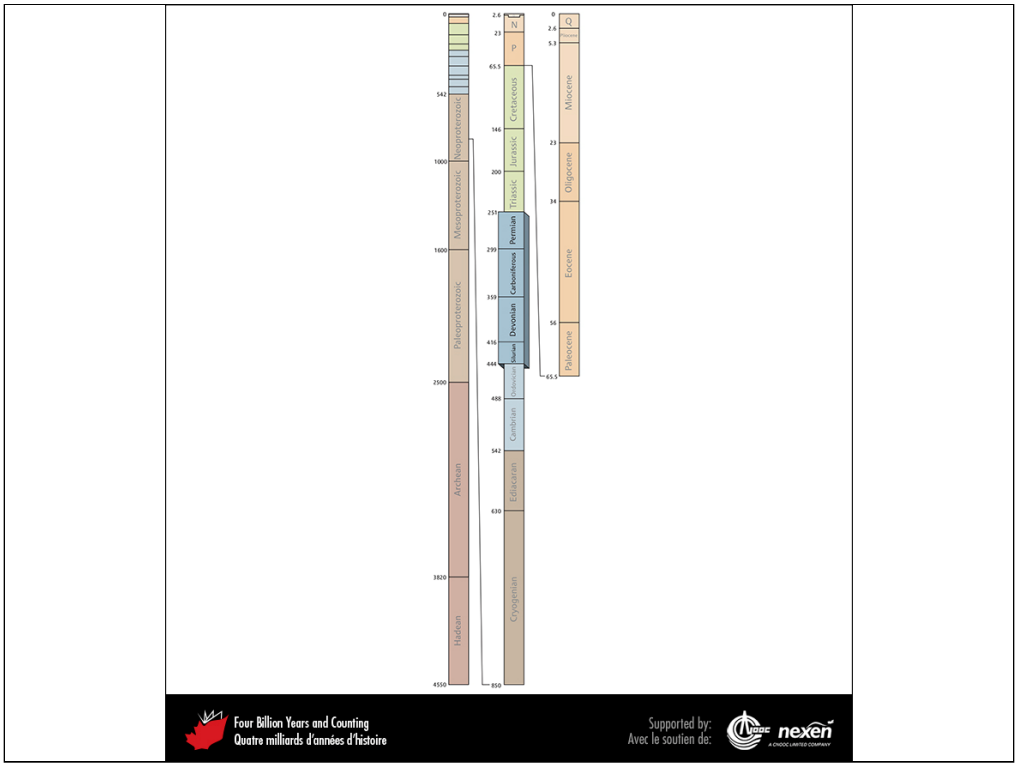
CHAPTER 8
Part 1 of 4

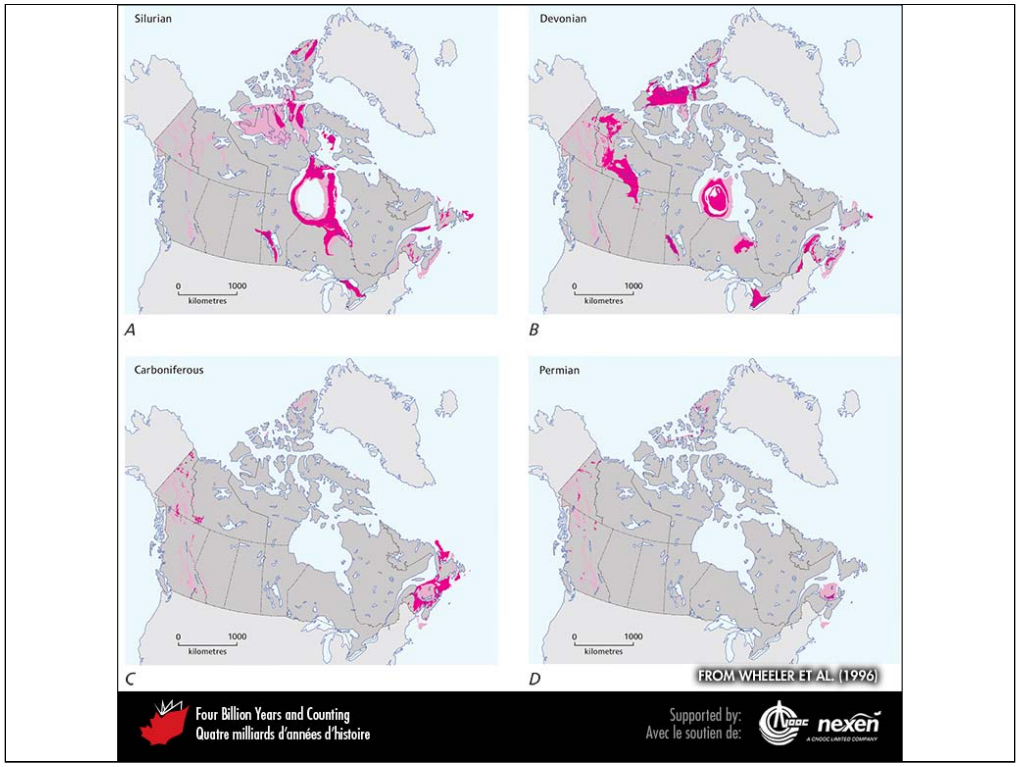
Cape Tryon, Prince Edward Island, where the cliffs consist of Permian red fluvial sandstone. RON GARNETT / AIRSCAPES.CA.



Geologic time scale, showing the interval covered in this chapter. Numbers indicate millions of years ago. P = Paleogene (Paleocene to Oligocene), N = Neogene (Miocene and Pliocene), and Q = Quaternary.

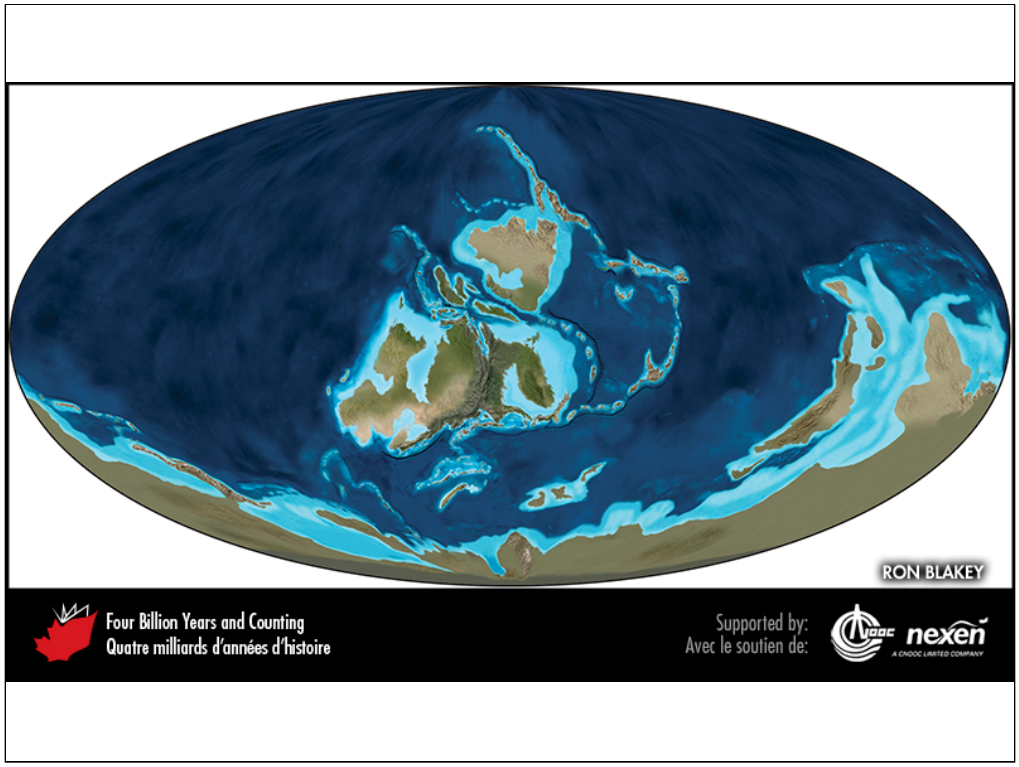
William Logan in his laboratory in Montréal. REPRODUCED WITH THE PERMISSION OF NATURAL RESOURCES CANADA 2013, COURTESY OF THE GEOLOGICAL SURVEY OF CANADA.

Tilted late Carboniferous rocks are exposed in the cliffs and on the beach at Coal Mine Point, Joggins, Nova Scotia. Note the coal seam extending from bottom right. ROB FENSOME.



General extent of Silurian (*A*), Devonian (*B*), Carboniferous (*C*), and Permian (*D*) rocks at the surface (beneath glacial deposits), onshore and offshore. The lighter shaded areas denote either uncertainty or areas where rocks of the particular age have been confirmed but are intimately associated with rocks of other ages and the scale of the map doesn't allow us to show them separately. ADAPTED FROM WHEELER ET AL. (1996).

Paleogeography of what was to become North America and adjacent regions in the Silurian, 420 million years ago. Land is shown in brown, with shading showing topography. The lighter blue areas represent possible coastal or nearshore areas, darker blue represents deeper ocean waters, and black indicates trenches. Aspects of modern geography are shown for orientation.



Global paleogeography 420 million years ago, during the Silurian. Colours as for previous figure.

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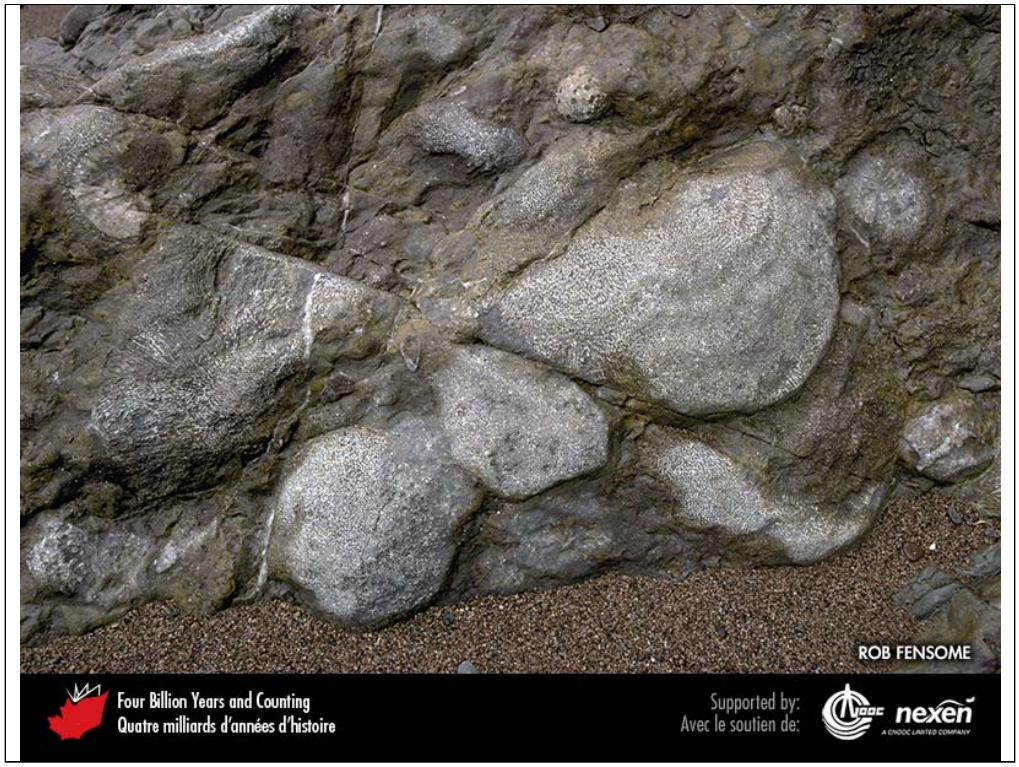
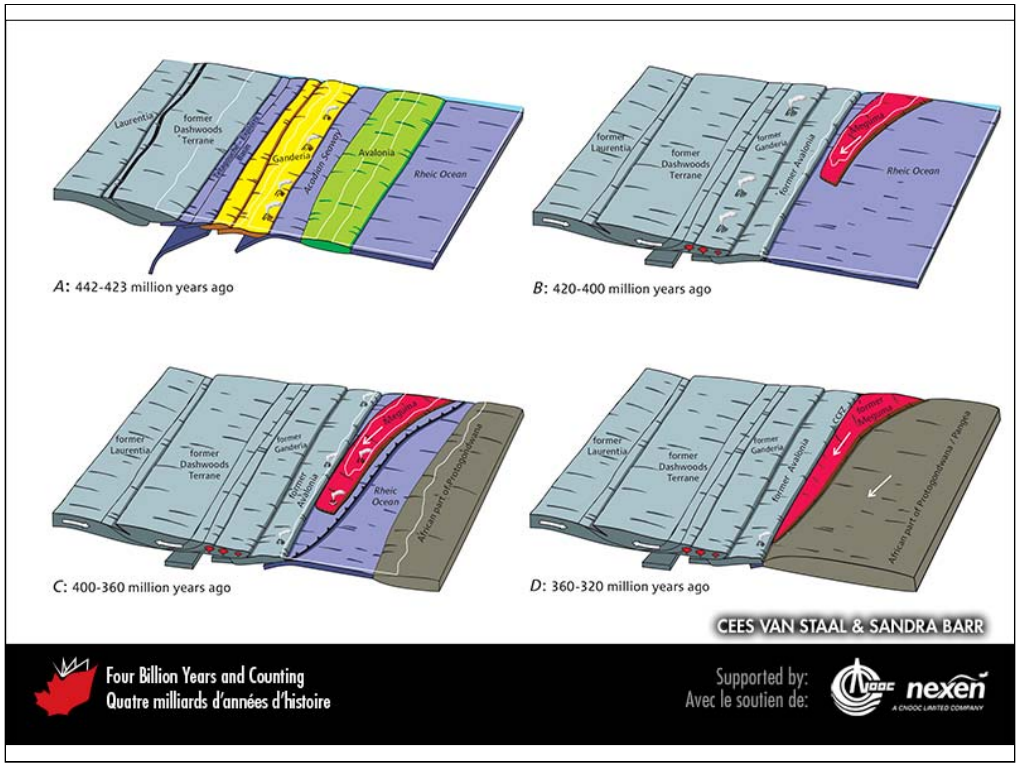
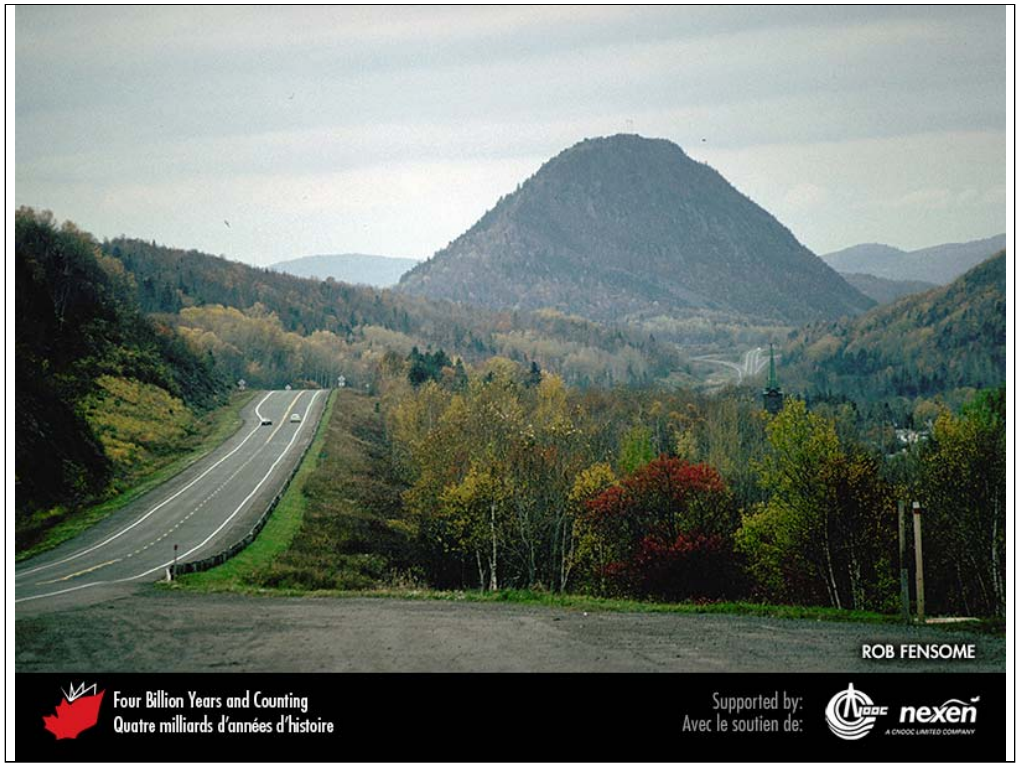


Colonies of the Silurian coral *Favosites* in strata at Quinn Point, near Jacquet River, New Brunswick. ROB FENSOME.

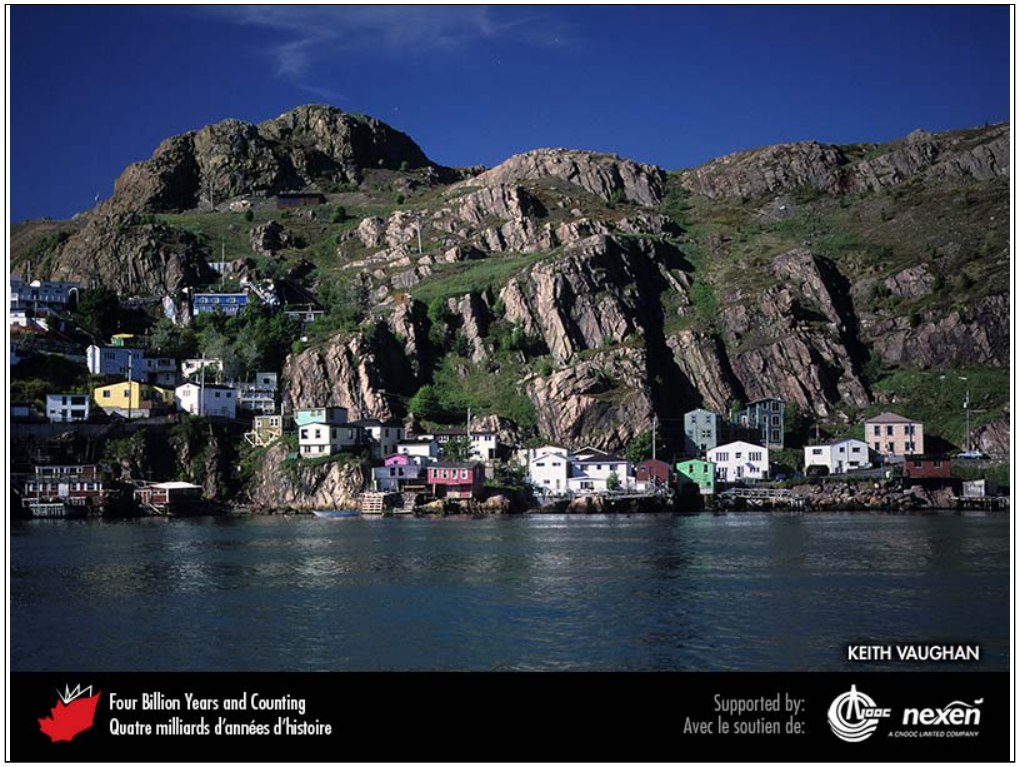


The relationships of the various Appalachian terranes and seaways with Laurentia during part of the early Silurian (*A*); and with Euramerica during the late Silurian to early Devonian (*B*), the middle to late Devonian (*C*), and the early Carboniferous (*D*). The white lines indicate sea level.

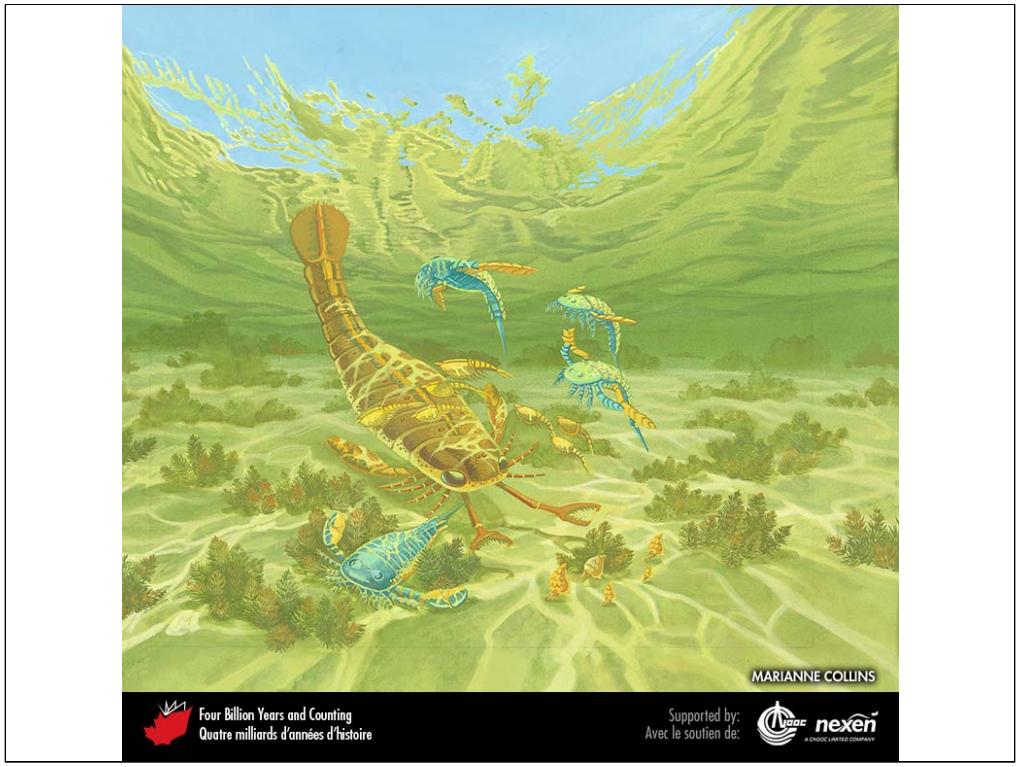


Sugarloaf Mountain near Campbellton, New Brunswick, is an eroded volcanic plug, reflecting magmatic activity in Ganderia during the early Devonian. ROB FENSOME.

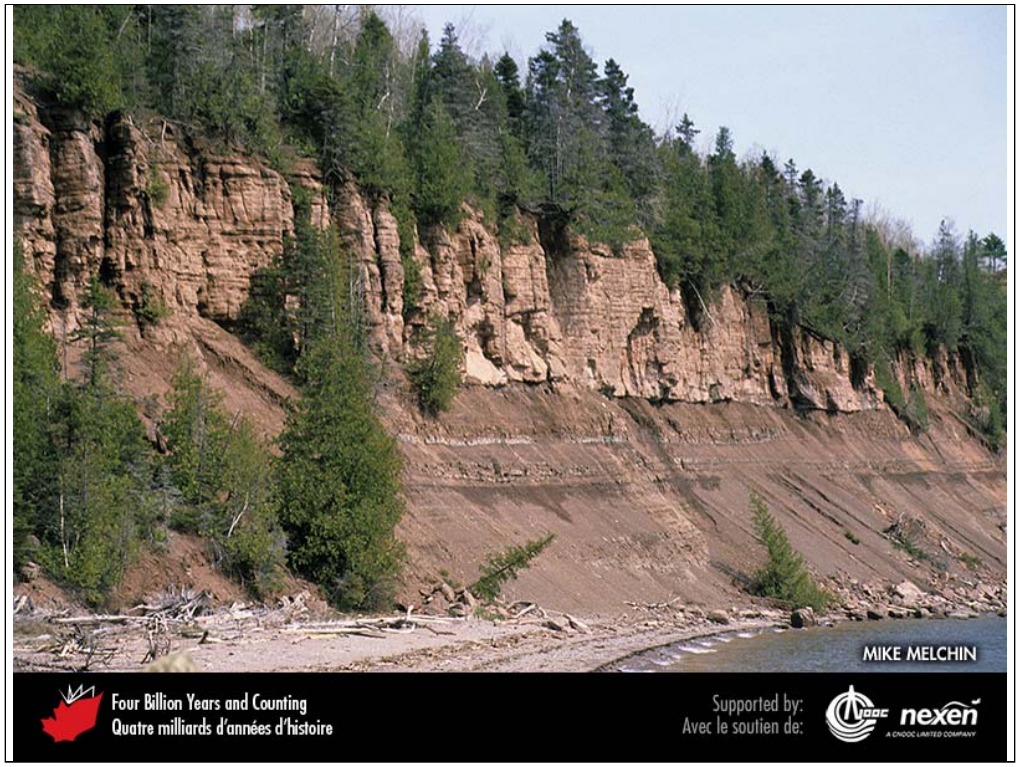
These late Ordovician to early Silurian muddy limestone beds are exposed in the gorge of the Saint John River at Grand Falls, New Brunswick. The original sediments were deposited in a sedimentary basin on former Ganderia, and were deformed between about 440 and 390 million years ago, during the Salinic and Acadian orogenies. ROB FENSOME.



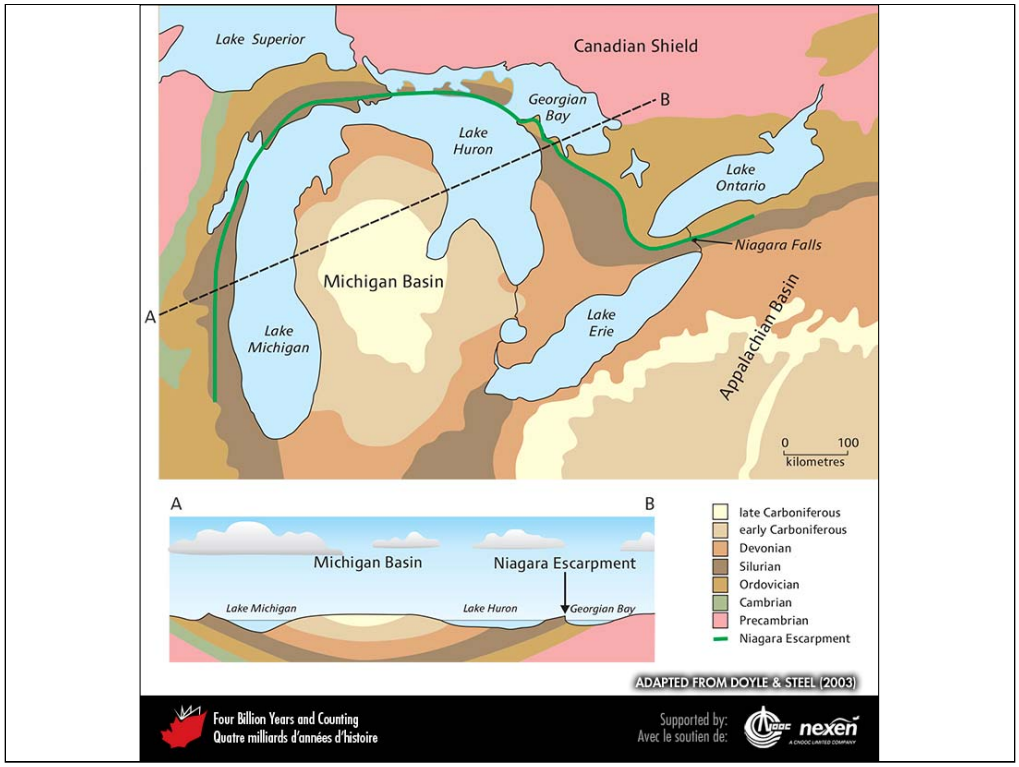
Ediacaran strata deposited on Avalonia and tilted during the Acadian Orogeny, St. John's, Newfoundland. KEITH VAUGHAN.



Life in a sheltered Silurian lagoon about 420 million years ago. Shallow, warm embayments were havens for eurypterids (sea scorpions), swimming predators up to 2 metres long and among the largest arthropods known. Their segmented bodies were usually streamlined and tapered to a tail end variably developed into a narrow spike or broad leaf-like structure. Their jointed limbs, which bore spines, pincers, and paddles, were attached beneath the head shield. Also shown are several small shrimp-like crustaceans, swimming across the path of the eurypterids, and a cluster of snails grazing among clumps of green algae on the seabed. PAINTING COPYRIGHT MARIANNE COLLINS, ARTIST.



By the middle Devonian, large areas of the Appalachian Orogen were land and washed by rivers that left redbeds as their legacy, as here west of Miguasha, on Quebec's Gaspé Peninsula. MIKE MELCHIN.



At the top is a geological map of the Michigan Basin and adjacent areas showing the ages of the rocks exposed at the surface (after glacial deposits have been removed) and the course of the Niagara Escarpment. Below is a section across the basin from west of Lake Michigan to the Canadian Shield as shown by the line from A to B in the map. ADAPTED FROM DOYLE AND STEEL (2003).

Looking out through the entrance of a cave cut in Silurian carbonate of the Niagara Escarpment. This cave faces Georgian Bay at Halfway Rock Point, Bruce Peninsula National Park of Canada, Ontario. D. A. WILKES, COPYRIGHT PARKS CANADA.

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An aerial view of the Niagara Escarpment in Bruce Peninsula National Park of Canada, Ontario. The Escarpment is formed of erosion-resistant Silurian carbonate deposited in the Michigan Basin. J. BUTTERILL, COPYRIGHT PARKS CANADA.

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Specimens of the Silurian brachiopod *Virgiana* surrounding a coral, in a carbonate rock from east of Churchill, Manitoba, within the ancient Hudson Bay Basin. GRAHAM YOUNG.

Stromatolite in Silurian carbonates, Prince Leopold Island, off the northeastern corner of Somerset Island, Nunavut. NORA SPENCER.

Silurian carbonates deposited on the Euramerican margin of the Ural Ocean, now exposed on Prince Leopold Island, off the northeastern corner of Somerset Island, Nunavut. NORA SPENCER.

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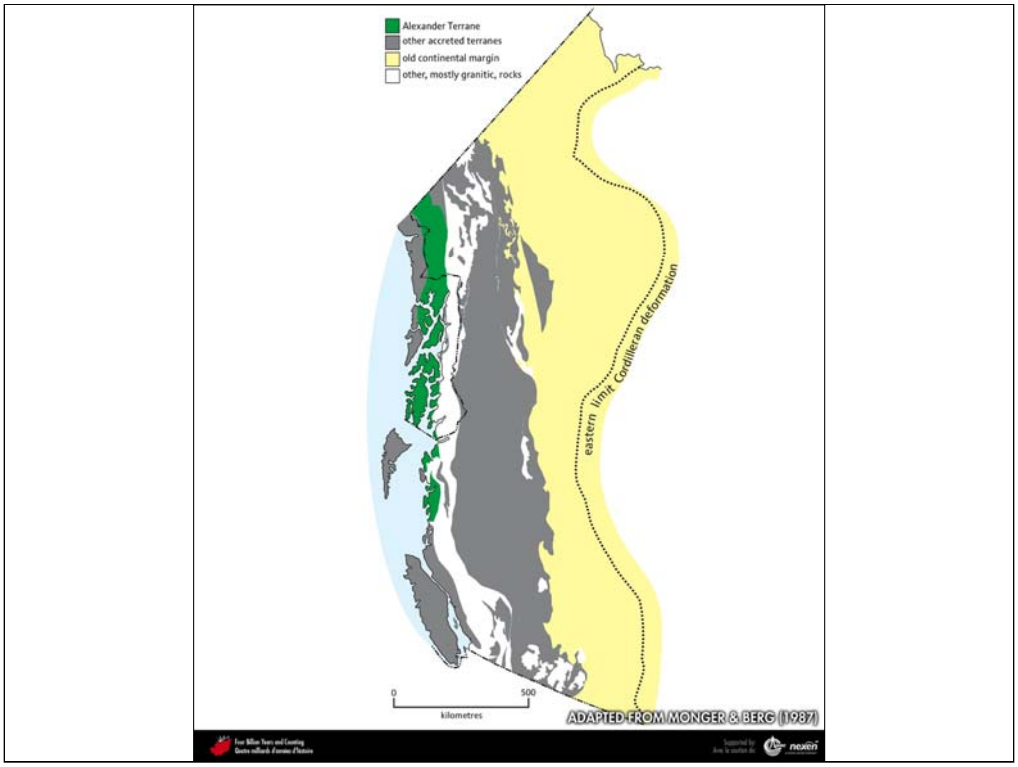
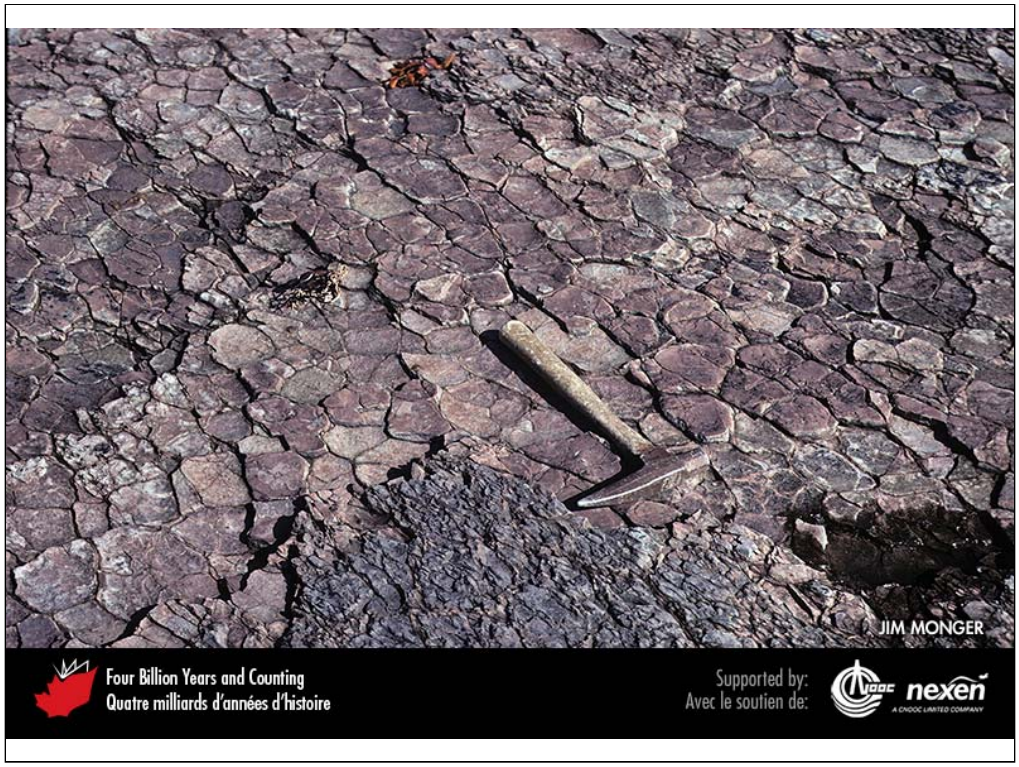
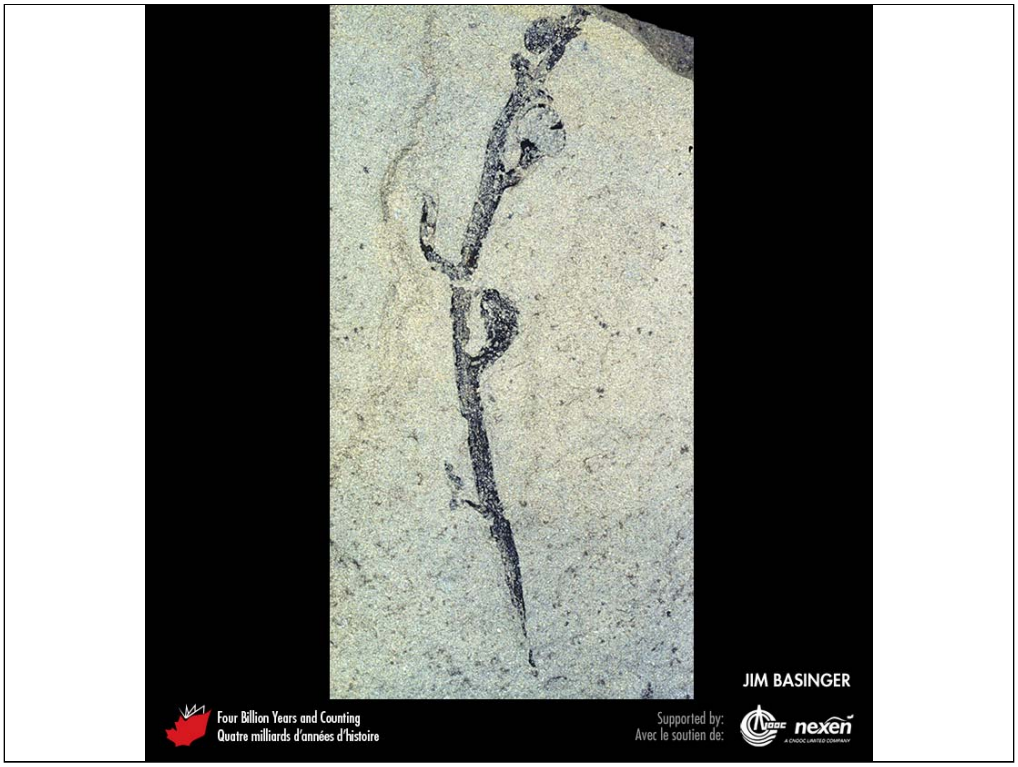


Modern distribution of rocks of the Alexander Terrane. ADAPTED FROM MONGER AND BERG (1987), COURTESY OF THE US GEOLOGICAL SURVEY.



Mud cracks in Devonian mudstone of the Alexander Terrane on Prince of Wales Island, southeastern Alaska. This rock is similar to parts of the Devonian "Old Red Sandstone" of northwestern Europe. Metamorphosed equivalents of these strata occur in the southwestern Coast Mountains of British Columbia. JIM MONGER.



An early land plant from late Silurian rocks on Bathurst Island, Nunavut. JIM BASINGER.

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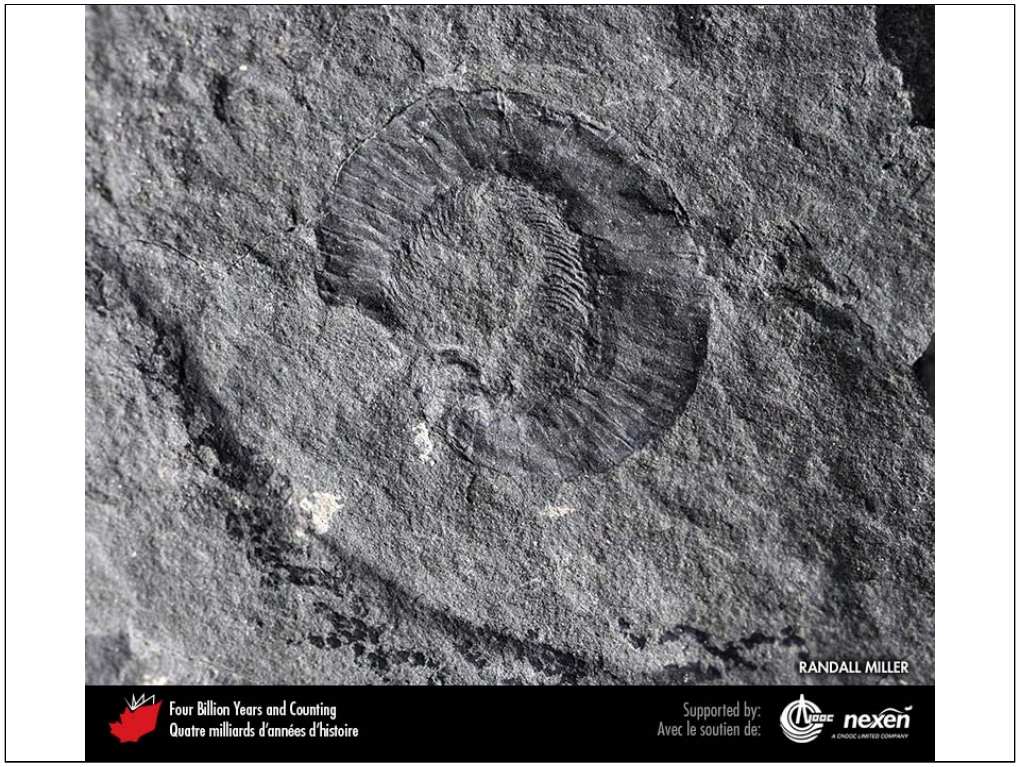
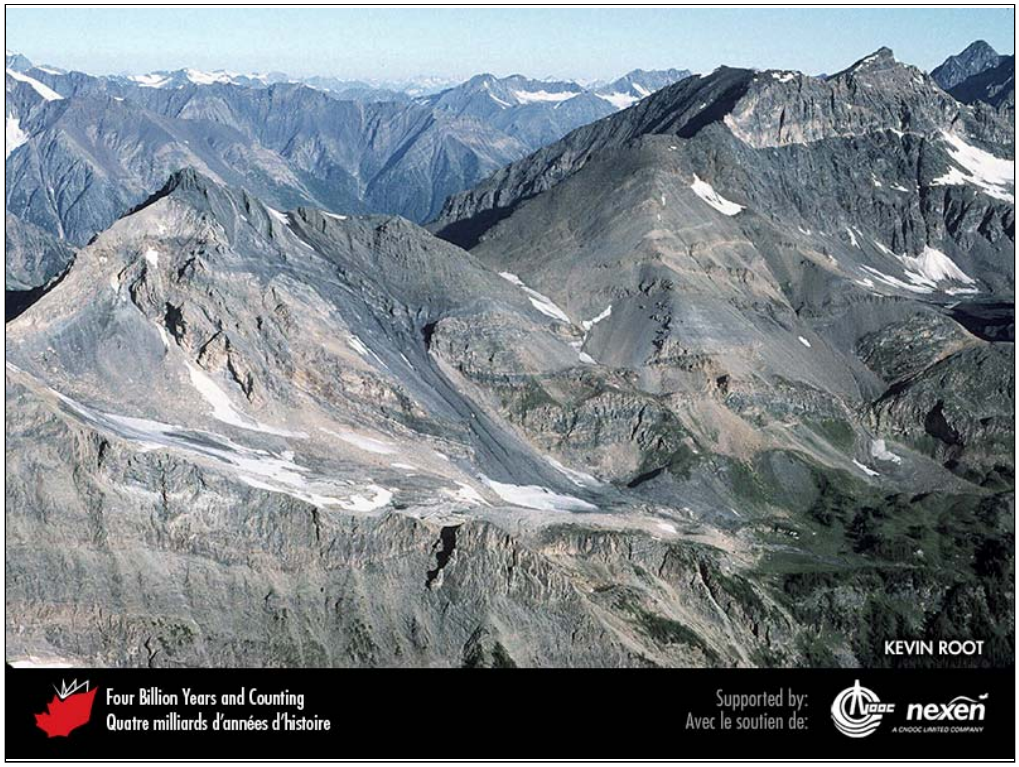
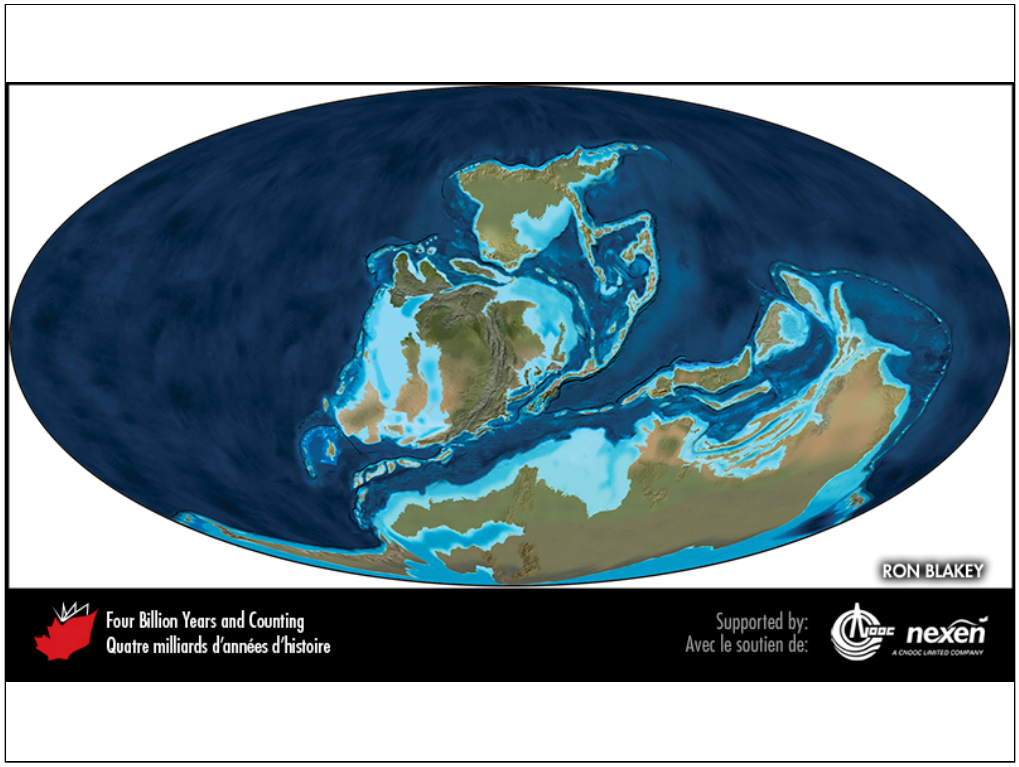


An early Devonian millipede, *Gaspestria genselorum*, from Point La Nim, near Dalhousie Junction, New Brunswick. This specimen is one of the oldest-known land animals in North America. RANDALL MILLER, COURTESY OF THE NEW BRUNSWICK MUSEUM.



View to the northwest of Devonian strata in the Columbia Mountains of British Columbia. Detailed mapping of these Devonian strata has yielded evidence of compression, marking the change from a passive intraplate margin to an active plate margin on the west side of Euramerica about 390 million years ago. KEVIN ROOT.

Paleogeography of what was to become North America and adjacent regions in the middle Devonian, 385 million years ago. Land is shown in brown, with shading showing topography. The lighter blue areas represent possible coastal or nearshore areas, darker blue represents deeper ocean waters, and black indicates trenches. Aspects of modern geography are shown for orientation.



Global paleogeography 385 million years ago, during the middle Devonian. Colours as for previous figure.

Late Devonian strata at Miguasha National Park, Quebec. These rocks contain beautifully preserved fossil fish, and other animals and plants. JEAN-PIERRE SYLVESTRE, COURTESY OF MIGUASHA NATIONAL PARK.

Fern-like foliage of *Archaeopteris halliana*, an early tree from late Devonian strata at Miguasha National Park, Quebec. *Archaeopteris* trees were up to 7 metres tall and formed the first forests. STEVE DESCHÊNES, COURTESY OF MIGUASHA NATIONAL PARK.

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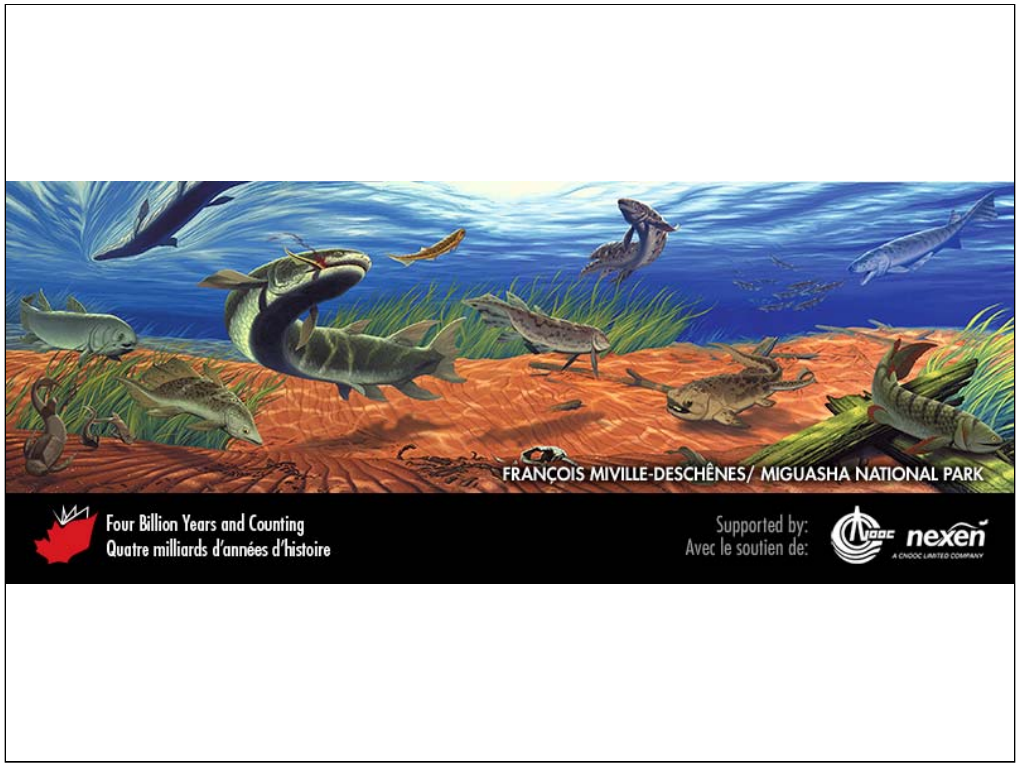

A Devonian underwater scene based on fossil fish found at Miguasha National Park in Quebec. Swimming toward the surface, to the right of centre and above the grass-like plants, is *Scaumenacia*, a member of the group of lobe-fins called lungfish. Dominating the scene and in the process of finishing a snack, *Eusthenopteron* is circling in search of additional prey. *Eusthenopteron* is also a lobe-fin but belongs to the group that gave rise to the tetrapods. Hugging the estuary bottom to the right and relatively small is the jawless *Escuminaspis*, and above it the much larger *Plourdosteus*, a voracious carnivore with jaws. FROM CLOUTIER (2001), USED WITH PERMISSION; PAINTING BY FRANÇOIS MIVILLE-DESCHÊNES.

Specimen of the Devonian lobe-finned fish *Eusthenopteron foordi* from Miguasha National Park, Quebec. This fish had pectoral fins similar to tetrapod limbs, lungs and gills, and internal nostrils that allowed it to breathe with its mouth closed. JEAN-PIERRE SYLVESTRE, COURTESY OF MIGUASHA NATIONAL PARK.

Braincase of the earliest-known shark, *Doliodus*, from early Devonian rocks at Atholville, New Brunswick. RANDALL MILLER, COURTESY OF THE NEW BRUNSWICK MUSEUM.

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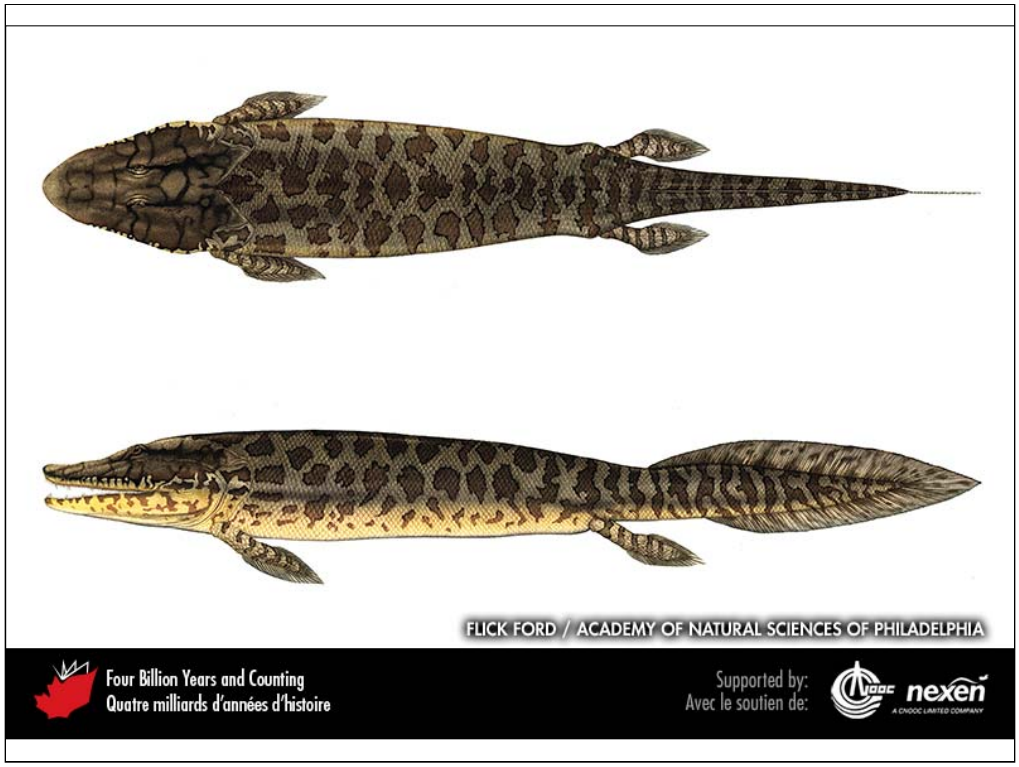
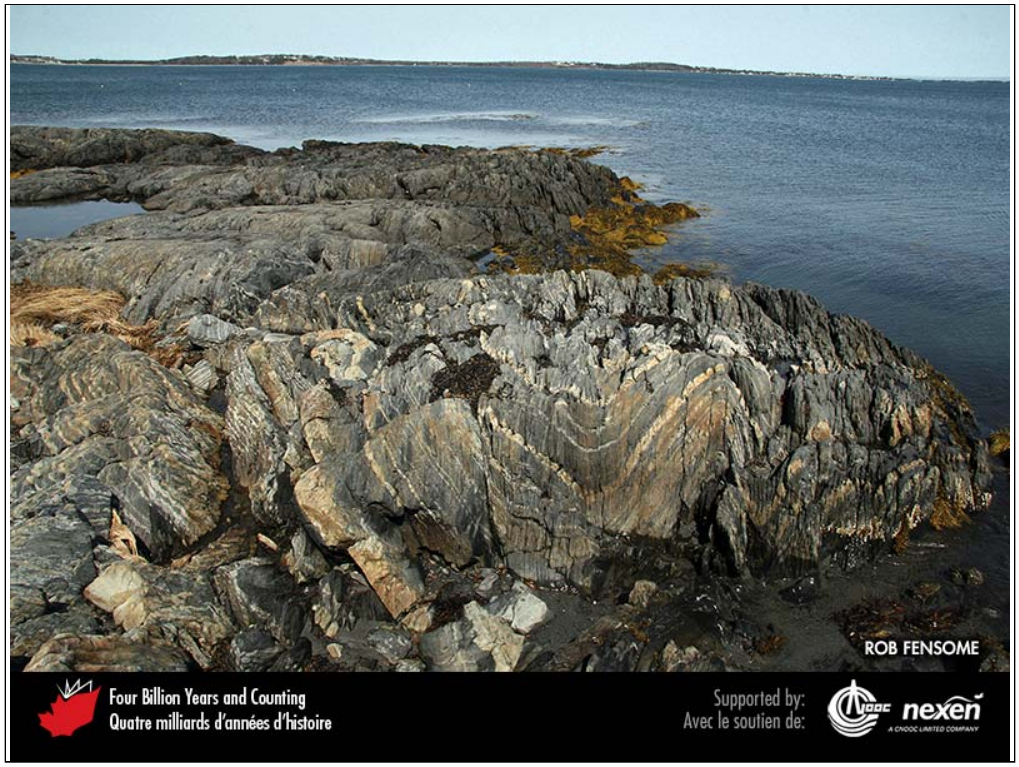


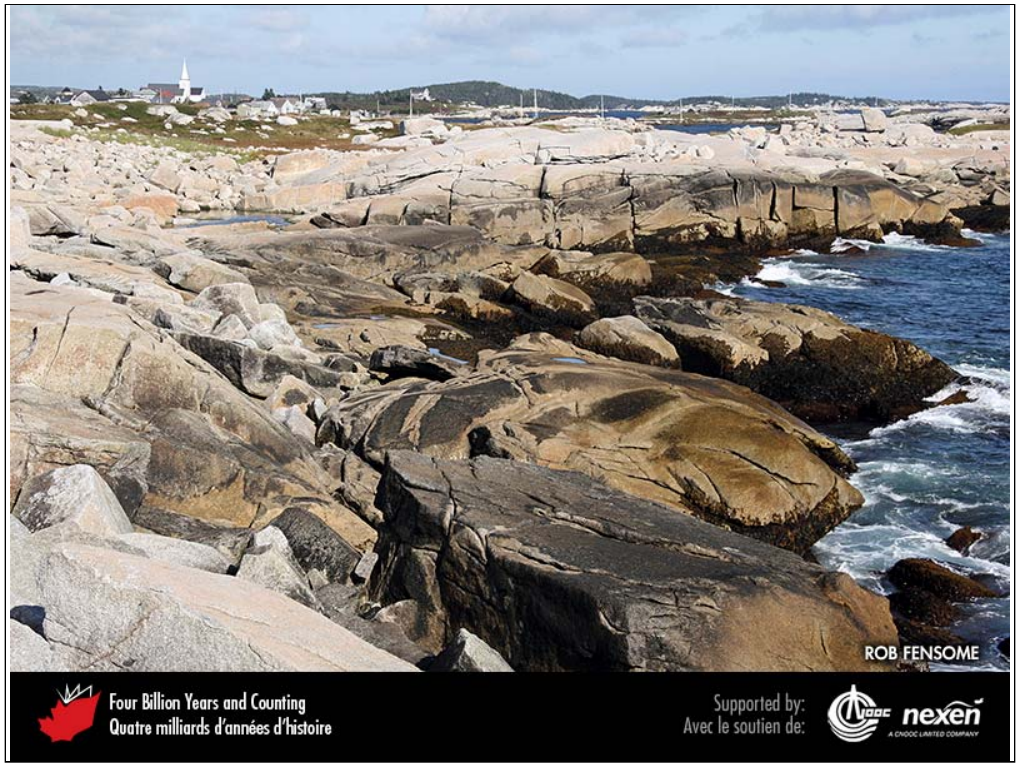
Artist's reconstruction of *Tiktaalik roseae* in top and side views. ARTWORK BY FLICK FORD, RECONSTRUCTION COURTESY OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

Part of the skeleton of *Tiktaalik roseae*, showing its flexible neck. This animal fills the gap between fish and land animals. This landmark fossil was found in late Devonian rocks, about 375 million years old, from Ellesmere Island, Nunavut. TED DAESCHLER, ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA (FOR IMAGE OF THE SPECIMEN).

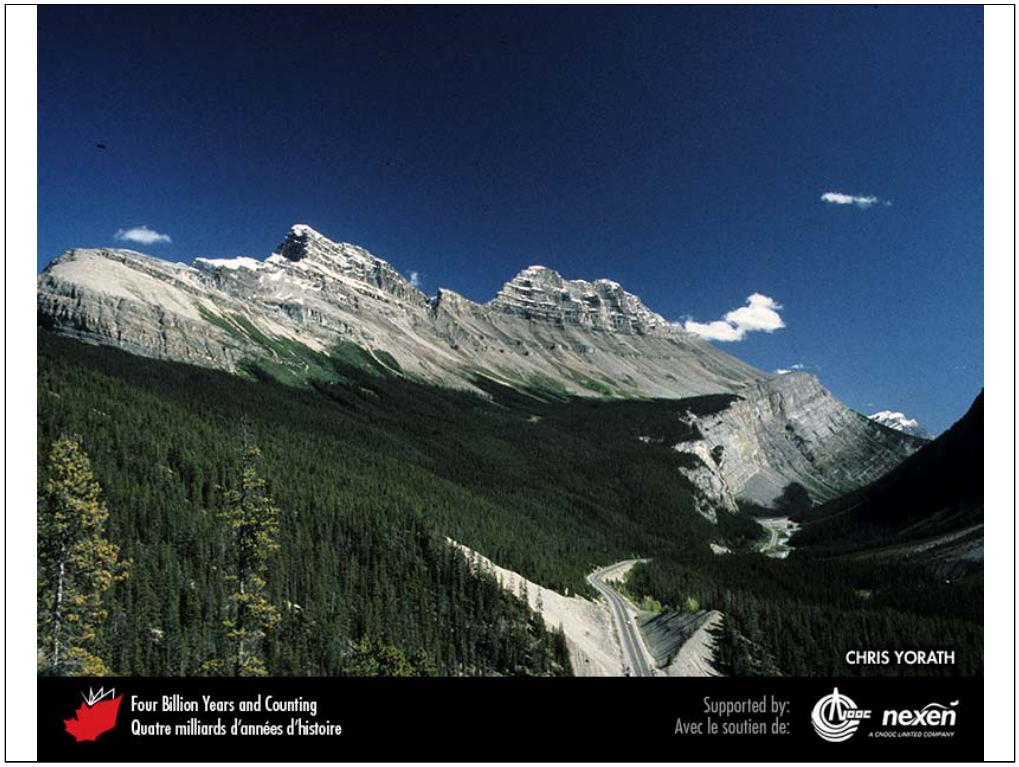
Aerial view of a road following the surface trace of the Cobequid Fault near Port Greville, Nova Scotia. This fault is a component of the Cobequid-Chedabucto Fault System along which the Meguma microcontinent docked with the Avalonian margin of Euramerica during the Devonian and Carboniferous. HOWARD DONOHOE.



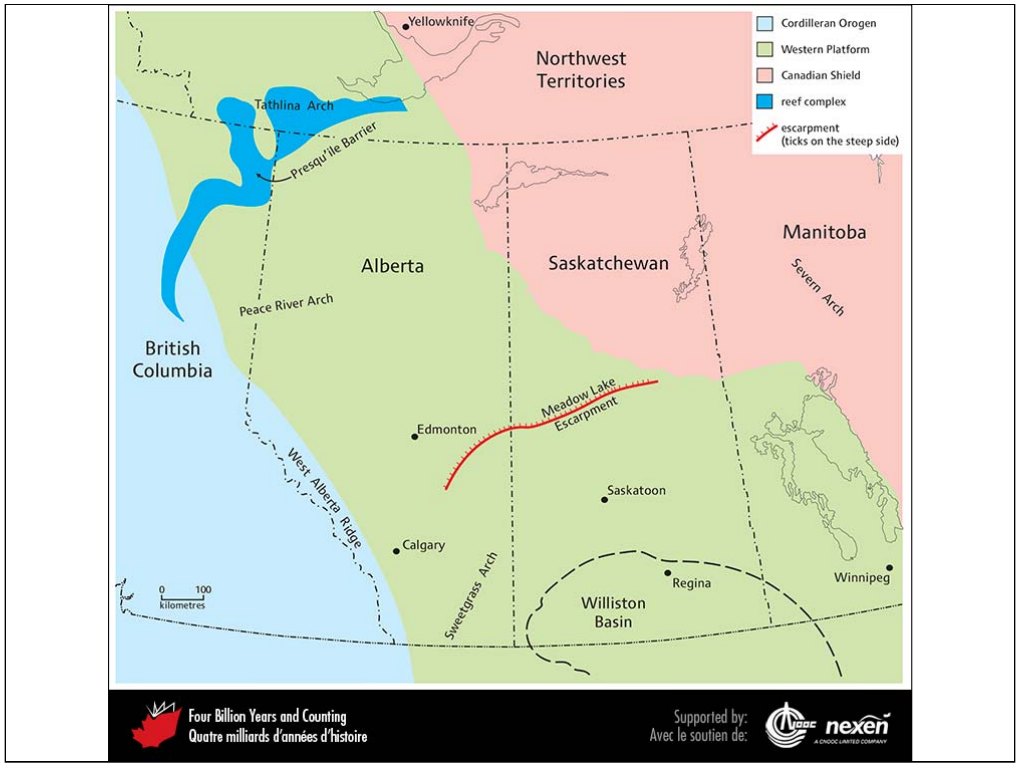
Cambrian-Ordovician metasedimentary rocks of the Meguma Terrane at Feltzen South, near Lunenburg, Nova Scotia. The strata were folded and metamorphosed during the Neoacadian Orogeny. ROB FENSOME.



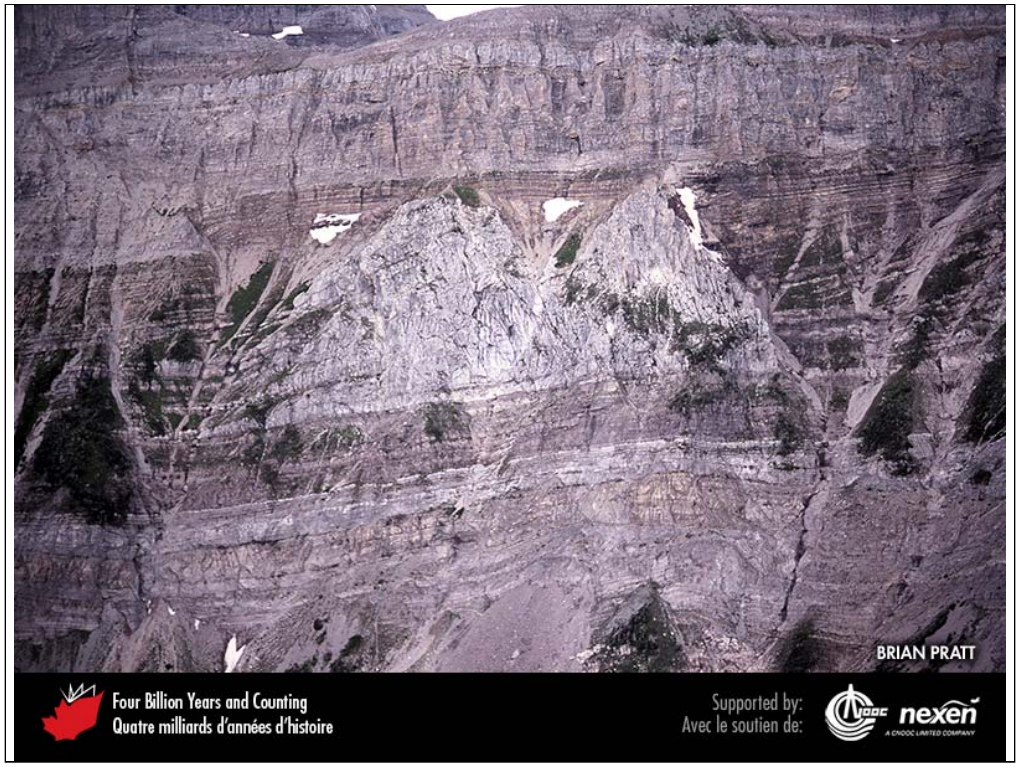
The shoreline at Prospect, Nova Scotia, is underlain by, and littered with boulders of granite from the Devonian South Mountain Batholith. ROB FENSOME.



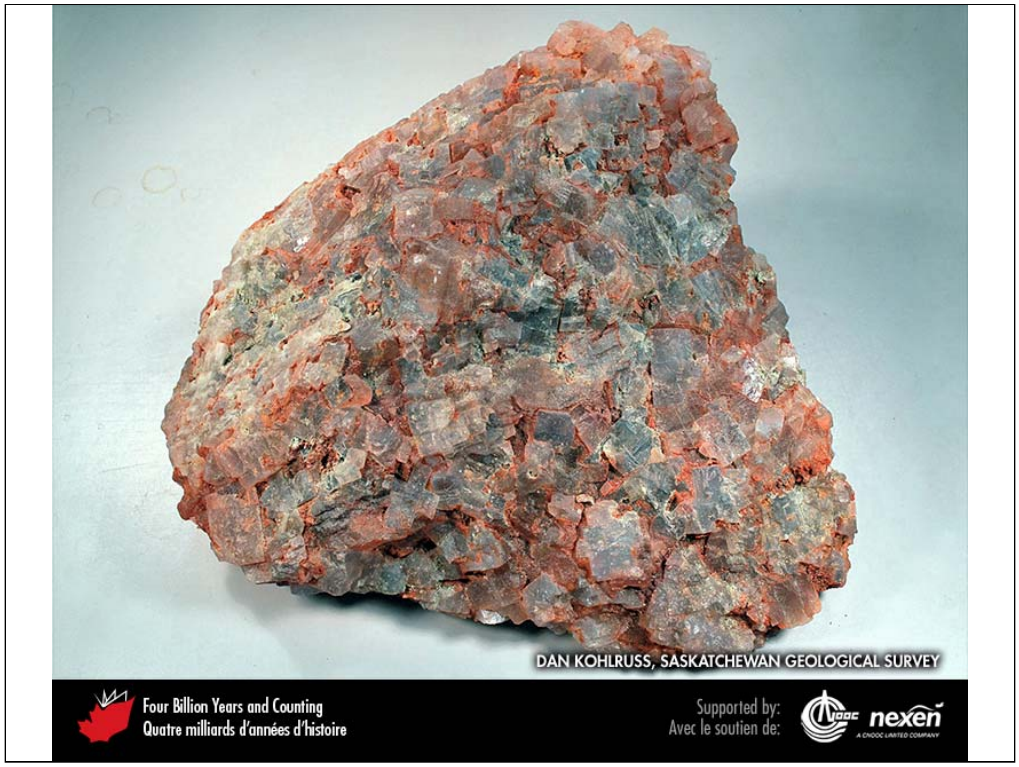
The west half of Cirrus Mountain (middle distance, viewed from the highway leading up to Sunwapta Pass in Alberta) exposes the classic threefold structure of the Front Ranges of the southern Rocky Mountains: lower cliffs of Devonian carbonate, middle slopes of Carboniferous shale, and upper cliffs of Carboniferous carbonate. CHRIS YORATH.



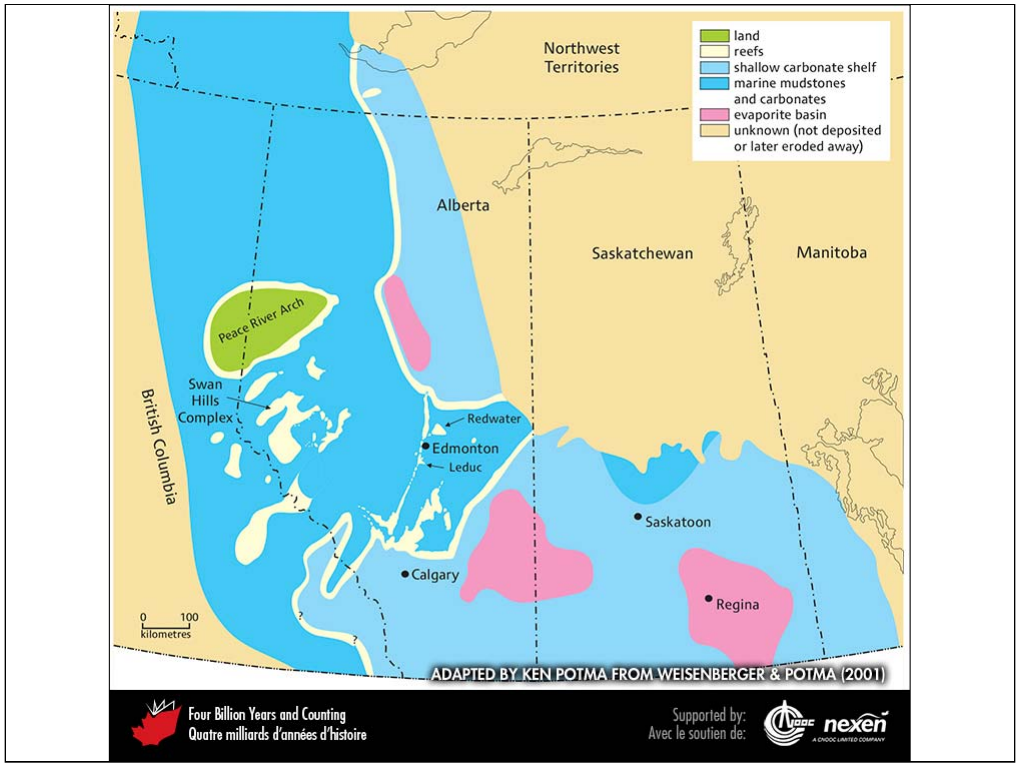
Some important paleogeographic and tectonic features on the Western Platform and adjacent areas during the Silurian to Permian. The Canadian Shield and Cordilleran Orogen are shown for orientation, but these areas represent more recent geological developments and were not present during the late Paleozoic. ADAPTED FROM VARIOUS SOURCES.



Mountainside exposing two late Devonian reefs, Flathead Range, southwestern Alberta. BRIAN PRATT.

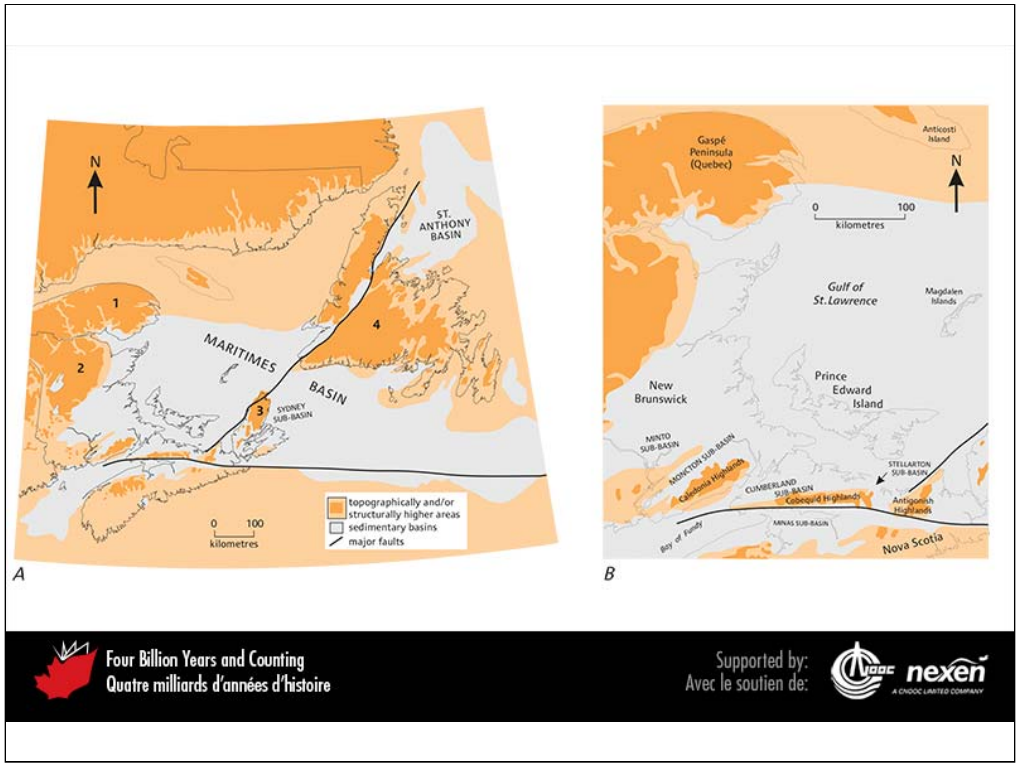


Potash ore from Devonian subsurface deposits in Saskatchewan. The ore, an evaporite rock called sylvinite, consists of a mixture of halite, sylvite (potassium chloride), carnallite (a complex mineral that includes potassium, chlorine, and magnesium), and other minerals. Sylvite is the principal ore mineral and source of potash. The red colour reflects iron oxide staining. DAN KOHLRUSS, SASKATCHEWAN GEOLOGICAL SURVEY.

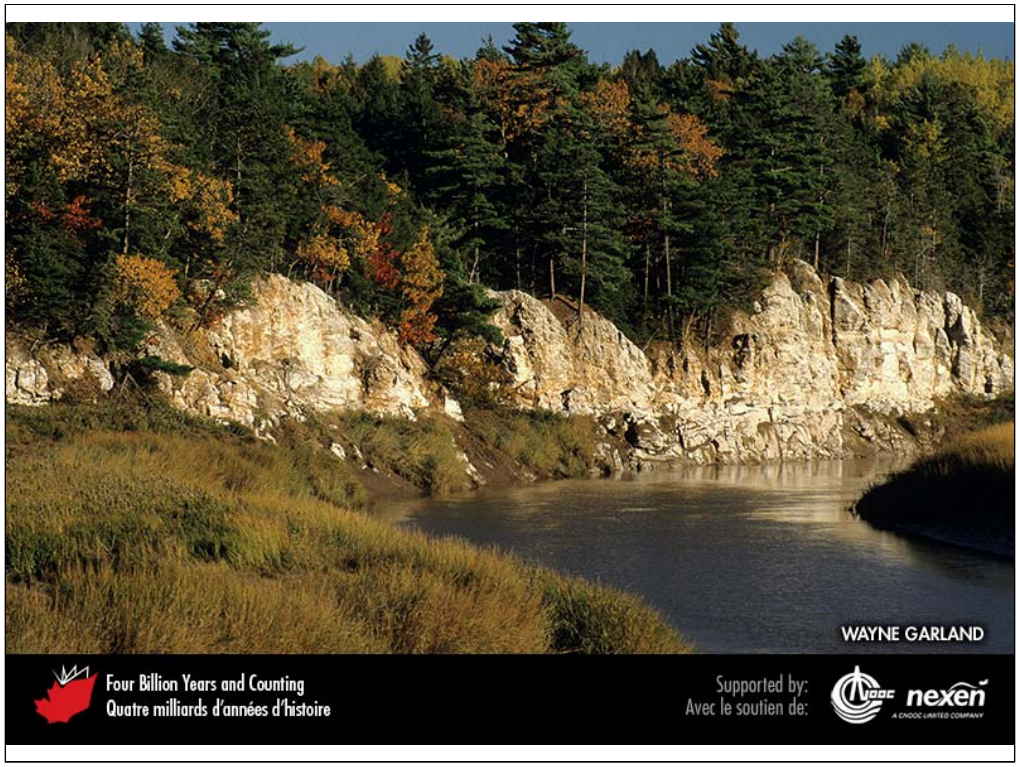


Reefs and other important features on the Western Platform and adjacent areas during the late Devonian. The locations of the reefs now found in the Rocky Mountains Foothills and mountains are shown on this map in their probable original locations before Paleozoic rocks were thrust eastward during the Mesozoic (Chapter 9). ADAPTED BY KEN POTMA FROM WEISENBERGER AND POTMA (2001).

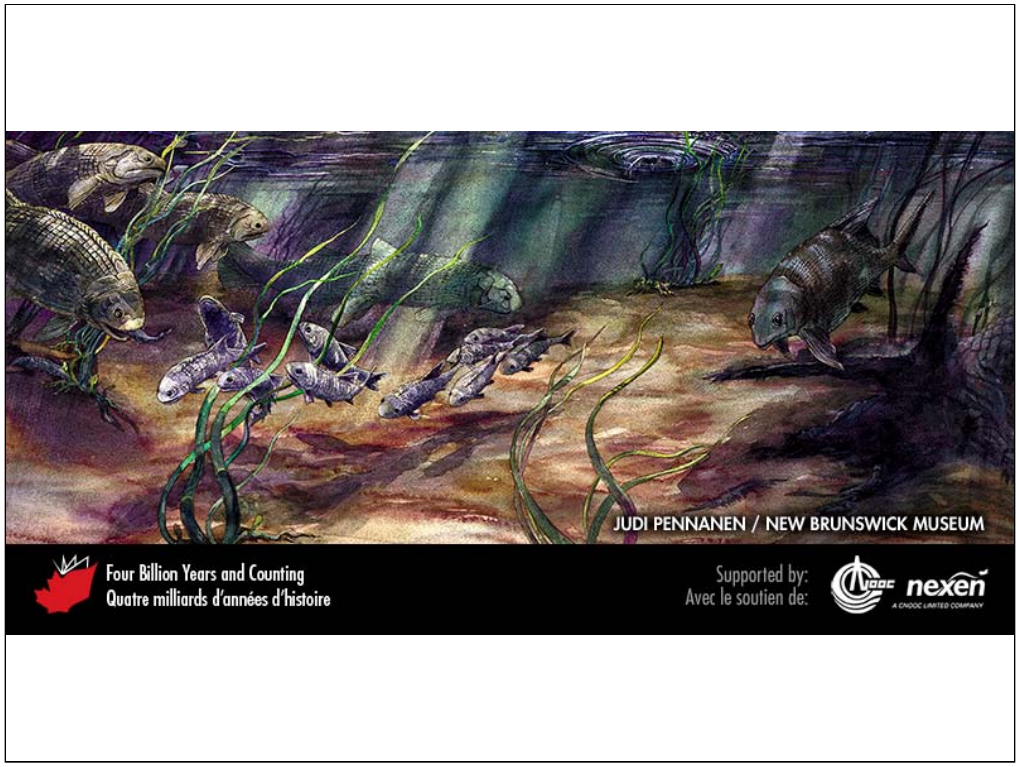
Late Devonian conglomerate (red rocks in foreground and to the left) and mafic volcanics (grey rocks), Ballantynes Cove, Nova Scotia. ROB FENSOME.



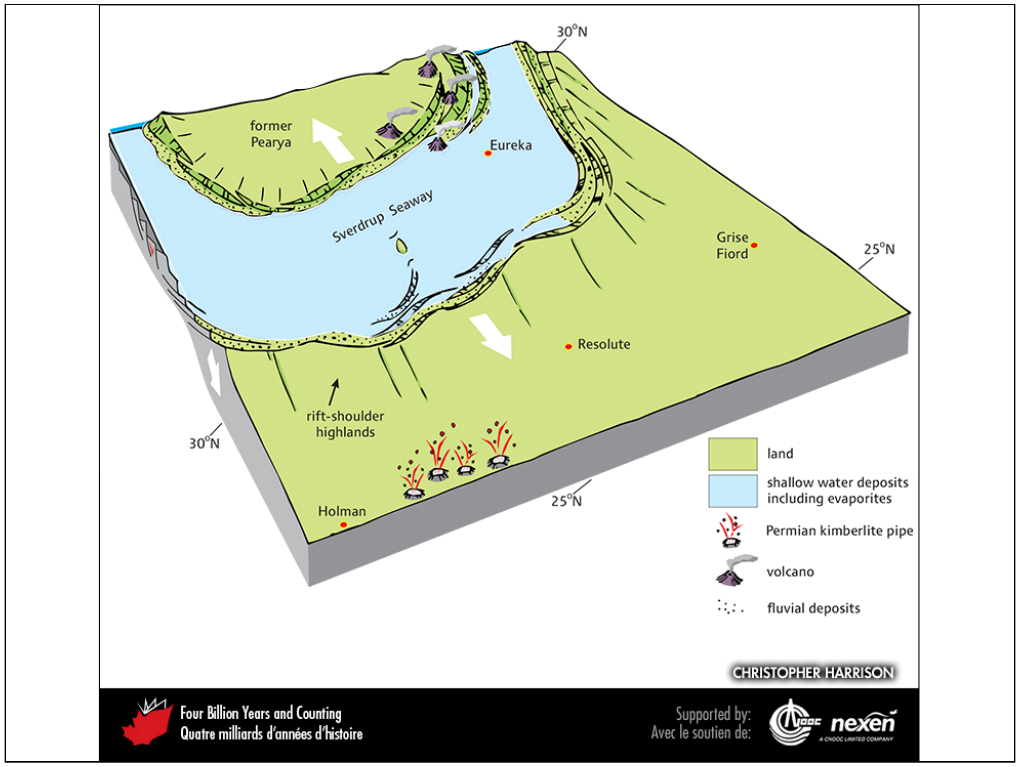
A. The late Devonian to Permian sedimentary basins and sub-basins of Atlantic Canada and surrounding areas. The highlands include: 1, Gaspé Highlands; 2, Miramichi Highlands; 3, Cape Breton Highlands; and 4, Western Newfoundland Highlands. *B*. Detail of the western Gulf of St. Lawrence and surrounding areas. ADAPTED FROM VARIOUS SOURCES.



Gypsum cliffs along the St. Croix River, near Windsor, Nova Scotia. The gypsum was deposited in the early Carboniferous Windsor Sea. WAYNE GARLAND.



An early Carboniferous underwater lake scene. Three types of early ray-finned fish are shown: silvery purple *Rhadinichthys* swimming in a school toward the left; three larger, brownish-grey *Elonichthys* on the left; and a deep-bodied form akin to *Eurynotus* at right. In the background, coloured green, is the large lobe-finned fish *Latvius*. The colours are guesses, but the morphology is based on fossil finds from rocks at Albert Mines, New Brunswick. PAINTING BY JUDI PENNANEN, COURTESY OF THE NEW BRUNSWICK MUSEUM.



Paleogeography of what was to become the Canadian Arctic in the middle Carboniferous to Permian, 325 to 285 million years ago. The approximate locations of Holman, Resolute, Grise Fiord, and Eureka are included to provide a guide for orientation, as well as paleolatitudes. The focus for the region, now approaching mid-latitudes, was the Sverdrup Seaway, a broad rift basin in which shallow-water deposits, including evaporites, accumulated. The arrows show the direction of crustal tension. Kimberlite pipes, the source of diamond deposits, are discussed in Chapter 12.

This cliff near Hare Fiord on Ellesmere Island, Nunavut, reveals changing Carboniferous environments. Redbeds near the base are sequentially overlain by evaporites (lighter bands in the lower part of the cliff), shales (thick brown-grey sequence), and carbonates (light-grey sequence near the top). CHRISTOPHER HARRISON.

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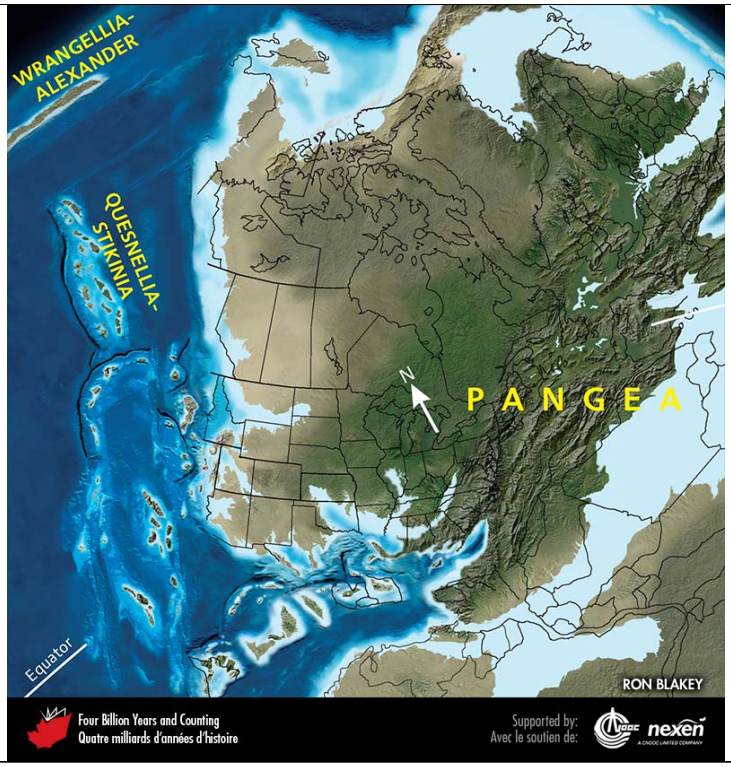
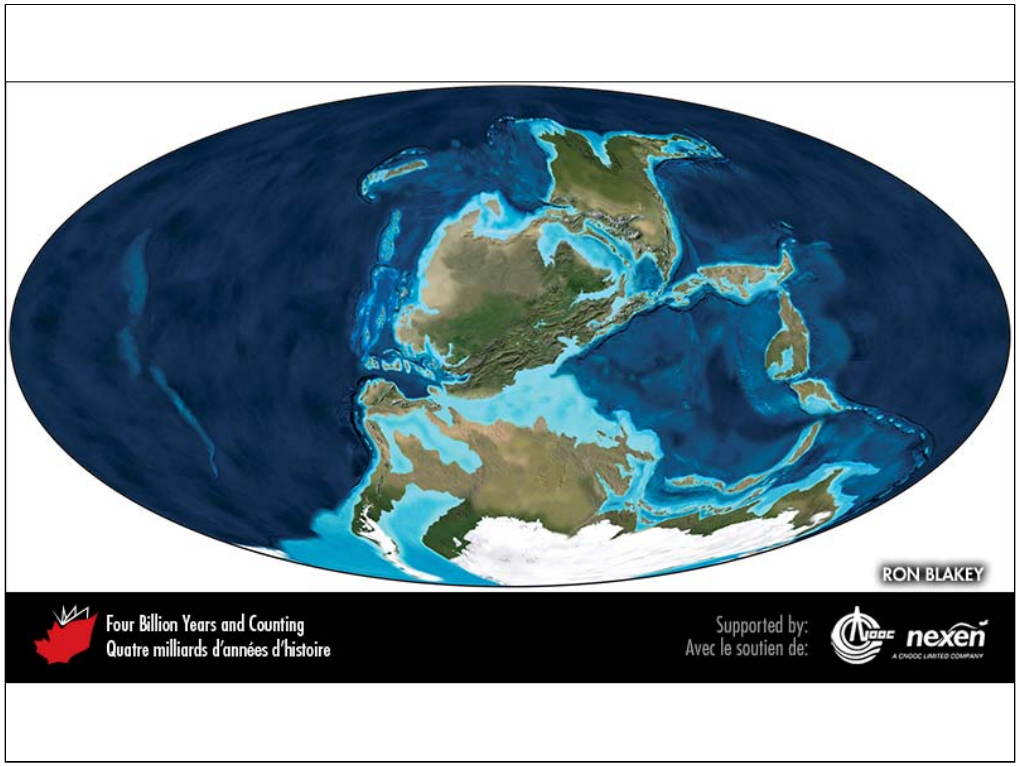
Colourful but complex geology is evident in this photograph of Strand Fiord, Axel Heiberg Island. At the upper right is a diapir of white Carboniferous salt, originally deposited in the Sverdrup Seaway. In the foreground are near-vertical, grey, fine-grained clastic Jurassic rocks; and on the slopes to the left are Triassic redbeds. CHRISTOPHER HARRISON.

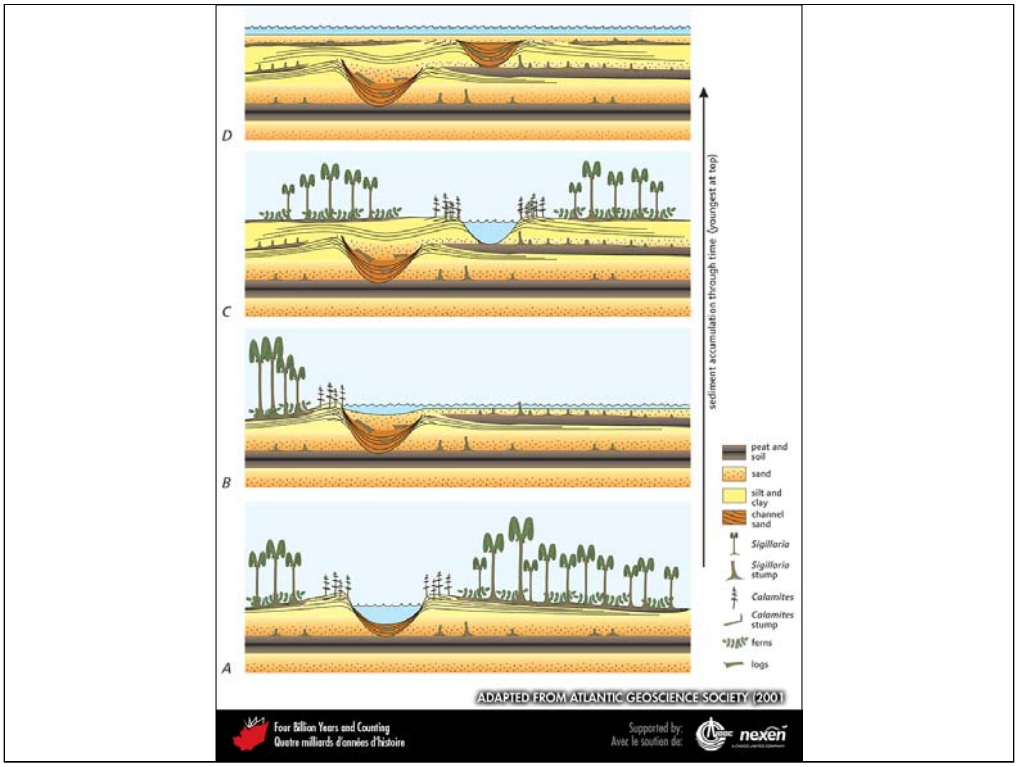


Paleogeography of what was to become North America and adjacent regions in the late Carboniferous, 315 million years ago. Land is shown in brown, with shading showing topography. The lighter blue areas represent possible coastal or nearshore areas, darker blue represents deeper ocean waters, and black indicates trenches. Aspects of modern geography are shown for orientation.



Global paleogeography 315 million years ago, during the late Carboniferous. Colours as for previous figure.

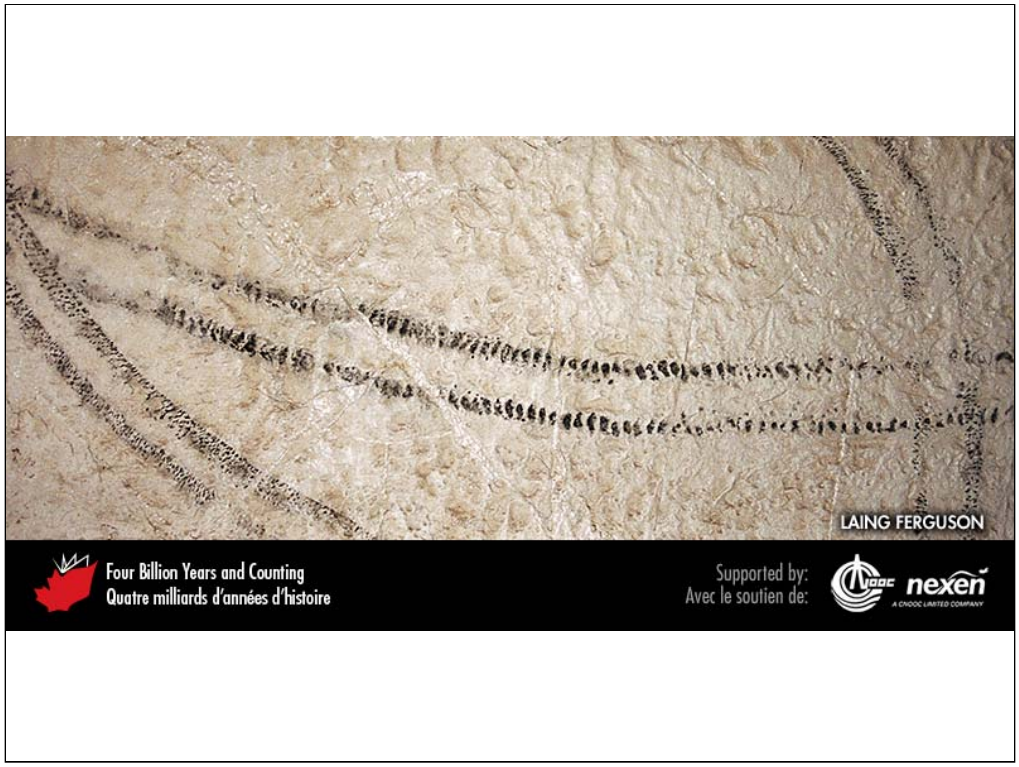
Late Carboniferous fluvial conglomerate and sandstone form the “flowerpot” sea stacks at Hopewell Cape, New Brunswick. The powerful Bay of Fundy tides undercut the rocks to form the unusual shapes. KEITH VAUGHAN.



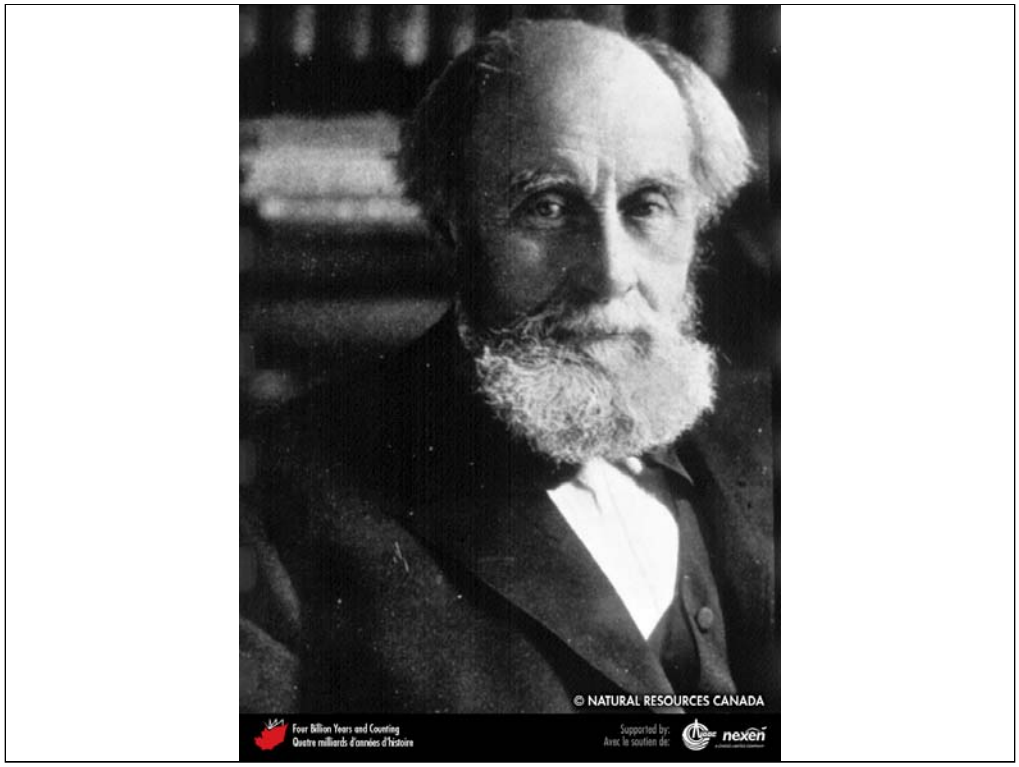
Deposits and environments associated with cyclothems in the late Carboniferous. *A* depicts a river cutting into older sediments and depositing sand and gravel in its channel. The horsetail *Calamites* is growing along the banks, beyond which is a flood plain supporting a forest of clubmoss (*Sigillaria*) trees and ferns. Organic debris from the forest is building up a layer of peat that may eventually form coal. *B* shows the river overflowing its banks during a flood. Sand is deposited by the flood waters, choking the forest, covering the peat, and filling the old channel. Only the stumps of the trees are preserved, protected by the new layer of flood-deposited sand. In *C*, a new river channel is established and a new forest is growing on the flood plain. Periodically this cycle is broken by more general aquatic flooding, as shown in *D*, with possibly brackish waters marginal to a sea whose level rose because of melting ice in distant former Protogondwana; during this aquatic phase, thin, dark limestones full of bivalves (so-called clam coals, not shown) were sometimes deposited. Through time, this process builds up repeating layers of peat, sand, silt, clay, and limestone to produce the cyclothems. ADAPTED FROM ATLANTIC GEOSCIENCE SOCIETY (2001).

Late Carboniferous foliage including horsetail (*Sphenophyllum*; centre), clubmoss branches (right), and a fern (lower left) from Clifton, New Brunswick. RANDALL MILLER, COURTESY OF THE NEW BRUNSWICK MUSEUM.

Clubmoss tree stump in the cliff at Joggins, Nova Scotia. ANDREW MACRAE.

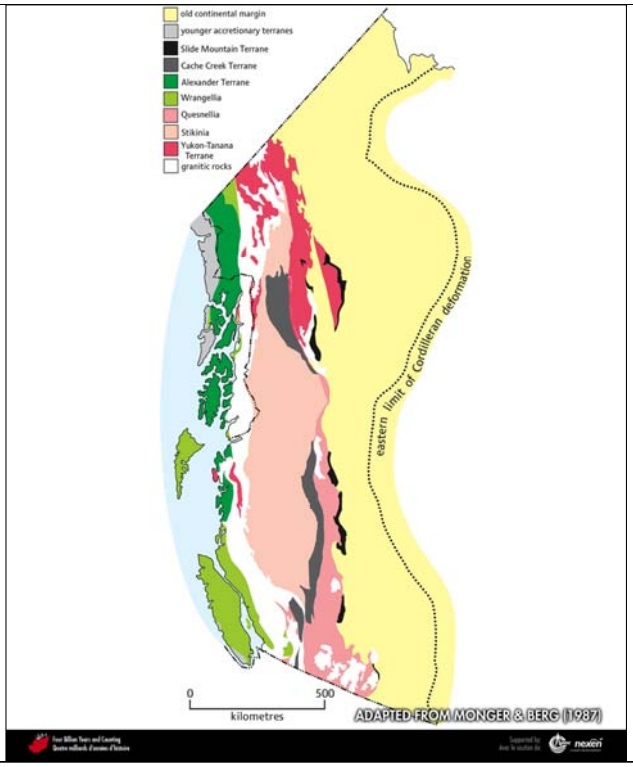


Artificial cast of trackways of the giant myriapod *Arthropleura* from late Carboniferous strata at Joggins, Nova Scotia. This myriapod was a giant, up to 2 metres long. LAING FERGUSON.



J. William Dawson from Pictou, Nova Scotia. Among many illustrious accomplishments, he was one of the first to interpret fossil plants in an ecological context. REPRODUCED WITH THE PERMISSION OF NATURAL RESOURCES CANADA 2013, COURTESY OF THE GEOLOGICAL SURVEY OF CANADA.

Model of *Arthropleura*, on display at the Fundy Geological Museum, Parrsboro, Nova Scotia. ANDREW MACRAE, SPECIMEN COURTESY OF THE FUNDY GEOLOGICAL MUSEUM.



The present-day Cordilleran collage of terranes. ADAPTED FROM MONGER AND BERG (1987), COURTESY OF THE US GEOLOGICAL SURVEY.

This road cut in Cache Creek, British Columbia, exposes jumbled rocks of the Cache Creek Terrane. JIM MONGER.

A 500-metre-high cliff on the north side of Marble Canyon, British Columbia, exposes massive middle Permian to late Triassic carbonate, part of the Cache Creek Terrane. JIM MONGER.

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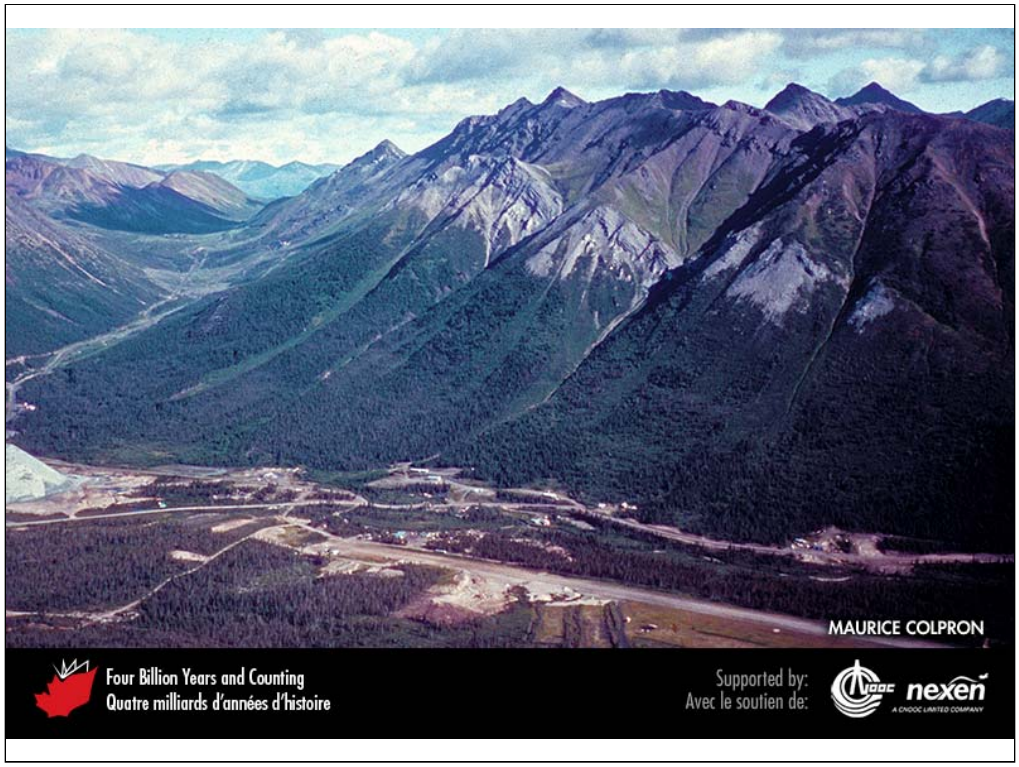
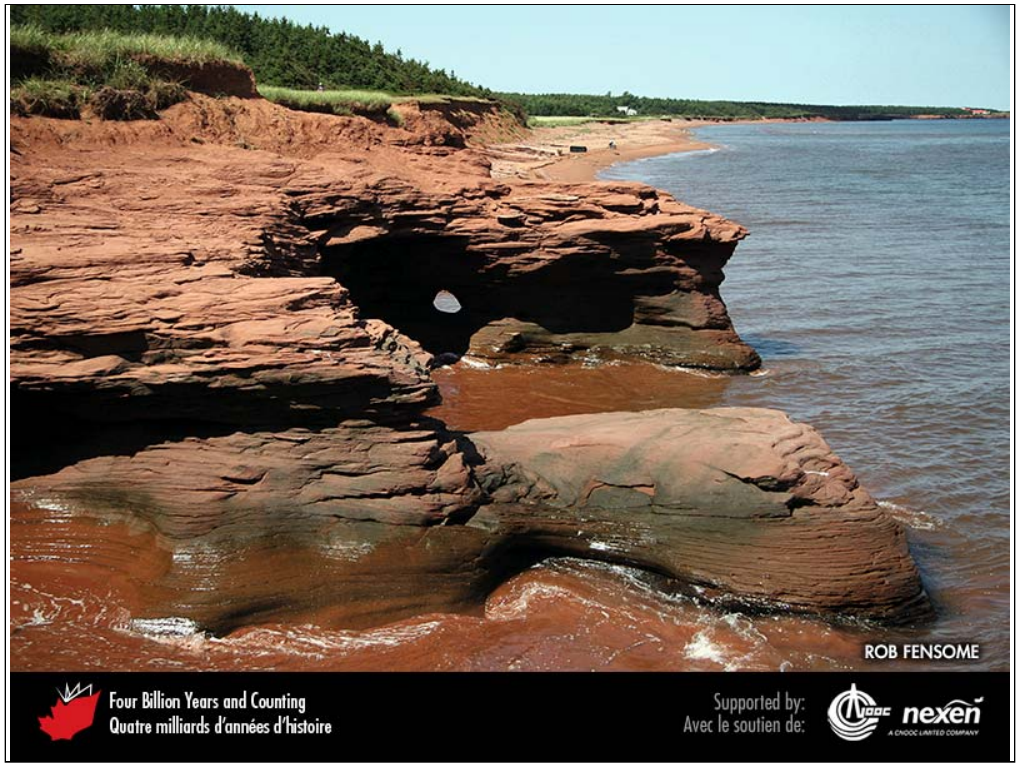


Dark brown oceanic or back-arc-basin rocks of the Slide Mountain Terrane cap a ridge near Cassiar, British Columbia. The rocks have been thrust over light-coloured middle Devonian carbonate deposited on the Euramerican continental margin. MAURICE COLPRON.

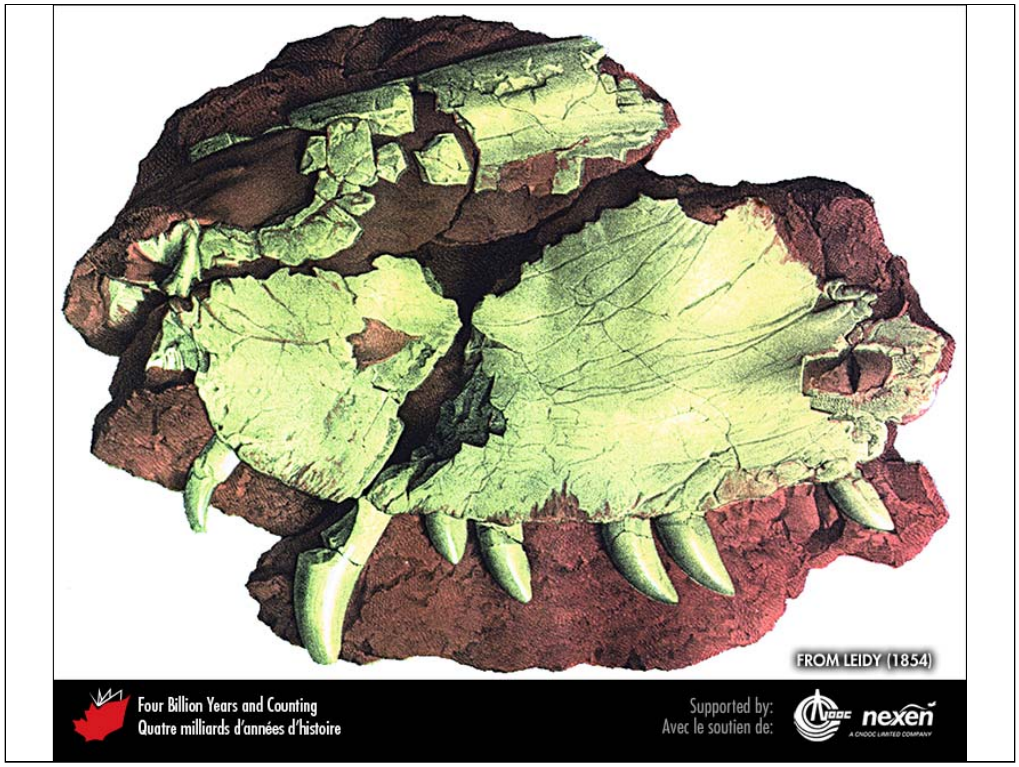
Eclogite containing a sliver of blueschist from the Cache Cheek Terrane, near Fort St. James, British Columbia. These distinctive metamorphic rocks result from deep burial in an accretionary complex. MIKE CHURKIN.



At Kildare Capes, Prince Edward Island, red cliffs expose the deposits of Permian rivers that flowed in the region soon after it had crossed into the Northern Hemisphere. ROB FENSOME.

Permian chert in the Otto Fiord area, northwestern Ellesmere Island, Nunavut. BENOIT BEAUCHAMP.

The underside of a sandstone block from Lord Selkirk Provincial Park, Prince Edward Island, reveals the trackway of a Permian tetrapod, dating from about 290 million years ago. MATT STIMSON.



A large skull fragment of *Bathygnathus* found in Permian strata at New London, Prince Edward Island. The specimen was once thought to be Canada's oldest dinosaur, but it is now known to be a mammal-like reptile. FROM LEIDY (1854), WITH PERMISSION FROM THE ACADEMY OF NATURAL SCIENCES, PHILADELPHIA.
