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Paleontology collections: a vital component of geo-heritage

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The cabinets and drawers of the Provincial Museum hold an increasing number of important fossil specimens from throughout Newfoundland and Labrador, including many "type specimens". Of particular importance is the Geological Survey's Paleontology Reference Collection (the "Boyce Collection"), which dates back to 1976 and comprises at least 3 000 samples. A recent cooperative agreement between the Museum and the Survey has seen the transfer of the bulk of the collection to The Rooms' Natural History Annex for secure, uninterrupted, long-term storage and study. Some samples temporarily remain at the Howley Building, but because of deterioration of the plastic sample bags, these samples will need to be re-bagged before removal. Recent processing of a fossiliferous block of Indian Islands Group from the Glenwood area (central Newfoundland) has yielded fossils — including a rare trilobite — that were not recorded in the field, a typical occurrence in collection studies.

Review of hydrocarbon traps in clastic Cambrian strata, western Newfoundland

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During the last round of hydrocarbon exploration and drilling by major oil companies operating in western Newfoundland, it became abundantly clear that Cambrian clastic strata can present excellent targets. As a result, and for much of the last 10 years, there has been a significant effort to come to a better understanding of the geology of these rocks. In order of appearance, the key elements to such traps include sedimentary environment, structural configuration and seal, and diagenesis.

For synrift strata of the Labrador and Curling groups, sedimentary environments are important determining factors for generating clean sand bodies containing porosity and permeability. Labrador Group rocks are shelf deposits containing broad sheets of shallow marine quartzose sandstones. In contrast, Curling Group strata tend towards deeper marine deposits from an outer shelf and including submarine fans; prospective strata may be more elongate bodies with a lensoid shape.

The structural configuration of traps and seals is determined by regional tectonic position. Traps of the Extensional Block Fault Fairway are dominated by extensional elements (horsts and grabens) of the synrift system. Here, large linear synrift sand bodies may trend along the axis of grabens. Elsewhere, sheets of younger sandstone may drape over horsts, and form broad compaction folds. The Inversion Fairway in the zone of compressional tectonism can contain all of the elements of the Extensional Block Fault Fairway; many are reactivated and normal faults become thrusts. In addition, there is a large variety of other fault related features. Thrusts in the allochthon can include ramp anticlines, accommodation folds and faults, and late-stage normal faults.

Diagenesis remains an important consideration for trap formation and preservation. Rocks that show little evidence for burial and tectonic deformation can retain significant porosity. As burial and deformation increase, grains fuse, minerals become altered, and fluids generate cements.

Preliminary seismic-stratigraphic interpretation and mapping results for the Paleogene - Neogene succession, Orphan Basin, offshore Newfoundland and Labrador

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The Orphan Basin that formed during Mesozoic rifting and Atlantic Ocean opening is one of the large under-explored basins along the eastern Canadian Margin. The basin has experienced an impressive history of extension and subsidence as indicated by its complex structural architecture and sequence stratigraphy. The sedimentary basin fill consists of Mesozoic and Cenozoic sediments that exceed ten kilometers in thickness in some places. The predominantly post-rift Paleogene-Neogene (Tertiary) interval is superbly imaged in more than 25 000 line kilometers of high-quality, 92-fold 2D seismic data that were recently (2000–2003) acquired by GSI and donated to Memorial University for research. These data provide an opportunity to separate the Tertiary interval into smaller subdivisions and identify regional sedimentation patterns.

Eight seismic horizons, including the seabed, the widespread *Base Tertiary Unconformity* marker, and a number of intra-Tertiary unconformities have been interpreted throughout the seismic grid. These horizons presently divide the Cenozoic succession into seven major seismic-stratigraphic units. Three of the mapped units (Units 2, 4 and 6) exhibit a chaotic, low amplitude internal acoustic character, and external forms that are consistent with mass transport deposits. In profile, these deposits occasionally show evidence of amalgamation of more than one failure event (e.g., Unit 2) and/or possible fluid escape structures at the top (e.g., Unit 4). Another apparent mass transport deposit appears to incorporate rotated blocks at the base (not yet mapped). The remaining seismic units consist mainly of alternating high and low amplitude parallel reflections. Time-structure and isochrone maps reveal surface morphologies and shed light on the distribution of key seismic horizons and units within the basin. Whenever possible, key sediment pathways (indicated by channels) and possible geohazards are identified. In particular, a number of slope failure deposits are delineated.

Evaluation and characterization of the nickel-copper-PGE potential of the Red Cross Lake intrusive suite, central Newfoundland

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The Red Cross Lake Intrusive Suite (RCLIS) is a small mafic to ultramafic intrusion within the Victoria Lake Group, central Newfoundland. Mapping identified well developed, subvertical, magmatic layering in dunite, troctolite, and olivine gabbro of the Lower Series (LS), and poorly layered, pyroxene amphibole gabbro in the Upper Series (US). Layering in the LS exhibits cumulate textures with gradational layering of olivine. A number of sheared, layer-parallel belts, containing 25 to 85% heterolithic xenoliths, were identified, which locally resemble hydrothermal or intrusion breccia. These belts are located parallel to the basal intrusive contact and parallel to the major boundary separating the LS and US. Sulfides are present throughout the most mafic basal units, up to a few percent, and comprise pyrrhotite, pyrite, chalcopyrite, and pentlandite.

Whole-rock lithogeochemical data indicate that the tholeiitic RCLIS was emplaced in a within-plate environment. Harker diagrams indicate fractional crystallization in the LS, and a relatively homogeneous, unfractionated evolved US. Calculated modal Ni-Cu-Fe sulfide abundances indicate that country rock samples contain greater amounts of Fe sulfides. Metal-silicate relationships suggest that the majority of Ni occurs in olivine rather than Ni-sulfides, that Cu is present primarily in Cu sulfides, and that Pt+Pd concentrations, which are quite low, correlate with MgO rather than sulfides.

Microprobe analyses indicate a primitive composition for the LS cumulates, averaging Fo=83 (n=176, SD=2); the US is more variable averaging Fo=48 (n=73, SD=14). The maximum Fo value is in a sample from the lower portion of the LS (Fo=87.4), and the minimum is from a sample of ambiguous origin near the transition zone between the US and LS (Fo=10). Though most samples have a positive correlation of MgO with Ni, some samples are clearly depleted in Ni, suggesting that a sulfide liquid interacted with olivine prior to crystallization of the LS. Most olivine grains exhibit little systematic internal zonation. Plagioclase compositions in the LS average An=73 (n=45, SD=5), whereas in the US, plagioclase averages An=55 (n=100, SD = 10). There is considerable rim-core zoning in US plagioclase, but the LS plagioclase is relatively homogeneous. Pyroxene, amphibole, and oxide microprobe data exhibit similar trends of being more Mg-rich in the Lower Series and more Fe-Ti rich in the Upper Series.

Taken together, field, lithogeochemical, and microprobe data indicate that the RLCIS is a strongly differentiated layered intrusion that may have been emplaced through multiple magma injections. Intrusion-spanning xenoliths belts, parallel to the base, may define remnant basal contacts to later pulses of magma. The lack of mapped sulfide mineralization, in combination with low concentrations of precious or base metals, is not encouraging for exploration. However, a narrow zone over one kilometer north of the basal contact in the SW corner of the RCLIS exhibits strong Ni depletion in olivine from ultramafic rocks, suggesting that locally at least, Ni may have been stripped by a sulfide liquid during emplacement.

Altius Minerals: adding energy to minerals to become a Newfoundland and Labrador natural resources company

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Altius Minerals Corporation was founded in Newfoundland and Labrador in 1997 to search for mineral deposits in the province. It has followed a strategy of concept generation followed by partnering with technical and financial expertise. It seeks to retain non-operating minority ownership positions and royalty interests in its projects. It has formed many exploration partnerships and joint ventures with a host of senior mining companies and has been the most consistently active mineral explorer in the Province since its inception. The acquisition of a royalty interest in the Voisey's Bay nickel district in 2003 represented an important milestone in the Company's history and allowed it to broaden its focus to other resource opportunities in Newfoundland and Labrador that it felt appropriate to its business strategy. While Altius continues to actively generate concepts and projects for traditional metal deposits it now also seeks opportunities to participate in energy related opportunities. Its steps to date to generate energy concepts and projects in Newfoundland and Labrador are outlined below.

In 2001, when uranium was trading at less than $10/lb, Altius decided to build a portfolio of uranium properties, believing that more than 20 years of underinvestment in the sector had created a long-term opportunity. Earlier this month it announced that Aurora Energy, a company it co-founded with Fronteer Development Group, was seeking a public listing to advance its Central Mineral Belt uranium holdings in Labrador. This follows three successful exploration seasons that have expanded upon known uranium resources in the district and the renewed recognition that it represents Canada's second most important uranium district. Going forward, Altius will hold a large minority interest in Aurora and a royalty on the Central Mineral Belt properties. In 2005 it responded to a Newfoundland and Labrador Hydro call for proposals with respect to the proposed development of the Lower Churchill hydro development. Altius proposed to acquire a royalty interest in the project and to create a Newfoundland and Labrador

based Income Trust. Altius' proposal is one of 6 that remain from an original list of 25 submissions.

Most recently, it has participated in the formation of Newfoundland and Labrador Refining Corporation which is studying the feasibility of a new 300 000 barrel per day oil refinery in Placentia Bay. The study will take approximately 42 weeks and be completed at a cost of $US 7 million. The refining industry has invested very little capital into new North American capacity during the past 25 years. Altius owns a large minority stake in the new company and the remaining shareholders are a group of Irish and UK based entrepreneurs and financiers with excellent track records in major project developments around the world.

The common themes to be pulled from this collection of projects and initiatives are natural resources, Newfoundland and Labrador and non-operating ownership/royalty interests.

Offshore Newfoundland and Labrador: exploration and production update for 2006

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While hydrocarbon exploration offshore Newfoundland and Labrador is still at a very low level, totally unjustified by the high price of commodities, oil production has reached record levels. Only one well, Husky Lewis Hill G-85, located in the long- neglected South Whale Basin on the southern Grand Banks, was drilled last year with yet unannounced results. No other well is planned in this area for the current year and some exploration licenses in the vicinity that are near to expiration date are in dispute. A large area under license in the Laurentian Basin is being actively explored by a group led by ConocoPhillips. Two possible prospects have been covered by 3D seismic data, but drilling is not likely to commence until 2007. Within Jeanne d'Arc Basin the most active explorer, Husky Energy, has prepared several locations for shallow and intermediate depth drilling targets and the program awaits an available drilling rig. The modern fifth generation, ultra-deep-water semi-submersible Eiric Raude, which has already been used in the Flemish Pass, Scotian Shelf, and North Sea, has been contracted by the Orphan Basin exploration group to drill a deep water location during 2006 within the East Orphan Basin. Seismic acquisition will continue through 2006 with 2D speculative data being acquired in the Labrador Sea and probably in the Maritimes Basin.

With the start of the White Rose field, offshore production levels have reached 400 000 bopd which represents 40% of Canada's light oil output and strengthens the Grand Banks' reputation as a prolific oil basin. Delineation of three approved production licences is almost complete and there is little room to increase daily production within present permit boundaries. Most likely, further delineation wells will be drilled around the White Rose complex for additional pools. The recent 2004–2005 landsales have attracted operators to Exploration Licenses in the immediate vicinity of Production Licenses. This activity suggests that the hunt for extension of the fields outside of their production permit areas, or for satellites easy to reach from existing infrastructure, is in play. The Hebron development is clearly in the cards, and will commence sooner rather than later, if a production agreement is reached between governments and the Chevron-led licence holders. Numerous smaller, dormant oil fields in the Jeanne d'Arc Basin are still to be considered. Gas development is at least 5 to 7 years into the future.

No doubt the Province, or at least the east coast of the Province, is experiencing a production mini-boom but we cannot quite compare now or the immediate future with traditional hydrocarbon production areas such as the North Sea or Gulf of Mexico. The present low level of exploration is partially justified by elevated geologic risk (low success ratio), high cost of drilling exploration wells ($25 to 60 Million), and the companies' focus in other areas or toward field development. Cautious optimism for the success the planned exploration wells and adequate pro-business attitude of all stake-holders is required to maintain the momentum in the petroleum industry of offshore Newfoundland and Labrador. In the absence of drilling success the role of fundamental applied research by public institutions will take on an even greater importance, in maintaining exploration interest and the hope for a major expansion of the industry.

Geologic evolution and petroleum potential of the Orphan Basin, offshore Newfoundland and Labrador

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The Orphan Basin region, situated north of the Grand Banks of Newfoundland, has undergone repeated extensional episodes. Crustal stretching of the mainly Paleozoic platform started in Late Triassic to Early Jurassic. Subsequent extensional episodes lasting until the Paleocene deepened the basin and enlarged it, by westward (landward) propagation of rifting. Seismic interpretation integrated with potential field data initially focused on two main regional transects and then extended to the entire basin, provides a regional understanding of the basin's structural setting and evolution and indicates the presence of a viable petroleum system. Mapped hydrocarbon traps include large extensional anticlines which were also modified by compression The presence of Jurassic source rock in the East Orphan Basin is convincingly supported by seismic correlation to source rock intervals within the adjacent Jeanne d'Arc and Flemish Pass basins, and by paleo-oceanic correlation with the Porcupine Basin off the western coast of Ireland.

Excluding the Orphan Knoll, which has a thin Mesozoic section, and several of the elevated basement blocks devoid of Mesozoic sediments, the entire Orphan Basin has hydrocarbon potential. Based on the age of basin fill, presence of source rock, timing of maturation, and seismic character correlation to adjacent basins, the Orphan Basin is predicted to be primarily oil-prone in its eastern part, and largely gas-prone in its western part. The East Orphan Basin is under active exploration, while there are no exploration plans for the West Orphan Basin in the incoming years.

Western Newfoundland petroleum geology and exploration opportunities

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The sedimentary basins of Western Newfoundland have been deposited and preserved in environments ranging from quiet tropical shelf to the tectonic upheaval of the Appalachian orogeny, and present many spectacular structures that are of interest to the structural geologist and the petroleum explorationist. Oil and gas prospects ranging in age from Cambrian to Silurian have been identified in a variety of structural domains - both offshore and onshore. This presentation will give an overview of the area's structural evolution and petroleum potential, and give a summary of current petroleum exploration activities.

Uranium mineralization in the Moran Lake area of the central mineral belt of Labrador: new models and developments from the Crosshair Exploration project

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The Moran Lake property consists of 2544 claims covering advanced uranium, as well as polymetallic Iron Oxide–Copper–Gold (IOCG; e.g., Olympic Dam, Australia) intrusion-related targets in the Central Mineral Belt of Labrador. The property lies approximately 135 km north of Goose Bay and approximately 75 km southwest of the coastal community of Postville. The property is situated in the west-central portion of the Central Mineral Belt, a Proterozoic sequence of plutonic, volcanic, and sedimentary rocks which stretch inland from the coast for over 250 km.

Uranium mineralization, known on the property since the 1950s, occurs both in altered sedimentary rocks lying just above a major unconformity ("C" Zone), as well as in altered intrusive and sedimentary rocks ("B" Zone). A third area of significance is known as the Moran Heights boulder field, where over 300 sandstone boulders have been located with an average grade of 0.5 % to 1.0 % U_3O_8 with grades as high as 4.54 % U_3O_8 reported from recent sampling.

The possibility of IOCG-type mineralization occurring on the property is supported by strong geological, geochemical, and geophysical evidence, including extensive iron-rich breccias and the presence of locally significant copper, silver, gold, and uranium mineralization, all of which are spatially associated with a significant airborne gravity anomaly.

Exploration activities in 2005 included the completion of a 7 062 line-km airborne magnetic and radiometric survey which has identified numerous radiometric anomalies considered prospective for uranium as well as IOCG-type mineralization. Ground follow-up of a selected number of airborne anomalies has resulted in the discovery of several potentially significant uranium and polymetallic IOCG occurrences. Drilling on the propery resumed in the winter of 2006.

Under-appreciated hydrocarbon potential of the Devonian to early Permian Maritimes Basin of eastern Canada

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Proven hydrocarbon reserves in the eastern Canadian offshore regions overshadow the potential for both oil and gas in the Late Devonian to Early Permian Maritimes Basin. The ~100 Ma history of basin development includes the superposition of at least four basin-wide subsidence episodes, separated by regional unconformities. Historic and recent discoveries, as well as current natural gas production, argue that this under-explored basin has real and significant opportunities for successful hydrocarbon exploration and development. All essential elements of the hydrocarbon system exist. Source-rock intervals range from mid Tournaisian to latest Westphalian in age. The older regionally distributed source rocks comprise organic-rich lacustrine shales of the Horton and Anguille Groups. Transgressive-regressive glacio-eustatic cycles in the Late Visean Windsor and Codroy Groups deposited thin but laterally extensive organic-rich marine carbonate rocks which have locally sourced liquid hydrocarbons. Coal measures ranging in age from Namurian to late Westphalian provide thick gas-prone source rocks over wide portions of the basin. Seals for Tournaisian-sourced material are provided by regionally extensive Visean evaporates, including thick halite deposits. Seals for natural gas generated from younger coal measures are provided by mudrocks which are interbedded with and overly source-rock intervals. With main hydrocarbon generation placed in the early Permian, proven natural gas in Tournaisian and late

Westphalian reservoirs attests to the effectiveness of these seals. Reservoirs include sandstones of fluviatile origin throughout the succession, but also include lacustrine shoreface sands in the Tournaisian succession. Reservoir quality is problematic, but is comparable to Carboniferous reservoir sands in the North Sea basins of western Europe where significant quantities of oil and gas have been recovered from the Carboniferous succession. A variety of structural and stratigraphic traps can be identified.

Stratigraphic investigations of this large sedimentary basin span more than one hundred and fifty years. Refinements to the stratigraphic framework in both onshore and offshore portions of the basin add new insights for regional understanding of basin evolution. Recent revisions to the Codroy and Barachois groups of western Newfoundland, enabled by newly acquired palynological data, provide an example of changing regional perspective. With an existing seismic database exceeding 40 000 line kilometers, the Maritimes Basin cries out for new and expanded exploration effort in order to reach its true potential.

Uranium potential in Labrador: don't neglect the Grenville Province!

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Recent renewed interest in the uranium potential in Labrador has, understandably, focused on the Central Mineral Belt, where previous exploration resulted in the discovery deposits of major significance and numerous other showings. The purpose of this communication is to draw attention to mineral exploration opportunities for U farther south, in the Grenville Province, at the same time suggesting potential geological linkage, in some instances, with uraniferous rocks in the Central Mineral Belt.

Four geological settings are identified here as being of interest, namely (i) pre- or early Labradorian (1710–1600 Ma) gneisses of supracrustal (mainly metasedimentary) origin, (ii) mid- to late- Labradorian supracrustal rocks, including some units derived from probable felsic volcanic protoliths, (iii) Grenvillian (1085–985 Ma) granite and pegmatite, and (iv) post-Grenvillian alkalic intrusions.

Uranium mineralization was discovered in pre- or early Labradorian gneisses of supracrustal origin in the Lake Melville area by the Geological Survey of Newfoundland and Labrador in 1978, and subsequently explored (including trenching and drilling) by Northgate Exploration Ltd. in 1979. The primary U-bearing mineral is uraninite, found in white-weathering diatexite derived from partial melting of high-grade pelitic gneisses. Potential for similar mineralization occurs both to the north and east. To the north, a belt of metasedimentary gneisses, and granitoid rocks derived from them, may provide a geological link between Lake Melville and Michelin regions. No U mineralization has been identified in this poorly exposed belt, but it is coincident with minor Fe-Cu sulphide showings and second-order U lake-sediment geochemical anomalies. To the east of the Lake Melville locality, U and Mo mineralization was discovered during reconnaissance mapping by the Geological Survey of Newfoundland and Labrador in 1980. Apart from high scintillometer readings, evidence of mineralization is provided by surface staining of the diatexites by secondary U minerals (e.g., uranophane). High-grade pelitic gneisses with associated diatexite define a belt that continues southeast to the south Labrador coast. These rocks host U mineralization in the Paradise River area. Even farther southeast, potential mineralization is suggested by one remarkably high-U lake sediment geochemical anomaly, and other lesser anomalies, spatially associated with the belt.

Mid- to late- Labradorian supracrustal rocks (1640 Ma) that are potential hosts for U mineralization occur in southeasternmost Labrador. Similar rocks are extensive, although poorly mapped, throughout eastern Quebec. No mineralization has been identified, but the rocks underlie a region characterized by U-Cu-Mo-Ag lake-sediment geochemical anomalies. In this area, there are indications that any mineralization might be remobilized and localized into early Phanerozoic faults. Although the geochemically anomalous areas are mostly restricted to the well-exposed coastal area, the same rock units continue west, then south, to link up with some unusual sillimanite-rich, nodular pelitic gneisses in the Brador Bay area. These have been claimed to represent metamorphosed sericitic to advanced argillic alteration zones analogous to those associated with hydrothermal deposits in volcanogenic settings. The metamorphosed felsic volcanic rocks in southeasternmost Labrador are coeval with (or marginally younger than) the highly prospective Bruce River Group in the Central Mineral Belt, and the two regions have been conceptually linked in a geodynamic model for the evolution of the region.

The last two of the four geological settings listed above, are considered here to have lesser potential for significant U mineralization, but should not be dismissed. Late-orogenic Grenvillian granite and pegmatite host U oxides and phosphates in places. The best-known example is the Lac Turgeon granite in eastern Quebec, but there are numerous similar intrusions in the eastern Grenville Province in both Labrador and Quebec. As many of these have only been recently identified, it is not surprising that this group of rocks remains a largely untested exploration target for U, or any other type of mineralization. Post-Grenvillian carbonatite and alkaline intrusions in Quebec, such as the Quinville and Cantley carbonatites, are recognized hosts for U-oxide and REE-mineralization. Similar rocks have yet to be recognized in Labrador, but could have easily escaped recognition during recent reconnaissance-level mapping in the poorly exposed tracts of interior southern Labrador.

Simulating 100 million years of radiation damage in six years

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Zircon ($ZrSiO_4$) is an important mineral in understanding the Earth's crustal evolution. The stability of zircon in nature over long periods of time has led researchers to focus on zircon as the preferred mineral for geochronology. In order to provide an explanation for zircon U-Pb analyses that are isotopically disturbed, it is desirable to acquire a better understanding of radiation damage mechanisms and processes that have led to alteration of the zircon structure and the enhanced mobility of the parent or daughter isotopes. Zircon has also been proposed as a potential storage material for actinides, including weapons-grade plutonium from dismantled nuclear weapons.

For investigations of self-irradiation damage effects taking place in zircon, one option is to use single crystals of zircon doped with ^{238}Pu. Due to the high alpha-emitting activity of ^{238}Pu ($t_{1/2}$ = 87.74 years, specific activity = 17.3 Curies/gram), accelerated alpha-induced radiation damage in zircon crystals on the laboratory time scale (months to years) can be investigated. This is opposed to thousands to tens of thousands of years for ^{239}Pu-doped ceramics ($t_{1/2}$ = 24 100 years, specific activity = 0.063 Curies/gram), or millions to hundreds of millions of years for natural zircon samples (depending on the initial U content and the geologic history of the sample).

In our investigation, single crystals of synthetic zircon doped with ^{238}Pu, up to 3.5 mm in size, were grown for the first time ever using a Li-Mo flux. The crystals were transparent, of pink-brown color, and free of inclusions of separated Pu-oxide phases. Approximately five months after zircon synthesis, the crystals changed color to gray-brown, and after 14 months, the gray color in the crystals increased. After 24 months, the crystals were still transparent and free of inclusions of separated Pu phases. The development of cracks in the crystals increased since crystallization, due to the cumulative dose of self-irradiation from the decay of ^{238}Pu to ^{234}U. Cathodoluminescence spectroscopy and single crystal and powder X-ray diffraction measurements also reveal a loss of long-range order in the zircon crystals as a function of dose of the ^{238}Pu alpha-induced radiation damage. Additionally, our results suggest that the damage incurred by the zircon crystals at different times, and thus resulting doses, is greater than what is predicted by currently accepted models for the behavior of radiation damage in natural zircon.

Petroleum exploration in onshore western Newfoundland: an historical overview

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Hydrocarbons have been recognized for nearly two centuries along the shores of western Newfoundland and numerous attempts to establish and exploit this resource have taken place over the ensuing years. The majority of this drilling occurred over three distinct time periods; the 1890s to 1920s, the 1950s to 1960s, and starting from the mid 1990s up to the present time. Approximately 60 wells were drilled over the two earlier time intervals (historic period), with most of them being located around Parsons Pond (27) and St. Paul's Inlet (8) on the Northern Peninsula, Shoal Point (13) on the Port au Port Peninsula, near the town of Deer Lake and the upper Humber River area within the Deer Lake Basin (9), and around Flat Bay and further to the south in the Bay St. George Basin (3). More than half of the wells put down had minor to good shows of crude oil, natural gas, oil shale and/or bitumen staining. Impressive as this may seem, even more importantly, the various hydrocarbon shows were encountered over all five areas of interest. Around the turn of the century, minor intermittent production was achieved at Parsons Pond and at Shoal Point, although based on available records, it is estimated that less than 8 000 barrels of oil in total was ever produced and consumed either within the local market or elsewhere on the island.

So why did individuals and their respective companies in colonial Newfoundland (1890s to 1920s) and then much later in the province of Newfoundland (1950s to 1960s) fail in their attempts to develop a viable petroleum industry along the west coast of the island ? The reasons are many and highly variable over the two time intervals. Some were controllable; however most were not.

The Lac des Iles palladium deposit, northwestern Ontario: a product of late magmatic mineralization and subsequent hydrothermal enrichment

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The Lac des Iles Palladium mine, with reserves of 88 Mt at 1.51 g/t Pd, is hosted by the 2.69 Ga Lac des Iles mafic-ultramafic complex in the western Superior Province and represents the only primary Pd-producing mine in Canada. The mineralization in the Roby and Twilight zones is characterized by low concentrations of sulphide and exceptionally high Pd (Pd/Pt ~10). The ore is associated with complicated textures in the host rocks including pegmatite, breccia, and magma mingling. Detailed mapping, petrography, and geochemical data suggest that the mineralization is primarily magmatic, where PGE are concentrated in immiscible magmatic sulphide melts. The mineralization is associated with a series of late melanocratic rocks derived through high degrees of partial melting of a depleted mantle source.

The volumetrically minor High Grade Zone on the margin of the main Roby Zone is economically important as it contains more than 35% of the Pd in the mine. The rocks are extensively altered to relatively low-temperature mineral assemblages. It displays positive correlations between Se and immobile elements (Ni, Co) but shows scatters on the diagrams involving mobile elements, such as Pd and S. The ore is higher in Pd and Pd/Pt (mean of 16.5; up to 25) compared to the Roby and Twilight zones. The distribution of ore and geochemical data suggest subsolidus enrichment of Pd by fluids originating from the mafic magmas.

Fractionation of olivine, chromite, and high-temperature platinum group minerals likely resulted in high ratios of Pt-group PGE/Ir-group PGE in the parental magmas. The extreme enrichment of Pd and high Pd/Pt ratios of the mafic magmas is interpreted to be due to incorporation of an earlier formed sulphide melt. The interpretation is supported by high Cu/Pd in early leucocratic rocks and low Cu/Pd in the late melanocratic rocks.

Based on textural evidence, the mineralization at LDI has been compared to contact-type mineralization. However, contact-type mineralization is localized in the margins of intrusions near country rocks, and the resulting sulphide formation is in response to host rock assimilation. By contrast, the LDI deposit is not located near the contact with the country rocks and evidence of country rock assimilation is lacking. The mineralization in the Lac des Iles deposit is more akin to stratigraphically controlled deposits in layered intrusions where pulses of primitive magmas introduce PGE. Unlike quiescent environments for the solidification of most layered intrusions, the intrusions at Lac des Iles were energetic, forming breccias and magma mingling textures.

Sources and transport routes for Cretaceous turbidite sands from the Newfoundland Basin, ODP site 1276

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ODP Site 1276 is located east of the Grand Banks and south of Flemish Cap, at a water depth of 4 560 m. Cores were collected from 800–1 739 m below the seafloor in lower Oligocene to lowest Albian rocks. The hole was not logged because of engineering problems. Sedimentation rate was <5–7 m/m.y. from the earliest Oligocene to the Cenomanian, but was ~20–100 m/m.y. during the Albian. The Cretaceous deposits are ~65% hemipelagic, bioturbated mudrocks, and ~33% turbidites (and their kin). Many of the turbidites are mud-dominated. Minor rock types are Coniacian-Turonian sandy contourites and Albian black shales containing mostly terrestrial organic carbon.

Deeper cores show bedding dips of ~10° in a borehole with a measured deviation of 7.4° from the vertical. Seismic reflections dip much less: ~2.5° toward an azimuth of 130º. These results strongly suggest that the borehole is deviated downdip. If true, the dip line in cores provides a geographic reference direction for paleocurrent measurements. Eleven current-ripple foreset dips and five sand-grain fabric determinations from the basal divisions of turbidites indicate paleoflow toward the NNE. These data and regional paleogeography implicate the Avalon Uplift and/or a broader area of eastern Newfoundland as the source of the Cretaceous detritus.

The average sandstone composition ($Q_{57}F_{23}L_{20}$) and the variety of metamorphic (including metasedimentary) and sedimentary lithic fragments are consistent with a source on the Grand Banks. The relatively low average K-feldspar content ($Qm_{71}K_8P_{21}$) is unlike that of time-equivalent Iberian sandstones, and appears to preclude a primary Iberian source for the Cretaceous sand fraction. At first sight, this conclusion seems to be at odds with results from Ar/Ar dating of detrital white micas. Fifty-seven detrital white micas were separated from five sandstone beds; 42% have Hercynian ages of 270–340 Ma, and only 9% have older ages (~400–600 Ma). An Appalachian provenance should have provided mostly >400 Ma detritus, whereas an Iberian provenance can more easily account for the Hercynian mica ages. The width and bottom morphology of the Albian ocean basin and our own paleocurrent data rule against direct sediment-supply from Iberia. Instead, we advocate recycling of the white micas from Hercynian foreland-basin deposits that likely covered the Grand Banks. The Hercynian Front is typically placed close to the line of continental breakup in this area, so the associated foreland basin should have extended westward onto the Grand Banks. The Site 1276 sandstones and other studied Grand Banks sandstones are quartzolithic and fall within the *Recycled Orogen* compositional field of W.R. Dickinson. In Iberia, by Jurassic and Cretaceous times, erosion had unroofed granite batholiths so that they became a major source of quartzofeldspathic sands deposited on the adjacent margin - the batholiths would not have been unroofed at the time the Hercynian foreland basin was being filled.

Unconformity-associated uranium deposits: characteristics, geological environments, and exploration methodology

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The recently completed EXTECH IV Athabasca Uranium Multidisciplinary Study has shed new light on the world-class unconformity-associated uranium deposits in terms of structural and stratigraphic controls and geophysical parameters. The deposits comprise pods, veins and disseminations of uraninite and/or pitchblende at or close to a profound unconformity between late Paleo- to Mesoproterozoic siliciclastic strata and Paleoproterozoic and older crystalline basement. The strata are mainly fluvial, areally extensive, and unmetamorphosed but pervasively altered red to pale tan quartzose conglomerate, sandstone, siltstone, and mudstone. They were deposited on paleo-weathered basement with a well developed lateritic profile. The basement is a complex of interleaved Archean to Paleoproterozoic highly metamorphosed granitoid and supracrustal rocks including graphitic metapelites that preferentially host shear zones and many of the uranium deposits. Other factors in localization the deposits are the basement topography and syn-sedimentary faults. Compositionally the deposits are grouped broadly into (1) polymetallic lenses (located just above or straddling the unconformity), with variable Ni, Co, As, Pb, and traces of Au, Pt, Cu, REE and Fe, and (2) monometallic veins (generally basement-hosted). Some 33% of the world's known conventional uranium resources are hosted by these deposits, mainly in Australia and Canada, with the highest grades and potential being in the Athabasca Basin (e.g., the McArthur River deposit with grade averaging 22.3 % U and resource of ~192 000 tonnes U).

A new national uranium research project for Canada

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Due to increased pressure on energy supplies, the Geological Survey of Canada under Earth Sciences Sector (ESS) has instituted a new "Uranium Resources in Canada" project. Planning includes stakeholder consultations and a review of uranium knowledge and potential. A national digital database will be upgraded. Resource assessment methodology will be revised and refined to include uncertainty measures, compliant in terminology with international standards. Fieldwork will be designed to reduce uncertainties in known and frontier areas. World uranium resources are contained mainly in the unconformity-associated, Olympic Dam and sandstone types among the 14 deposit types defined by the International Atomic Energy Agency. In Canada there is potential for unconformity-associated deposits in Mesoproterozoic basins other than the Athabasca. The lone Olympic Dam deposit of Australia contains ~31% of world resources as a secondary component of an iron oxide-copper-gold bearing volcano-plutonic breccia complex. Analogues in several Canadian environments include southern Labrador. Sandstone hosted deposits (>30% of world resources) are mostly in Kazakhstan, Niger, and USA, with high potential in Asia and uncertain potential in Appalachian basins and across Canada. A range of volcanic associated deposit settings (e.g. Streltskova in Russia and Makkovik Belt in Labrador) are gaining new attention.

The geologist's guide to Gros Morne National Park: a report on an advanced GAC Newfoundland section project

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Gros Morne National Park, in western Newfoundland, is designated as a UNESCO world heritage site largely on the basis of remarkable geology and its profound influence upon the development of the theory of plate tectonics. It may not be the *best* place to view the Cambro-Ordovician shelf sequence, or provide the most *complete* illustration of the anatomy of oceanic crust, but it is the only place where many diverse elements of the Appalachian Orogen came together to be sculpted by the forces of nature into a landscape of elemental beauty. The park is best-known for its huge peridotite-dominated ophiolites, but it also contains remarkable continental-slope sedimentary rocks, fresh alkaline mafic volcanic rocks, world-class fossil localities, global stratotypes, deep oligotrophic lakes, and much more besides.

There are already several publications that explain aspects of the park geology in nontechnical language for a tourist audience, and there are many specialized geological field trip guides that include stops within its boundaries. However, there is a need for something that lies between these extremes, to enable visitors with intermediate (i.e., undergraduate) Earth Science knowledge to locate, appreciate, understand, and learn from the many key geological localities. We are now working towards such a product, on behalf of the GAC Newfoundland Section, and hope that it will promote further learning and research within the park, as well as aid geologists in their professional development and recreation. An integrated guide of this type could perhaps also serve as a model for similar projects in other areas of outstanding geology in Newfoundland and Labrador, and across North America.

This presentation will highlight some of the remarkable geological features of Gros Morne and surrounding areas, provide an outline of the guidebook structure, and report on the progress of the project. We are now at the second draft stage, with all text complete, but much work remains to be completed on diagrams, maps, and bibliographies. With luck, and with some additional volunteers, we hope to have a "trial version" of the guide available by summer 2006 for non-destructive field testing.

Orphan Basin: an overview of geology and exploration history

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Orphan Basin lies under the deep waters off the continental shelf approximately 500 km northeast of St. John's, Newfoundland. Water depths range from over 500 m to over 2500 m. This region made news in 2004 due to the results of a land sale held by the Canada-Newfoundland and Labrador Offshore Petroleum Board. The team of Chevron, ExxonMobil and Imperial Oil bid over 672 million dollars in work commitments for the right to explore 2 124 630 hectares. During 2004, the partners conducted a 101 382 km (CMP) 3-D seismic survey. This was followed in 2005 with additional 3-D seismic as over 268 545 km (CMP) were recorded using two seismic vessels. Shell subsequently acquired an interest in all the blocks from ExxonMobil. In 2005, ExxonMobil announced that the deepwater, semi-submersible rig, Eirik Raude had been leased for 2006.

No wells have been drilled on the current licences in the basin. Prior to 2003, 9 wells had been drilled on the flanks of the basin. In 1970, the Deep Sea Drilling Project drilled and cored a 249 m well centred on the Orphan Knoll at Sites 111. The hole was terminated in sandstones dated as Middle Jurassic (Bajocian). Of note was the well, Texaco Shell et al. Blue H-28 drilled to 6103 m in 1486m of water. Abandoned in 1979, Blue H-28 drilled through a section of Tertiary, Cretaceous and Carboniferous sediments. Drilled in the adjacent Flemish Pass Basin, Esso PAREX et al. Baccalieu I-78 reached a depth of 5135 m. The well encountered Tertiary, Cretaceous, and Jurassic sediments and was abandoned in 1985.

In 2004, Petro-Canada et al Mizzen L-11 was drilled to a depth of 3823 m. Potential Jurassic reservoir sands were encountered in well but were determined to be water-bearing. Live oil was recovered from sandstone at 3350.8 m using a repeat formation tester. This oil-bearing sandstone may be equivalent to sandstone drilled at Baccalieu I-78, approximately 25 km south of Mizzen L-11 well. Jurassic source rocks have been identified in Baccalieu I-78. An active petroleum system is suggested by the Mizzen L-11 well.

Based on the review of 2-D seismic data, large structures can be mapped in the Orphan Basin. However, trap type, presence of seals, adequate reservoir beds as well potential source associated with advantageous timing are still to be proven in the Orphan Basin. A well could answer these questions.

Hydrocarbons in the Paleozoic basins of eastern Canada: significant newly recognized potential

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The Cambrian to Middle Devonian successions at the continental margin of Laurentia consist of marine to continental sediments deposited during alternating passive margin and foreland basin episodes. Two significant orogenic pulses, the Ordovician Taconian Orogeny and the Late Silurian-Middle Devonian Salinian-Acadian event, controlled tectono-sedimentary patterns.

Good hydrocarbon source rocks are found in the Upper Ordovician foreland basin shales (TOC up to 14%, Type I/II), in the Middle Ordovician oceanic shales (TOC up to 10.7%, Type I) and in the Lower Ordovician passive margin shales (TOC up to 10.4%, Type I/II). Fair hydrocarbon source rocks are found in Lower - Middle Devonian foreland basin limestones and coals (TOC from 2% to 50%, Type II/III respectively). Maturation suggests that the Cambrian-Ordovician St. Lawrence Platform has a gas (southern Québec) to oil (western Newfoundland) potential; the coeval Humber Zone has a gas (Québec) to gas and oil (western Newfoundland) potential. The Late Ordovician to Middle Devonian Gaspé Belt has both gas and oil potential.

Clastic reservoirs are found in Cambrian-Ordovician passive margin and foreland basin coarse sandstone and conglomerate slope facies and in Silurian-Devonian nearshore sandstones. The potential for secondary carbonate reservoirs is recognized in the recent documentation of hydrothermally-altered carbonates (Lower to Upper Ordovician passive margin and foreland basin; Lower and Upper Silurian and Lower Devonian foreland basin). The recognition of hydrothermal dolomites is based on the burial scenario, tectonic framework, and detailed petrography and geochemistry. Production of natural gas and oil has recently started in the Lower Devonian dolomites in Gaspé. GC-MS and GC-IRMS fingerprinting of hydrocarbons, bitumen and potential source rocks indicate a most likely dominant Ordovician source. Based on crosscutting relationships and basin modeling, multiple events of hydrocarbon migration are recognized with a significant Late Silurian (syn-Salinian orogeny) and a late Early Devonian migration.

Traps and seals are multiple and include various stratigraphic (pinch-out, impermeable layers and unconformities), tectonic (fault closures, anticlines, duplexes and triangle zones), and diagenetic (HTD) types.

Exploration is picking up rapidly in these Lower Paleozoic basins in eastern Canada with large areas under exploration permits and promising recent drilling results.

Uranium mineralization in the Makkovik province, central mineral belt, Labrador: the ongoing Fronteer Development Group – Altius Minerals project

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The CMB Uranium Property is located near the north-east coast of Labrador in proximity to the town of Postville on Kaipokok Bay. Postville is approximately 250 km north by north-east of the community of Happy Valley-Goose Bay, Labrador. Uranium mineralization on the CMB Property is hosted by Paleoproterozoic supracrustal sequences of the Post Hill and Aillik Groups and is represented by approximately forty uranium showings, including seven significant uranium deposits and prospects.

The uranium mineralization is typically hosted within strongly foliated, pelitic metasedimentary rocks of the Post Hill Group and fine-grained felsic metavolcanic rocks of the Aillik Group. Uranium is associated with strong to intense pervasive hematite alteration with magnetite+actinolite+calcite veining. Mineralization is concentrated in high strain corridors, giving a plunging shoot-like geometry to the Michelin deposit. Alteration associated with uraninite + magnetite mineralization in the CMB area is distinct, but is broadly similar to that seen in iron-oxide copper-gold deposits.

The Central Mineral Belt was initially explored for uranium by the British Newfoundland Exploration Company Limited (Brinex) during the early 1950s to early 1980s. Brinex completed a plan to develop the Michelin and Kitts uranium deposits as a combined mining operation, but the project was compromised by the collapse in the price of uranium in the early 1980s. Exploration in the region tailed off and the area has remained relatively dormant until recent years.

Fronteer and Altius entered the belt through a 50:50 strategic alliance to evaluate the district for IOCG-style targets. Due to a recovery in the uranium price in 2004, a shift in exploration strategy was made to once again examine the district for its uranium potential. A preliminary exploration program was carried out by the Fronteer-Altius Alliance in 2004 and included airborne magnetic and radiometric surveying in addition to geological mapping, prospecting and rock/soil sampling. The survey identified a large number of radiometric anomalies that formed the focus of the 2005 exploration program.

In 2005, an exploration program was completed including additional airborne magnetic and radiometric surveys, air photo imagery, geological mapping, geochemical sampling, scintillometer surveys and track etch surveys. This was followed by a 9 400 m 27-hole diamond drill program at the Michelin, Otter Lake and Jacques Lake targets. The 2005 program doubled the Michelin resource from the historic 18.3 million lbs to a new measured and indicated resource of 22.2 million pounds with an additional inferred resource of 13.4 million pounds. Additional 2005 drilling highlights included the discovery of a new zone at Jacques Lake and a high-grade zone at Otter Lake. The 2006 program will involve extensive delineation drilling at Michelin with further drilling targeting Jacques Lake, Otter Lake, White Bear Lake, Melody Hill, and the Rainbow Zone. Additional surface mapping, sampling, and geophysical surveys will be carried out over the course of the field season.

Sandstone uranium deposits: examples from the grants district, New Mexico - the largest uranium producers in the U.S.A.

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New Mexico ranks second in uranium reserves in the U. S., which amounts to 15 million tons ore at 0.277% U_3O_8 (84 million lbs U_3O_8) at $30/lb (13.6 million tonnes ore at 0.237% U at $78/kg U) (Energy Information Administration, 2000). The most important uranium deposits in the state are sandstone uranium deposits within the Morrison Formation (Jurassic) in the Grants uranium district, San Juan Basin. More than 340 million lbs of U_3O_8 (130 000 tonnes U) have been produced from the Grants uranium deposits from 1948 through 2000, accounting for 97% of the total uranium production in New Mexico and approximately 30% of the total uranium production in the United States. During a period of nearly three decades (1951–1980), the Grants district in northwestern New Mexico produced more uranium than any other district in the United States. The Grants district is one large district in the San Juan Basin, extending from east of Laguna to west of Gallup and consists of eight subdistricts. The Grants district is probably 4th in total world production behind East Germany, Athabasca Basin in Canada, and South Africa. However, as of spring 2006, all of the conventional underground and open-pit mines in New Mexico remain closed. However, several companies are currently exploring for uranium in sandstone in the Grants district for possible in situ leaching.

Sandstone uranium deposits are defined as epigenetic concentrations of uranium in fluvial, lacustrine, and deltaic sandstone formations. Three types of sandstone uranium deposits are recognized: tabular (primary, trend, blanket, black-band), roll-front (redistributed, post-fault, secondary), and fault-related (redistributed, stack, post-fault). In addition, a fourth type is found in the Grants district, remnant-primary sandstone uranium deposits. All three types are found in the Grants district.

Only one company in New Mexico, Quivira Mining Co. now owned by BHP Billiton (successor to Rio Algom Ltd and Kerr McGee Corporation), produced uranium in 1984–2000 from mine waters recovered from inactive underground operations at Ambrosia Lake (mine-water recovery). Quivera is reclaiming their uranium properties in the Ambrosia Lake and has sold their remaining assets to Strathmore Minerals Corp. Hydro Resources Inc. (HRI) has delineated 7 350 tonnes of U_3O_8 at

Churchrock and 15 000 tonnes of U_3O_8 at Crownpoint. HRI plans to mine uranium by in-situ leaching at Churchrock starting in 2007. Reserves at Churchrock are estimated as 15 million pounds of U_3O_8. Strathmore has demonstrated uranium resources at Roca Honda of 11 321 200 contained lbs U_3O_8 and at Churchrock of 5 502 000 contained lbs of U_3O_8 and plans for in situ leaching are underway. Strathmore also has uranium resources at the Noserock property. Quincy Energy Corp and NZU LLC also are planning to mine 5 000 tonnes of U_3O_8 at Hosta Butte by in-situ leaching. Rio Grande Resources Co. is maintaining the closed facilities at the flooded Mt. Taylor underground mine, in Cibola County. Laramide Resources Ltd. acquired the La Jara Mesa uranium deposit in Cibola County, which was discovered in the late 1980s in the Morrison Formation and contains approximately 8 million pounds of 0.25% U_3O_8. Laramide also acquired the Melrich deposit. Future development of these reserves and resources will depend upon the lowering of production costs, perhaps by in-situ leaching techniques and timely approval of required permits.

Magmatic-hydrothermal iron oxide-Cu-Au-Ag-U deposits

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Magmatic-associated hydrothermal vein, breccia and replacement deposits, characterized by abundant Fe-oxide and enrichment in Fe-Cu-Au ± U, rare earth elements, Co, Bi, Ag, W, and other metals comprise the distinct, yet highly variable, IOCG class of mineral deposits. They are attractive targets for exploration and development due to their polymetallic nature and enormous size and grade potential. The type example, Olympic Dam in Australia, is quoted by WMC as containing 3.81 billion tonnes @ 1.1% Cu, 0.5 g/t Au and 400 g/t U_3O_8. Other important examples include Kiruna in Sweden (>2 billion tonnes grading 60% Fe), Bayan Obo in China (~50 million tonnes grading 6% REE oxides and 1.5 billion tonnes grading 35% Fe), Candellaria in Chile (470 million tonnes grading 0.95% Cu, 0.22 g/t Au and 3.1 g/t Ag), Salobo in Brazil (~450 million tonnes grading 1.15% Cu and 0.5 g/t Au), Sossego in Brazil (219 million tones grading 2.19% Cu, 1.14 g/t Au), and many others.

Iron-oxide copper-gold (IOCG) deposits formed along extensional and collisional cratonic margins, both modern and ancient, both incipient and mature, which promoted partial melting of deep continental crust to uppermost mantle rocks and production of magmas of a wide range of compositions. They are most abundant in Proterozoic terrains, although Phanerozoic and Archean examples are present. IOCG deposits occur in felsic to intermediate volcano-plutonic terrains, but in some cases there is a spatial, if not direct genetic relationship to mafic and ultramafic magmas, as is the case with Olympic Dam and carbonatite-associated Fe-phosphate-REE deposits (e.g., Bayan Obo). They are often associated with the root zones of volcanic centers, and some IOCG deposits have many similarities to Fe-rich porphyry copper systems. Also, there is a continuum of IOCG deposits types and forms ranging from deeper-seated replacement and breccia styles to iron-oxide rich epithermal type deposits. They formed along and at the intersections of major crustal lineaments, and often display strong structural control over their morphology and ore textures. The wide range of geotectonic settings and associated magma compositions generate an equally complex range of deposit sub-types. Different investigators have placed a range of deposit sub-types within the IOCG class including:

1. Felsic to intermediate breccia hosted deposits (Olympic Dam).
2. Stratabound replacement and breccia ironstone hosted deposits.
3. Hydrothermal iron-apatite deposits.
4. Graphitic-sediment hosted ISCG (iron-sulphide copper-gold).
5. Iron-phosphate-REE carbonatite associated deposits.
6. Iron oxide-fluorite breccia pipes.
7. Iron oxide-rich epithermal veins and breccia.

IOCG deposits display close time-space relationships with distinct alteration styles. The ores are associated with widespread alkali-Fe metasomatism, including multiphase sodic to sodic-calcic and potassic alteration, sometimes associated with alkali-rich intrusions. Enrichment in one or more of PO_4, CO_2, and F is common. Other common hydrothermal alterations may include proximal apatite, Fe-rich amphiobole and biotite, carbonate, fluorite and tourmaline veins, breccia, disseminations, and replacement. Distal alterations include sericite, silicification, quartz veining, and phyllic and prophyllitic styles. Iron is usually magnetite and/or hematite, but can include and is occasionally dominated by Fe-silicates, Fe-carbonates and/or Fe-sulphides. Generally, magnetite forms at deeper levels, as a higher temperature and/or more reduced form of Fe-oxide. In contrast, hematite occurs at shallower depths or in peripheral halos surrounding core regions in lower temperature and more oxidizing environments. However, considerable overlap and superposition occur amongst the various alteration assemblages due to the episodic and dynamic nature of IOCG systems. The source of hydrothermal fluid is orthomagmatic ± circulation of ground water driven by heat of the intrusion. Metals are derived from source intrusions, but can also be leached from host rocks.

Despite their attractive economic potential, IOCG deposits have only recently emerged as a deposit type of choice for exploration in Canada. Vast and largely unexplored, yet highly prospective terrains abound, including Central Mineral Belt, Grenville Province, Southern Province, Mid-Continent Rift, Trans-Hudson Orogen Wernecke Mountains, and the Great Bear Magmatic Zone (GBMZ). Several of these districts host past-producing mines that are now classified as IOCG-type deposits. The GBMZ remains Canada's premier emerging IOCG district, with delineation of the Sue-Dianne Fe-oxide Cu-Ag-Au diatreme breccia and recent discovery of the NICO Co-Au-Bi ironstone replacement type deposit. However, the GBMZ also hosts ~10 past-producing mines that exploited high-grade U-Ag-Cu deposits that are best described as quartz-carbonate-hematite rich IOCG associated epithermal vein systems.

Metal associations in IOCG deposits are highly variable and controlled largely by composition and chemistry of source intrusions, but also are affected by circulation of groundwater and magmatic fluids with resultant fluid-host rock exchange reactions. Uranium is enriched in many deposits but economic concentrations are restricted to only a few. The most important U-bearing IOCG is the Olympic Dam deposit, which at 400 g/t U_3O_8 (roughly one pound per tonne) is the world's largest individual uranium concentration. In Canada, the former mines of the Great Bear Magmatic Zone comprise an extensive IOCG-province with proven uranium potential. Uranium occurs primarily as pitchblende, and is not uncommon as small veins peripheral or distal to the centers of hydrothermal alteration and mineralization. More significant concentrations are associated with structurally higher-level hematite-rich breccias, and quartz-hematite and quartz-carbonate-hematite veins and breccias. Due to their unique metal association, IOCG deposits can be targeted during exploration using magnetic, gravity and multiparameter radiometric geophysical surveys. Other geophysical techniques such as IP, resistivity, and EM are sometimes useful, but may be difficult to interpret due to the interference of magnetite and hematite, and the widespread distribution of barren disseminated and vein sulphides. Various geochemical exploration techniques can also be used under appropriate climatic and overburden conditions, to delineate anomalous metals in the secondary environment. However, regional and targeted geological, alteration, and structural mapping remains the most effective exploration tool in areas with reasonable outcrop exposure.

Geology and geobotany: examples of the influence of local conditions governing alpine plant habitats in the Nain region of Labrador

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Alpine plants, strictly those that inhabit mountainous regions above the tree-line and below the snowline, are especially adapted to survive under extreme conditions that would destroy most perennials. These generally very-slow-growing, diminutive flora withstand long cold winters and short, occasionally hot, summers (a lot like St. John's!), low mean air temperatures, high light levels, and great fluctuations in diurnal conditions. Snow provides an insulating blanket from desiccating winter winds, and they are generally kept from baking even on the hottest summer days by cool breezes. Many of the common Alpine plants native to northern latitudes and high elevations can be found in Labrador, but local conditions clearly influence where some take root. At the latitude of Nain there is a diversity of habitats: elevations from sea level to 1000 m, environments from tide-inundated coastlines to barren uplands, and an eclectic array of rocks. Certain plants have clearly found their niches within this varied geomorphic and geologic domain. For example, sandy beaches, are home to the beach sandwort (*Hockenya peploides*) and seaside potentilla (*Argentina anserina*). Well-drained shoreline and upland terraces provide ideal conditions for moss campion (*Silene acaulis*) and diapensia (*Diapensia lapponica*). Moist hillsides have colonies of common butterwort (*Pinguicula vulgaris*), and more swampy regions have eye-catching carpets of fluffy cotton grass (*Eriophorum scheuchzeri*) and the less-obvious blacktop (*Bartsia alpina*). Mountaintops are generally devoid of significant plant communities, but local nooks and crannies below the peaks provide enough shelter for mounds of mountain avens (*Dryas integrifolia*) and solitary Arctic poppy (*Papaver radicatum*). Nutrients offered by local rock substrate plainly dictate where some plants grow: bird's-eye primrose (*Primula mistassinica*) on mafic dykes but not on the adjacent granitic gneisses, woodsia ferns (*Woodsia alpina*) on residual soils from iron-rich diorite but not on adjacent anorthosite, and live-long saxifrage (*Saxifraga paniculata*) on calcareous rocks. Other plants, such as the Alpine rhododendron (*Rhododendron lapponicum*), locoweed (*Oxytropis campestris*), and bearberries (*Arctous alpina*) have more tolerance for differing physical and chemical attributes of the substrate, and are widely distributed.

The amazing geology of Mars

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Mars is the most Earth-like of the planets in our Solar System. For this reason it has featured prominently as an exploration target since the advent of space travel. Mars is a complex planet. Because of its size (approximately half the diameter of Earth, and twice the diameter of the Moon), Mars has remained dynamic for much of its life, and may still be capable of volcanic activity. It also has an atmosphere, presently dominated by CO_2, but one that is very thin compared to that of Earth's (the Martian atmosphere exerts ~1% of the surface pressure realized on Earth). There is evidence that water flowed freely during the early history of Mars, but that water was lost and/or became frozen at or near the surface later in the planet's evolution. Because of the continued activity of the planet, the presence of an atmosphere with dynamic wind systems, and the existence of seemingly abundant frozen H_2O, there has been considerable speculation in the last 30–40 years as to whether forms of life may have existed, or even currently exist, on Mars. The search for life has been the driving force for prioritizing the exploration of Mars, which has marked the late 20th (e.g., NASA's Viking missions of the 1970s) and start of the

21^{st} centuries (e.g., NASA's MSL and ESA's ExoMars missions, with launch dates of 2009 and 2011, respectively). Interest has been enhanced by purported evidence of biomineralization in the martian meteorite ALH84001 (McKay et al. 1996) and, more recently, other martian meteorites. The discovery of water-lain lake deposits in impact craters (e.g., Gusev), as visited by the Mars Exploration Rovers Spirit and Opportunity, which are entering their third year of operation, has also affirmed the past existence of standing water. These scientific findings and more are reviewed in order to present an overview of the amazing Red Planet.

The great U-turn: the resurgence of uranium and an overview of deposit types

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Uranium exploration is enjoying a renaissance due to a five-fold increase in price to $37.0/lb since 2001. The increase reflects a growing shortfall in uranium production compared to reactor requirements worldwide. The shortfall has been filled until recently by recycling from obsolete nuclear weapons. The declining amounts of this source coupled with the increasing supply demands of new "Greenhouse Gas-friendly" reactors has acerbated the supply equation. In 2005, Canada contained 12% of the world's resources, but was also the world's largest uranium producer.

Uranium is intrinsically an incompatible element that has great mobility in oxidizing hydrothermal fluids. In its primary origin, uranium is associated with felsic magmatic rocks, but can be mobilized into a variety of other rock types to form mineral deposits. Uranium mineralization is predominantly a high-level phenomena associated with crustal processes.

Uranium occurs in a number of different deposit types. The main ones are: 1) unconformity-related (along unconformities between sandstones and basement rocks, *e.g.*, the Athabasca Basin, Saskatchewan, 2) roll-front sandstones (as reduction fronts within permeable sandstones), 3) IOCG (iron-oxide-copper-gold) deposits (byproduct), 4) granitic (primary magmatic mineralization), 5) shear zones, 6) Archaen paleoplacers (detritus in quartz-pebble conglomerates), 7) simple vein deposits, and 8) surficial environments (calcrete).

Uranium ore minerals are dominated by primary uraninite (UO_2) and brannerite ($(U,Ca,Ce)(Ti,Fe)_2O_6$) and a range of secondary phases such as carnotite ($K_2(UO_2)_2(VO_4)_3$-$3H_2O$) to coffinite ($U(SiO_4)_{1-X}(OH)_{4X}$). Uraninite has proven to be notoriously difficult to date due to the ready mobility of U from the crystal lattice by oxidizing meteoric fluids. Remobilized Pb from uraninite can produce galenas with very radiogenic signatures. Uraninite incorporates abundant REE and derived REE patterns are often diagnostic of the type of deposit.

Differentiation of silicic segregations in the Ferrar dolerites, Antarctica

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The upper parts of the 100–300 m thick Ferrar Dolerite sills in Antarctica contain coarse-grained leucocratic segregations, in the form of sharply defined, anastomosing, sub-horizontal 0.1–3 m thick lenses,which extend tens of meters along strike. Most segregations range in composition from diorite to granodiorite, are enriched in P_2O_5, TiO_2, and FeO_T, and have linear trends in Harker diagrams that are compatible with simultaneous crystallization of pyroxene and plagioclase from the host dolerite.

The Singular Value Decomposition (SVD) matrix technique and the thermodynamic program MELTS were used to determine the temperature and crystallization conditions at which these segregations formed. MELTS models show that segregation compositions are best approximated by wet fractional crystallization at 1 kb of the dolerite adjacent to the segregations. The segregations can be grouped according to the calculated temperatures at which they crystallized. A global crystallization path (GCP) can be defined from the most primitive segregations in each temperature group, and several local crystallization paths (LCPs) can be defined by the compositions of segregations formed at each temperature interval. Each segregation is described by one of five mass balance relationships (RC_1-RC_5). When they are plotted in a CaO versus SiO_2 plot, segregations above 6 wt % CaO are mushes represented by RC_1-RC_4, and below 6 wt% CaO are fractionated liquids represented by RC_5. The GCP represents differentiation during cooling of the sill to form mushes, and LCPs represents local differentiation involving subsequent segregation of the residual mush by an imperfect filter-pressing mechanism. Compositional variation within each *RC* group reflects addition or subtraction of varying amounts of crystals by this mechanism.