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# GAC - Newfoundland and Labrador Section Abstracts: 2019 Spring Technical Meeting

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# Geological Association of Canada, Newfoundland and Labrador Section

## ABSTRACTS

*2019 Spring Technical Meeting*

St. John's, Newfoundland and Labrador

The annual Spring Technical Meeting was held on February 18 and 19, 2019, in the Johnson GEO CENTRE on scenic Signal Hill in St. John's, Newfoundland and Labrador.

The meeting kicked-off Monday evening with a Public Lecture entitled "Meteors, Meteorites and Meteorwrongs of NL" by Garry Dymond from the Royal Astronomical Society of Canada. Tuesday featured oral presentations from students and professionals on a wide range of geoscience topics.

As always, this meeting was brought to participants by volunteer efforts and would not have been possible without the time and energy of the executive and other members of the section. We are also indebted to our partners in this venture, particularly the Alexander Murray Geology Club, the Johnson GEO CENTRE, Geological Association of Canada, Department of Earth Sciences (Memorial University of Newfoundland), and the Geological Survey of Newfoundland and Labrador, Department of Natural Resources. 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 AND ALEXANDER PEACE
TECHNICAL PROGRAM CHAIRS
GAC NEWFOUNDLAND AND LABRADOR SECTION

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## Automatic microearthquake locating using characteristic functions in a source scanning method

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Microearthquake locating has broad application in monitoring volcanic activities or human-induced earthquakes. However, typically large amounts of data are involved and those data are quite noisy. Hence, an automatic procedure is needed that can accurately locate these microearthquake events. In this research, we tackle this problem by stacking Characteristic Functions (CFs) in the Source Scanning Algorithm (SSA). The CFs allow us to consider waveform characteristics such as amplitude and polarization in the locating problem; and the SSA allows us to search the solution space automatically with minimum computing effort. Furthermore, we use multi-scaled CFs to accommodate earthquake signals within a wide frequency band. We successfully locate synthetic events generated at 6km using the SIL Network in Reykjane Peninsula, SW Iceland. The SIL Network has a geometry of around 60 x 30 km. We also locate 215 events recorded by the same network with very similar results (less than 5% outliers with 80% of the result within an error of 2.5 km, 0.1s) to the manual picking method. In conclusion, stacking CFs in SSA is a noise-robust automatic method to locate microearthquakes in a reginal scale. It also avoids the need of manual phase picking and reduces human intervention.

## Identifying past and present life at a terrestrial site of serpentinization: the Tablelands, western Newfoundland, Canada

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Serpentinization, the hydration of ultramafic minerals, is hypothesized to occur on Mars as well as other planetary bodies including Jupiter's moon Europa, and Saturn's moons Titan and Enceladus. Serpentinization also occurs in terrestrial settings in ophiolites that can be considered analogues for these less accessible sites. The Tablelands is an example of a terrestrial analogue. The serpentinization process results in the production of highly reducing, ultra-basic fluids that cause a characteristic travertine deposit when these fluids emerge. The fluids at sites of serpentinization are rich in methane and hydrogen gas. The methane can be produced biotically or abiotically; therefore, its detection alone is insufficient evidence to indicate the presence of life. Affinity calculations were performed to identify other likely biochemical reactions that could be occurring at these sites to identify alternative products indicative of present life at active sites of serpentinization. The results from these predictive calculations indicated the oxidation of methane should be favoured at the Tablelands. This hypothesis was tested through a series of laboratory experiments using sediment and fluids containing native microbial communities from a spring at the Tablelands.

A microbial observatory was also created in 2017 by drilling three holes and inserting incubators into the subsurface. These incubators were left for a year to collect microbial communities that are representative of life in the subsurface. Extractions will be performed on these incubators to identify lipids that can be used to indicate the presence of life at these springs. Experiments will also be performed to better understand how these lipids degrade over time and how they are preserved. Together, these techniques will help identify biosignatures that could indicate present and past life at sites of serpentinization.

## A paleomagnetic study of ca. 580 Ma volcanic rocks near Grand Bank, Avalon Zone of Newfoundland, Canada, and implications for true polar wander in the Ediacaran

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Paleomagnetic studies suggest that Laurentia moved from the equator to the pole and then back again within ~60 Ma during the Ediacaran. Since plate tectonic speeds are not fast enough to allow this to happen, it has been hypothesized that inertial interchange true polar wander occurred, causing the Earth to tumble through 90° and then back again. To help test this hypothesis, this study provides new paleomagnetic data for ca. 580 Ma volcanic rocks of the Marystown Group collected near Grand Bank in the Avalon zone of Newfoundland. The volcanic rocks were studied with alternating field and thermal demagnetization which showed that remanence is carried mostly by magnetite rather than hematite. Seven sites provide stable remanence directions with mean tilt-corrected declination and inclination of 287° and 58° ($\alpha_{95}$ = 13°). The corresponding paleolatitude is 39° -12/+16. A positive conglomerate test, using rhyolitic

crystal-lithic tuff clasts from an agglomerate, shows that the magnetite-bearing clasts carry primary remanence. Magnetic polarity reversals are present within the section. The Marystown Group results, along with other stable paleomagnetic data from Avalonia, suggest that Avalonia remained at mid- to low-latitudes during the mid-Ediacaran.

## Geophysically constrained microplate fragmentation model and microplate-controlled evolution of Mesozoic basins – rifted North Atlantic borderlands, offshore Newfoundland, Canada

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Borderlands of offshore Newfoundland comprise a deformed collage of fault bound crustal blocks, assembled during the formation of the Pangaean supercontinent and closure of the ancient oceans in the Mississippian. Reactivation of these inherited terranes and structural fabrics occurred as the North Atlantic Ocean opened. At least three rift phases increased basin accommodation and are recorded by tectonostratigraphic sequences within the offshore Mesozoic basins. An intact tectonostratigraphic rift package will display: (1) A basal rift onset unconformity (ROU) under syn-tectonic units that thicken into fault zones; (2) Post-extension thermal subsidence dominated by back-stepping units; and lastly (3) Waning post-rift basin deepening deposits often associated with capping carbonate marker units e.g., Petrel, Marker-A, Rankin, Iroquois. These rifting phases were driven by global plate motions which include: (1) Late Triassic to Early Jurassic divergent motion between Africa and North America; (2) Middle Jurassic divergent motion between Newfoundland and Iberia; (3) Late Jurassic to Early Cretaceous oblique rifting of Newfoundland away from Baltica (including Ireland); and (4) Early Cretaceous to Late Cretaceous extension associated with the opening of the Labrador Sea and Baffin Bay and the separation of Greenland from North America.

Recent articles on dynamic plate modelling have made use of the open source plate tectonic modeling environment GPlates and led to interest in development of an updated 4-D dynamic microplate model. This project intends to deliver a dynamic tectonic model able to simulate the crustal block kinematics, and deformation patterns along the continental borderlands of offshore Newfoundland. The completed model will be geophysically constrained while infinitely expandable, improving our visualizations of the distribution and control of crustal blocks on the evolution of sedimentary basins. The preliminary results show an increased understanding of crustal block fragmentation is important in understanding stress/strain partitioning, basin evolution, and tectonostratigraphy along deformable continental margins, including Newfoundland and its conjugates.

## Geologizing the East Coast Trail: Could it be a candidate for a "classic rock tour"?

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In 2018, Geoscience Canada initiated a new series of thematic articles entitled Classic Rock Tours. The idea is to combine technical and historical context for well-known and geologically informative areas with practical advice that facilitates independent visits. We see such articles as educationally valuable, but also as a service to those who seek simply to combine recreation with some learning. The series commenced with an article about James Hutton's unconformity at Siccar Point in Scotland, and we hope soon to publish an article about hiking through the remarkable stratigraphic sequence of the Grand Canyon in Arizona. We are seeking ideas for future articles, but it is important to go beyond mere ideas, and actually complete such papers for submission to the journal. Ideas are the easiest part of the process!

Newfoundland's East Coast Trail, established through many years of hard work and volunteer effort, has become an important attraction for locals and visitors alike. It currently starts in the area near Bauline, Conception Bay, and extends around Cape St. Francis, right through the greater St. John's area, and then along the Atlantic coast to the area around Cappahayden. En route, it traverses late Precambrian (Cryogenian and Ediacaran) rocks of the Harbour Main, Conception, St. John's and Signal Hill groups, which collectively define the type area for the larger crustal province termed Avalonia. The trail also reveals much about glaciation, landscape evolution and modern coastal processes. There are few other places where such striking geological features conveniently coexist with an urban centre, and can be experienced so easily from a high-quality, accessible trail network. Since 2015, I have been trying intermittently to document interesting geological sites along several segments of the East Coast Trail, with an emphasis on the northeast Avalon. A short guidebook for a "Geohike" between the Flatrock area and Torbay, produced

by GAC Newfoundland, was an initial result from this work. This is probably one of the most interesting sections of the trail, but there is also great potential in the Cape St. Francis area, which has long been used by Memorial University for field-work training. The entire northern section of the East Coast Trail presents an ideal candidate for an article in the Classic Rock Tours series, and this is an obvious project for GAC Newfoundland and others to support. Four years ago, I might have seen it as something to try and pursue alone, but it is now very clear that completing it will require assistance from many others with greater knowledge of specific units and localities. Preparing such an account would not only be a contribution to GAC's scientific journal, but also a benefit for the Canadian and International geoscience communities.

## Investigating the role of Iberia and its interplay with the Newfoundland, Canada, and Irish offshore margins using plate reconstructions

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The tectonic evolution of the southern North Atlantic Ocean is a subject of increasing interest due to its continental margins playing host to several world-class frontier regions for oil and gas exploration. The Newfoundland-Iberia conjugate margin pair serves as one of the best studied non-volcanic rifted conjugate margin pairs in the world and is a topic of constant scientific debate due to its complex plate kinematic history and geological evolution. Recent adaptability of the GPlates freely available plate tectonic reconstruction software provides an excellent tool for gaining insight on complex geological problems. The ability to account for regions of deformation, integration of various geological and geophysical datasets, and the ability to calculate temporal variations in crustal thickness, strain rates, and velocity vectors provide an optimal environment for solving crustal-scale geological and geophysical problems. Several uncertainties remain regarding the plate kinematic history of Mesozoic Iberia, such as its position and orientation at the Triassic-Jurassic boundary and its Cretaceous displacement and rotation prior to the Pyrenean orogeny. The aim of this research is to investigate the role of Iberia during the formation of the southern North Atlantic and its interplay with the Newfoundland and Irish offshore margins using deformable plate tectonic reconstructions. The aim of this approach will be to divide various regions of Iberia into smaller continental fragments where appropriate and accounting for deformation within these regions. These deformable plate models will be integrated with potential field datasets and various geological datasets such as the orientation of Triassic structures and dykes originating from the Central Atlantic magmatic province (CAMP). The need for more complicated plate tectonic models of Mesozoic Iberia using detailed geological and geophysical constraints is necessary for satisfying geological observations in the Pyrenees and the role of Iberia during the breakup of the Pangean supercontinent and preceding oceanic sea-floor spreading.

## Potential for porphyry- and epithermal-style precious metal deposits in the Mira terrane of Cape Breton Island, Nova Scotia, Canada

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Numerous features indicate significant potential for precious metal deposits in the Mira terrane of southern Cape Breton Island, in particular, those in the broad class of epithermal Au(-Ag) and porphyry Cu(-Mo-Au) deposits. The Mira terrane is closely analogous to the Avalon zone of Newfoundland, which is experiencing increased exploration activity focused on these deposit styles, including extremely active exploration on the Burin Peninsula – notably at Big Easy (Cartier Iron) and Heritage (Puddle Pond Resources). Farther to the southwest, rocks of Avalon zone age host the Hope Brook Mine, the richest producing Au deposit in the late Neoproterozoic of North America to date. In the Newfoundland Avalon zone, metallogeny is clearly related to specific episodes of granitoid plutonism (at ca. 620 Ma, ca. 575–580 Ma and ca 565 Ma), and contemporaneous episodes of similar plutonism and associated volcanism are recognized in the Mira terrane (Coxheath Hills-East Bay Hills-Sporting Mountain belts, and Fourchu and Main-à-Dieu groups in the Coastal belt). Some workers have also made the analogy with more modern Andean or Cordilleran terranes with respect to the evolution of the broader Avalon terrane (Avalonia), an environment considered auspicious for these styles of deposit.

The Mira terrane hosts the former Coxheath Mine, a Cu-Au porphyry deposit within the ca. 620 Ma Coxheath Hills Pluton. This indicates strong potential for additional porphyry-style and related epithermal-type deposits,

although affiliated epithermal-type Au-Ag deposits have remained unrecognized in the broader Coxheath Hills-East Bay Hills-Sporting Mountain belts to date. However, both low- and high-sulfidation epithermal-style deposits can be cryptic. For example, some styles of low-sulfidation veins (e.g., low vein density peripheral occurrences) can go unrecognized as such during prospection, and high-sulfidation systems can have substantial volumes of relatively Au-barren alteration surrounding a smaller auriferous core.

## Early Avalonian arc paleogeography: preliminary paleomagnetism and $^{40}Ar/^{39}Ar$ geochronology of Neoproterozoic units, Burin Peninsula, Newfoundland, Canada

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We report a reconnaissance paleomagnetic survey of volcanic and associated intrusive rocks of the Burin Group and overlying clastic strata, to compare with Ediacaran results from elsewhere in Avalonia (Avalon zone in Newfoundland) and interpret the paleogeography for the Avalonian arc. Previous work shows the Burin Group to have a juvenile, oceanic arc affinity, with ca. 760–766 Ma U–Pb zircon ages in two locations along the length of the Wandsworth gabbro. Reconnaissance paleomagnetic sampling of the gabbro, along with pillowed basalt and mafic dykes in twelve sites yields stable remanence in nine. At Epworth, moderately SW-dipping mafic dykes of unknown age show a positive backed contact test with respect to the 764 Ma gabbro host, with the simplest tilt correction to dyke vertical making their primary remanence SE and upwards-directed, implying a 27 degree paleolatitude that is similar to the low paleolatitude previously found for the ca. 575 Ma Marystown Group. The host Wandsworth gabbro carries steep down directions that likely predate the dyke emplacement, possibly representing a high paleolatitude for Avalonia in the mid-Neoproterozoic. At Burin, pillow basalts and interbedded SW-dipping marine strata are cut by numerous moderately NW-dipping dykes. The basalts and dykes at Burin record NW steep down in situ directions that are retained at high coercivities and unblocking temperatures, becoming W and moderately down after structural tilt correction. One dyke yielded hornblende single crystal separates that are confirmed to be free of alteration by in situ micro X-ray diffraction. Two hornblende separates provide precise step fusion $^{40}Ar/^{39}Ar$ plateau ages of 608.1 ± 1.7 and 605.4 ± 1.2 Ma, indicating that the Burin dykes are similar in age to the Connecting Point Group and the Bull Arm Formation in the Isthmus of Avalon. If remanence in these ca. 607 Ma Burin dykes is primary, then their tilt-corrected result, which is similar to younger Ediacaran directions on the Burin Peninsula, implies that Avalonia resided at low- to mid-paleolatitudes at ages bracketing the 580 Ma Gaskiers glaciation. Previously published paleomagnetic results from the Bull Arm Formation are now known to be of 592 Ma age at their Bonavista Peninsula locality (Plate Cove volcanic belt), further implying that Avalonia remained at low- to mid-paleolatitudes through the mid Ediacaran. In global paleogeography, these results collectively are consistent with Avalonia having been associated with either the Amazonia portion of West Gondwana, or the Timanian-north Urals margin of Baltica during the early to mid Ediacaran.

## Late Neoproterozoic magmatism of northwestern Avalonia, Newfoundland, Canada: Love Cove Group vs. Bull Arm Formation

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The Love Cove Group (LCG), originally Love Cove schists, comprises greenschist-facies, calc-alkaline to tholeiitic, (continental) volcanic arc rocks that are commonly strongly foliated and lineated. A previous age constraint of ca. 620 Ma for LCG is consistent with previous and more recent geochronological constraints on the adjacent and overlying, flysch-dominated Connecting Point Group (CPG). Previous geochronology yielded ca. 610 Ma for a 3-m-thick tuff situated 10-m above a regionally extensive olistostrome that occurs near the stratigraphic middle of the CPG. In the Sweet Bay area, the top of the CPG occurs above a ca. 605 Ma shallow marine tuff and below the unconformably

overlying ca. 600 Ma molasse of the terrestrial-to-marine, terminal Neoproterozoic Musgravetown Group (MG). However, a previous unpublished age of ca. 589 Ma for the LCG at its type locality conflicts with existing stratigraphic nomenclature, being younger than the base of the MG at Sweet Bay and also younger than the ca. 605 Ma banded rhyolite of the Bull Arm Formation (lower MG) near its type locality (Isthmus of Avalon). The tuff dated at the LCG type locality is similar in age to ca. 592–591 Ma intermediate tuffs from Bull Arm Formation (BAF) rocks of the Plate Cove volcanic belt on Bonavista Peninsula. A previous age of ca. 570 Ma (now refined to 569 Ma) for banded rhyolite formerly assigned to BAF and then to the overlying Rocky Harbour Formation is the youngest Neoproterozoic volcanic unit dated in northwestern Avalon Terrane in Newfoundland, demonstrating a protracted (and perhaps episodic) history of magmatism. Lithogeochemical investigations elucidate a tectonomagmatic setting that shifts from arc-dominated, subduction-related magmatism to an extensional or transtensional regime that was likely established prior to 569 Ma. The combined geochronological and lithogeochemical data do not support the simplistic NNE-trending, fault-bound stratigraphy that dominates the map pattern in the northwestern Avalon zone in Newfoundland.

## Public reporting of reserves/resources in the Newfoundland and Labrador offshore, Canada

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Public disclosures regarding natural resources are an important part of the C-NLOPB's mandate on communicating about what is happening in the development of the Newfoundland and Labrador offshore. Board's staff of professional engineers and geoscientists bring evidence and expertise to provide society with resource reports and estimates (e.g., characteristics, geometry, quantity and quality) that are then publically disclosed. As a regulator in the Newfoundland and Labrador offshore, the C-NLOPB represents the public interest in the stewardship of petroleum resources and strives to provide a stable, efficient and impartial regulatory regime for operators who invest in the development of these resources. The Resource Management department of the C-NLOPB is tasked with those objectives as well as communication to the industry, governments and the public that work. This presentation looked at how the Resource Management at the C-NLOPB fulfills its mandate and reports to the public with some examples of public reporting.

## Pb isotopes signatures from melt inclusions, host rock, and mineralization in the El Laco magnetite-apatite deposit, Chile

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El Laco is the most pristine example of magnetite-apatite (so-called Kiruna type, or Iron Oxide Apatite) deposits worldwide. The ore body is located on the flanks of the 2 Ma El Laco Volcanic Complex, which is a part of the Pliocene-Pleistocene volcanic arc in northern Chile. Previous studies of the El Laco ore body describe immiscible melt inclusions preserved in plagioclase and clinopyroxene phenocrysts in the andesite hosting the iron mineralization. The immiscible melt inclusions document the presence of un-mixed Fe-rich and Si-rich melts in the system. To investigate the relationship between immiscible melt inclusions, iron mineralization and the andesitic host rocks, Pb isotope concentrations were determined in situ in melt inclusions, in plagioclase and clinopyroxene phenocrysts by secondary ion mass spectrometry, and from whole rock analyses of the magnetite-apatite ore body and the andesite hosting melt inclusions by isotope dilution thermal ionization mass spectrometry. The results plotted on Pb evolution diagrams show that melt inclusions and phenocrysts samples are dispersed between the mantle and upper crust reference lines, indicating that the source magma was heterogenous and likely contaminated by interacting with the crust during its ascent. Iron mineralization and host rock samples have different $^{206}Pb/^{204}Pb$ ratios (e.g., 18.22–18.47 and 18.80–18.96 respectively) suggesting that they did not originate from a similar source, or that iron mineralization lost radiogenic lead during its formation. The host rock Pb concentrations occupy a limited field which is located in the middle of the melt inclusions and phenocrysts field, implying that the whole rock Pb data are averages of the Pb isotopes derived from the in situ analyses.

## Epigenetic, structurally-controlled polymetallic (Cu-Ag ± Pb ± Au ± Zn) mineralization at the Bridal Veil and associated showings, Gander Lake Subzone, northeastern Newfoundland, Canada

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The Bridal Veil and associated showings immediately north of Gander Lake in the Gander Lake subzone (NTS 2D/15) are hosted by chlorite- to biotite-grade psammite, less common semipelite and rare pelite of the Jonathon's Pond Formation (JPF), Gander Group. Compositional layering dips shallowly to the west-northwest and is parallel to a composite, regional $S_{1-2}$ transposition foliation. The JPF hosts $S_0$-$S_1$-$S_2$ - parallel, fine-grained metadiabase sills/dykes now consisting of chlorite-albite-actinolite-magnetite schist. Mineralized zones are ≤5 m thick, intensely quartz-veined and silicified topographic ridges occurring in northwest-dipping, subparallel psammite horizons separated by ~900 m across strike. Preferential silicification of psammite was coincident with at least three generations of quartz veins; the first set pre- and the second two syn- to post- $D_3$ regional deformation. Narrow (≤5 cm) remnant muscovite ± biotite semipelite horizons in altered psammite contain sinuous, mm-scale septae of chalcopyrite ± galena ± sphalerite in quartz, minor chlorite, albite and sericite. Chalcopyrite is variably altered to goethite. Samples of the silicified zones have variable anomalous metal concentrations, with up to 8.9% Cu, 19.5 % Pb, 218 ppm Ag and 723 ppb Au, and weakly anomalous Bi, Sb, Mo and Sn. The youngest, rectilinear, sulphide-poor quartz veins form conjugate riedel shears. These late veins are typically anomalous in the same metals as the psammite, but at lower concentrations. Collectively the three quartz vein generations were developed in a biotite-grade, NE-trending (065), steeply –dipping (86°) shear zone, likely of Acadian (Middle Devonian) age. The Bridal Veil showing represents a Cu-Ag ± Pb ± Au –bearing shear zone-hosted epigenetic mineralized zone with granitophile metal associations suggestive of a fluid contribution from an S-type igneous source.

## Marathon's Valentine Gold Camp: the largest gold deposit in eastern Canada with 2.7 million oz. gold (measured and indicated) and 1.5 million oz. gold (inferred)

Phillip Walford and Sherry Dunsworth

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Marathon Gold Corporation's 100% owned Valentine Gold Camp hosts the largest gold deposit in Eastern Canada with a current global resource of 2 691 400 oz Au at 1.85 grams per tonne (measured and indicated) and 1 531 600 oz Au at 1.77 grams per tonne (inferred). The resource is contained in four near-surface, mainly pit-shell constrained gold deposits which are open along strike and to depth. The deposits, as well as numerous other gold showings within the property, occur proximal to a major deep crustal structure called the Valentine Lake Shear Zone, which juxtaposes Precambrian granitoids of the Valentine Lake Intrusive Suite against the Silurian Rogerson Lake conglomerate. The gold occurs in dominantly shallow-dipping, en-echelon stacked quartz-tourmaline-pyrite veins of variable thicknesses that intrude the Precambrian granitoids and to a lesser extend into the Silurian conglomerate.

The success of Marathon Gold in discovering new gold deposits and occurrences along an 18-kilometer strike length of the Valentine Lake Shear Zone, has sparked a rejuvenation of exploration by numerous other junior companies along this major structural feature which runs for over 400 km through the island of Newfoundland. Our understanding of the depositional model for these classic structurally controlled orogenic-style gold deposits hosted within a NE-SW striking greenstone belt, has led to Marathon Gold's repeated success in discovering new blind gold deposits and showings over the entire strike length of the Valentine Gold Camp. Detailed prospecting and trenching have contributed greatly to the exploration success while various geophysical and geochemical methods have had mixed success in identifying gold mineralization. Our revised PEA released in October, 2018, demonstrates an open-pit production profile of more than 225 000 oz. of gold per year over greater than a 12-year mine life. Ongoing exploration and infill drilling up to 1000 m depth continues at the Valentine Gold Camp as we focus on discovering new resources, increasing both Measured and Indicated as well as the Inferred resource categories as we advance the property towards a Pre-Feasibility Study.

## Investigating the Goban Spur rifted continental margin, offshore Ireland, through integration of new seismic reflection and potential field data

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The Goban Spur, offshore Ireland, represents one of the magma-poor rifted continental margins that once lay conjugate to the Newfoundland and Labrador margin. Published studies have demonstrated that a 70-km-wide zone of exhumed serpentinized mantle lies between oceanic crust and stretched continental crust at the Goban Spur margin, although the along-strike extent of this zone has, until now, been unknown due to insufficient data coverage. Significant complexity is expected regarding the width of the different crustal zones due to the margin's complicated tectonic history. Here, six newly acquired multi-channel seismic reflection lines are processed and interpreted, along with vintage seismic profiles. These profiles reveal significant variations along strike of the Goban Spur margin, revealing different rifting stages. In the northwest, the transitional zone between the oceanic crust and stretched continental crust appears to consist of a narrow zone of shallower peridotite ridges and a wider zone of deeper exhumed serpentinized mantle, much like what is seen on the conjugate Iberian and Newfoundland margins to the south. The different types of exhumed mantle are inferred to reflect different extension rates. Toward the southeast along the Goban Spur margin, the zone of peridotite ridges appears to pinchout and is replaced by oceanic crust. By combining potential field data and seismic data, it is discovered that magmatic contributions increase from NW to SE along the Goban Spur rifted continental margin, evidenced by contrasting characteristics of the basement morphology along the seismic profiles. In total, five distinct crustal zones related to different rifting stages are identified and their regional extents assessed, significantly increasing our understanding of the Goban Spur rifted continental margin. When combined with complementary studies on the Newfoundland and Iberian conjugate margins, a clearer understanding of the rift evolution of the southern North Atlantic Ocean will be possible.