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Geological Association of Canada Newfoundland Section

ABSTRACTS

2015 Spring Technical Meeting

February 16-17, 2015

JOHNSON GEO CENTRE, SIGNAL HILL, ST. JOHN'S, NEWFOUNDLAND AND LABRADOR

For the tenth time the Spring Technical Meeting was held in the depths of the Newfoundland winter in the Johnson GEO CENTRE on scenic Signal Hill in St. John's.

The meeting featured a special session on Monday afternoon and Tuesday morning entitled "Climate Change: Global Trends and Local Consequences" which covered local to international subjects and ranged from ancient to modern examples. In addition, general sessions (Monday morning and late Tuesday morning and afternoon) included papers on an eclectic range of topics, as is normally the case at these meetings.

On Monday evening the "Public Lecture" series, sponsored by the Professional Engineers and Geoscientists of Newfoundland and Labrador (PEG-NL), was given by Professor John England from the Department of Earth and Atmospheric Sciences, University of Alberta, with a talk entitled "Life in a tent: perspectives and adventures from a half century unravelling Arctic environmental change."

As always, this meeting was organized by volunteer efforts, and would not have been possible without the time and energy of the executive and other members of the Newfoundland and Labrador Section of the Geological Association of Canada. We are also indebted to our partners in this venture, particularly the Alexander Murray Geology Club, the Johnson GEO CENTRE, the Geological Survey of Newfoundland and Labrador, Department of Natural Resources, and our corporate sponsors: Nalcor Energy; Professional Engineers and Geoscientists of Newfoundland and Labrador; and the Geological Survey of Newfoundland and Labrador. We are equally pleased to see the abstracts published in Atlantic Geology. Our thanks are extended to all of the speakers and the editorial staff of the journal.

James Conliffe, Andrew Kerr, and Sheridan Thompson
Technical Program Chairs
GAC Newfoundland and Labrador Section

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Distinguishing the "signal" from one source of "noise" in Labrador Lake sediments

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An association consisting primarily of the elements Al, Ba, Hf, K, Li, Mg, Na, Nb, Rb, Sc, Sr, and Ti is universal in the analyses of lake sediments from Labrador. Analyses of seven of these twelve elements were made available for the first time in a program of re-analysis whose results were released in 2012. The element association appears to be related to the amount of inorganic clastic material in the sediment, and may mask the responses of these elements (some of which are of potential economic significance) to local geology. It is not, however, directly complementary to the amount of organic material in the sediment, as represented by loss-on-ignition (LOI).

Modelling the clastic component numerically by regression analysis enables the identification of departures from the model, in the form of regression residuals. The effectiveness of this method of removing the clastic contribution from the lake sediments' composition, thereby highlighting local areas of enrichment and depletion, is demonstrated by the emergence of a number of features whose geological significance is indisputable. Furthermore, the method has drawn attention to certain well-defined features whose source is unknown, but which may be related to mineralization: specifically, the Colville River and Bondurant Lake Ba anomalies, and the Thompson Lake/Michikamats Li anomaly, all in western Labrador.

Revised trilobite identifications and their significance– "illustrations of paleontological specimens from the Table Point, St. Paul's inlet and other areas" [C.H. Kindle, undated — NFLD/3250]

W. Douglas Boyce

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Recently released Open File NFLD/3250 (C.H. Kindle, undated) includes two historically significant trilobite plates, examination of which has revealed many outdated taxonomic names.

The "St. George Trilobite Plate" comprises (1) *Petigurus nero* (Billings), (2) *Strigigenalis brevicaudata* Boyce, (3) *Bathyurellus* abruptus Billings, and (4) *Punka flabelliformis* Fortey. *Strigigenalis brevicaudata* Boyce — diagnostic of the *S. brevicaudata* Zone — most probably was collected at Barbace Point, Port aux Choix Peninsula, from the Barbace Cove Member of the Boat Harbour Formation or the overlying basal Catoche Formation. *Petigurus nero* (Billings) ranges between the *Strigigenalis brevicaudata* and *Benthamaspis gibberula* zones, whereas *Bathyurellus abruptus* Billings and *Punka flabelliformis* Fortey range from the *Strigigenalis caudata* to the *Benthamaspis gibberula* zone; all three probably were obtained from the Catoche Formation at Catoche Point, Port aux Choix Peninsula.

The "Table Head Trilobite Plate" includes material from the autochthonous Table Head and allochthonous Cow Head groups.

North of Table Point, the Table Point Formation yielded (1) *Uromystrum validum* (Billings) — the nominate species of the *Uromystrum validum* Zone. From the overlying *Pseudomera barrandei* Zone at Table Point, (19) *Illaenus consimilis* Billings, (11, 17) *Nileus affinis* Billings, (13) *Niobe quadraticaudata* (Billings) and (14) *Stegnopsis huttoni* (Billings) were figured, and (5, 6) *Pseudomera barrandei* (Billings) was illustrated from two miles south of Bellburns.

At Table (Point) Cove, the following *Cybelurus mirus* Zone taxa were figured from the Table Cove Formation: (15, 16) *Ceraurinella polydorus* (Billings), (4, 9) *Cybelurus mirus* (Billings), (12) *Endymionia schucherti* Raymond, (2) *Harpides atlanticus* Billings, and (3) *Triarthrus fischeri* Billings. The formation 1.5 miles north of Port Au Port yielded other *Cybelurus mirus* Zone taxa: (21) *Ampyxoides semicostatus* (Billings), (10) *Anisonotella glacialis* (Billings) and (8) *Niobe morrisi* (Billings).

The Factory Cove Member of the Shallow Bay Formation (Cow Head Group) at Lower Head contains a long known carbonate megablock — the 'Lower Head boulder' or 'alpha boulder' — from which Kindle illustrated: (7) *Apatolichas jukesi* (Billings), (24) *Heliomera albata* Whittington, (23) *Kawina vulcanus* Billings, (18, 22) *Nileus affinis* Billings and (20) *Punka nitida* (Billings).

Local climate variability through the Holocene era in coastal British Columbia: insights from archeology and high-resolution stable oxygen isotope sclerochronology

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Coastal shell midden sites can provide millennial-scale records of human-environmental interaction as well as insights into past environmental change. Marine shells within these archaeological deposits record changes in ambient environments in both the shell chemistry and within their micro-growth structures. Micro-growth lines are deposited on a daily basis as bivalves secrete calcium carbonate to build their shell when submerged during periods of high tides; the growth patterns are referred to as lunar daily growth increments (LDGI). This paper will discuss how the biogeochemical analysis of archaeological shells has shown changes in local climates on the northern coast of British Columbia. It will also discuss how these data can be used to identify cultural and climatic events that contributed to the collapse of the salmon economy between 4000–2000 years BP.

Climate change projections and potential implications for Newfoundland and Labrador

Gerald Crane

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Climate change is happening in the province, marked by rising temperatures, milder winters and increased incidence of tropical storms and other extreme weather events. In 2013, the provincial government released a set of climate projections for the province. These projections, which were developed by "down-scaling" global climate model projections to better reflect potential climate changes from end of the last century to the middle of the current century, provide a common baseline to inform planning, facilitate improved decision making and reduce risks by government and stakeholders in areas such as infrastructure, public health, agriculture and tourism, among others. This session will include an overview of climate change projections for the province, including temperature and precipitation, and will highlight potential implications for the geology and mining sectors.

Geological setting and genesis of high-grade iron ore depositsin the eastern Labrador Trough, Newfoundland and Labrador

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High-grade (>55% Fe) iron ore deposits have been intermittently mined in the Schefferville area since 1954, where they are commonly called Direct Shipping Ore (DSO) deposits. However, all mining to date has been concentrated in a narrow zone straddling the Labrador-Québec boundary, and little information has been published on high-grade iron ore deposits outside of this zone. High-grade iron ore deposits in the eastern Labrador Trough differ markedly from the soft DSO ore bodies of the Schefferville area. They form stratabound, tabular ore bodies and are composed mainly of hard, massive to laminated hematite-rich ore with lesser pockets of soft friable ore. The high-grade ore bodies are surrounded by altered iron formation with bands of partially leached chert and secondary hematite. A later, low-temperature alteration has variable affected both the high-grade ore bodies and the surrounding altered iron formation. Geochemical analyses show that the high-grade ore and altered iron formation are strongly depleted in Mg, Ca, and Na compared to unaltered Sokoman Formation taconites. Enrichment of Fe is not associated with a corresponding enrichment in immobile elements such as Al and Ti, indicating that the formation of these deposits was associated with the addition of Fe rather than simple leaching of silica. Hematite from the high-grade ore bodies is also associated with a strong depletion of $\delta^{18}O_{VSMOW}$ compared to magnetite in unaltered taconites.

The geological and geochemical characteristics of high-grade iron ore deposits in the eastern Labrador Trough are consistent with supergene-modified hypogene enrichment model. The main stage of iron enrichment is associated with the flow of large volumes of meteoric and/or formational waters during the deformation of the Sokoman Formation in the New Quebec Orogeny. These fluids were focused in structural zones (faults and fold hinges) and silica was leached and replaced by the precipitation of secondary hematite. Late-stage supergene alteration, which partially transformed hematite to goethite and remobilized Mn, may represent the same pre-Cretaceous supergene alteration recorded in the DSO deposits of the main ore zone or more recent groundwater circulation.

Climate change and cold-water corals

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Cold-water corals are diverse and abundant in the Newfoundland and Labrador region, where more than 30 species have already been recorded, and this number is likely to increase with further research. Some of them can be hundreds or thousands years old, and might have slow growth rates. They can form habitat for other species, but are vulnerable to several anthropogenic activities including fisheries, mining, and oil and gas activities. They are also threatened by climate change, although it is not clear yet at which extent it will affect them. Increasing water temperature and ocean acidification are the two factors most likely to affect these organisms.

Cold-water coral species are usually restricted to narrow temperature ranges, being sensitive to changes in water temperature. For instance, recent studies have shown that increased water temperature can lead to an increased body metabolism and a change in food requirements. Similarly, the other factor expected to have an effect on cold-water corals is ocean acidification, which is predicted to change the carbonate chemistry of the oceans. Most cold-water corals have a calcareous skeleton entirely or partially composed of calcium carbonate (calcite or aragonite). Therefore, a decrease in the water pH is one of the main concerns regarding organisms bearing calcareous structures.

The high diversity and abundance of cold-water corals in the Newfoundland and Labrador region make these organisms an important component in the ecosystem. Therefore, the impact of climate change on cold-water

coral communities can have broader consequences. More laboratory and in situ studies on the influence of environmental factors on these organisms are necessary in order to better understand how environmental changes might affect them in the Newfoundland and Labrador region.

Onshore petroleum exploration activity in western Newfoundland: past work, current activity, and the road ahead

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The province of Newfoundland and Labrador is home to some of the largest unexplored sedimentary basins in the world, with less than 6% of the acreage currently held under license. For the onshore jurisdiction, seeps and shows of hydrocarbons have been observed in western Newfoundland for over a century. Onshore exploration activity, which is regulated by the Newfoundland and Labrador Department of Natural Resources, Energy Branch, has slowed in recent years.

Oil exploration in western Newfoundland dates back to 1865 when hydrocarbon seeps were reported at Shoal Point in the Port au Port region. Earliest exploration drilling began in 1867 in the Parson's Pond area. Despite numerous drilling programs, both historic and modern, and the acquisition of hundreds of kilometers of seismic data, the region has seen a significant reduction in exploration activity in recent years and fewer exploration companies continue to operate.

As part of the Provincial Government's Energy Plan released in September 2007, policy actions were introduced to encourage and promote onshore and offshore exploration activity in the province. The onshore Petroleum Exploration Enhancement Program (PEEP) emerged and was allocated $5 million, an investment that has successfully funded source rock studies, regional mapping, aeromagnetic surveys and a data scoping study. Funds remain available for new and innovative projects in onshore western Newfoundland. These funds, coupled with the availability of released well and seismic data, for which we will present an overview, provide a good foundation from which to renew interest and investigation of western Newfoundland's onshore potential.

Examples of abrupt environmental change – ancient and modern – from a 2000 km transect across the Canadian Arctic Archipelago

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Four decades of fieldwork on the former Laurentide and Innuitian ice sheets in the Canadian Arctic Archipelago (CAA) have clarified their extent, chronology, and dynamics. The Laurentide and Innuitian ice sheets either approached or exceeded their all-time maximum during MIS 2, advancing seaward onto the polar continental shelf – possibly nourished by a split jet stream and buttressed by landfast sea ice. Ongoing seafloor mapping will clarify the offshore extent and chronology of these margins. New perspectives include: (1) the rapid and late MIS 2 buildup of both the northwest Laurentide and Innuitian ice sheets; (2) their primary ice divides and ice streams that delivered deep-draft icebergs that scoured the Arctic Ocean seafloor; (3) the role of former Antarctic-scale ice shelves during both the buildup and catastrophic breakup of land-based ice, notably in the western Arctic; (4) the chronology of deglaciation that includes an early phase of regional retreat closely aligned with MWP-1A followed by; (5) a Younger Dryas stabilization and readvance in the western CAA that serves as an analogue for potentially catastrophic, modern ice sheet collapse. A pan-archipelago sea level record spanning deglaciation to modern (>2000 ^{14}C dates) clearly delineates zones of modern emergence and submergence that complement the ice sheet history. Numerous examples of abrupt environmental change characterize Arctic Canada but perhaps the most overlooked is the ongoing demise of the Ellesmere Island Ice Shelf, the oldest sea ice in the Northern Hemisphere. Once used as a sledging platform by late 19th century explorers - when it covered 10 000 km^2 - it is now reduced to a few precarious fragments. Arctic environmental change now envelopes the full spectrum of the cryosphere (including glaciers, sea ice and permafrost) through to its ecology and human habitation. Perspectives based on long-term records of environmental variability are vital because they place modern change and their underlying processes in a meaningful context that should inform public policy (IPCC 2014).

Modeling change: benefits and limitations of climate projections for adaptation planning

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As concerns surrounding climate change grow, so does demand for reliable information on likely impacts. Climate models are the primary tool available to provide this information. However, while these models have provided considerable insight into the workings of the climate system, their capacity to inform adaptation planning remains limited. In order to effectively use climate projections, stakeholders must become familiar with the limitations of these models and their output, and reframe their questions (and potentially their decision-making strategies) to better reflect model capacities. Towards this end, the capabilities and limitations of the latest model products are presented, along with concrete examples of their potential use.

Magmatic signatures encrypted in the dolomites of the Esino and Breno formations in central southern Alps: a comparison with the St. George Group dolomites in western Newfoundland, Canada

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Petrographic examinations identified three generations (dolomicrite D_1, eu- to subhedral crystals D_2 and fracture filling anhedral saddle dolomite D_3) of dolomites that occur as both replacement and fracture-filling cements in the Esino and Breno formations. The near-micritic grain size coupled with low mean Sr concentration (76 ± 37 ppm) of D_1 indicates an early dolomitization of shallow burial environment at near-surface conditions. The larger crystal sizes, homogenization temperatures (108 ± 6°C and 111 ± 14°C, respectively) of primary two-phase fluid inclusions, and estimated salinities (23 ± 2 eq wt% NaCl and 20 ± 4 eq wt% NaCl, respectively) of D_2 and D_3 suggest that they formed at later stages under mid- to deeper burial settings at higher temperatures from basinal fluids of higher salinity. This is consistent with their high Fe (1460 ± 900 ppm and 4462 ± 6888 ppm, respectively), Mn (556 ± 289 ppm and 1091 ± 1183 ppm, respectively) and low Sr contents (53 ± 31 ppm and 57 ± 24 ppm, respectively).

The estimated $\delta^{18}O$ values of the parent dolomitizing fluids of D_1, D_2, and D_3 suggest that D_1 was formed at temperature ~40–50°C in shallow burial setting with possible contributions from volcanic-associated fluids, which is consistent with its abnormal high Fe (4438 ± 4393 ppm) and Mn (1219 ± 1418 ppm) contents, and that D_2 and D_3 developed from fluids of similar isotopic compositions at higher temperatures of deeper burial settings. The similarity in shale-normalized REE patterns, Ce $(Ce/Ce^*)_{SN}$ and La $(Pr/Pr^*)_{SN}$ anomalies of the investigated carbonate generations supports the genetic relationship between the dolomite generations and their calcite precursor. Positive Eu anomaly, coupled with fluid-inclusion gas ratios (N_2/Ar, CO_2/CH_4, Ar/He) and halogen molar ratios (F/Cl and Cl/Br) suggest an origin from diagenetic fluids associated with volcanic activities or circulated through the co-occurring volcanic lenses.

In the St. George Group dolomites in western Newfoundland, earlier studies have also identified three generations with similar crystal sizes and shapes but different cathodoluminescence features in D_2 and D_3 comparing to their counterparts of the Esino and Breno formations. The compositions of major, minor and trace elements, O-isotopes, REEs, fluid-inclusion gases, and halogens in the St. George Group dolomites in western Newfoundland suggest they are typical hydrothermal dolomites developed mainly by basinal fluids without magmatic contributions.

Current trends of coastal evolution in Newfoundland and Labrador, Canada

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Geological, biological, and geographic characteristics are all partly responsible for variations in coastal sensitivity to environmental change in Newfoundland and Labrador. If the climate changes, there will be a modification of the impact of key variables that influence the evolution of coastal environments. For example, rising rates of relative sea level, changes in storm frequency and intensity, the extent and duration of sea-ice cover, and alterations in precipitation will change the geomorphic evolution of coastal environments. It is important to have an understanding of how coastal areas change and will change, as they have cultural, environmental, and economic significance, and critical infrastructure has been built there.

In order to better understand the evolution of coastal environments in Newfoundland and Labrador, and their vulnerability to flooding, erosion, and slope movement in the future, the Geological Survey of Newfoundland and Labrador initiated a coastal monitoring program in 2011. This program uses and extends a network of coastal monitoring sites established by the Geological Survey of Canada, which allows for a longer period of data evaluation. There are 112 beach and cliff sites in the program.

Results from this program indicate that erosion rates are variable, and can be rapid. High rates of cliff erosion have been measured in Point Verde, Holyrood Pond, and Point au Mal, whereas lower rates have been measured in Kippens, Sandy Cove, Norris Point, and in Conception Bay South. Dunes on the southwest coast in the Sandbanks and J.T. Cheeseman Provincial parks are also experiencing rapid rates of erosion. Coastal erosion is caused primarily by wind, waves, groundwater flow, and surface run-off. The effect of these agents on the evolution of coastlines is likely controlled by the interaction of factors that include sediment composition, beach, bluff, and nearshore geometry, orientation of the coastline towards the predominant storm direction, sediment budget, vegetation, and rate of relative sea level rise.

Effects of pH and grain size of porous media on the transport of titanium dioxide nanoparticles in water-saturated sand columns

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Nanoparticles, mineral colloids, and natural organic matter (e.g., humic substances) have important environmental functions in soil and groundwater. These small particles may occur naturally or can be produced unintentionally or intentionally engineered. Nanoparticles have an important role in pollutant chemistry. Nanoparticles potentially pose risks to aquatic ecosystems as well as human health. Titanium dioxide nanoparticles are toxic to human cells and aquatic organisms. In order to understand the fate and distribution of nanoparticles after they are released to the environment, it is important to understand the factors that influence nanoparticle transport and mobilization in the vadose zone and groundwater.

This research examined how grain size of the transport media influences the transport of titanium dioxide nanoparticles using bench-top column experiments. Pure quartz sand with size ranges of 0.250 to 0.355 mm (fine sand) and 0.600 to 0.710 mm (coarse sand) was used to pack the columns. Titanium dioxide particle suspensions prepared at a concentration of 20 mg/L with or without Xanthan gum (a surfactant) were injected into the columns at pH 5 and pH 9, and the effluents from the columns were collected with a fraction collector. A spectrophotometer was used to measure the absorbance of the influent as well as the effluent samples in order to quantify particle concentration. The results of our column experiments showed that there is no significant change in the effluent when Xanthan gum was used, on the other hand without using the Xanthan gum the normalized effluent concentration (C/C_0) of titanium dioxide particles in the coarse sand columns at pH 5 was close to 0 whereas at pH 9 it was near 90%. At pH 9 without using the Xanthan gum, the normalized effluent concentration (C/C_0) for the fine sand column gradually increased and reached its maximum at 4.5 pore volume (V/V_p) whereas for the coarse sand column the normalized effluent concentration (C/C_0) sharply increased and reached its maximum at 2.5 pore volume (V/V_p). Our results indicate the importance of pH and grain size on nanoparticles transport.

Paladin Energy's Michelin Uranium Project status and geology, Labrador, Canada

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Paladin Energy, through its wholly-owned subsidiary Aurora Energy, holds mineral rights to 945 km^2 in the Central Mineral Belt of Labrador, Canada. Paladin owns and operates two open pit uranium mines in Africa, with Langer Heinrich in Namibia and Kayalekera in Malawi. Despite weak uranium prices since March 2011, Paladin's objectives for the Michelin Project are to (1) expand its existing uranium resources in the region through a five-year exploration program, and (2) to develop Michelin in the 2020–2025 timeframe as a long-life mining and milling operation, subject to economic viability and regulatory approval.

Paladin's Michelin deposit in Labrador is located 140 km north of Happy Valley-Goose Bay and 40 km southwest of Postville. Paladin's uranium resources in the Central Mineral Belt of Labrador are contained in six deposits (Michelin, Jacques Lake, Rainbow, Nash, Inda, and Gear) for a total of 139M lb U_3O_8. Michelin contains the bulk of the resources with 107M lb U_3O_8 grading 0.1%. It is the fourth largest uranium deposit in Canada; however, uranium grades are relatively low. The Michelin deposit is about 1200 m long, 5 to 50 m thick, and has been drilled to depths of 800 m. The deposit strikes N60˚E, dips 55˚SE and the thicker core of the deposit plunges 60˚SW. Uranium mineralization occurs as three en echelon lenses slightly discordant to stratigraphy. Engineering studies show that the upper third of the deposit could be mined by open pit methods and the rest by underground mining at uranium prices >US$70/lb U_3O_8. Metallurgical testing indicates acid leach recoveries of 85 to 90%.

The Michelin uranium deposit is hosted in strongly foliated felsic volcanic rocks of the Lower Proterozoic Aillik Group (ca. 1850 Ma). The host rocks are intercalated with finely and coarsely porphyritic rhyolites with quartz and K-feldspar with minor plagioclase, calcite, biotite, hornblende, pyroxene, magnetite and hematite, and traces of titanite, apatite, and zircon. The volcanic package has been intruded by equigranular and porphyritic granite and granodiorite dykes and plutons dated at 1650 Ma. Diorite and gabbro dykes cut the felsic volcanic rocks and post-date uranium mineralization. The Michelin host rocks were subject to intense sodic metasomatism, with replacement of K-feldspar by albite and biotite by sodic amphibole and sodic pyroxene. Quartz phenocrysts show dissolution textures and are partially replaced by albite. Pink to red coloration of mineralized rocks is caused by finely disseminated hematite. Carbonate and sulphide minerals are uncommon and typically comprise <1% of the ore. Uranium minerals are finely disseminated and along grain boundaries with

grain sizes of 5 to 10 microns. The dominant ore mineral is uraninite in albite, aegirine, titanite, and zircon, with lesser uranophane, brannerite, and coffinite.

Role of mudstones and shales in the localization, genesis, and palaeo-environment of volcanogenic massive sulfide (VMS) deposits of the Tally Pond volcanic belt, central Newfoundland, Canada

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The Cambrian Tally Pond VMS belt in central Newfoundland contains numerous VMS deposits and prospects associated with metalliferous mudstones. Deposits in the belt are bimodal felsic VMS deposits that are both, base metal- (e.g., Duck Pond, Boundary) and precious metal-enriched (Lemarchant). At the Lemarchant deposit, hydrothermal mudstones are stratigraphically and spatially associated with mineralization: they cap the mineralization, are interlayered with exhalative barite, and underlain by rhyolite domes and/ore breccias, as well as interlayered with post-mineralization pillow lavas. The Duck Pond and Boundary deposits are also associated with black shales, but their relationships are spatial and less obvious, and may not be genetically related to mineralization. Metalliferous mudstones at Boundary West and Old Camp predominantly occur at or adjacent to the contact of the footwall felsic and the hanging wall mafic volcanic rocks and represent a distal equivalent to the mineralized horizon at Boundary. Other sampled Tally Pond belt prospects include Keats Pond, South Moose Pond, North Moose Pond, Duck West, Cooks Town, Higher Levels, and Beaver Lake, which also have occurrences of metalliferous mudstones and shales associated with felsic and/or mafic volcanic units. In some cases, there is also an immediate association of sulfide mineralization with mudstones.

The sulfide-rich mudstones of the Tally Pond belt represent a hiatus in the volcanic activity, where the deposition of hydrothermal matter dominated over the abiogenic background pelagic sedimentation. Lithogeochemical signatures distinguish between whether the mudstones are predominantly hydrothermal or detrital (i.e., non-hydrothermal). Upper Cambrian to Lower Ordovician black shales from Bell Island in eastern Newfoundland were utilized as an example for detrital sediments. Hydrothermal mudstones, like those at Lemarchant, have hydrothermal signatures with elevated Fe/Al and base-metal values, have shale- normalized negative Ce- and positive Eu anomalies, and Y/Ho ~27, indicative of deposition from high temperature (>250°C) hydrothermal fluids within an oxygenated water column. The presence of barite in the mudstones and massive sulfides suggests free SO_4^{2-} in the water column and supports precipitation under oxygenated conditions. Mudstones and shales sampled from other Tally Pond prospects have more variable signatures ranging from hydrothermal (signatures as above) to non-hydrothermal black shales (no positive Eu anomalies) with detrital constituents that were deposited under partially anoxic conditions (flat REE-patterns), and to those that have mixed lithogeochemical values. Accordingly, mudstones from those areas with a Lemarchant-like hydrothermal and vent-proximal character might be better exploration targets than those mudstones and black shales that seem to have predominantly detrital and less hydrothermal contributions.

Possible correlatives of the Bull Arm Formation: preliminary lithogeochemistry for mafic volcanic rocks from the Bonavista Peninsula northeastern Newfoundland, Canada

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The Bonavista Peninsula is underlain predominantly by Neoproterozoic siliciclastic rocks comprising two distinct depositional basins. The Spillars Cove–English Harbour fault zone is a regional tectonic boundary that demarcates the western extent of the marine and deltaic, Conception, St. John's and Signal Hill groups. Shallow marine to fluvial rocks of the Rocky Harbour and Crown Hill formations (Musgravetown Group) occur west of the fault zone. The Bull Arm Formation is a dominantly volcanic assemblage found near the base of the Musgravetown Group. Three, potential Bull Arm-equivalent volcanic suites crop out on the Bonavista Peninsula. The approximately 2-km-wide Plate Cove volcanic belt comprises mafic, intermediate, and felsic volcanic and volcaniclastic rocks, is fault-bound to the east and west, and extends more than 20 km southward from Plate Cove East.

In the Sweet Bay area (west of the Plate Cove volcanic belt), plagioclase glomerocrystic basalt and intercalated red pebble conglomerate unconformably overlie, or are in fault contact with, shoaling upward marine siliciclastic rocks of the upper Connecting Point Group. These volcanic rocks are therefore possible correlatives of the Bull Arm Formation. Vesicular to amygdaloidal basalt exposed at Dam Pond, approximately midway between Catalina and Upper Amherst Cove (central-eastern Bonavista Peninsula), has been previously correlated with the Bull Arm Formation. It is overlain by green-grey siliceous rocks that have been assigned by previous workers to either the Rocky Harbour or the Big Head formations.

Lithogeochemical results for 22 samples of mafic volcanic rocks from these three distinct stratigraphic settings on the Bonavista Peninsula are presented. Mafic volcanic rocks of the Plate Cove volcanic belt are transitional to (weakly) calc-alkaline basalts with variable Th/Nb and La/Nb relationships and were derived from a lithosphere-contaminated, slightly enriched, E-MORB-like, shallow mantle source. Plagioclase porphyritic basalts from three prominent headlands in the Sweet Bay area are evolved, calk-alkaline basalts with well-developed negative HFSE anomalies and show the highest degree of lithospheric recycling. The basalts exposed at Dam Pond, however, have distinct ocean island basalt-like chemistry with minor lithospheric input as indicated by supra-asthenospheric Th/Nb values and are clearly not correlative with the transitional arc-like rocks of the Plate Cove volcanic belt exposed 30 km to the west.

Understanding habitat in a changing ocean: modeling the distribution of Atlantic Wolffish

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The global increase of atmospheric greenhouse gases contributes to rapid changes in coastal and marine systems, including temperature, acidity, circulation, stratification and oxygen concentration. As conditions change, critical marine habitats may shift, deteriorate, or disappear completely. Understanding current and future changes in our oceans can help managers predict species distributions and support conservation and resource management efforts.

To explore how rare species can be impacted by such changes in coastal Newfoundland, our study focuses on Atlantic Wolffish habitat in Conception Bay. Since the 1980s, the Atlantic Wolffish has declined significantly in abundance and occupied area, primarily due to fisheries bycatch. Following an estimated loss of 60% of the mature population, the Atlantic Wolffish was listed under the Species at Risk Act in 2003. Due to the narrow preferred temperature range (0 to 4°C) and reduced population size, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recognizes Atlantic Wolffish as a species that may be vulnerable in a changing climate. Recent research on temperature acclimatization of fish also suggests that cold water species are among the most impacted, even by small temperature changes.

This project combines movement data from tagged Atlantic Wolffish, high resolution bathymetry from multibeam sonar, underwater videos, sediment samples and moored thermographs to develop habitat maps and predictive distribution models. The study area for this project includes 30 km^2 of coastal waters along the northeastern side of Conception Bay, Newfoundland and Labrador. Of particular interest is an area near Bauline, where Atlantic Wolffish have been recorded pairing, feeding, and guarding developing eggs in dens formed by coastal bedrock and boulder features. Hourly temperature records from thermographs installed near wolffish dens at 2 m and 24 m depth indicate that this area experiences high temperature variability. In 2013, 30% of temperature readings at 24 m exceeded 4°C and 10% exceeded 8°C, suggesting that current temperatures may already place Atlantic Wolffish at the upper range of their tolerance. Underwater videos, sediment samples, and the analysis of the multibeam sonar from Conception Bay indicate that the bedrock and boulder features necessary for wolffish dens are rarely present at greater depths where water is colder and temperatures are more consistent throughout the year. If temperatures continue to rise, the areas used by Atlantic Wolffish for denning and nursery habitat may become inaccessible.

This presentation will discuss possible changes to Atlantic Wolffish habitat and the tools we are using to understand, monitor, and predict species distribution in a changing ocean.

Comparing the effects of temperature and oxyge exposure time on decomposition in boreal peatlands

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Boreal peatlands store organic carbon for millennia, mainly due to low rates of decomposition. We used a series of biochemical indicators, including amino acids, carbohydrates, and lignin phenols, to assess the extent of decomposition in peat cores from the West Siberian Lowland, Russia, and the James Bay Lowland, Canada. Spatial and temporal variability in the extent of decomposition were used to determine the relative influence of temperature and oxygen exposure time on peat decomposition. First, a latitudinal transect of peat cores from the West Siberian Lowland was analyzed. This exploited spatial variability in temperature and oxygen exposure time: mean annual temperature at the northern sites in the transect were as much as 7°C cooler than the southern sites, but the southern cores had higher peat accumulation rates, resulting in faster burial beneath the water table and lower oxygen exposure time. The northern cores were more extensively decomposed, indicating the importance of oxygen exposure time in decomposition. A core from the James Bay Lowland experienced temporal variability in environmental conditions during the last 7000 years. Oxygen exposure time (indicated by a reconstruction of the water table depth) was highest in a 100-cm section in the middle of the core, which was significantly more decomposed than peat above and below. Warmer temperatures during the Medieval Climate Anomaly and Holocene Climatic Optimum did not appear to have any effect on the extent of decomposition of peat deposited during these periods. Both spatial and temporal comparisons indicate oxygen exposure time is an important control on peat decomposition, while temperature appears to be of secondary importance.

Study of individual soil organic horizons cannot predict the elevated temperature sensitivity of respiration observed in warmer climate boreal forests

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Soil is the largest reservoir of terrestrial carbon compared to the atmosphere and vegetation. To predict the impact of climate warming on the global carbon cycle and possible feedbacks, we must address the dynamics of soil organic carbon (SOC), particularly in high latitude ecosystems where >31% of Earth's SOC reservoir resides. Previous studies have demonstrated a relationship between soil bioreactivity (respiration per unit C at constant temperature) and the temperature sensitivity of SOC mineralization (typically reported as Q_{10}, which represents change in C decomposition rate to a 10°C temperature increase). Few studies, however, have addressed the role of in situ climate warming or the influence of soil profile substrate availability or exchange on the temperature sensitivity of soil respiration. Does a warmer climate history yield SOC that elicits a more temperature sensitive respiratory response? Can the respiratory response of individual organic soil horizons or their bioreactivity be used to predict the response of an organic soil profile?

To address these questions we conducted three parallel incubations experiment with (a) intact organic profiles, (b) isolated organic horizons of the same soil, and (c) profiles rebuilt from the isolated organic horizons. Soil samples were collected from podzolic boreal forest sites in two regions similar except a mean annual temperature difference of 5.6°C. The soils were incubated at 5°C, 10°C, and 15°C for 438 days with soil respiration measured at 6 time points. The experiments provided a way to compare respiratory responses of soil horizons with (intact and rebuilt) or without (isolated horizons) the exchange of substrate across horizons typical of an intact soil profile.

Cumulative respiration was greater in the cooler relative to the warmer region soils, regardless of incubation temperature or experiment type indicating that the warmer climate soils were indeed less bioreactive. We found that Q_{10}, however, was influenced by how the organic horizons were incubated suggesting that microbial access to different soil C pools, represented by the different organic horizons, can regulate the Q_{10} of soil respiratory losses. The respiratory response of the individual horizons incubated in isolation could not predict the significant climate history effect observed in the more realistic rebuilt and intact organic profiles. This indicates that factors beyond soil C composition, or its bioavailability, regulate the Q_{10} of soil respiration in these boreal organic soils. Therefore, future investigations need incorporate the study of intact soil profiles as well as factors, other than the "quality" of individual soil pools, such as soil microbial substrate availability when assessing the temperature responses of soil respiration.

Age and petrochemistry of rocks from the Aucoin gold prospect (NTS 13N/6) Hopedale block, Labrador: Late Archean, alkali monzodiorite-syenite hosts Proterozoic orogenic Au-Ag-Te mineralization

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The Aucoin gold prospect is located 70 km west of the community of Hopedale in the southwest Archean Nain craton of Labrador (NTS 13N/6), near the southern extremity of the Torngat orogen. Mineralization consists of anastamosing, discontinuous, NE- and NW-trending orogenic quartz veins (typically <20 cm wide) proximal to and within the ≤5 m thick, SE-trending shear zone associated with chlorite-ankerite-epidote-talc ± phengite alteration. Elevated gold correlates with silver and tellurium, reflected by argentiferous electrum and petzite (Ag_3AuTe_2) occurring as inclusions in sulphides and in rutile replacing ilmenite. Alteration and mineralization is hosted in four rock types. The oldest is massive to weakly foliated, medium-grained, alkalic clinopyroxene-hornblende syenite that is strongly enriched in incompatible elements. The syenite is intruded by sinuous, non-chilled dykes of medium-grained, silica-undersaturated, clinopyroxene-hornblende monzodiorite that has ocean island basalt (OIB) affinity. These rocks are intruded by a ≤50 m thick, irregular sill of medium-grained, silica-undersaturated, hornblende-porphyritic monzogabbro. The youngest rocks are thin (≤5 m), epidote altered and quartz-veined, northwest-trending diabase dykes tentatively assigned to the ca. 2235 Ma Kikkertavak swarm.

U-Pb Shrimp zircon geochronology indicates that the syenite intruded the Mesoarchean Maggo Gneiss at ≤2567 ± 4 Ma. This is contemporaneous with granulite facies metamorphism and granitic magmatism reported in the Hopedale Block, corresponding with an interval interpreted to record late Archean reworking along the Saglek-Hopedale boundary zone subsequent to amalgamation of the Nain craton. $^{40}Ar/^{39}Ar$ step-heating analysis of phengite from altered syenite yielded a plateau age of 1873 ± 6 Ma, broadly corresponding with early orogenic events in Torngat orogen and collision of the southeast Churchill Province core zone with Nain Province (ca. 1870–1850 Ma). This Paleoproterozoic interval is widely recognized as a global, "gold fertile" metallogenetic time and highlights the potential for comparable mineralization along the Torngat orogenic front.

The international climate change policy process – a brief history and the current state of play

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The United Nations Framework Convention on Climate Change (UNFCCC), one of the three Conventions adopted at the Rio Earth Summit in 1992, has the ultimate aim to "…stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Given that there was a lot less scientific evidence at the time of its adoption, countries aspired to fulfil this goal in the face of scientific uncertainty. Several important milestones have been achieved since the Convention was ratified, including the adoption of the Kyoto Protocol, and many important but less well-known decisions have been made to strive for greater ambition and action on all levels. But the international response has not kept pace with the mounting scientific evidence over the past two decades. Although many countries have taken steps to reduce greenhouse gas emissions, a gap remains between what science indicates is necessary to avoid catastrophic climate change, and countries' actions. Present-day emissions are higher than they have ever been, and global temperatures are on the rise: 2014 was the 38th consecutive year with a global temperature above the 20th century average, and the hottest year ever measured. Given this disparity, as well as the increasing scientific evidence on what is at stake, mounting pressure from citizens, religious leaders, an increasing engagement of private sector leaders and businesses, governments have set themselves a deadline to agree a global treaty to address climate change, that includes and specifies actions from all nations. The 21st Meeting of the Parties to the UNFCCC (COP 21) will take place in Paris, in December of this year. In addition to a legal treaty, countries will also make crucial decision on current climate change actions from now and until 2020, a financial package to support developing countries' action to reduce emissions and adapt to the impacts of climate change, and the so-called Intended National Determined Contributions (INDCs), which are actions that countries intend to take under a global agreement from 2020.

Adaptation to climatic impacts: a local perspective

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Whether it is in the face of extreme events in the short term or environmental changes developed over time, adaptation to climate variability and impact on Atlantic coasts is essential to human health. The ways in which a community responds to climatic events depends on a number of local factors, including physical geography, economics, history, and culture. One approach recently initiated is a citizen science focused project to encourage Newfoundland coastal communities to experience, observe, record and input data into a GeoWeb platform for analysis by researchers. The project provides individual communities with a coastal field excursion as an introduction into methods of observation and data collection. Participants will learn to identify types of coastline (soft, consolidated, rock type), geomorphology and processes (wave, storm, frost action) and about marine pollution as well as debris distributed along coastal areas.

The intention of the project is threefold: (1) to re-engage citizens to participate in nature from the experiential perspective of scientific observer, (2) to create data for a Geo Web site accessible to organizations, planners and decision makers to contribute to future risk management, monitoring, policy and additional educational initiatives, and (3) to provide communities with a deeper knowledge about the changes occurring in their local area that might lead to better response to short and long term climate impact within their region.

10 climate change myths (geologists' edition)

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To paraphrase Churchill: "Never in the field of human conflict was so much said by so many who knew so little about the issue that could affect so many." I will try to cut through some of the most persistent myths and half-truths surrounding climate change, with particular attention to those that may be of interest to Earth scientists. These include claims about the inability of science to understand and predict climate, questioning the very existence of climate change, attributing it to the natural factors, mixing up weather with climate, and misleading with statistics. I will also briefly touch on the social angle of the debate, including: God and climate, conspiracy theories, and Canadian claims ("Kyoto was unfair to Canada, we are responsible for only 2% of global emissions, we have a plan to combat climate change").

Influence of variogram and geostatistics models on 3D reservoir simulation results

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From basin exploration to reservoir simulation, models play a very important role in understanding and predicting a reservoir's geological and geophysical information and production performance. A detailed and reliable geological model which integrated stratigraphy information and rock properties collected by seismic or logging tools can be used to guide the drilling path and make a more scientific field development plan. Since field data are usually limited, probabilistic models may be used to represent the formation and rock properties in locations where seismic survey and logging data are not available. Geostatistics is a branch of statistics focusing on spatial or spatiotemporal datasets and was developed originally to predict probability distributions of ore grades for mining operations. The data generated in geostatistics is correlated spatially or temporally. The key objective of geostatistics is to manage the spatial relationship and balance the weight between local mean and global mean. Common models include stratigraphy modeling, geophysics modeling, structural framework modeling, property modeling and geostatistic modeling, upscaling, and reservoir modeling.

This paper shows a case study that indicates the influence of variograms and geostatistic models on 3D reservoir simulation results. Based on the same porosity data used as constraints, different geostatistics realizations will yield different reservoir production performance. Numerical simulation is used in this paper to demonstrate this and to compare results using parameters like lag distance, separation, search ellipsoid, etc., to create geostatistic realizations and compare production performance indices like oil flow rate, gas to oil ratio and water cut. The potential updating of geo-models with real-time data is also discussed.

U-Pb, Hf, O, and Nd constraints for the Kiruna apatite iron oxide deposits, Sweden

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The world-class iron deposits in the Norrbotten region of northern Sweden (e.g., Kiirunavaara) are considered the type locality of apatite iron oxide (IOA) deposits, but whose origin has been debated for several decades. Two contrasting theories for their formation suggest that these iron ores were emplaced through either: (1) immiscible silicate liquid–iron oxide melts; or (2) that the iron was transported and emplaced by hydrothermal fluids. Similarities with the iron oxide–copper–gold (IOCG) class of deposits have been proposed based on the latter. Here, for the first time using spatially well constrained samples, detailed in situ U–Pb dating of accessory minerals and tracer isotope geochemistry on the mineral and whole-rock scale are combined to provide a better understanding of the ore genesis of these ore deposits.

Our U–Pb dates of zircon agree with previously reported dates (1900 to 1880 Ma), but our data provide a more accurate time frame of 1884 to 1880 Ma for the emplacement of the metavolcanic country rocks that host the main ore body at Kiirunavaara. Syenite and granite that intruded the footwall of the deposit have been dated at ca. 1880 and ca. 1874 Ma, respectively. Zircon crystals that were dated from the ore main body are similar to the granite intrusion (ca. 1874 Ma).

The oxygen and Hf isotopic composition has also been determined in situ on the zircon grains that were previously dated in these samples. Zircon grains from metavolcanic host rocks and the granite and syenite intrusions have $\delta^{18}O$ ~3‰, and εHf_i = -6 to -10), whereas the zircon grains from the ore samples have $\delta^{18}O$ ~7‰, and εHf_i = -5 to +3) and are distinctly different. Whole-rock Sm-Nd data shows a similar contrast with εNd of ~-6 for host rocks and εNd ~-3 for the ore.

The U–Pb data suggests that the ore formed a few million years after the metavolcanic host rocks were emplaced, but close to the emplacement of the granite intrusion. The differences observed in all isotopic systems points towards an origin for the iron ore distinct from its magmatic host rocks. Furthermore, the low oxygen isotopic values strongly indicate the involvement of high-temperature hydrothermal fluids. Therefore, a magmatic-hydrothermal fluid system, driven by the heat produced by the intrusions, seems most likely to have mobilised iron and concentrated it in these massive iron oxide deposits.

Influence of humic acid on the dispersion and transport of $nTiO_2$ particles in quartz sand and ferric oxyhydroxide-coated sand media

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The increasing applications of synthetic nano-materials and our very limited knowledge on their potential environmental and health effects have caused increasing public concerns. Many engineered nanoparticles such as $nTiO_2$ are highly reactive and may cause extensive damage to eco-systems and people's health. To evaluate the scope of nanoparticle contamination in soil and groundwater, information on how nanoparticles are dispersed and transported in subsurface environment is essential.

Natural organic matter such as humic acid (HA) are ubiquitous in soil and groundwater and are frequently reported for effectively stabilizing nanoparticle suspensions by steric repulsion and electrostatic effects. However, the knowledge of how HA influences the behaviors of nanoparticles is not clear. Besides, as most of studies on nanoparticle transport were conducted in well-defined porous media, they do not accurately represent the variety of mineral surface types and surface charge heterogeneities encountered in real soil systems. The objective of this study is to investigate the influence of HA on the stability and transport of $nTiO_2$ particles in ferric oxyhydroxide-coated quartz sands media. Batch experiments indicated $nTiO_2$ adsorption to sands (clean sands and Fe-coated sands) were generally lower with the presence of HA at pH 5 and pH 9. Stability tests showed that $nTiO_2$ suspensions were susceptible to aggregation at intermediate HA concentrations ranging from 0 to 1ppm, which can also be reflected by the changes of zeta potential and hydrodynamic diameters. Transport experiments showed that in the absence of HA, mobility of $nTiO_2$ was lower at acidic pH than that at alkaline pH. A low concentration of HA substantially enhanced $nTiO_2$ transport in an Fe-coated sand column due to increased electrostatic repulsion and steric effects between $nTiO_2$ and the sand grains.

Origin of carbonate cements in Flemish Pass Basin sandstone reservoirs: controls on porosity development

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The Flemish Pass Basin is a deep water basin located on the continental passive margin of the Grand Banks, approximately 400 km east of St. John's, Newfoundland, which is currently a target of hydrocarbon exploration. Calcite cement acts as a main factor controlling reservoir quality in the Flemish Pass sandstones, and this study investigates the origin of carbonate cements in the Ti-3 Member, a primary clastic reservoir interval of the Bodhrán Formation (Upper Jurassic) in the Flemish Pass Basin.

The Ti-3 sandstones are quartzarenites to sublitharenites, and contain a high volume of intergranular poikilotopic (300–500 μm) and minor fracture-filling (0.375–2 mm) calcite cements. Grain contact feature and high minus-cemented porosity (or intergranular grain volume, IGV) suggest that the calcite cements precipitated in an early stage of the diagenetic history. Petrographically, these cements postdate feldspar leaching process, and were followed by the corrosion of quartz grains. The intergranular cement exhibits bright to moderate luminescence under cathodoluminoscope with non-concentric zoning. All-liquid inclusions are common in the core of the intergranular calcite cement crystals, while primary two-phase (liquid and vapor) fluid inclusions occur along the rims of calcite crystal in the intergranular calcite cements and in fracture-filling calcite cement. Two-phase fluid inclusions in intergranular calcite cements have mean homogenization temperatures (T_h) of 70.2 ± 4.9°C and salinity estimates of 8.8 ± 1.2 eq. wt.% NaCl, while inclusions in fracture-filling calcite cement have the higher mean T_h of 136.5 ± 1.8°C and salinity estimates of 10.0 ± 1.8 eq. wt.% NaCl. Fluid-inclusion gas ratios (CO_2/CH_4 and N_2/Ar) are consistent with diagenetic fluids that originated from modified sea. The profiles of the shale normalized REE (REE_{SN}) of calcite cements are similar and exhibit slightly negative Ce anomalies. The $\delta^{18}O$ and $\delta^{13}C$ isotopic mean values of calcite cements are -8.31 ± 1.23‰, VPDB and -3.02 ± 1.32‰, VPDB, respectively. The combined evidences from petrographic, microthermometric and geochemical analyses suggest that (1) the intergranular calcite cements precipitated from diagenetic fluids of mixed marine and meteoric waters in suboxic conditions; (2) $\delta^{13}C$ values of intergranular calcite cements reflect influence of organic matter, associated with the dissolution of bioclasts or fossil fragments within sandstone beds or adjacent silty mudstones; and (3) circulating hot basinal fluids were probably involved in the forming of the intergranular calcite cements.

Over 75% of initial porosity loss in Ti-3 sandstones was due to early calcite cementation. The reopening of secondary porosity (mostly moldic, enlarged pores) and throats by major calcite dissolution was the key process in improving reservoir quality. Highly porous horizons occur below silty mudstone beds with coal stringers, which suggest that the acid was released after organic maturation and that dissolution of calcite by organic acids played a significant role in porosity development.

