Public engagement: the key to the success of UK science

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British scientists “punch above their weight”. Despite lower levels of funding compared to North American colleagues, their work is more innovative and highly cited. Yet, conversely British scientists are poor at public dialogue. This results in (1) public opposition to certain research, e.g. GM foods, (2) a dearth of private funding and (3) a lack of appreciation of the societal benefits of science. In the course of my Winston Churchill Memorial Traveling Fellowship, I wanted to learn how North American practitioners communicate science in order to help British scientists become more “outward-facing” professionals. Such Trans-Atlantic transfer of principles of ‘best practice’ is of special strategic importance given the current squeeze on research funding as a result of the 2011 spending review.

In my proposal I planned to undertake four week-long placements at (1) Stonehammer Geopark, New Brunswick, (2) Smithsonian Museum of Natural History, Washington DC, (3) the Press Office of the University of Chicago, and (4) the Alumni Foundation of the University of Chicago. Directly related to each of these placements, the four questions I wanted to address were: (1) How can scientists develop the economic potential of regions of special scientific interest through tourism? (2) How can scientists educate the public about the importance of science for their daily lives? (3) How can scientists maximize the private funding potential of their work through networking? (4) How can scientists maximize the impact of their research in the international media? Unfortunately, due to strategic staff changes and budget cuts, the Chicago placements became untenable; however, a media opportunity arose in January 2012 (discussed below), which allowed me to fill the gap left by the fourth placement.

In a general sense, across all the various placements, I was particularly interested in exploring the role of “new media” in developing the impact of scientists and their science. Specifically, I wanted to explore how social networking (e.g. facebook, twitter, ning, linkedin) and viral advertising (e.g. YouTube) complement traditional approaches to media, education, funding and outreach. In this report, I summarise my initial findings and discuss some actual and proposed impacts of the work including (1) creation of educational/outreach resources for the Stonehammer GeoPark – see Appendix A; (2) advice to UK’s Jurassic Coast World Heritage Site, and (3) seminars to university colleagues.

1. Stonehammer Geopark

I had the pleasure of spending 7 days at Stonehammer Geopark, near Saint John, New Brunswick in late August 2011, kindly hosted by the executive director of the site, Gail Bremner. The UNESCO-sponsored geopark was created in 2010 and remains the only geopark in North America. In the course of my visit, I had the opportunity to meet with a variety of stakeholders from the Saint John Municipality (the site owners), business people working in the tourism and hospitality industry, education and outreach workers, as well as scientists concerned with the conservation and geological significance of the site.
The following is a brief summary of a few of the key meetings and the discussions that took place:

**Gail Bremner** of Bremner and Associates is the Executive Director of the Geopark. We discussed the management structure of the geopark, in particular, issues around branding and public ownership, business partnership and sponsorship, and investigated the role the social media and viral advertising was playing in forming the identity of the geopark and transforming it into a global product.

**Hemant Kumar** is Economic Development Officer at Enterprise Saint John and is responsible for marketing and job creation. We discussed the potential for maximizing the regional economic impact of the geopark.

**Brittany Kitchen** is the Cruise Development Officer for the Saint John Port Authority. She reported that Saint John annually welcomes 200,000 visitors on cruise ships out of a total tourist volume of 1.5 m visitors. Although the cruise ship season is relatively short (June-September), it coincides with the optimum time to experience the Geopark and we discussed opportunities to better integrate site visits with the itinerary of the main carrier, Carnival Cruises.

**Bill Merrifield** is an independent Wealth Management Consultant and advisor to the geopark. We discussed the challenges and opportunities associated with corporate investment.

**Beth Kelly Hatt** is Director of Aquila Tours and **Wanda Hughes** is the Program Manager at Go Fundy Adventures. In separate meetings we discussed the development of a new generation of tours aimed at telling the story of the “last billion years” to cruise ship visitors. The average spend on shore is $100 but if high quality tour opportunities became available, the potential to increase that spend would be significant.

**Randall Miller** is a geologist at the New Brunswick Museum and Science Chair for the geopark. We discussed ways to promote scientific research in the geopark, issues of site conservation, and education and outreach.
**Education and outreach.** In addition to meetings with these various stakeholders, I also spent three days exploring various sites in the geopark in the company of Randall Miller. Together we agreed to write a field guide to the geopark, which is attached to this report as Appendix A; it will be shortly published in the magazine, *Geology Today*. The field guide describes the billion years of history preserved in the geopark and comprises the first authoritative location-by-location introduction for visitors to the geopark.

**Unexpected academic outcomes.** Also in the course of our field explorations, Randall and I located some interesting new fossil sites in the Tynemouth Creek area of southern New Brunswick. As a result of these discoveries we got in touch with Nic Minter, a fossil specialist at the University of Saskatoon, and commenced a new collaborative research project in October 2011. An unexpected outcome of this work is that Nic applied to join my research group as Leverhulme Early Career Fellow in March 2012. His application is pending with results known in May 2012.
2. NMNH Smithsonian Institution, Washington D.C.

I had the pleasure of visiting the National Museum of Natural History (NMNH) Smithsonian for 5 days in September 2011, hosted by palaeontologist, Bill DiMichele. In the course of my visit, I had the opportunity to meet with members of the education, outreach and exhibits teams. The questions that I was keen to address were as follows: How does the NMNH Smithsonian share, promote and educate the public about science? How does it secure financial support through government agencies and private partnerships? How does it utilize technology and new media in these areas, and how does it measure success?

The following is a brief summary of a few of the key meetings and the discussions that took place:

**Shari Werb** is the Director of Education and Outreach. We discussed the role of social media (twitter, facebook, ning) in developing public networks and strategies for engaging with those networks to meet educational goals and funding targets.

**Bill Watson** is Chief of Onsite Learning. We discuss the strategies utilized to create and maintain the global reach and brand identity of the NMNH Smithsonian.

**Amy Bolton** is Education Center Project Manager. She showed me the Smithsonian’s innovative Discovery Room in which children and young people can explore their own interests at their own pace – guided by an army of well-trained volunteers.

**Rebecca Bray** is Education Center Technology Project Lead and Interactive Design Manager. We discuss a wealth of issues and possibilities in the areas of interaction design, new media, animation, graphic design, web design, sustainability planning and marketing, installation design, and environmental education with a particular focus of science outreach.
Bill DiMichele is a palaeontologist at the NMNH Smithsonian. We discussed private partnerships and the challenges/opportunities presented by alumni sponsored research.

**Education and outreach.** The NMNH Smithsonian visit also provided the opportunity to feed information and ideas into the development of a new educational and conservation site in New Mexico, U.S.A. called Prehistoric Trackways National Monument. Subsequent visits to the monument have provided the opportunity for long-term educational and scientific collaboration with NM state palaeontologist, Spencer Lucas. These experiences, both in New Mexico and in the NMNH Smithsonian, will be fed into outreach work at UK’s Jurassic Coast World Heritage Site through ongoing interactions with site manager, Richard Edmonds.

3. **Interaction with North American media**

Although planned visits to the press office and alumni office at the University of Chicago proved untenable, as noted above, an opportunity arose in January 2012 to gain some equivalent experiences remotely. That month I ran a press release about some of Charles Darwin’s fossils that I’d discovered in a warehouse of the British Geological Survey in Nottingham, UK – which had been lost to science for the previous 165 years. The “Darwin’s lost fossil” story got global pick-up with about 100 million hits worldwide and especially strong pick in the USA, where the story ran coast-to-coast on the six ‘o’ clock news and hundreds of other print/online outlets.

In addition to promoting the story, I took the opportunity to study the US media and develop a large network of media contacts. I’ve been feeding back information learned in the course of this experience through media training sessions at my university and through the British Science Association.

4. **Conclusion**

Overall, I’m enormously grateful for the opportunities I’ve had through the WCMT Fellowship, especially the new network of people with which I’ve interacted. Although the fellowship has ended, it feels like the real journey has only just begun and I look forwards to interacting with WCMT Fellows at future alumni events.
Appendix A. Publication resulting from WCMT fellowship (to be published June 2012, in Geology Today)

Classic Localities Explained:
Stonehammer Geopark, New Brunswick, Canada

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Stonehammer Geopark of New Brunswick, Canada is one of the newest destinations in the UNESCO-assisted Global Geoparks Network, and the first in North America. Its rocks tell the amazing billion-year story of the evolution of eastern North America. Highlights include some of the finest Precambrian stromatolites in the world, a Cambrian site that yielded one of the world’s largest trilobites, and a Silurian section with a rich fauna of fish, crustaceans and sea scorpions. At the famous ‘Reversing Falls’ in Saint John, visitors can also see the boundary between the Late Precambrian Brookville Terrane and the western part of the Avalon Terrane, and learn about the late Silurian closure of the Iapetus Ocean during the final stages of the accretion of North America. In and around the city, Devonian pebbly sandstones represent the erosive remnants of the highlands formed as a result of that terrane accretion event, and slightly younger Carboniferous exposures further shed light on the evolution of life at a time when the region lay on the equator. These include early Carboniferous clubmoss forests preserved on the main highway east of Saint John, and late Carboniferous deposits rich in the remains of fossil plants, insects, giant arthropods, and some of the earliest reptiles – the latter recorded by spectacular trackways. Scattered Mesozoic outcrops and Quaternary moraines continue the story to the present day. Positioned at the gateway of Atlantic Canada, Stonehammer Geopark is a strategic part of an emerging geotouristic network that also includes UNESCO World Heritage Sites at nearby Miscouche, Quebec (Devonian coastal ecosystems) and Joggins, Nova Scotia (Pennsylvanian fossil forests). It presents a brilliant opportunity to teach visitors of the extraordinary story of Earth’s evolution.

Saint John, New Brunswick is Canada’s oldest incorporated city. However, the 225 years since its foundation is a mere blink of the eye compared to the deep recesses of geological time accessible in and around this coastal city. The region’s complex geology reveals the evolution of eastern North America across an amazing one billion years of history. That story is laid out in beautiful detail as a result of the last Ice Age, which has stripped the landscape back to bare rock over large areas. With bedrock lying so close to the surface, even a short walk through Uptown Saint John takes you past dozens of rugged exposures protruding from street corners. Yet this is just the tip of the iceberg compared with the spectacular sea-cliffs of the adjacent Bay of Fundy, many kilometers of road cuttings, and the innumerable rocky river and stream sections – all accessible within an hour’s drive of the city.
The complex and beautifully exposed geology of Saint John and its surroundings has been a magnet for geologists for nearly two centuries. One of the earliest explorers was Abraham Gesner (1797–1864), who is best known for his pioneering work on the distillation of kerosene from a local bitumen deposit (known as ‘albertite’). Gesner was the first Provincial Geologist in the British Empire and produced an influential series of reports on the geology of New Brunswick beginning in 1839. This work saw him travel far and wide and, in 1842, he opened one of Canada’s first public museums in Saint John to display his many rocks and fossils. That same year, he also hosted British geologist, Charles Lyell (1797–1865) in the course of the latter’s epoch-making excursions around North America.

With its close cultural and industrial ties to Great Britain, it is no surprise that Saint John developed as an enclave of traditional Victorian science, complete with its own naturalist society, mechanics’ institute, and their museums. In 1857, the Steinhammer (or Stonehammer) Club was founded to stoke the enthusiasm of the growing numbers of dedicated amateur and professional geologists in the city. Prominent early members included George Matthew (1837–1923), who became Canada’s Cambrian fossil expert, and Fred Hartt (1840–1878), who went on to lead a geological survey of Brazil for many years. This enthusiastic group was nurtured from afar by William Dawson (1820–1899), Canada’s most influential scientist and the long time Principal of McGill University, Quebec.

In 2010, Saint John and its surroundings became one of the newest destinations in the UNESCO-assisted Global Geoparks Network, and the first in North America. Stonehammer Geopark, named in honour of the region’s nineteenth century pioneers, covers an area of 2500 km$^2$ in southwest New Brunswick (Figure 1), and contains an almost complete record of the last billion years of our planet’s history including 107 rock formations and igneous suites. Only rocks of the Jurassic and Palaeogene periods are missing from the onshore succession. The region’s long history of exploration and complex geology means that many sites in the geopark are now considered ‘classic localities’ of global or regional importance. The new geopark designation aims to promote conservation, education and geotourism.

In this article, we provide a fieldguide to Stonehammer Geopark using coordinates from Google Earth to locate key sites (listing them from oldest to youngest). The sites are variously located in public parks and on private land. Access to certain sites requires permission from landowners (as we indicate in the text), but be aware that private land ownership and access arrangements can change at short notice. Please also note that fossils are legally protected under New Brunswick under the Heritage Conservation Act and a permit is required to collect them.

**Locality 1. Neoproterozoic of Green Head**

Some of the oldest rocks in Stonehammer Geopark are visible just 5 km northwest of Uptown Saint John at Green Head near Dominion Park (45°16’42.19”N, 66°07’51.98”W). These rocks belong to the Green Head Group and are of Proterozoic (late Precambrian) age, i.e., about one billion years old. They can be reached by a 1 km hike along an unmarked trail, beginning near the north end of Green Head Road on the outer edge of the city. Alternatively, the site can be accessed by kayak from Dominion Park (45°16’07.09”N, 66°07’11.05”W). Outcrops are located on the shore of the strongly tidal Saint John River and best viewed at low tide.

These exposures have a very important place in the history of geology because it was here, in 1890, that George Matthew in one fell swoop described the world’s first Precambrian fossil and the first Precambrian stromatolites under the name,
Archaeozoon acadiense (the term stromatolite wasn’t coined until 1908).

Stromatolites are the product of cyanobacteria that live in shallow seas and salty intertidal lagoons. The cyanobacteria secrete a sticky film that traps sediment and causes the gradual build-up of a finely laminated mound. Stromatolites provide some of the earliest evidence for the existence of life on Earth. The Green Head stromatolites are amongst the most spectacular in the world. They comprise beautiful columns, up to 60 cm high, preserved in astonishing detail (Figure 2).

Localities

**Locality 2. Cambrian of Hanford Brook**

Another globally important site is Hanford Brook, located about 40 km east of the city (45°27’58.26”N, 65°37’58.79”W), and exposing Lower to Middle Cambrian strata of the Saint John Group. The Saint John Group actually straddles both the Precambrian-Cambrian boundary and the Cambrian-Ordovician boundary in Stonehammer Geopark. Hanford Brook is most easily accessed from Saint John by taking Highway 1 as far as Junction 158 (Hampton) and following Routes 860, 820 and 111 to the community of Hanford Brook. The site comprises the rocky stream section that begins where the river intersects Route 111 (Figure 3). Although access is across private land and only with permission, similar Cambrian outcrops can be viewed where Highway 111 crosses the Hammond River.

In 1895, George Matthew described a rich fauna from Hanford Brook that has become one of the standard sections for Lower Cambrian palaeontology and biostratigraphy. The lowermost beds include ancient, shallow marine tidal deposits of the Ratcliffe Brook Formation. These rocks pre-date the evolution of trilobites and contain microscopic fossils that are enigmatically termed “small shelly fossils”, a group that Matthew was among the first to recognize. The origin of these tiny fossils is somewhat mysterious. Some represent the disarticulated armour of a variety of bizarre, primitive animals such as halkieriids whose evolution eventually led to modern groups like the segmented worms and brachiopods, others like Aldanella are small molluscs. The Hanford Brook site sheds light on the dawn of animal life, when invertebrates were evolving hard parts for the first time, resulting in an ‘arms race’.

Overlying these beds are further Lower Cambrian deposits formed in a variety of wave-dominated coasts and areas of poorly oxygenated marine shelf. These deposits contain diverse assemblages of some of the first trilobites to evolve. The trilobites are of great importance for relative age dating, and for working out palaeogeography (as discussed further under Locality 5). Also present are amazing burrows of Taphrhelminthoida dailyi, feeding traces made by an echinoderm or mollusc-like animal. Rich fossil collections are still made from the streambed at this site. In 1863, not far from here along another brook, Loring Bailey (1839–1925), a professor at the University of New Brunswick, accompanied by Hartt and Matthew, discovered the first Cambrian trilobites described in Canada.

**Locality 3. Cambrian of Uptown Saint John**

If access precludes an excursion out to Hanford Brook, several other important Cambrian sites can be easily visited in Uptown Saint John. One of these is Somerset Street (45°16’45.58”N, 66°03’53.61”W), where a relative recent road cutting below Fort Howe Hill has revealed a Lower Cambrian succession spanning the same time interval as the Hanford Brook site. Although far less fossiliferous, important features include a number of volcanic ash bands that have been radiometrically dated. These allow the New Brunswick succession to be tied precisely to global stratigraphy.
Another important outcrop can be visited about 1 km away (45°17′03.69″N, 66°03′32.59″W) on the corner of nearby Seely and Gooderich Streets, and along Wright Street. Here, a near-complete Cambrian succession unconformably overlies late Precambrian volcanics of the Coldbrook Group. Back in 1887, George Matthew and colleagues collected a rich marine assemblage from this site including trilobites, brachiopods, molluscs, echinoderms and sponges. At a nearby locality, now gone, one of the most famous discoveries was of a gigantic trilobite, *Paradoxides regina*, which at 38 cm in length was the largest known specimen in the world at that time. This spectacular find was actually made by Matthew’s teenage son, William, who later was a well-known palaeontologist in his own right (Figure 4).

**Locality 4. Silurian of Cunningham Creek**

Another important Early Palaeozoic fauna can be found at the Silurian Cunningham Creek site (45°24′04.00″N, 66°19′35.15″W), although access is difficult and limited. This can be reached by heading west out of Saint John along Highway 1 before taking Highway 7 north as far as Blagdon. The site has yielded numerous marine to lagoonal fossils including jawless fishes (heterostracans and anaspids), spiny-sharks (acanthodians), crustaceans, and the remains of giant sea scorpions (eurypterids). George Matthew again played a leading role in some of these discoveries, finding *Cyathaspis acadica* in 1886, the first Silurian fish known from North America. The site has since been visited by generations of palaeontologists from museums around the world, with research yielding information about the largest thelodont fish, *Thelodus parvidens* and more recently the oldest spiny-sharks.

**Locality 5. Silurian-Devonian terrane collision at Reversing Falls**

The next site on our itinerary is the famous ‘Reversing Falls’. This is one of the most well-trodden tourist sites in Saint John, though few of the tens of thousands of visitors that flock to see it each year realise its wider geological significance (45°15′33.60″N, 66°05′12.55″W). The ‘falls’ are, strictly speaking, spectacular rapids formed at the mouth of the Saint John River as the tide on the Bay of Fundy rises and falls by as much as 8 m. As the tide rises, water surges over a submerged ledge of Precambrian marble (Green Head Group), creating upstream rapids and as the tide falls, the direction of the river reverses. To better describe this phenomenon, the locality is now commonly referred to as the Reversing Rapids, the same name Charles Lyell used when he visited in 1852.

Of especial interest to the geologist is the excellent exposure through the boundary between two ancient microcontinents (or terranes). The Precambrian Green Head Group exposed to the northwest is part of the Brookville Terrane while to southeast the Cambrian-Ordovician Saint John Group belongs to the Avalon Terrane (Figure 5). The story of the closure of the Iapetus Ocean at the end of the Lower Palaeozoic will be one that is well known to readers. That event brought England and Wales (eastern Avalon) into juxaposition with Scotland and Northern Ireland (Laurentia), unifying the British Isles for the first time. However, further west in Atlantic Canada, the situation was more complex with the small Brookville Terrane docking against Laurentia just prior to the collision of the western end of the Avalon Terrane. The same Cambrian trilobite species visible in the Saint John Group at Hanford Brook and Uptown Saint John can be also found in England and Wales demonstrating the palaeogeographic continuity of Avalonia.

Related to this story of terrane accretion are the Late Devonian pebbly sandstones of the Kennebecasis Formation, which are well exposed in the north end
of Saint John and easily accessed along the beach at the city’s Tucker Park on the Kennebecasis River (45°18’40.50”N, 66°05’55.99”W). These ancient river deposits resulted from the erosion of the mountains created by the closure of the Iapetus Ocean, and unconformably overlie the older Palaeozoic basement in and around Saint John. The first fossil in these rocks was only found a few years ago. Remains of a single lobefin fish, *Holoptychius* suggest a richer fauna of fish or even early amphibians and their ancestors might lie hidden in these beds.

**Locality 6. Earliest Carboniferous of Norton**

Also widely exposed in the geopark are early Carboniferous deposits dating from a time when Atlantic Canada was close to the equator. One such locality is found on Highway 1, 50 km northeast of Saint John. This road was widened about fifteen years ago and the blasting revealed spectacular rock sections between Junction 166 (Bloomfield) and Junction 175 (Norton). The rocks represent the deposits of large rift lakes, similar to those of the East African rift today, but perhaps at times distantly connected to the sea. Rifting was caused by the sideways convergence of Gondwanaland, which open up a series of strike-slip basins. Some of the deposits of the rift lakes contain rich assemblages of fossil plants, fish and trace fossils.

One particularly striking exposure is located on the northeast-bound carriageway of Highway 1. Here beds stand in near vertical position, creating some huge bedding plane exposures that run parallel to the highway. On one of these, the coaly stumps of several hundred trees are preserved. The stumps resemble giant tulip bulbs with small roots radiating off them. They represent the bases of small clubmoss trees that formed dense, tangled thickets fringing the edge of the rift lakes. The trees, which are over 350 million years old, represent some of the oldest fossil forests in the whole of Canada (Figure 6). They were preserved when earthquakes caused the margin of the rift to abruptly subside below lake level, drowning the forests. From this site, a trail leads to the covered bridge over Moosehorn Creek (45°36’32.84”N, 65°43’14.84”W) where the first plant fossils here were discovered by the Geological Survey of Canada in the early 1900s.

**Locality 7. Late Carboniferous of the Fern Ledges**

Late Carboniferous rocks are amongst the best exposed in Stonehammer Geopark and found all along the Fundy coast. Although this was the age when steamy tropical rainforests flourished across much Europe and North America, there are relatively few coal deposits preserved in the region. The nearest late Carboniferous coal deposits are found near Jemseg (45°49’49.64”N, 66°06’46.79”W), just beyond the northern edge of the geopark. These deposits have an important place in history for it was here that coal was mined for the first time in the whole of North America. Commercial mining began in 1639 and supplied the nascent Massachusetts Bay Colony, 500 km to the southwest.

For the casual visitor, the most easily accessible late Carboniferous rocks are located in west Saint John on the beach near Seaside Park (45°14’43.48”N, 66°04’55.32”W). These wave-battered rocky outcrops are not much to look at but they have been the subject of scientific study and controversy for the past 150 years and continue to be intensely scrutinized today. The site came to prominence in 1861 as a favourite collecting ground for the Steinhammer Club. Members dubbed it the Fern Ledges because of its beautiful fossil plants. However, other prized specimens that emerged included insects (Figure 7), one example putatively preserving a stridulating organ. This specimen, mentioned by Charles Darwin in *The Descent of
**Locality 8. Late Carboniferous of Gardner Creek**

Some other striking late Carboniferous outcrops in Stonehammer Geopark can be found in the high sea-cliffs of the Bay of Fundy, near Gardner Creek. To get to this site, you need to take Highway 1 east out of Saint John as far as Junction 137 (Rothesay) and follow Route 111 and 825 to Gardner Creek. You can park near the bridge where the road crosses the big tidal creek (45°16’37.16”N, 65°43’11.01”W) and then explore the coastal cliff section for 2 km southwest as far as McCoy Head (45°15’34.43”N, 65°43’53.34”W). Be warned that this section is subject to 8 m tides and can only be safely accessed on falling tides.

At Gardner Creek in the early 1980s, Canadian geologist Guy Plint found amazing trails left by the passage of a giant bug called *Arthropleura*. Along with colleagues, he described a five metre long trail that wound its way through a thicket of fossil horsetails. The animal that made this trail looked similar to a British woodlouse but attained a length of two metres! Bugs probably reached giant size in the Carboniferous as a result of the high oxygen levels, which may have topped 30%. Atmospheric oxygen concentration is a key constraint on the maximum body size of insects today. While Plint’s original trail has long since weathered away, many other examples can be still found along the length of the section (Figure 8). Trackways of a rather different animal can be found at other locations near Gardner Creek. Last year, we were both involved in the exciting discovery of hundreds of footprints left by some of the earliest reptiles to evolve on our planet (Figure 8). The tracks were impressed in the muddy deposits of an ancient watering hole that developed on an arid river plain. The animals may have come to the river to drink. The dominance of reptiles in these dryland deposits suggests that reptiles may have had an ecological advantage over their amphibian cousins. This is because reptiles lay eggs with hard shells that can be laid in dry soils whereas amphibians need to return to water to spawn.

**Locality 9. Permian-Triassic of St. Martins**

Heading 20 km eastwards from Gardner Creek (along Route 825 and 111), eventually takes you to St. Martins, the seaside tourist hub of the geopark. The rocks of this region erode to form scenic sea-caves and ‘flowerpots’ (Figure 9), but more importantly reveal the origin of the Atlantic Ocean. The Bay of Fundy, on which St. Martins is located, developed as an aborted arm of the rift system that eventually created the Atlantic, splitting ancient Avalonia across a modern ocean.
On the east side of St. Martins (45°21’29.69”N, 65°31’24.41”W), and at various nearby locations along the coast, there are good exposures of the earliest sediments to fill the North Atlantic rift. These include Permian and Triassic red beds formed on river plains and deposited by wind-blown dunes that date from a time when Atlantic Canada lay in the arid climate belt. On the other side of the Atlantic, identical deposits can be seen in the British Midlands. Further east of St. Martins, the Fundy Trail Parkway is a 10 km drive or hike to Big Salmon River along the top of the plateau overlooking the rocks (45°23’45.78”N, 65°27’11.88”W). Hiking trails at places like Melvin Beach provide an opportunity to inspect these ancient deposits close-up (Figure 9).

**Locality 10. Cretaceous at Vinegar Hill**

New Brunswick has a single known outcrop representing the Cretaceous Period located near the eastern margin of the Stonehammer Geopark at Vinegar Hill about 50 km northeast of Saint John (45°36’23.01”N, 65°32’19.48”W). Unfortunately, these sediments are preserved in a working quarry and not accessible to the public; however, they can be viewed from the road. Here, the Cretaceous comprises the sand and gravel of ancient rivers that flowed across Atlantic Canada during a time of globally warm ‘greenhouse’ climate. Under these hot, wet conditions, only the quartz survived the intense weathering, resulting in clean, white sand. These sediments are now used as an aggregate resource and to produce high quality sand for filters and golf course bunkers. To date, a single fossil of *Araucarioxylon*, related to the modern Monkey Puzzle tree provides the only window into life during New Brunswick’s Cretaceous past.

**Locality 11. Late-glacial of Sheldon Point**

The penultimate site in our itinerary sees us leave the balmy Cretaceous for the frozen late Quaternary. At Sheldon Point in the Irving Nature Park, Saint John (45°13’33.32”N, 66°07’00.74”W), a record of the final stages of the last Ice Age are preserved. Here, coastal sections preserve the deposits of a tidewater glacier that created an interfingering of moraine, marine clay and glacial outwash deposits. Fred Hartt first documented the fossils here in 1865, and clams, sea urchins and brittlestars continue to weather out of this ancient sea bottom today (Figure 10). Widespread glaciation of eastern North America during the Quaternary was probably responsible for the removal of much of the post-Cretaceous sedimentary record.

**Locality 12. Postglacial rivers**

Our billion-year story of Stonehammer Geopark ends with the spectacular postglacial rivers found at various sites. Best developed are those north and east of the Saint John at Brundage Point (45°20’52.40”N, 66°13’27.36”W) and Hampton (45°32’29.32”N, 65°50’12.07”W). These were formed as the inland seas that drowned the river valleys following sea level rise at the end of the Ice Age, drained away as the land rebounded. Pollen records associated with these valleys show that as the Appalachian Ice Complex, which covered all of New Brunswick until as recently as 14,000 years ago, finally melted from the landscape passed through tundra and northern boreal vegetation before reaching the mixed Acadian forest that we see today.

**Bright future for last billion years**
This brief guide just gives a just taste of the treasure trove of geological sites found in Stonehammer Geopark. A well-written and beautifully illustrated book that provides further details about sites is *The Last Billion Years* available from the Atlantic Geoscience Society for about £15 (ags.earthsciences.dal.ca/AGS_Pubs.php). This book comprises an essential companion for any would be geologist, venturing out into the landscape of Atlantic Canada. Another useful ‘resource’ is the New Brunswick Museum at Market Square, Saint John (45°16'22.96"N, 66°03'47.78"W), which contains many excellent and innovative exhibits.

Atlantic Canada has long been a popular tourist destination, recognized for its outstanding natural beauty. However, the designation of Stonehammer Geopark now offers the potential for further development as a geotouristic hub. Strategically positioned near UNESCO World Heritage Sites at nearby Misguasha, Quebec (Devonian coastal ecosystems) and Joggins, Nova Scotia (Carboniferous fossil forests, see Geology Today, v. 26, 108-114; 2010), Stonehammer Geopark comprises part on an emerging geotouristic network that will promote ongoing science, protect and conserve fragile fossil resources and educate visitors about the amazing billion-year story of North America’s evolution.

**Further Reading**


**Acknowledgments.** Howard Falcon-Lang was funded from a Winston Churchill Memorial Traveling Fellowship

**Figure captions**

Figure 1. Geological map of Stonehammer Geopark, southern New Brunswick, Canada, a member of the Global Geoparks Network. Numbers (1–12) refer to sites mentioned in the text.

Figure 2. Spectacular Precambrian stromatolites named *Archaeozoon acadiense* by George Matthew, in 1890, can be reached on foot or by kayak at Green Head, north of Saint John.

Figure 3. The Precambrian-Cambrian Hanford Brook site east of Saint John, New Brunswick has produced some amazing fossils like this echinoderm or mollusc-like feeding trace, *Taphrhelminthoida dailyi*.

Figure 4. Teenager, Will Matthew, discovered the giant trilobite *Paradoxides regina* about 1885 (left, painting by Judi Pennanen for the New Brunswick Museum, 1999).
Figure 5. The boundary between the Precambrian Brookville Terrane (white marble) and the Early Palaeozoic Avalon Terrane (dark cleaved beds) at the Reversing Rapids in Saint John, New Brunswick.

Figure 6. Early Carboniferous rift lakes near Norton have produced clubmoss tree stumps that look like giant tulip bulbs and beautiful palaeniscid fossil fishes of *Elonichthys brownii*.

Figure 7. The famous late Carboniferous Fern Ledges of Saint John has yielded a rich flora including *Alethopteris lancifolia*. One associated insect fossil may preserve a stridulating organ.

Figure 8. Late Carboniferous sea-cliffs near Gardner Creek have recently revealed some of the earliest known reptile footprints, together with the trails of the giant woodlouse-like animal, *Arthropleura*.

Figure 9. Permian and Triassic rocks were the first sediments to infill the newly formed North Atlantic rift. Along the Fundy coast they erode to form sea caves and ‘flower pots’.

Figure 10. Sheldon Point in the Irving Nature Park near Saint John preserves 14,000 year old deposits of a tidewater glacier, complete with a rich coldwater fauna including brittlestars like *Ophiura sarsi*.