point of view;
- Estimate the effects of added fertilisers (Inipol® and new formulae) on the behaviour of selected strains, particularly their ability to eliminate the residual toxicity generally observed at the end of the treatment (by the Canadian team at ISMER/UQAR);
- Establish how quickly microbial populations can return to their natural structure after the degradation of all hydrocarbons, by pursuing the bacteriological and chemical monitoring of sediments contaminated in 1997 and soils contaminated in 2001;
- Understand the evolution of a natural site without any treatment of the spill, by monitoring the contaminated area at the Alfred Faure station;
- Search for those chemical species potentially responsible for the residual toxicity of degraded hydrocarbon residues; and
- Work on the development of a genuine toxicological test using one or many species from the studied sites.

Dr Pelletier will join Dr Delille at the end of November 2005 for a two-month mission to Port-aux-Français to set up a soil bioattenuation experiment using a promising new fertilizer containing dry fish meal and a high molecular-weight surfactant. He will also install a Microtox® analyser in the biological laboratory and teach a technician how to run solid-phase tests on contaminated soils and sediments over the austral winter 2006.

Financial Support

This research program is supported: by the Institut Polaire Français Paul-Émile Victor (IPEV), that provides logistic support for travel and accommodation at Antarctic stations; by an annual operating grant to Dr Delille, the Canada Research Chair in coastal ecotoxicology, under the direction of Dr Pelletier, for travel expenses and chemical laboratory expenses; and by the Belgium region Wallonne scientific program, for Dr Feller's laboratory and personal expenses.

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Author affiliations

1 Observatoire océanologique, Université Pierre et Marie Curie, UMR-CNRS 7621, Laboratoire Arago, 66651 Banyuls-sur-mer cedex, France.

2 Institut des Sciences de la Mer de Rimouski (ISMER), Université du Québec à Rimouski, Rimouski, Québec G5L 3A1, Canada (emilien_Pelletier@uqar.qc.ca).

3 Laboratoire de Biochimie, Institut de Chimie, B6, Université de Liège, B-4000 Sart Tilman, Belgium.

4 Unité d'Océanographie Chimique, MARE, Institut de Physique, B5, Université de Liège, B-4000 Sart Tilman, Belgium.

Photosynthesis on the Edge: Phytoplankton Life in the Ice-Covered Lakes of the McMurdo Dry Valleys

Rachael M. Morgan-Kiss

I began my work in cold-adapted phytoplankton as a Ph.D. candidate in the laboratory of Prof. Norman Hüner (Department of Biological Sciences, University of Western Ontario). This work involved the elucidation of adaptive mechanisms in a psychrophillic green algal species, *Chlamydomonas raudensis,* isolated from the deepest biotic zone of Lake Bonney (Taylor Valley, Antarctica), to the extreme environment of a permanently ice-covered lake, where year-round low temperatures are combined with an extreme shade environment of unusual light quality (blue-green). The perennial ice cover also prevents vertical mixing of the water column which leads to a very stable, vertically stratified ecosystem.

One of our earliest observations during laboratory-controlled experiments was that the psychrophile lacked a major photoacclimatory response common to mesophilic green algae, which is an ability to down-regulate light-harvesting capacity when exposed to a growth regime of low temperature in combination with high light. This down-regulation in photosynthetic function is accompanied by dramatic adjustments in pigmentation in mesophilic algae (such as *Chlorella vulgaris,* Fig. 3) in low (LL) *vs.* high-light (HL) environments. It is clear to the eye that cultures of the Antarctic *C. raudensis* do not undergo comparable adjustments in pigmentation when exposed to similar light regimes. In later studies, we showed, through functional and structural studies, that the organization of the photosynthetic apparatus of this enigmatic alga was significantly altered in relation to its mesophilic counterparts. In addition, two recent reports have shown that *C. raudensis* lacks the highly conserved short-term acclimatory mechanism of state transitions and also possesses a deficiency to acclimate and grow in a red-light environment. These studies point to the fact that the psychrophillic alga possesses unique photo-adaptive strategies to thrive in the Dry Valley lake aquatic environment. However, the price of adaptation to an invariable natural environment has meant the loss of several photo-acclimatory mechanisms.

This austral summer (October–December 2005), I had the unique opportunity to visit natural populations of *C. raudensis* when I accompanied the McMurdo (MCM) LTER research group of Prof. John Priscu (Department of Land Resources & Environmental Sciences, Montana State Univer-

Figure 1
R. Morgan-Kiss and Marie Sabacka (left) drilling through 6 m ice cover of Lake Fryxell.

Figure 2
Ready to monitor PAR and Chl fluorescence at Lake Hoare.

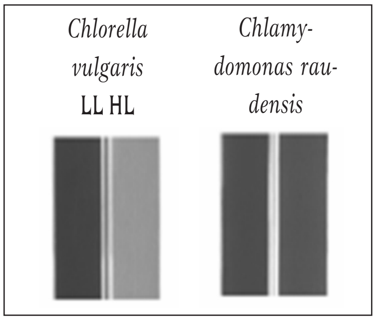

Figure 3
Effect of growth irradiance regime under low temperatures on pigmentation in cultures of a typical mesophilic alga (*C. vulgaris*) and the Antarctic psychrophile, *C. raudensis.*

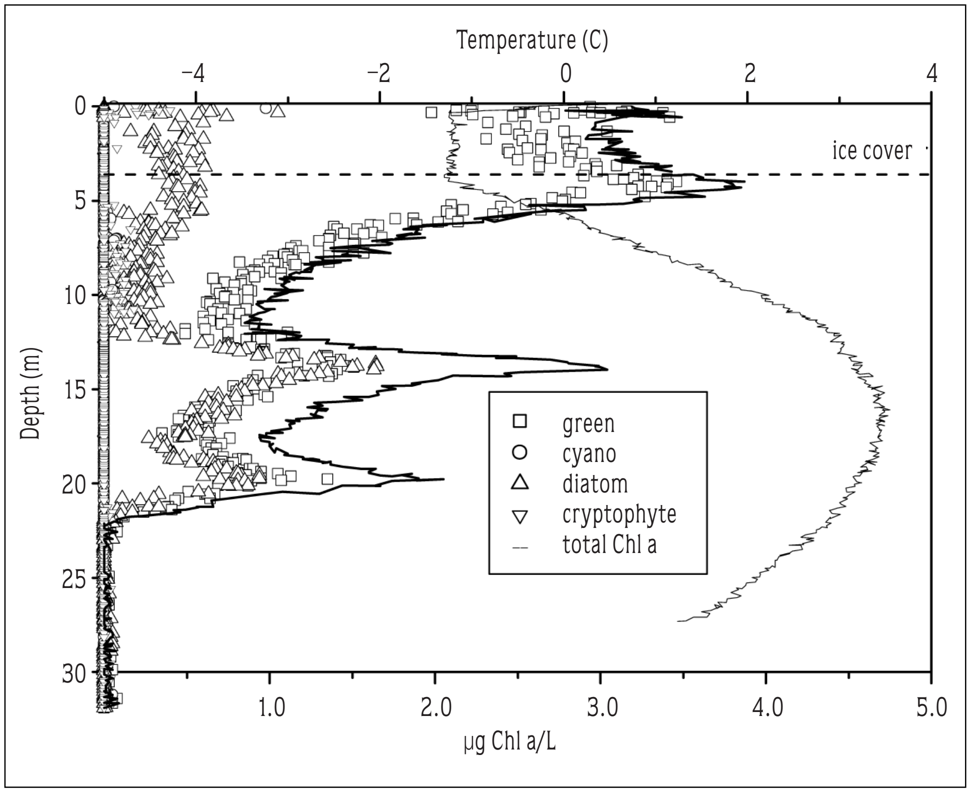

Figure 4
Profile of spectral phytoplankton classes in Lake Bonney. Algal classes were estimated using a bbe FluoroProbe and identified by the characteristic fingerprints of fluorescence excitation spectra of representative members.

sity) to the Taylor Valley lakes in the Dry Valleys of Antarctica. My contribution to the MCM LTER was to improve existing methods for biodiversity assessment of phytoplankton numbers in Lake Bonney, as well as Lakes Fryxell and Hoare, by validating a new instrument, the bbe FluoroProbe (bbe Moldaenke GmbH, Germany). This spectral fluorometer relies on the characteristic differential fluorescence excitation spectra of accessory light-harvesting pigments of four major algal groups (green algae, cyanobacteria, diatoms, and cryptophytes). Initial FluoroProbe-generated estimates of phytoplankton numbers were very promising, and showed high diversity and stratification of algal classes. These preliminary data are very exciting and I am currently working at the University of Delaware with Prof. Thomas Hanson to confirm the results by independent analyses of phytoplankton biodiversity at the level of phylogenetics, as well as fatty acid methyl ester and pigmentation analysis. It is our hope that completion of both the phylogenetic analysis, as well as characterization of lipid and pigment biomarkers, will not only provide independent validation of the bbe FluoroProbe as an accurate and viable new estimator of algal class diversity in the Dry Valley lakes, but will also provide new insight into adaptation of the photosynthetic process and membrane composition of natural algal populations thriving in this extreme ecosystem.

R. Morgan-Kiss grew up on Vancouver Island where she obtained a B.Sc. from the University of Victoria. She completed her Ph.D. with Prof. Norman Hüner (Department of Biological Sciences, University of Western Ontario). She is currently a research associate at the Delaware Biotechnology Institute, University of Delaware (rkiss@life.uiuc.edu).

The Antarctic Toothfish as a Model System for Lens Biology

Andor Kiss

I began my Ph.D. research in the austral summer of 1999 at McMurdo Sound, under the supervision of Prof. Arthur DeVries (Department of Animal Biology, University of Illinois at Urbana-Champaign). I was investigating the cold stability of the eye-lens crystallin proteins from Antarctic toothfish (*Dissostichus mawsoni*). This is a perciform fish, belonging to the Suborder Notothenioidei, endemic to the inshore waters of the Southern Ocean. It is large, often reaching 1 m in length, weighs 34–55 kg and lives up to 50 years. As the mean annual water temperature in the Southern Ocean is −2°C, at or near the freezing point of seawater, the toothfish displays biochemical and physiological adaptations to the cold. The most notable and prominent adaptation is the evolution of a blood-borne antifreeze glycoprotein which prevents these fish from freezing.

Previously, the cow lens has been the one most widely used to model the human lens cataract. A cataract is any state of the lens that decreases the amount or quality of light, regardless of aetiology. It is estimated that >50% of the U.S. population older than 65 will develop some form of mature onset, or senile cataract. Cow lenses undergo a reversible cold-cataract when cooled from body temperature (~37°C) to ~10°C. In the cow, a γ-crystallin, one of the three main groups (α, β, γ) of vertebrate lens crystallins, has been identified as the principal driving force for this cold-cataract. Several congenital human cataracts also occur as a result of point mutations within γ-crystallins. Thus, cold-cataracts in cows can be used to model human cataracts of both thermal and non-thermal origin. Unlike ectothermic mammals, the toothfish eye lens is crystal clear at its normal sub-freezing environmental temperature of −2°C. Because it lives at this perennially cold temperature and has a large eye lens, the toothfish presents a unique opportunity to study the cold stability of vertebrate eye lens crystallins.

We have been able to demonstrate that the toothfish lens is composed of crystallins which are similar to most vertebrates, including humans. More specifically, we have shown that the cold-stability of the toothfish lens can largely be attributed to its γ-crystallins (*J. Exp. Biol.,* **207**(26),

Bob Teuscher (left) and author (right) hoisting a toothfish inside a fish hut on the sea ice, McMurdo Sound, Fall 1999.

2004, 4633–49). Subsequently, we have determined that within the toothfish lens there is a much richer abundance of γ-crystallin proteins and cDNAs than previously reported for well-characterized terrestrial vertebrates.

Further biochemical and functional analyses have shown that cold stabilities, expression levels, and mRNA abundance differ amongst the γ-crystallins expressed within the toothfish lens. In collaboration with Dr J. Sam Zigler (National Eye Institute, NIH, U.S.A.), we are using two-dimensional polyacrylamide gel electrophoresis (2D PAGE) matrix-assisted laser desorption ionization-time of flight (MALDI-TOF), to identify candidate γ-crystallins which are the major contributors to the toothfish lens cold stability.

The ultimate aim is to understand how subtle changes in these conserved γ-crystallins have affected their long-term stability at low temperatures. By determining which aspects are critical to toothfish crystallin protein stability, we may be able to translate this knowledge to preventing the instability of human γ-crystallins, thus preventing cataracts.

Andor Kiss graduated in Biochemistry and Microbiology from the University of Victoria before receiving his M.Sc. from the University of Western Ontario. He has just completed his Ph.D. with Prof. Arthur DeVries (University of Illinois at Urbana–Champaign). In January 2005, he began a post-doctoral fellowship with Prof. Melinda Duncan (University of Delaware) and is examining the developmental expression of lens epithelial and lens crystallin genes.

International Polar Year (2007–08)

The following are the Canadian IPY Expressions of Interest with significant Antarctic content (listed by EoI number), taken from the IPY International Program Office website (www. ipy.org). To monitor other IPY developments check the Canadian National IPY website (www.ipy-api.gc.ca) or that of the Canadian IPY Secretariat (www.ipy-api.ca).

132: Biorestoration of contaminated soils and sediments near scientific stations in polar regions (Émilien Pelletier, ISMER/UQAR)

321: Atmospheric inputs of mercury to the polar ocean: rates, significance and outlook (Dolores Planas, UQAM)

462: Canadian IPY publications database (Ross Goodwin, ASTIS, University of Calgary)

465: Mission Antarctique (Jean Lemire, Glacialis TV, Montréal)

528: Ocean–seafloor–ice interactions in the Amundsen and Bellingshausen Seas (David Holland, McGill University)

631: Mercury contamination of polar regions (David Lean, University of Ottawa)

642: The impacts of climate change on the biogeochemical cycling of carbon, nutrients and methyl mercury in polar regions (Vincent St. Louis, University of Alberta)

645: A spatial data infrastructure for polar science: a framework for organization and outreach (Fraser Taylor, Carleton University)

650: Canadian Antarctic Research Program (CARP) (Wayne Pollard, McGill University)

652: Fundamental geophysical data to study change in Antarctica (Calvin Klatt, Natural Resources Canada)

655: Remediation of organic contaminants in polar soils (John Poland, Queen's University)

661: The development of a polar-based bioreactor for the production of bioactive compounds by indigenous micro-algae and cyanobacteria (Susan Boyd Watson, NWRI, Burlington)
678: In-situ investigation of the polar climates using a distributed sensor web (Brendan Quine, York University)
711: Biological transport of anthropogenic contaminants to polar ecosystems: a paleoenvironmental perspective (Marianne Douglas, University of Toronto)
720: Atmospheric Chemistry Experiment, ACE (Peter Bernath, University of Waterloo)
807: The structure and evolution of the stratospheric polar vortices during IPY and its links to the troposphere (Norman McFarlane, SPARC IPO, University of Toronto)
849: Latitudinal sensitivity of soil to anthropogenic impacts (Steven Siciliano, University of Saskatchewan)
870: RADARSAT polar science gateway (Paul Briand, Canadian Space Agency)
962: Viral mediated processes in polar seas (Curtis Suttle, University of British Columbia)
976: Carbon in sea ice: fluxes and biogeochemistry (Lisa Miller, Fisheries and Oceans Canada)
1028: Ends of the Earth: from polar bears to penguins. A travelling exhibit from Science North, Sudbury, Ontario (Jennifer Pink, Science North)
1056: Identification and quantification of mercury species formed during the polar atmospheric mercury depletion events (Julia Lu, Ryerson)
1095: Vulnerability of ice-cored environments (Wayne Pollard, McGill University)

News in Brief

Kevin Hall (UNBC) was with the Italian Program working on rock weathering in the Terra Nova region from October through to December 2005.■

SCAR now has implementation plans for all five its new Scientific Research Programmes: Antarctic Climate Evolution (ACE); Subglacial Antarctic Lake Environments (SALE); Evolution and Biodiversity in the Antarctic (EBA); Antarctica and the Global Climate System (AGCS); and Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR) (see www.scar.org/researchgroups).■

The Physiology of Polar Fishes 22 has been published by Academic Press. It is edited by **Anthony Farrell,** Professor and Chair in Sustainable Aquaculture at the DFO UBC Centre for Aquaculture and Environmental Research, University of British Columbia, and John Steffensen of the University of Copenhagen (see elsevier.com/locate/ISBN/0123504465).■

Garry K.C. Clarke (UBC) and **Warwick Vincent** (Laval) are members of the US National Academy of Sciences committee on Principles of Environmental and Scientific Stewardship for the Exploration and Study of Subglacial Lake Environments.■

Evgeny Pakhomov, who has some 22 years of research experience in the Southern Ocean, has joined the Department of Earth and Ocean Sciences at the University of British Columbia. He is currently involved in a GLOBEC project with German scientists from the Alfred Wegener Institute and some collaborations with the British Antarctic Survey.

He is a marine ecologist who works both with invertebrates and fish.■

Recent Canadian Contributions to Antarctic and Bipolar Science. Space limitations have prevented us from running this section. We hope to provide a consolidated list of Antarctic-related publications by Canadian scientists on the CPC website later this year. Readers should send the editor information on publications they wish to have included.■

Forthcoming meetings. The CPC maintains a consolidated list of forthcoming meetings of interest to polar scientists. Readers should go to www.polarcom.gc.ca and check under Events.■

CCAR/CCRA Members and Advisers

CARN Newsletter

Editor: C. Simon L. Ommanney
Please send contributions and correspondence to:
C. Simon L. Ommanney
Editor, CARN Newsletter
Address at left.

Canadian Polar Commission
Suite 1710, 360 Albert Street
Ottawa, Ontario K1R 7X7
Tel.: (613) 943-8605
Fax: (613) 943-8607
mail@polarcom.gc.ca
www.polarcom.gc.ca/ccarhome.htm