Deposits and Tectonics – A Trip Across A Golden Island

Society of Economic Geologists Student Chapter Field Trip
Newfoundland, Canada, May 2022

Group picture from Baie Verte of the MUN, Queen's, and U-Laval-INRS SEG students and Prof. Greg Dunning from MUN

ULaval – INRS-ETE SEG Student Chapter

Queen's University SEG Student Chapter

With assistance from Memorial University of Newfoundland SEG Student Chapter

Prepared by:
Liam Maw (ULaval-INRS SEG Student Chapter President)
Siobhán Keane (Queen's University SEG Student Chapter President)

Acknowledgements

First and foremost, we would like to thank all of our sponsors for their financial contributions, and the in-kind contributions that helped make this trip a success. Without them, we would not have been able to bring as many students to Newfoundland and run an affordable trip for undergraduate and graduate students alike. A special thanks goes to our platinum sponsor New Found Gold Corp, and to our other supporters, the Society of Economic Geologists - Stewart R. Wallace fund, the Geological Association of Canada – Mineral Deposits Division, Barrick Gold, SRK Consulting, and E4m - Centre de recherche sur la géologie et l'ingénierie des ressources minérales.

Secondly, this trip would not have been the success that it was without the contribution of time and knowledge we received from Dr. Greg Dunning of the Earth Sciences Department of the Memorial University of Newfoundland. The three days spent with Greg in Gros Morne and Baie-Verte were paramount to build the group's understanding of the regional geology and tectonics of the Northern Canadian Appalachians. This left the group better prepared to understand the regional context of the following mineral properties we visited. Greg was also invaluable when it came to sharing his knowledge of the local area, economy and history – an excellent addition as many students had never been to Newfoundland, or were foreign students unaccustomed to Canada's East Coast.

Financial Sponsors

In-kind Sponsors

UNESCO

Parks Canada Parcs Canada

Newfoundland Labrador CANADA

Rambler METALS AND MINING

MARITIME RESOURCES

Table of Contents

Introduction

The SEG Student Chapters of INRS-ULaval and Queen's both commonly run international field trips; however, this became increasingly challenging after the onset of the COVID-19 pandemic for logistical and public health reasons. Acknowledging this challenge, the groups decided that Newfoundland would be an ideal location to run a field trip – it has incredible geology and a history of mining, it is culturally distinct from central Canada where Queen's, INRS and ULaval are located, and most of all, Newfoundland is currently undergoing a modern-day staking rush with an abundance of companies developing exploration projects targetting multiple commodities across the island.

This trip is designed to cross-cut the island, thus providing an idealized section through the Northern Canadian Appalachians and its allochthonous terranes that host many mines – both past-producing and producing – and advanced exploration projects, including the largest in Canada currently underway, New Found Gold's Queensway project.

The visits throughout this trip occurred between May 19th and May 30th. The trip was primarily run by the INRS-ULaval and Queen's Chapters, with the company of five students from the Memorial University of Newfoundland SEG Student Chapter from May 20th to May 24th.

List of participants

Name	Email	University	Program
Liam Maw	Liam.maw@inrs.ca	INRS-ETE	MSc.
Ana Carolina Mirandes	ana.rodrigues-miranda.1@ulaval.ca	Laval	PhD.
Samuel Coulombe	samuel.coulombe.4@ulaval.ca	Laval	MSc.
Jérémie Darveau	jeremie.darveau.1@ulaval.ca	Laval	BSc.
Philippe Mongeau	philippe.mongeau.1@ulaval.ca	Laval	BSc.
Siobhán Keane	siobhan.keane@queensu.ca	Queen's	MSc.
Hannah Brommecker	16hgb1@queensu.ca	Queen's	MSc.
Catherine Gavaris	16ceg@queensu.ca	Queen's	MSc.
Collette Pilsworth	16chp@queensu.ca	Queen's	PhD.
Allison Howes	allison.howes@queensu.ca	Queen's	PhD.
Sarah Reese	16sfr3@queensu.ca	Queen's	BASc.
Richard Barette	17rarb@queensu.ca	Queen's	BSc.
Amanda Hyslop	a.hyslop@queensu.ca	Queen's	MASc.

Field trip objectives

The main objectives of this trip were to:

- Acquire first-hand knowledge of the economic geology and tectonics of Newfoundland and the Northern Canadian Appalachians through guided tours with an experienced professor from the area, and by visiting active exploration and mine sites with industry personnel;
- Visit different deposit styles for multiple commodities – including orogenic gold, volcanogenic massive-sulphide (VMS), alkaline epithermal Au, podiform chromite and asbestos;
- Visit mining districts that have operated for centuries and see the long-term effects of mining and the difference between historical and modern operations;
- Expose students to the various roles of geologists in industry;
- Present different exploration methods for different styles of mineralization and orebody geometries;
- Educate students with various backgrounds on the differences between operating mines, early and advanced-stage exploration projects;
- Discuss the environmental, social and governance impacts (ESG), as well as technical and financial challenges facing exploration companies and their operations in the area;
- Offer networking opportunities to students that could lead to employment or mentoring during and after their studies.

Group expenses

Table 2: Summary of estimated costs per participant for the Newfoundland field trip for Queen's Chapter, all prices are in Canadian dollars.

Air Travel Expenses		
To	Toronto	St. John's
Arrival Date		19-May
From	St. John's	Toronto
Return Date		30-May
Cost per flight + tax	$	720
Subtotal	$	5760
Cost per participant	**$**	**720**

Rental Vehicle Expenses		
Vehicle Expenses		
Vendor	Enterprise	
Vehicle Type	Ford Edge	
Seats	5	
Number of vehicles	2	
Cost per vehicle	$	1640.31
Total cost	**$**	**3280.32**

Accommodation Expenses		
Note: Day 1-4 we will be staying in 4-person hotel rooms, the other days we will be staying in hotels and motels which are 2-3 people per room		
Day 1	$	320
Day 2	$	300
Day 3	$	290
Day 4	$	290
Day 5	$	410.55
Day 6	$	410.55
Day 7	$	410.55
Day 8	$	460
Day 9	$	460
Day 10	$	460
Day 11	$	460
Subtotal	$	4271.65
With tax	$	4912.4
Cost per participant	**$**	**614.05**

Fuel Costs		
Fuel Type	Gasoline	
Fuel Costs per day per vehicle	$	50.18
Total Fuel cost	$	1104
Total vehicle Expenses		
Cost Per vehicle	$	2192.16
Total cost	$	4384.32
Cost per participant	$	548.04
Entrance and Parking Fees		
Estimated Entrance fees	$	200
Parking estimate	$	600
Total Cost	$	800
Cost per participant	**$**	**100**

Expense Summary

Category	Total Cost	Per Participant
Flights	5760	720
Accommodations	4912.40	614.05
Vehicle Rental	4384.32	548.04
Entrance Fees and Parking	800	100
Total	**15856.72**	**1982.09**

Table 3: Summary of estimated costs ULaval-INRS Student Chapter

Air Travel Expenses - Roundtrip			Rental Vehicle Expenses	
From	Participants	Halifax	Vehicle 1	1390.78
To	3	St. John's	Vehicle 2	1142.1
Cost	659.23	1977.69	Consumption (L/km)	0.1
From		Québec	Mileage	2200
To	2	St. John's	Fuel (CAD$/L)	2.00
Cost	842.94	1685.88	Fuel total (per vehicle):	440
Total:		**3663.57**	**Total**	**3412.88**
Total per person:		732.71	Total per person:	682.58
Acommodations			Activites	
Date	Cost:	Per person:	Location	Group rate
19/5/2022	287.58	57.516	Terra Nova	12.75
20/5/2022	319.36	63.872	Gros Morne	21
21/5/2022	250	50	Gros Morne	21
22/5/2022	250	50	Signal Hill	35
23/5/2022	342.7	68.54	Total:	89.75
24/5/2022	342.7	68.54	Total per person:	17.95
25/5/2022	309.35	61.87	Trip total	
26/5/2022	309.35	61.87	Per person:	2054.50
27/5/2022	299	59.8	**Total**	**10272.51**
28/5/2022	396.27	79.254		
29/5/2022	0	0		
Total:	**3106.31**	**621.26**		

Trip itinerary

Day	Date	Location	Description
1	Thursday, May 19	St. John's	- Arrival - Travel south along the coast to Calvert, NL
2	Friday, May 20th	Mistaken Point	- Visit the Mistaken Point UNESCO World Heritage site with Ediacaran fossils - Travel west to Clarenville, NL. - *Guided by Mark King*
3	Saturday, May 21st	Terra Nova National Park	- Travel day to western Newfoundland, with stop at Terra Nova National Park to learn about sensitive habitats and ecological challenges in the area
4	Sunday, May 22nd	Gros Morne National Park	- Gathering of all 3 SEG Chapters, and commence tour of Gros Morne National Park with focus on tectonics of the area. Visit Green Point International Stratigraphic Committee Cambrian-Ordovician contact, Cow Head and Rocky Harbour - *Guided by Dr. Greg Dunning of the Memorial University of Newfoundland*
5	Monday, May 23rd	Gros Morne National Park	- Second day with Dr. Dunning in Gros Morne. Visits of Grenville thrust slices and unconformity, base-metal mineralization in allochthonous mafic volcanic package, and trilobites. Finish with a hike through the Tablelands Ophiolite sequence, which hosts Cr mineralization
6	Tuesday, May 24th	Baie-Verte	- Visit various sites in the Baie Verte mining district with Dr. Greg Dunning, including the past producing Tilt Cove mine, open-pit asbestos mine, local gold showings, virginite outcrop - Discuss tectonic setting of the camp and its relation to regional metallogeny.
7	Wednesday, May 25th	Rambler Mine, Baie-Verte	- Visit the Rambler Mine, operated by Rambler Mining & Metals, including a tour of the core shack, drills, and discussions with geologists - Finish the day learning about the history of the mine, and the negative impact of previous tailings storage methods that continue to produce acid rock drainage
8	Thursday, May 26th	Maritime Resources, Springdale	- Visit Maritime's office, lithotech and core shack, followed by a tour of their Hammerdown project, a past-producing mine. Afterwards, we joined them on some logging roads outside of town to their stripped outcrops surrounding an alkaline epithermal prospect with elevated REE's
9	Friday, May 27th	New Found Gold Corp, Gander	- Visit New Found Gold's headquarters in Gander, NL - Meet their geologists and receive a presentation on their property, and exploration methods. - Tour of the coreshack and show core with visible gold. - Visit surface showings of the Queensway property with VP of exploration Melissa Render and Exploration Manager - Hunt for visible gold in the quartz veins - Walk along beach-side exposures and sea stacks of felsic-intermediate volcanic complex adjacent to our cabins in Bellevue
10	Saturday, May 28th	St. John's	- Visit National Historic Sites at Cape Spear and Signal Hill - Participate in a Newfoundland Screech-In ceremony
11	Sunday, May 29th	INRS-ULaval departure	- Travel day for INRS-ULaval group. Queen's visited Signal Hill and downtown St. John's
12	Monday, May 30th	Queen's departure	- Travel day back to Kingston for Queen's SEG Chapter

Itinerary overview map

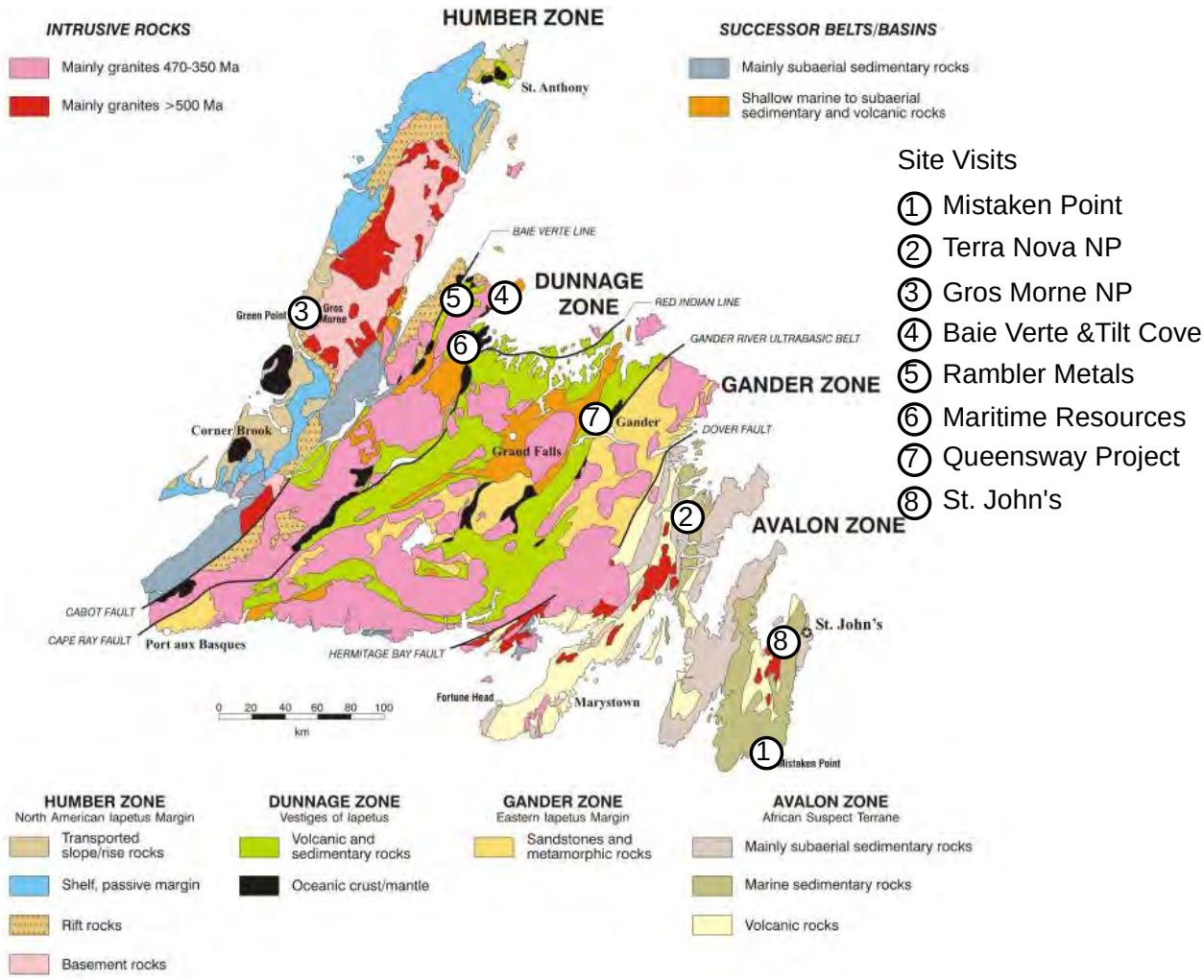

Figure 1: Geologic map of Newfoundland with the National Parks and sites visited. Modified from Coleman-Sadd et al. (1990)

General Geology

The geology of Newfoundland is composed of a diverse assemblage of terranes in the Northern Canadian Appalachians, and is divided into 4 distinct zones, from east to west: the Avalon, Gander, Dunnage and Humber. This section has been compiled from Coleman-Sadd et al., (1990).

The Avalon zone is composed primarily of Late Proterozoic submarine and subaerial volcanic rocks and thick successions of turbiditic, deltaic and fluviatile sedimentary rocks. The Avalon forms a distinct crustal block from the remainder of Newfoundland, bounded by the Hermitage Bay and Dover faults. The Avalon is effectively interpreted as a fragment of continental Africa that remained attached to the developing eastern North American continental margin during the opening of the Atlantic Ocean. Various deposits occur in the Avalon, such as the Bell Island iron mine, hosted within siliciclastic shelf sedimentary rocks, and the Saint-Lawrence fluorspar mine, associated with a late Devonian granite. The Burin Peninsula and the northeastward continuation of its geology are dominated by bimodal volcanic rocks and granitoid intrusions, which host high-sulphidation epithermal gold deposits and are a current focus of ongoing exploration.

The Gander zone is composed of Cambrian to Ordovician quartz-rich siliciclastic rocks of the Exploits, Gander Lake, Meelpaeg and Mount Cormack subzones. These supracrustal subzones are heavily intruded by Silurian to Devonian granitoid suites. New Found Gold's Queensway project is located along the Appleton Fault Zone, which has drawn a great deal of attention to the area, looking for similar epizonal orogenic gold deposits. These are often compared to the Fosterville deposit in Australia, and have spectacular intercepts with abundant free gold in vuggy, white quartz veins hosted within tightly folded shales and siltstones.

The Dunnage zone is one of the areas in Newfoundland with the greatest density of ore deposits, namely VMS deposits and orogenic gold hosted within the Cambrian to Middle Ordovician submarine volcanic rocks, and Early Ordovician ophiolite suites that dominate the stratigraphy. Volcanic rocks in this zone have geochemical affinities typical of island arc and back-arc environments. It is also heavily intruded by various granitoid suites.

The Humber zone extends from southwest to northwest Newfoundland, dominating the Great Northern Peninsula of Newfoundland. The zone has a basement of continental crust, metamorphosed and intruded during the Middle Proterozoic Grenville orogeny. Late Proterozoic to Middle Ordovician sedimentary rocks form an unconformable cover sequence, deposited during development of the ancestral North American continental margin and Taconian foreland basins. Large areas are interpreted as Taconian allochthons, including the ophiolites in the Bay of Islands (Gros Morne National Park), and near St. Anthony, at the northern extremity of the peninsula.

Although the field trip is focussed on ore deposits and various geologic sites of interest across Newfoundland, the tectonic history of the island is key to building a better understanding of regional metallogeny. Many stops focus on the regional geology in Gros Morne National Park and Baie-Verte, two areas with large exposures of ophiolites interpreted as vestiges of oceanic crust within the Iapetus ocean.

Gros Morne National park has incredibly diverse geology summarized below from structural bottom to top, from Stevens *et al*., (2003). There is a high degree of structural complexity, as many units were emplaced as allochthonous slices during the Taconic orogeny.

The structural bottom within the park also represents the oldest rocks in the area; assorted Precambrian gneisses and plutonic rocks from the Grenville represent an extension of the Canadian Shield and form the basement throughout much of the park, but are locally thrust over Lower Paleozoic rocks. The Grenvillian basement is unconformably overlain by a sequence of basal, late Proterozoic volcanic rocks and late Proterozoic to Cambro-Ordovician shallow-water sedimentary rocks. These are followed by a series of slices of the deep-water Cambrian and Ordovician sediments of Humber Arm Supergroup, separated by mélange.

The following tectonic slices represent distinct groups of volcanic and igneous rocks. The Skinner Cove Formation is an extremely well-preserved sequence of late Precambrian alkaline olivine basalts metamorphosed to zeolite facies. Basalts of the Skinner Cove Formation are interpreted to have erupted from a mature oceanic volcano (Baker, 1979).

The Little Port Complex is a variably deformed group of ultramafic to silicic igneous and metamorphic rocks with associated red cherts and minor shale, unrelated to the Skinner Cove Formation. It is also host to minor base metal mineralization, as observed during the field trip.

Lastly, the tectonically disrupted mafic and ultramafic massif of the Bay of Islands ophiolite shows the classic igneous, metamorphic and sedimentary stratigraphy of an ophiolitic complex. It forms the structurally highest unit in the area, and forms remarkable landscapes in the Tablelands Mountains.

Field Trip Visits

Day 1 – Arrive in Newfoundland

May 19th, 2022

Participants travelled to St. John's, Newfoundland from Ontario and Québec. The groups picked up the rental vehicles and drove south down the coast through Precambrian sedimentary rocks of the Avalon zone to reduce the following days' drive.

Day 2 – Mistaken Point UNESCO Heritage Site

May 20th, 2022

The SEG student participants from INRS-ULaval and Queen's University had the privilege of receiving an educational tour of the Mistaken Point Ecological Reserve and UNESCO World Heritage Site by Mark King, the Reserve Geologist. We were fortunate, as educational tours for geologists and paleontologists are brought to different sites not shared with the general public.

Figure 2: Pigeon Cove stop outside of the Mistaken Point Ecological Reserve. Photo credits - Sarah Reese

We first stopped at Pigeon Cove, outside of the park, in order to get an introduction to the taphonomy and sedimentology of Mistaken Point. There were large Ivesheadiopmorph fossils as well as Rangeomorphs. The main fossil surface lies beneath a thick volcanic tuff layer which buried the organisms on the seafloor, preserving them as fossils. This scenic stop was is situated along a beautiful pebble beach where the surf came crashing in.

Figure 3: Iveshediomorph fossil from Pigeon Cove.
Photo credits - Samuel Coulombe

Figure 4: Paleontology discussion with Mark King at Pigeon Cove.
Photo credits - Sarah Reese

We then drove into the Ecological Reserve and walked across the barrens where we examined the D, B, and E surfaces of Mistaken Point. The D surface is a narrow outcrop by the water with an overturned bed of well-preserved fossils. There are over 8 taxa at this site, including Fractofusus, Bradgatia, Pectinifrons, and Charniodiscus fossils. Following the D face stop, we continued walking to the B face where we saw turbidite sequences with large sedimentary structures. This stop provided a wide-open area for us to have lunch on an outcrop, and spot a few whales.

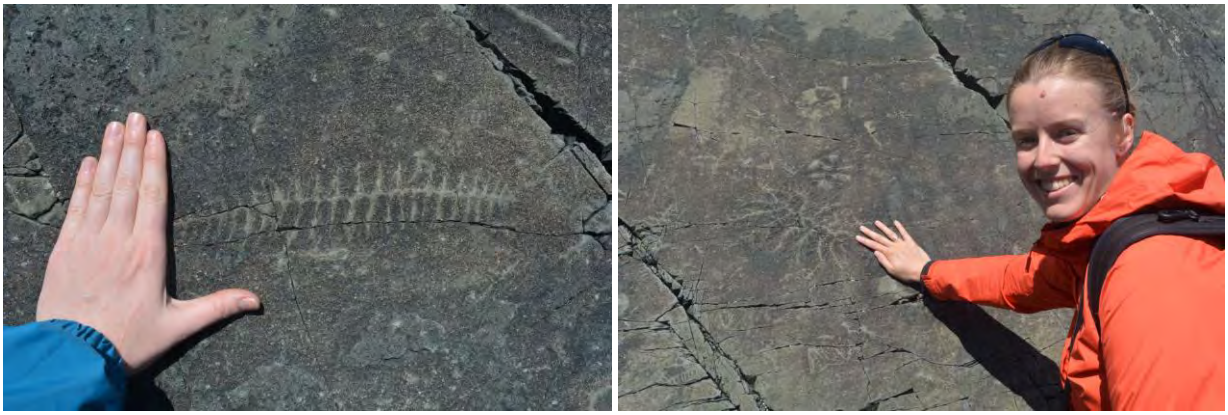

Figure 5: a) Fractofusus fossil from the D face at the Mistaken Point Ecological Reserve. b) Allison Howes with a Rangeomorph (Hapsidophyllas) fossil. Photo credits - Siobhán Keane

Figure 6: Hannah Brommecker with a large rip-up clast from the B face. Photo credits - Siobhán Keane

Figure 7: Exploring the turbidite sequences at the B face. Photo credits - Sarah Reese

Our final, and most exciting stop at Mistaken Point was the E surface. We had to take off our boots prior to walking on the outcrop in order to help preserve the fossils. During paleontology classes at Queen's, Dr. Narbonne – who completed many studies on these fossils – often says "you can't walk on the E surface without stepping on a fossil," and the students on the trip realized how true that saying is. The E surface is the most ecologically diverse and abundant face at Mistaken Point with Charniodiscus fossils comprising over 50% of the surface. While this was a trip for SEG students, the organizers believed that Mistaken Point is an important site for any geologist to visit as it has played a key role in understanding early life and evolution.

Figure 8: a and b) Frond fossils from the E face. Photo credits - Allison Howes

Figure 9: Queen's and ULaval-INRS students with Reserve Geologist, Mark King at the E face

Day 3 – Travel West and Terra Nova National Park

May 21st, 2022

The third day of the trip was primarily a travel day across Newfoundland to Gros Morne, with a few stops along the way to explore Newfoundland's diverse ecology. The highway runs west, crossing major deformation zones between the Avalon, Gander, Dunnage and Humber zones. The group made a stop at Terra Nova National Park, a beautiful park where inland rivers run into a shallow saltwater bay bordered by pristine boreal forest. The group took advantage of the interpretation centre's resources, learning about the unique ecology of these coastal habitats, and the ecological challenges the boreal forest faces in Newfoundland. Students learned about anemones, sea cucumbers, anadromous trout and flounder. Figure 11 displays the many shallows bays and rocky hills of Precambrian sediments of the Avalon zone in Terra Nova National Park.

Figure 10: View from the Terra Nova look out point. Photo credits - Sarah Reese

Day 4 – Gros Morne National Park: Green Point, Cow Head and Rocky Harbour

May 22nd, 2022

The geology of Gros Morne National Park is highly variable and unique, and was declared a UNESCO World Heritage Site in 1987 because it hosts "outstanding examples of major stages of the Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features". The material in this section was presented to the group by Dr. Greg Dunning of the Memorial University of Newfoundland, with references

found in the Geological Association of Canada's guidebook: *From the Intertidal Zone to the Upper Mantle - The Amazing Geology of Gros Morne Park*, Stevens *et al.,* (2003).

The day began with a short lecture from Dr. Dunning, providing an overview of the geology we would be examining over the following days, and its geologic and tectonic context. The stops throughout the day display a rare record of near-edge continental margin and of Middle Ordovician time that is represented by unconformities over most of North America. The series of stops offered excellent outcrops of various sedimentary facies that define an upwards deepening succession on the continental margin during development of the North American continental margin, as shown in Figure 12 below, at Green Point.

Figure 11: Geologic discussion at Green Point. Photo credits - Sarah Reese

At Green Point, the group visited the World Stratotype for the Cambro-Ordovician Boundary, as defined by the International Union of Geological Sciences (IUGS) International Stratigraphic Committee. This site, shown in Figure 13, offers exceptional exposure of this important boundary along a cliffside and beach at low tide. The stratigraphy is a deep marine expression of the Cow Head Group. Beautifully preserved load casts and trace fossils are visible in the succession of siltstones, shales, limestone conglomerates and rare sandstones. The limestone conglomerates were produced by the same debris flows that dominate the Cow Head Group at the following stop, and are interpreted to have run down the slope to this deep marine environment.

Figure 12: Allison Howes standing at the Cambro-Ordovician Global Stratotype. Photo credits - Sarah Reese

The Cow Head stop displays time-equivalent rocks to the previous outcrop, and is the type locality of the Cow Head Group. However, the outcrop at Cow Head contests greatly with that at Green Point. The exposures along the show are dominated by debris flows of limestone conglomerate, with boulder-sized clasts cutting down up to 4 metres into underlying strata. Flint nodules are locally found within the succession.

Figure 13: Liam Maw inspecting the sedimentary rocks at Cow Head

The final stop of the day was back in Rocky Harbour, where outcrop along the beach is composed of mélange, a chaotic material with a shaley matrix. These outcrops are visually unremarkable, but significant to the comprehension of the regional tectonics. They represent an extensive zone along the base of the Humber Arm Allochthon, and are interpreted as the result of near frictionless movement across zones of load-induced high hydrostatic pressure lubricated by water and bitumen from the incorporation of organic-rich black shales.

Day 5 – Gros Morne National Park: trilobites, unconformities and ultramafic rocks

May 23rd, 2022

The second day in Gros Morne National Park was focussed on the top and bottom of the stratigraphic column within the park, which are both dominated by allochthonous rocks including the Bay of Islands ophiolite. These rocks host typical styles of mineralization associated with submarine volcanic processes and ultramafic rocks, and also facilitated a discussion on modern fluid-rock reactions and aqueous geochemistry.

The first stop of the day featured a roadcut of sandstones and siltstone of the Lower Cambrian Hawke Bay and Forteau Formations (Labrador Group). Despite the roadcut being oblique to bedding, this site is important due to the well-preserved fossils casts of the large trilobite, *Olenellus thompsonii*, pictured below in Figure 15.

Figure 14: Large trilobite fossil from the Forteau Formation

Immediately north of this stop, the road crosses the trace of a thrust fault that brings allochthonous metamorphic rocks of the Grenville province and its Cambrian cover over younger platform carbonate rocks. The following stop exposes this contact along two roadcuts on either side of the highway. At this locality, green-grey gneisses of the Grenville are cut by pink pegmatite dykes and then truncated along the unconformity by a highly variable package of siliciclastic and carbonate sedimentary rocks, with minor basalt along the unconformity, as shown in Figure 16.

Figure 15: Road cut outcrop of Grenville gneiss and unconformity with Cambro-Ordovician stratigraphy. Photo credits – Sarah Reese

The following outcrop is interpreted as the upper part of the ophiolitic basement to an island arc system; mafic volcanic rocks have a distinct boninitic affinity. The outcrop is dominated by pillow lava and pillow breccia with intercalated chert and red shales. A prominent rusty zone is visible within the outcrop, which likely represents a small sulphide body as a result of submarine hydrothermal fluid flow and sulphide deposition.

Figure 16: Ophiolite with possible sulphide weathering. Photo credits - Liam Maw

The highlight of the day was most definitely the visit to the lherzolitic ophiolite rocks at Table Mountain. The mountain offers a spectacular view of the lherzolite massif as it is nearly barren of any vegetation due to elevated nickel and chromium content, along with the nature of the water flowing through the rock. The mountain hosts the most alkaline seeps from spring water on Earth, with a pH of 12. In the 1960s, a massive graphite vein was intersected within a zone of serpentine while drilling an EM anomaly within the lherzolites. These observations led to the conclusion that serpentinization of fresh lherzolite is ongoing due to interaction of groundwater at ambient temperatures. A seep on the hillside is picture in the bottom right of Figure 18b and shown in the close-up of Figure 18c - the grey calcrete in the orange lherzolite is a product of adsorption of carbon dioxide and calcite precipitation upon interaction with the atmosphere, akin to the process operating at the seafloor with the formation of white smokers.

Figure 17: a) Panoramic view from Table Mountain. b) Group discussions about lherzolites and the ophiolite, and c) Calcrete-cemented pebbles from alkaline seep from Table Mountain. Photo credits - Sarah Reese

Day 6 – Baie Verte: Tilt Cove, Virginite, Coachman's Cove

May 24th, 2022

The first day in the Baie Verte area was spent visiting outcrops of particular geological and economic importance under the guidance of Dr. Greg Dunning.

The geology of Baie Verte is dominated by a supracrustal assemblage of submarine volcanic rocks and ultramafic rocks within ophiolite suites along a major suture zone of the Appalachians, the Baie Verte-Brompton Line. Consequently, the Baie Verte area is an historically important area in Newfoundland's mining history; it hosts asbestos, VMS and orogenic gold deposits.

The first stop of the day was to a lookout over the past-producing chrysotile pit immediately west of Baie Verte. This deposit was first discovered in 1955, and closed in 1981 as the public became more aware of health hazards associated with asbestos fibres. The deposit itself is a large, tabular body of serpentine within a pyroxene-rich peridotite protolith, first described in the SEG's Scientific Communications by Bichan, in 1960.

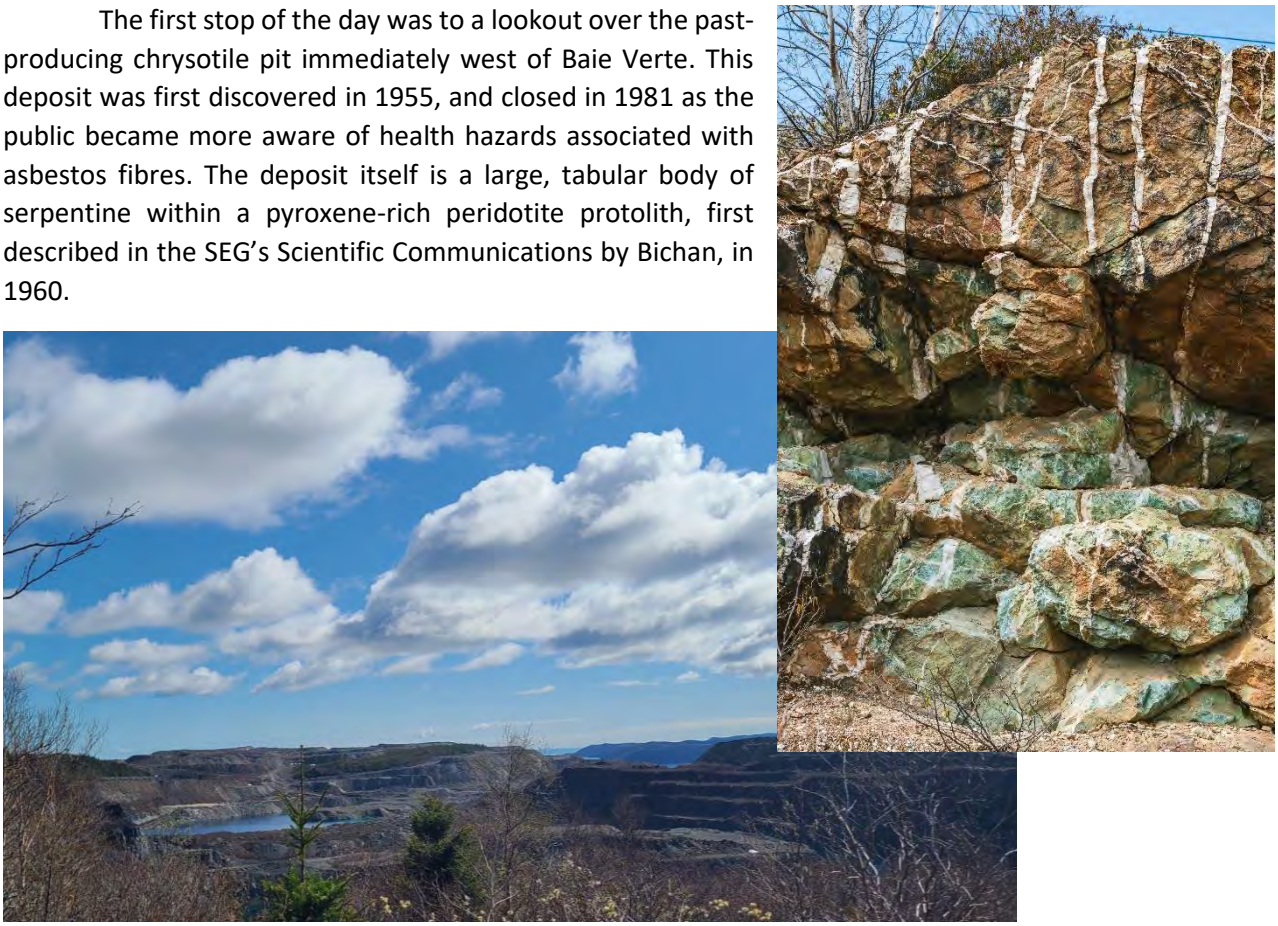

Figure 18: a) Chrysotile pit from Baie Verte and b) virginite outcrop. Photo credits – Liam Maw

The second stop of the day was an outcrop of mantle peridotite along Hwy 410, across from Flatwater pond. Highway 410 roughly parallels the Baie Verte-Brompton Line suture in the area. In this locality, the peridotite is pervasively altered and cut by carbonate veins, forming a rock locally termed *virginite* (more commonly named *listwanite* in other jurisdictions). This peridotite, pictured in Figure19b above, has been completely replaced by carbonate, quartz and micas. The turquoise-green hue is due to the presence of fuchsite and mariposite (chromium-rich micas) within the rock. The chromium within the

ultramafic protolith is relatively immobile, therefore it remains in the altered rock, despite the intense carbonatization and silicification. *Virginite* is recognized in numerous orogenic gold districts worldwide, namely in the Mother Lode district of California and in the Abitibi Greenstone Belt along the Cadillac-Larder Lake fault zone of Québec and Ontario. As many students in our group work in the Abitibi, this observation drove a discussion on the uncanny resemblance between the geology of Baie Verte and the Abitibi.

Our following stop was at Coachman's Cove, a sea-side outcrop with exceptional exposure of polydeformed mafic volcanic rocks. The outcrop is located along the same suture zone that controls the emplacement of ophiolite slices and consequently, the asbestos deposits and virginite. There is a penetrative foliation throughout the outcrop, which anastomoses around boudinaged quartz-carbonate veins within the outcrop. Small areas of epidote and manganiferous silicates reflect seafloor hydrothermal alteration, and help to distinguish two episodes of folding within the rocks. Fold interference patterns are shown within zones in Figure 20b below.

Figure 19: Folds from Coachman's Cove in basalt flow (a) and silicates with epidote (b). Photo credits – Liam Maw

The final stop of the day brought us to the community of Tilt Cove, the smallest town in all of Canada - population five. The road into town is also featured as "Atlantic Canada's Worst Highway" - we spotted a few moose along the bumpy track that takes you past old smelter sites where mounds of slag remain as a legacy from past mineral processing in the area. Tilt Cove is an historically important site; it was the location for the first mine in Newfoundland, and eventually became the richest copper deposit in the British Empire, prior to Newfoundland joining the Dominion of Canada. Mining began in 1864 and stopped in the 1920s. Government encouraged a resurgence of mining in the community in the 1950s, but was short-lived. Today, the claims are split between a few companies; there has been intermittent production of copper and gold from small operations facilitated by the proximity of the deposits to Rambler Mining & Metals' Nugget Pond Mill. The town is largely built on crushed waste rock, with relics of the port used to ship ore to Wales remaining by the water. Acid-rock drainage continues to be produced from the waste rock, as seen running from the culvert in Figure 21b below.

Figure 20: a) Tilt Cove hill leading to the ancient stopes, b) acid rock drainage from sulphides into the Atlantic Ocean. Photo credits - Sarah Reese

The mineral deposits in Tilt Cove are copper-gold ± zinc VMS deposits hosted within subaqueous mafic volcanic rocks that represent a portion of the ophiolite slice. Deposits are composed of pyrite, chalcopyrite, magnetite and hematite, with minor sphalerite and covellite. The footwall rocks are strongly chloritized mafic volcanic rocks, which form large cliffs around the communities with talus slopes of waste rock and ore. Old workings and adits are visible throughout the cliffs that were once built up with an array of scaffolding to access the deposits.

Day 7 – Baie-Verte: Rambler Mine

May 25th, 2022

The second half of our trip focused on mine and exploration site visits, starting with the historic Ming Mine which is owned and operated by Rambler Mining & Metals. We arrived at the site and were given a safety and corporate presentation by Mr. Peter Mercer, the Vice President of Rambler Metals & Mining. We learned that safety is of paramount importance at the Ming Mine, and they have won the Safest Mine in Canada award from the Canadian Institute of Mining (an award that takes them 2 years to achieve due to the scale of their operations) in 2017, 2019, and 2021.

During the corporate presentation we learned about the geology of the deposit. The Ming Mine is located within the Dunnage Zone of central Newfoundland which hosts over 20 copper deposits in the Baie Verte district. The Ming Mine is a bimodal-mafic VMS deposit, and during deposition, the fluids supersaturated the footwall with copper, leaving a copper-dominant footwall stringer zone and copper-gold rich massive sulphide lens, with lesser zinc. The lack of impurities in the ore body reduces the cost of smelting, and makes it highly sought after by other mines and smelters that wish to dilute the impurities in their own ore. They also incur no smelter penalties with their operations.

Following the presentation, we had the opportunity to visit the core shed, and talk to the production geologists. The core and hand samples with coarse, euhedral chalcopyrite and pyrite would catch the eye of anyone, geologist or not. One of the highlights of this visit for many students was getting to check out the ore stockpiles as we were allowed to fill our pockets with samples. The site visit gave students exposure to a working mine site, and we saw first hand how important it is to keep safety in mind when working near heavy machinery.

Figure 21: a) Wall rock from the Ming Mine containing bornite, chalcopyrite, and minor chalcocite, b) euhedral pyrite in drill core. Photo credits - Siobhán Keane

The most jarring part of this visit was a stop at the legacy tailings site down the road from the current mine, which was used before Rambler owned the Ming Mine. There were no environmental practices in place when this tailings facility was developed, and it has destroyed the property and local watershed. The past tailings site is now owned by the Government of Newfoundland and has an estimated remediation cost of 900 million CAD$. Mr. Mercer brought us here to highlight that as the next generation of geologists, we have to ensure that this does not happen again. It is our responsibility to ensure that mining operations are more sustainable and proper reclamation plans are in place.

Figure 22: a) Acid rock drainage from the former Ming Mine Tailings site. Photo credits - Sarah Reese. b) panoramic view of the area destroyed by the former tailings site. Photo credits - Richard Barrette

Figure 23: Group picture of the MUN, Queen's, and U Laval-INRS SEG students at the Rambler Metals and Mining ore stockpiles

Day 8 – Springdale: Maritime Resources

May 26th, 2022

Our site visit with Maritime Resources started with a presentation at their office in Springdale, NL on the Hammerdown Deposit and the other exploration sites. Our group was impressed with the ESG focus at Hammerdown as they're focused on having a small environmental footprint during development of the site. In addition to the Hammerdown Gold Project, we also learned about the other exploration sites that Maritime Resources is focusing on, and the various mineralization styles that they have. Most of the exploration properties owned by Maritime Resources are on the eastern edge of the Baie Verte Peninsula, which hosts VMS-style mineralization, as well as porphyry and epithermal gold associated with what is interpreted as an alkaline volcanic centre with caldera collapse features.

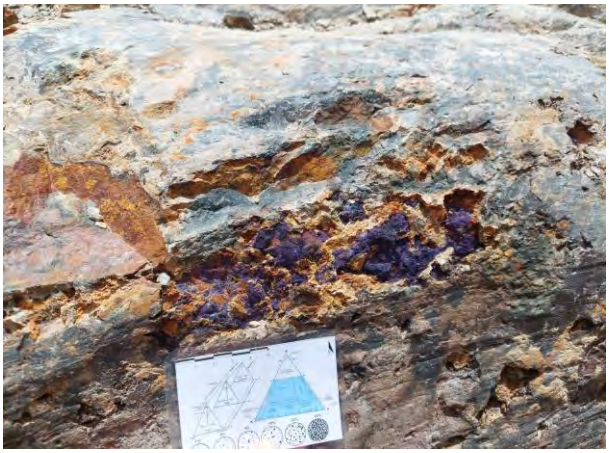


Figure 24 a) Purple fluorite from an REE prospective outcrop. Photo Credits – Samuel Coulombe. b) Group discussion at a Whisker Valley outcrop. Photo credits – Larry Pilgrim (Maritime Resources)

Figure 25: Whisker Valley Trench. Photo credits - Larry Pilgrim (Maritime Resources)

Figure 26: Jasper-style alteration of an alkaline rhyolite. Photo credits – Liam Maw

Following the presentation, we went out to the Green Bay and Whiskey Valley prospects, testing the AWD capabilities of our rental vehicles. We visited some of the Orion and Whiskey Valley outcrops with the Maritime Resources team and had a great lunch in the field with them. One of the students' favourite trenches that we saw was in the Whiskey Valley area. This site has an REE showing with purple fluorite at the surface, associated with a jasper-style alteration of an alkaline rhyolite with honey-yellow sphalerite. There are also locally anomalous gold values from some samples in this outcrop. The visit to Maritime Resources showcased the diverse geology of Newfoundland and allowed the SEG students to see atypical styles of mineralization with diverse alteration assemblages that have yet to be fully understood.

Figure 27: Queen's and U Laval-INRS students with the Maritime Resources geologists and field technicians

Day 9 – Gander: New Found Gold Corp

May 27th, 2022

Our final exploration site visit was the Queensway Project owned by New Found Gold Corp. We started the day with a presentation in their Gander office learning about the geologic and mining history in the area, as well as the general geology of the deposit. The Queensway Project is on the Dog Bay Line, which is a suture zone that formed as the Iapetus Ocean closed. New Found Gold is exploring along this structure as significant gold deposits have been found along parallel fault zones that formed at the same era in England in the southern Appalachians. The gold is hosted in large, milky white, vuggy quartz veins within Middle Ordovician shales and siltstones. Gold is generally native within the veins, and associated with minor amounts of boulangerite and ammonium-rich phengite.

Figure 28: Learning about the drill core from the Keats Zone with Melissa Render, the VP of Exploration at New Found Gold Corp. Photo credits - Richard Barrette

The Queensway Deposit was discovered after outcrops with visible gold were found, and a comprehensive review of all data was completed. The first drillhole on the project returned 90 g/t Au over 19 metres. Compared to other orogenic gold deposits, the deposit doesn't have a strong alteration halo nor a significant contrast with surrounding host rocks making exploration with geophysical methods difficult. Because of this complexity, the company must rely solely on mapping and structural models from Borehole Televiewer data to understand the deposit and vector towards more veins. Oriented drilling was also attempted, but the data was not worth the effort due to the poor rock quality. Consequently, the company drills an incredibly tight grid for an exploration company (as little as 15 metre spacing on some targets) to make further discoveries. The drill collars strewn through a mulched field are an astounding sight to see, and give context to the level of detail in their drill campaign.

Figure 29: Samples of visible gold a) drill core from the Keats Zone, b) hand sample from the discovery outcrop. Photo credits - Siobhán Keane

Following the presentation, we had the opportunity to see core from the Lotto, Dome, and Keats targets along the Appleton Fault Zone. This was exciting for many students who hadn't seen visible gold in diamond drill-core before. One of the most exciting parts of this visit was the field portion; in addition to seeing the drill casing at the Keats target, we also visited the Dome and Discovery outcrops where many students were allowed to hammer away and collect samples with visible gold. Our visit with the New Found Gold team displayed the potential of this site and why it is currently one of the most discussed exploration projects in Canada.

Day 10 – St John's: National Historic Sites

May 28th, 2022

On the last day for the ULaval-INRS group we visited Cape Spear, a headland located in the Avalon Peninsula and the easternmost point in North America. Originally constructed in 1836, the Cape Spear lighthouse is the oldest surviving lighthouse in Newfoundland and was kept by the Cantwell family for 150 years, with two intermissions. The original lighthouse and lighthouse keepers living quarters have been restored and are designated a National Historic Site of Parks Canada.

Figure 30: a) Cape Spear light house, b) Hannah Brommecker checking out some cross-bedding in sedimentary rocks of the Avalon Zone

Day 11 – St John's: INRS-ULaval departure and Signal Hill (Queen's)

May 29th, 2022

On the last day for the Queen's students, we went to Signal Hill which overlooks St. John's, with its summit reaching roughly 167 metres above sea level. There are commanding views of the Narrows, a channel through which all ships must pass when entering St. John's Harbour from the Atlantic Ocean. This site was important for communications and defence. Its fortifications defended St. John's harbour for centuries and in 1901 Guglielmo Marconi received the first transatlantic wireless transmission at Signal Hill.

As the French and British battled for Canada, Signal Hill became an important military post and after the departure of the British in 1870 it remained an active flag signalling and communication post that supported the rise of St. John's as a commercial centre. During the second world war, it was an important port for departing merchant marine vessels and the allied forces that protected them. Consequently, German U-boats would roam the rocky seafloor in order to ambush ships leaving the Narrows. The Narrows receive plenty of traffic today, as St John's remains an active port city.

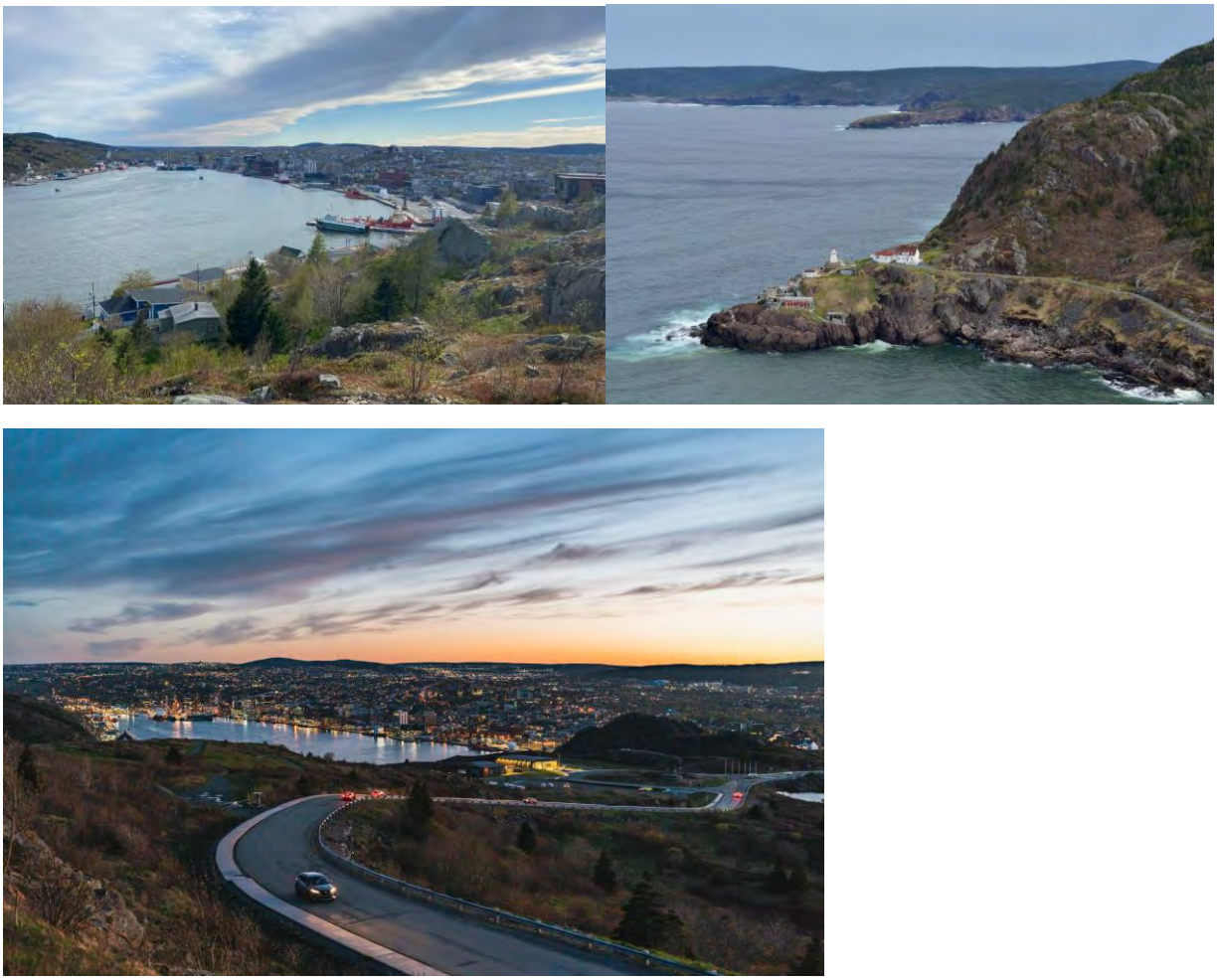

Figure 31: Views from Signal Hill on a sunny afternoon and at sunset. Photo credits - Siobhán Keane and Sarah Reese

References

Baker, D. F. (1979). Geology and geochemistry of an alkali volcanic suite (Skinner Cove Formation) in the Humber Arm Allochthon, Newfoundland. Master's thesis, Memorial University of Newfoundland.

Bichan W. J. (1960). Commercial chrysotile deposits, Baie Verte, Notre Dame Bay District, Newfoundland - Preliminary Notes. *Economic Geology,* Vol. 55, pp. 399-401.

Geology of the Island of Newfoundland, (1990). Geological Survey Branch, Department of Mines and Energy, Government of Newfoundland and Labrador.

Stevens, R.K., Calon, T. and Hingston, R. (2003). From the Intertidal Zone to the Upper Mantle - the Amazing Geology of Gros Morne National Park. Geological Association of Canada, Newfoundland Section, St. John's, Field Trip Guidebook, 39 pages.