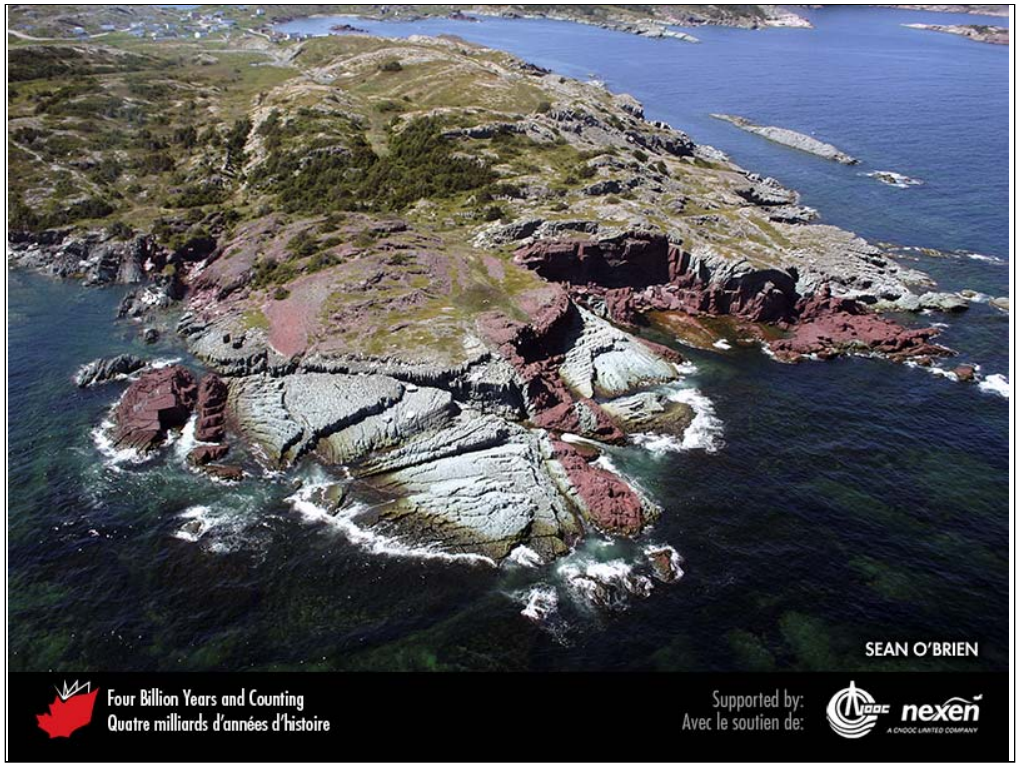
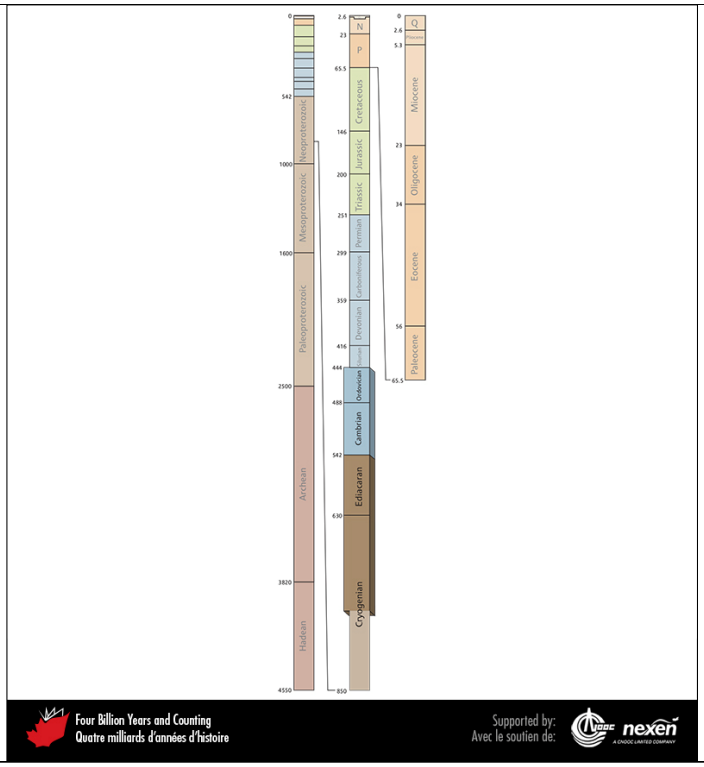
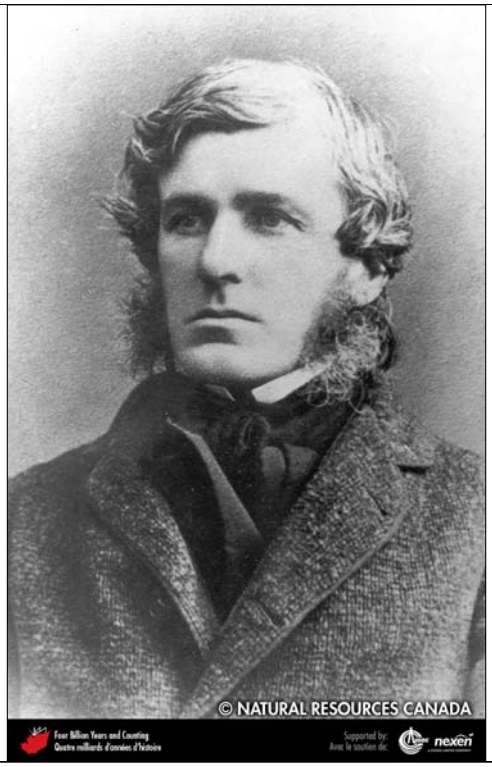
CHAPTER 7
Part 1 of 4



Aerial view near Keels, Newfoundland, of Cambrian fluvial clastic rocks deposited on Avalonia, a microcontinent associated with the ancient Iapetus Ocean. SEAN O'BRIEN.



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.



Elkanah Billings, Canada's first professional paleontologist. REPRODUCED WITH THE PERMISSION OF NATURAL RESOURCES CANADA 2013, COURTESY OF THE GEOLOGICAL SURVEY OF CANADA.

A specimen of *Aspidella* from the Avalon Peninsula, Newfoundland. DOUG BOYCE.

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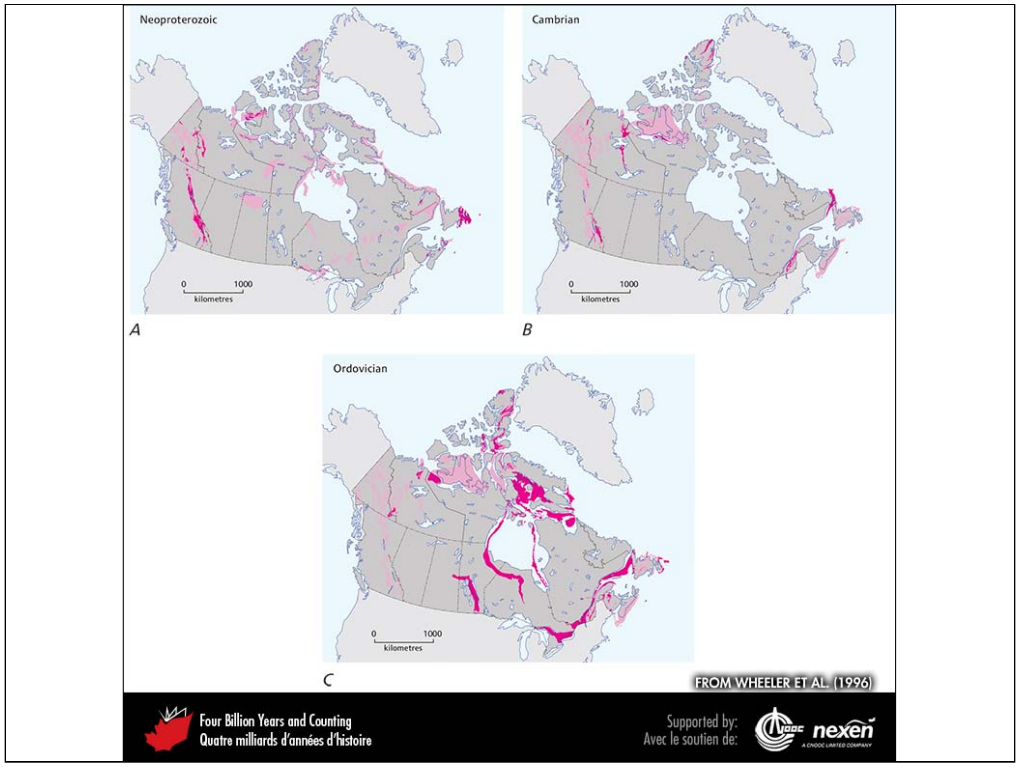
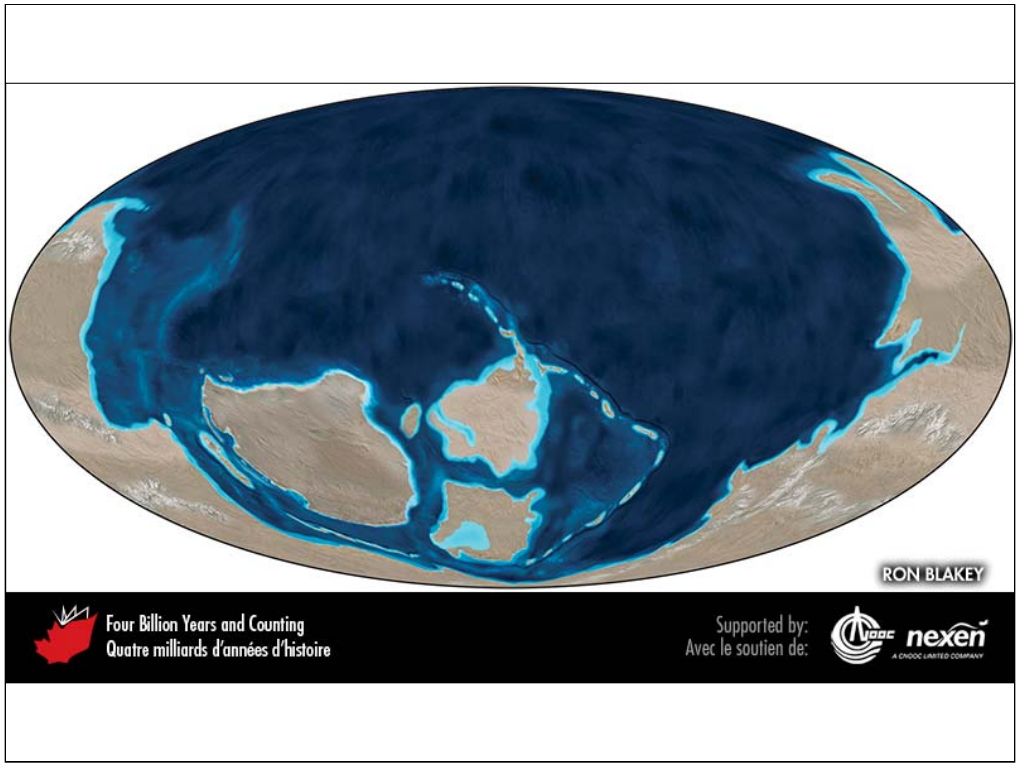
Charniodiscus, a rangeomorph, from Mistaken Point, Newfoundland. BRIAN PRATT.



General extent of Neoproterozoic (*A*), Cambrian (*B*), and Ordovician (*C*) rocks at the surface (beneath glacial deposits), onshore and offshore. The lighter shaded areas show 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 does not 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 late Ediacaran, 550 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 (including provincial and state boundaries) are shown for orientation.



Global paleogeography 550 million years ago, during the Ediacaran. Colours as for previous figure.

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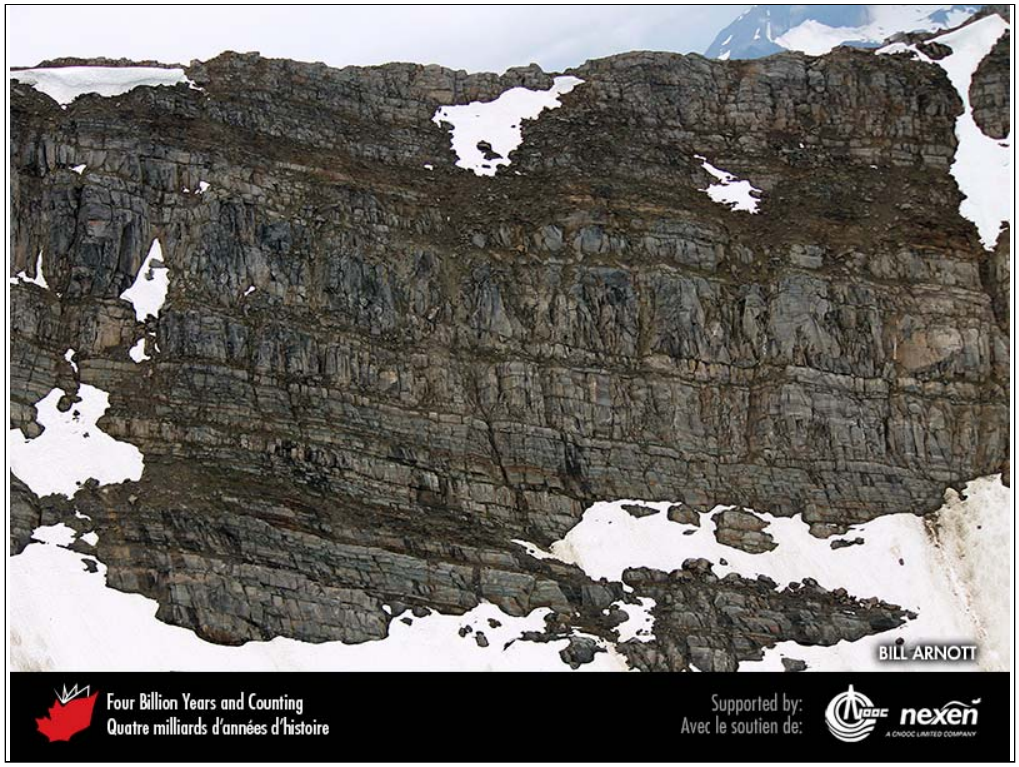
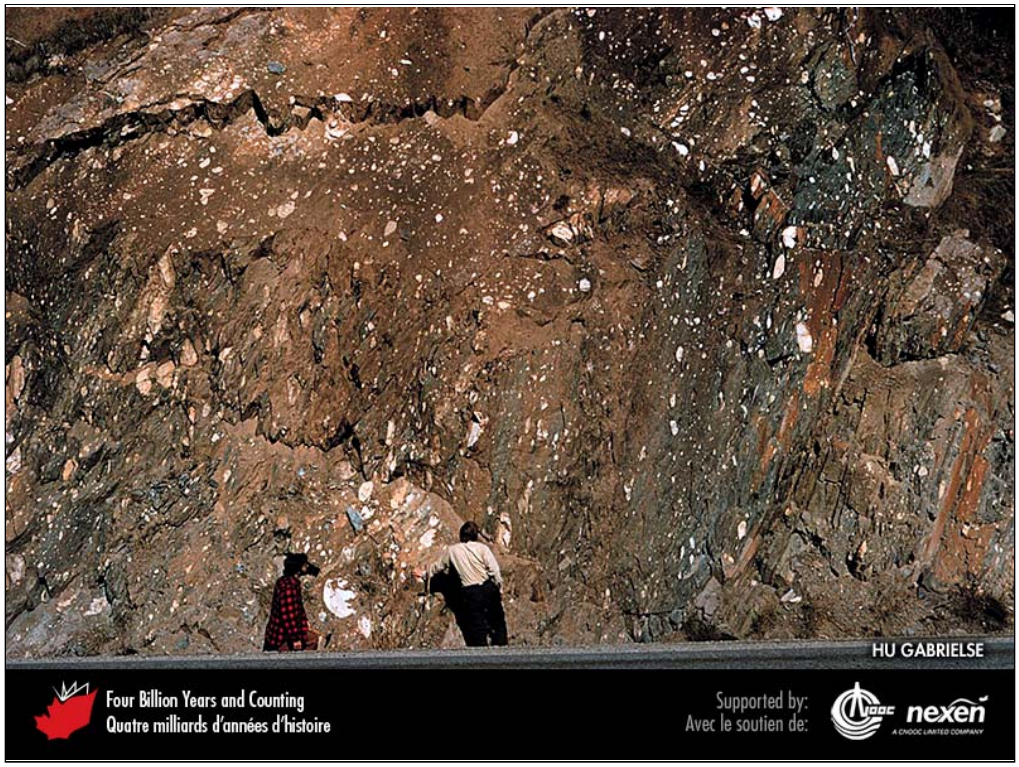


Deep-water Neoproterozoic strata of the Windermere Seaway exposed at Cushing Creek, British Columbia. These strata, dominated by thick sandstone beds, are interpreted as turbidites. BILL ARNOTT.

Outcrops in the headwater region of Castle Creek, British Columbia, expose a deep-sea channel that formed on the flank of the Windermere Seaway during the Neoproterozoic. The channel deposits are lighter-coloured and steeply tilted. BILL ARNOTT.



Neoproterozoic strata with dropstones in a roadside exposure along Highway 3 near Creston, British Columbia. HU GABRIELSE.

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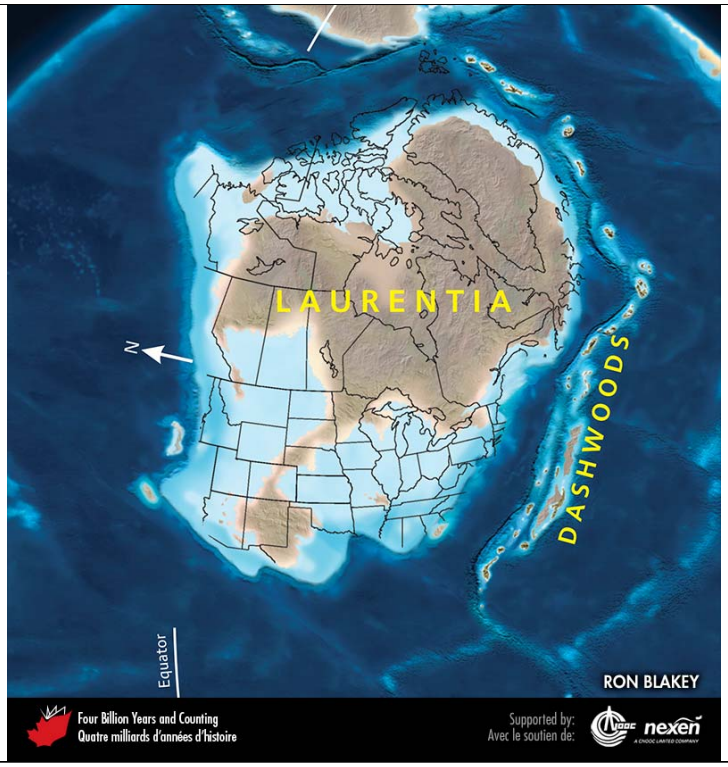
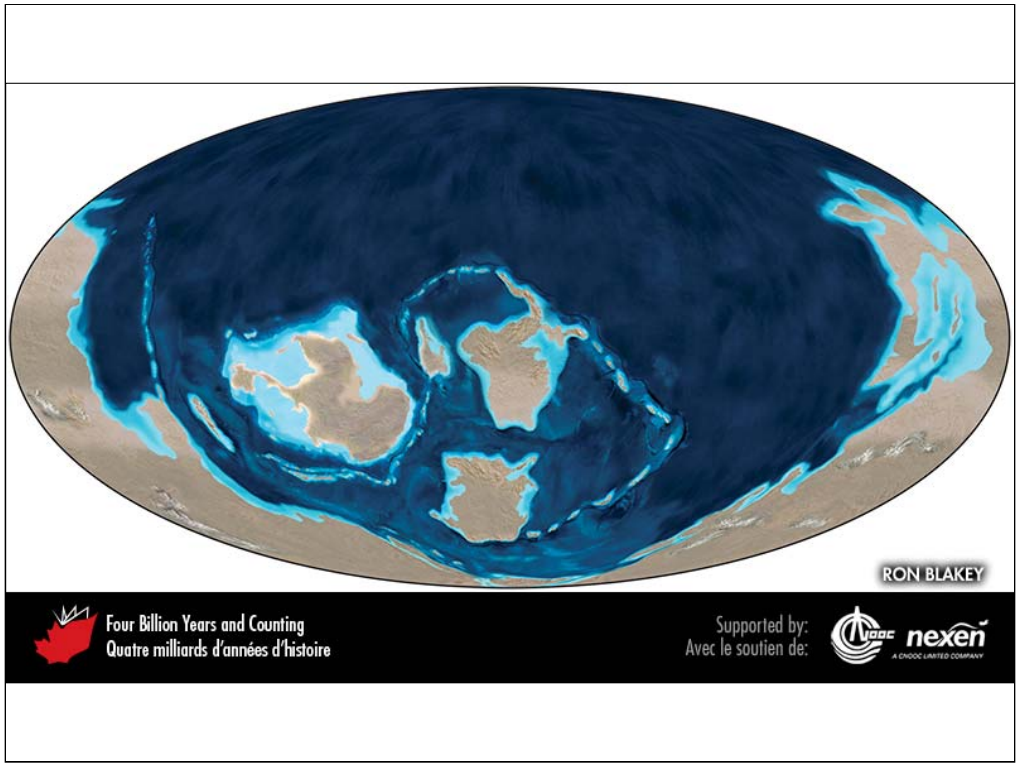
Reconstruction of *Namacalathus*, one of the first animals to produce a skeleton formed of calcium carbonate, but of the mineral aragonite rather than the more usual skeletal mineral calcite. The stalk, which attached the animal to the sea floor, is about 2.5 centimetres long. The cup can be up to 2.5 centimetres wide but is usually less than 1 centimetre. *Namacalathus* occurs in the late Ediacaran rocks of British Columbia. The colours shown are not intended to be a true reflection of the colour of *Namacalathus.* FROM GROTZINGER ET AL. (2000); REPRODUCED WITH PERMISSION OF WES WATTERS, JOHN GROTZINGER, ANDREW KNOLL, AND THE JOURNAL *PALEOBIOLOGY*. A CREATIVE SHARE-ALIKE ATTRIBUTION ONLY IMAGE.

CHAPTER 7
Part 2 of 4

Trace fossil known as *Psammichnites gigas* from earliest Cambrian rocks near St. Martins, New Brunswick. The animal that made this trace must have been a soft-bodied creature similar to a marine slug. HEINZ WIELE, COURTESY OF THE ATLANTIC GEOSCIENCE SOCIETY; SPECIMEN COURTESY OF THE NEW BRUNSWICK MUSEUM.



Paleogeography of what was to become North America and adjacent regions in the Cambrian, 500 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.



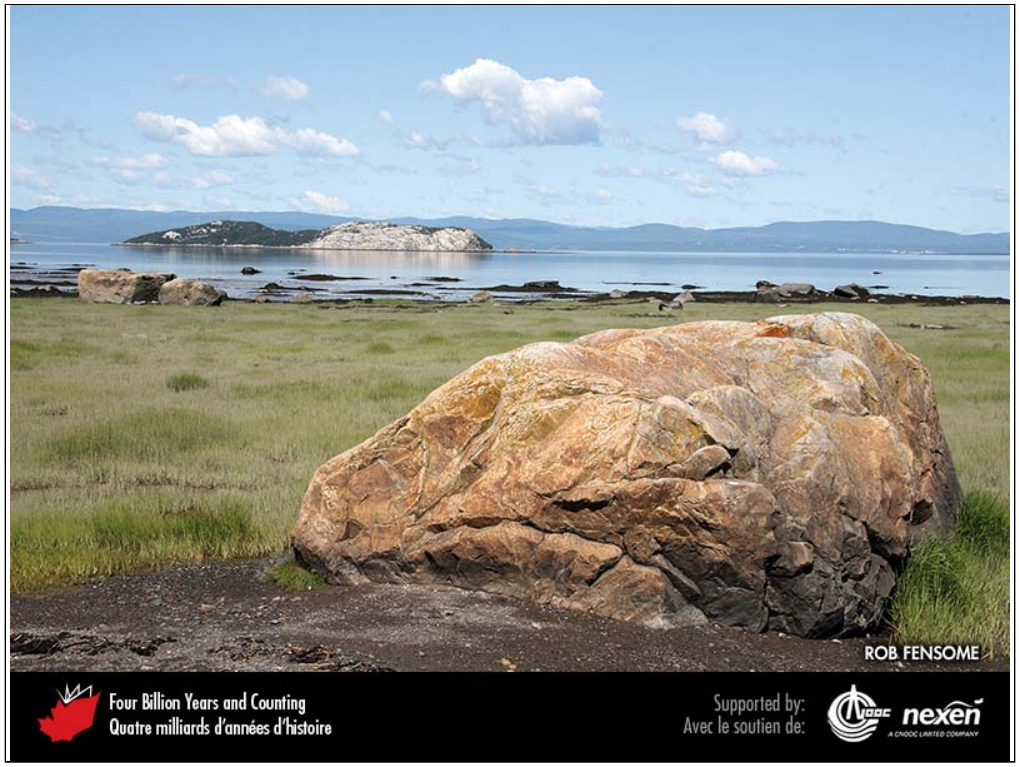
Global paleogeography 500 million years ago, during the Cambrian. Colours as for previous figure.

Early Cambrian archaeocyathans encrusted with dark-grey calcite precipitated through the activity of microbes and set in a reddish mudstone, Pointe Amour, southern Labrador. BRIAN PRATT.

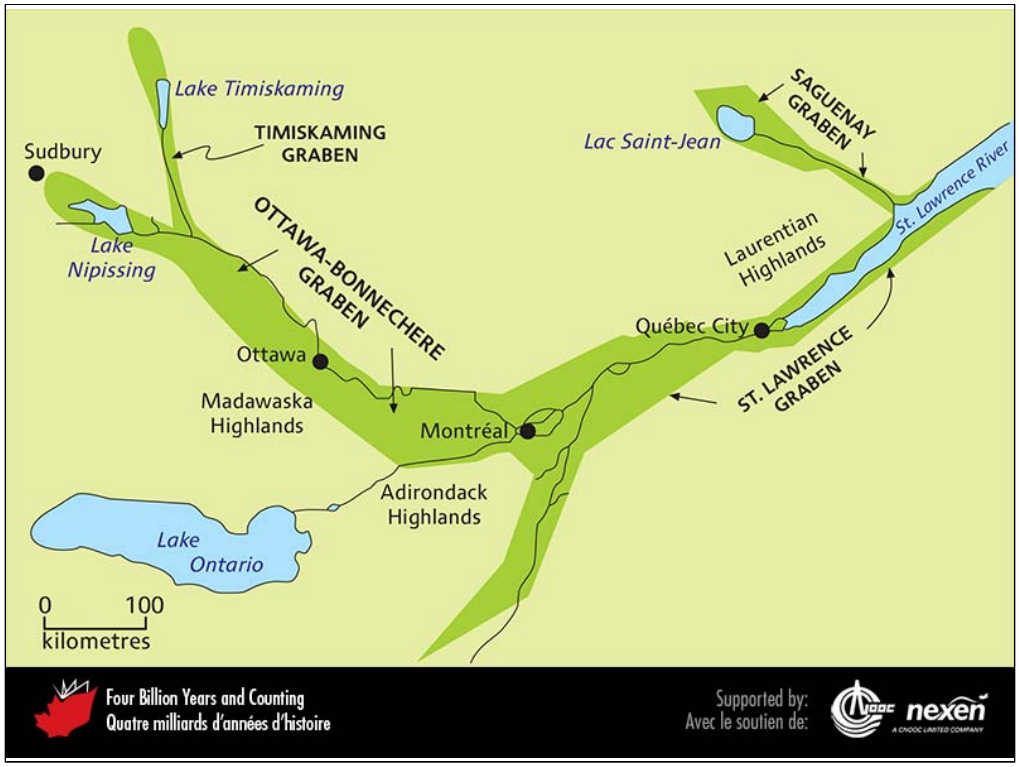
The middle Cambrian trilobite *Paradoxides davidis,* from Manuels River, Newfoundland. RICCARDO LEVI-SETTI.

Part of the filtration feeding structure of a branchiopod crustacean (not to be confused with brachiopods), preserved in middle Cambrian rock retrieved from a subsurface core in Saskatchewan. The specimen is about 0.15 millimetres long. NICK BUTTERFIELD.

The Cambrian trackway *Protichnites* from near Kingston, Ontario. ROBERT MACNAUGHTON.



Resistant quartz-rich Cambrian-Ordovician sandstones form distinctive hills and islands, such as the one in the distance, near Notre-Dame-du-Portage along the South Shore of the St. Lawrence River in Quebec. The sandstone was deposited in deep marine channels cut into the continental slope of Laurentia's passive margin. In the foreground is a glacial boulder that is probably of the same rock. ROB FENSOME.



As a prelude to the opening of the Iapetus Ocean, crustal stretching and the resulting normal faulting produced a series of rifts (or grabens) near what was to become the paleosouthern margin of Laurentia. Several of these late Neoproterozoic and earliest Paleozoic rifts underlay modern valleys, such as those of the St. Lawrence and Ottawa rivers. The modern southeastern margin of the St. Lawrence Graben was subsequently overridden by the thrust-and-fold belt of the Taconic Orogeny, as we will discover later in the chapter. ADAPTED FROM VARIOUS SOURCES.

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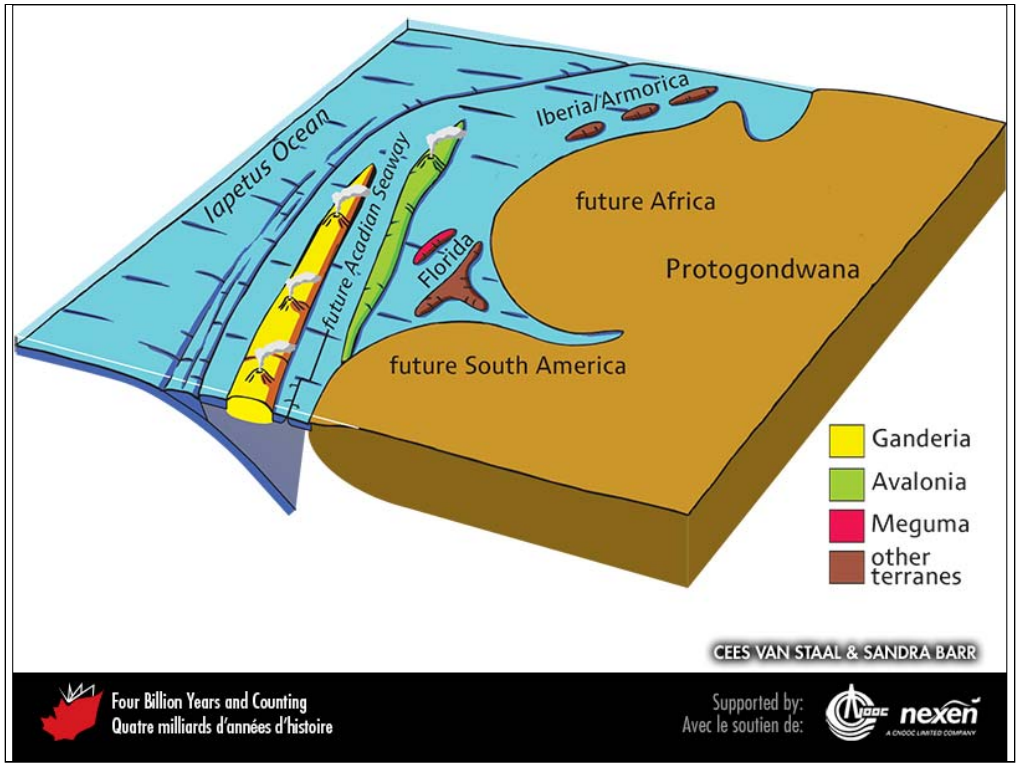
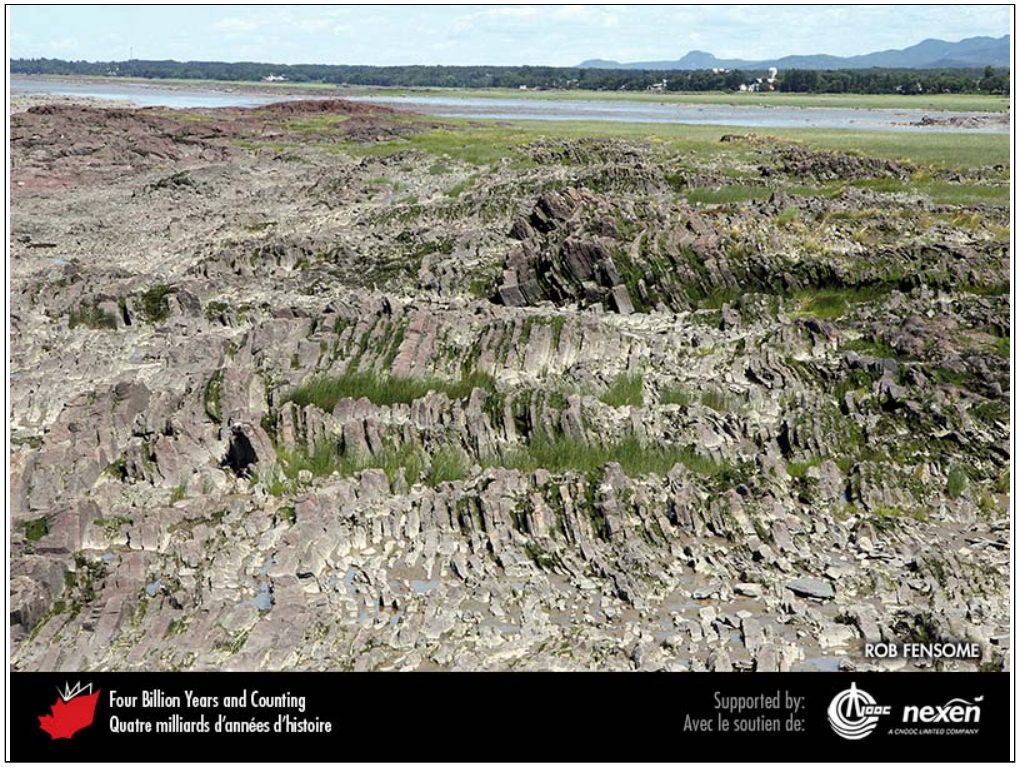
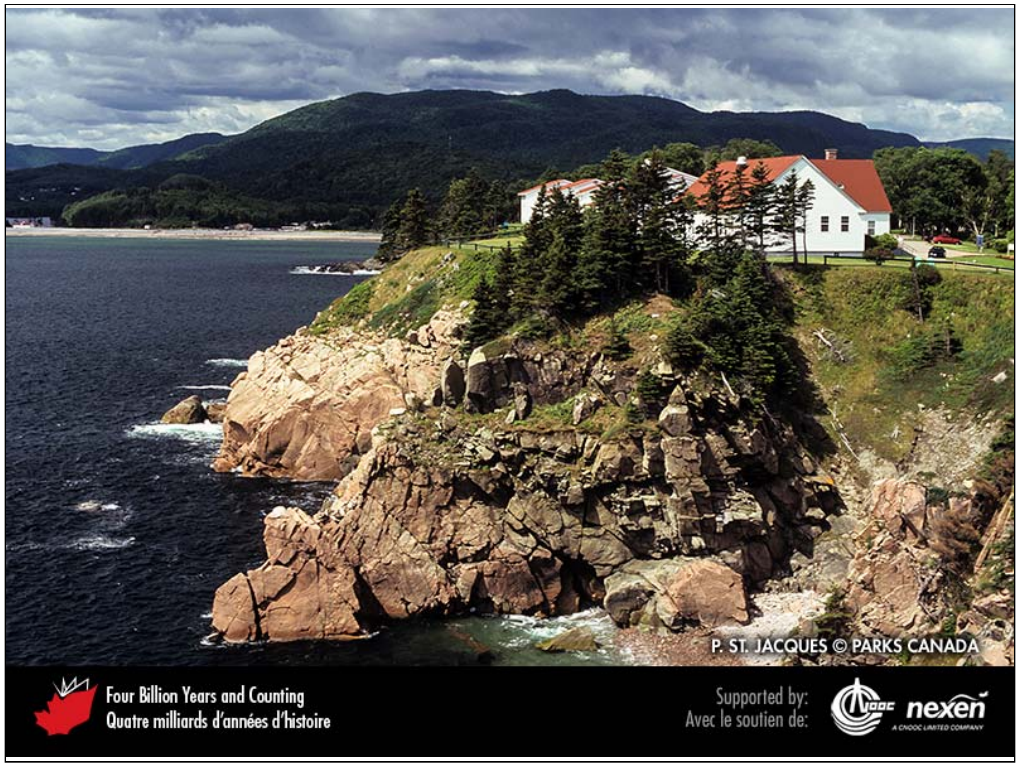


Initial stages of drifting of the three terranes—Ganderia, Avalonia, and Meguma—across the Iapetus Ocean about 490 million years ago.



Vertically tilted, early to middle Cambrian turbidites at L'Islet-sur-Mer on the South Shore of the St. Lawrence River, Quebec. The turbidites accumulated on the passive margin off Laurentia. ROB FENSOME.

CHAPTER 7
Part 3 of 4



Ediacaran diorite intruded by late Cambrian granite at Middle Head, Cape Breton Highlands National Park of Canada, Nova Scotia. These rocks were part of Ganderia. P. ST. JACQUES, COPYRIGHT PARKS CANADA.

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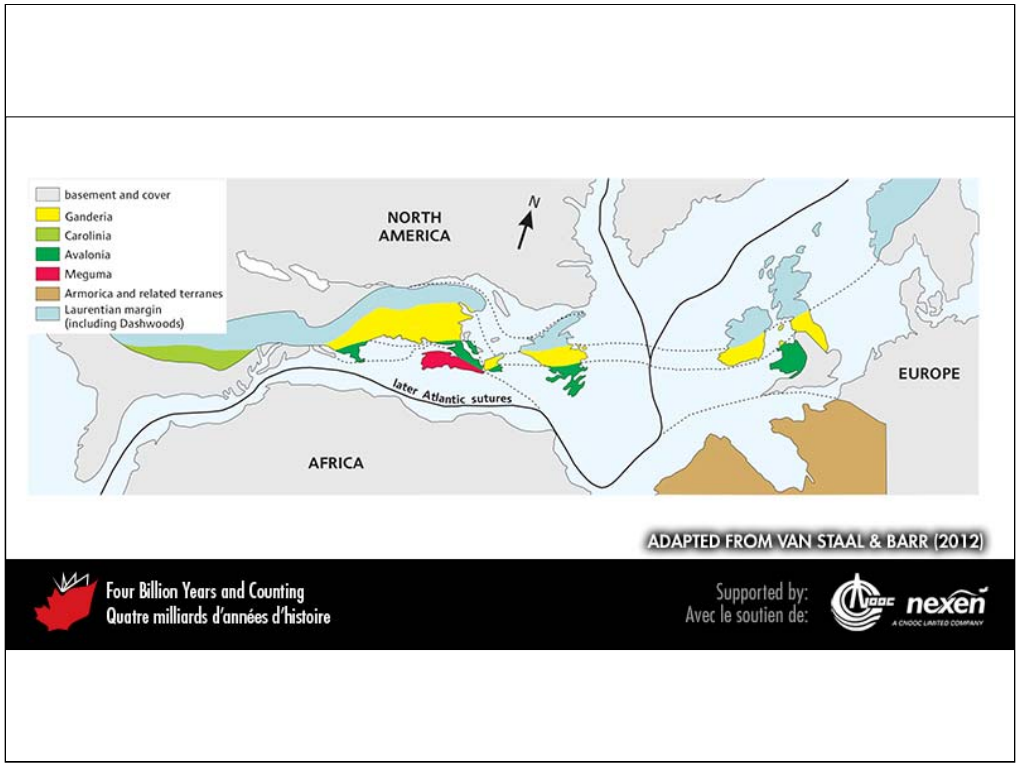

Geological collage of terranes as distributed today in North Atlantic borderlands, but with later oceanic lithosphere removed to better represent their relationships in the late Paleozoic. This distribution has been complicated by latest- and post-Paleozoic tectonic activity, such as movement along strike-slip faults, so the match in not perfect. And we do not have a full understanding of the extension of the terranes beneath the cover of young rocks. ADAPTED FROM VAN STAAL AND BARR (2012).

Neoproterozoic marine sedimentary rocks of Ganderia, exposed at Swallowtail Head, Grand Manan Island, New Brunswick. FRANCIS KELLY, COURTESY OF FISHERIES AND OCEANS CANADA.

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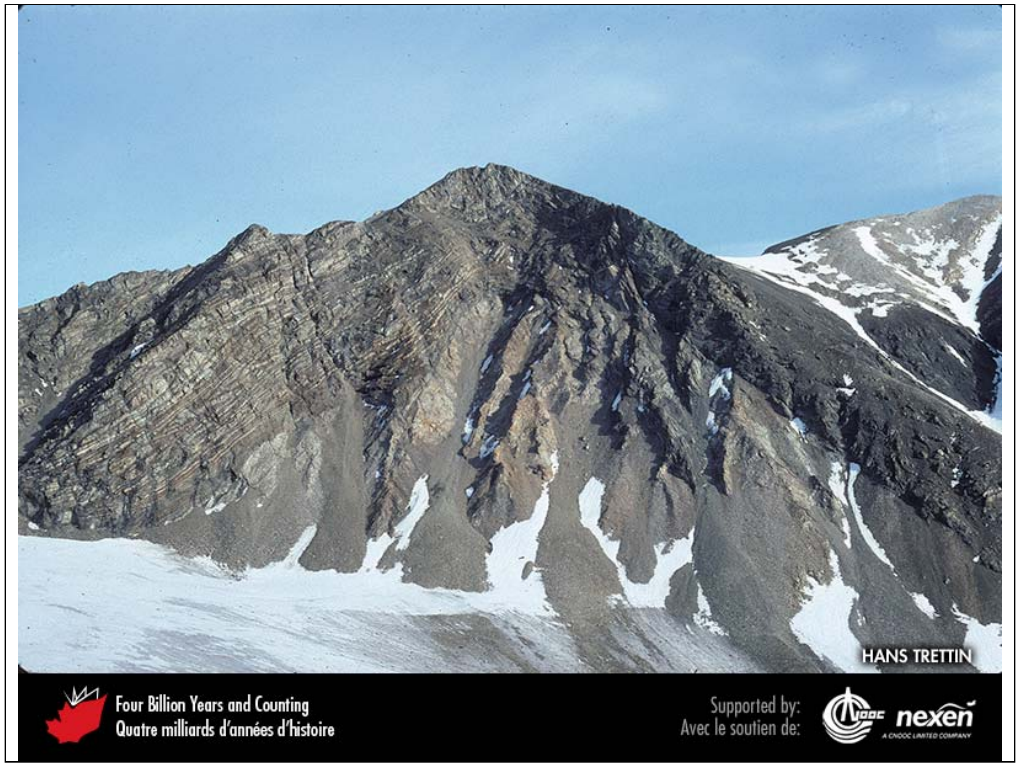
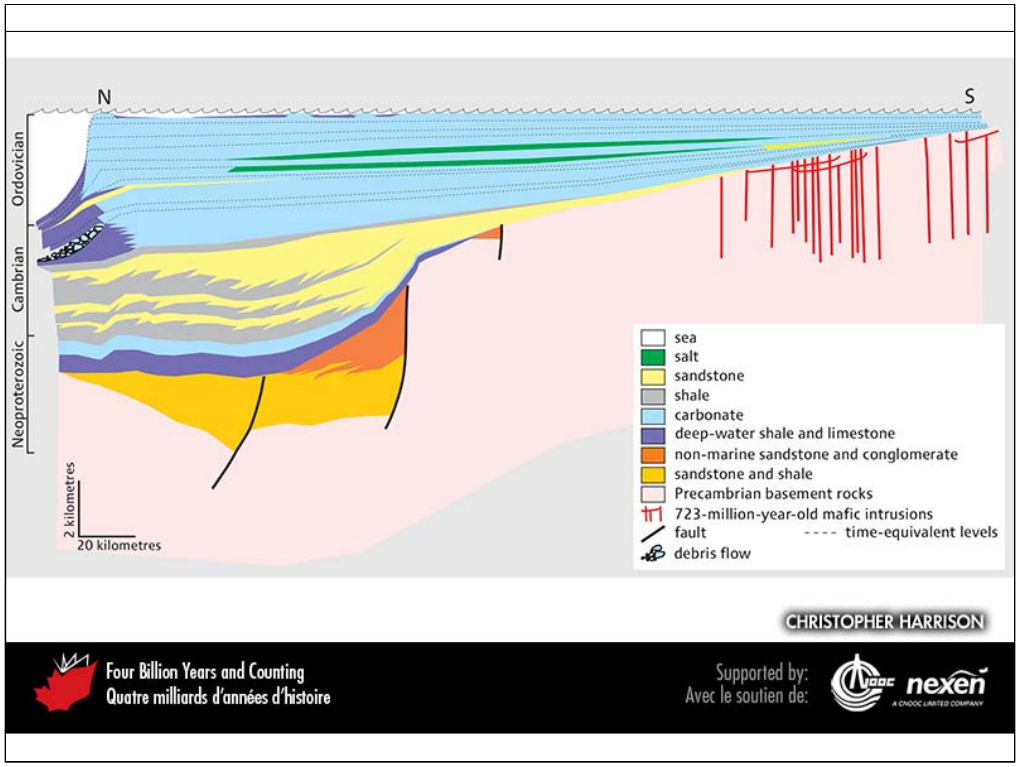
Early Ordovician metasedimentary rocks of the Meguma Terrane at Blue Rocks, near Lunenburg, Nova Scotia. The original bedding is reflected in the lighter and darker bands. These rocks were tilted and metamorphosed during the Neoacadian Orogeny (Chapter 8). ROB FENSOME.

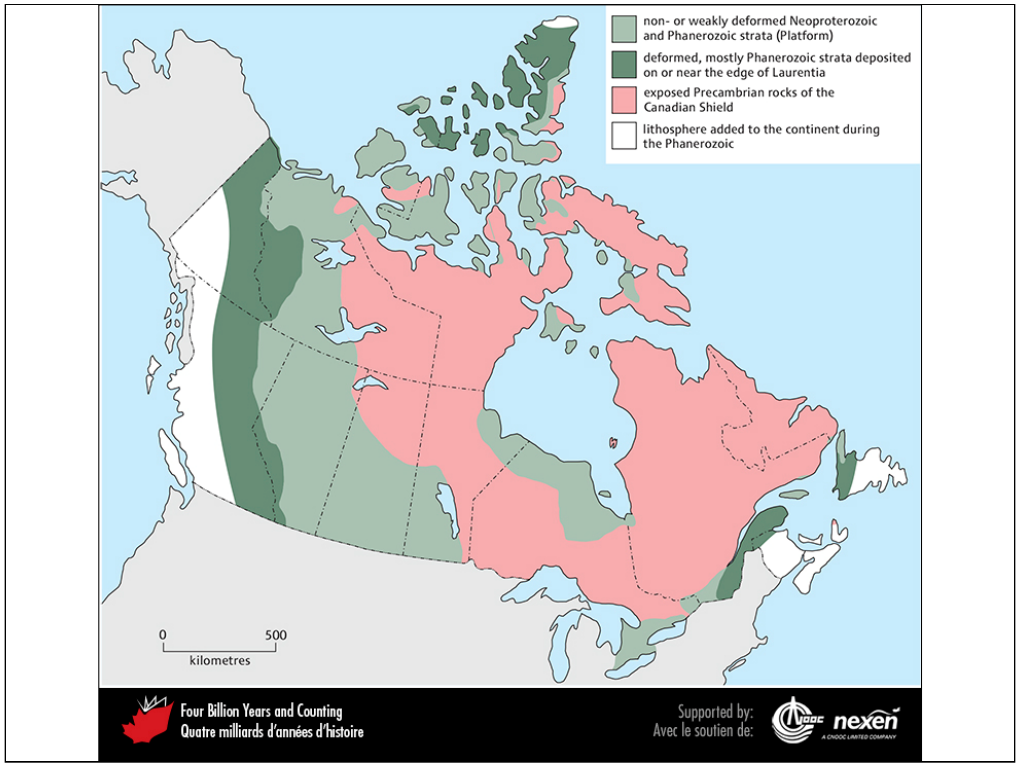
The dark band seen in this aerial view of Brock River, Tuktut Nogait National Park of Canada, Northwest Territories, is a mafic sill associated with the 720-million-year-old Franklin Dyke Swarm. The sill cuts through later Neoproterozoic sediments of the Amundsen-Mackenzie Mountains Basin. HANS WIELENS.



Rocks northeast of Ayles Fiord at the northern tip of Ellesmere Island, Nunavut, record the geological history of Pearya, a continental fragment that drifted within the Ural Ocean during Cambrian and Ordovician times. This outcrop shows an anticline, with latest Neoproterozoic or Cambrian schist and quartzite overlying Mesoproterozoic gneiss. HANS TRETTIN.

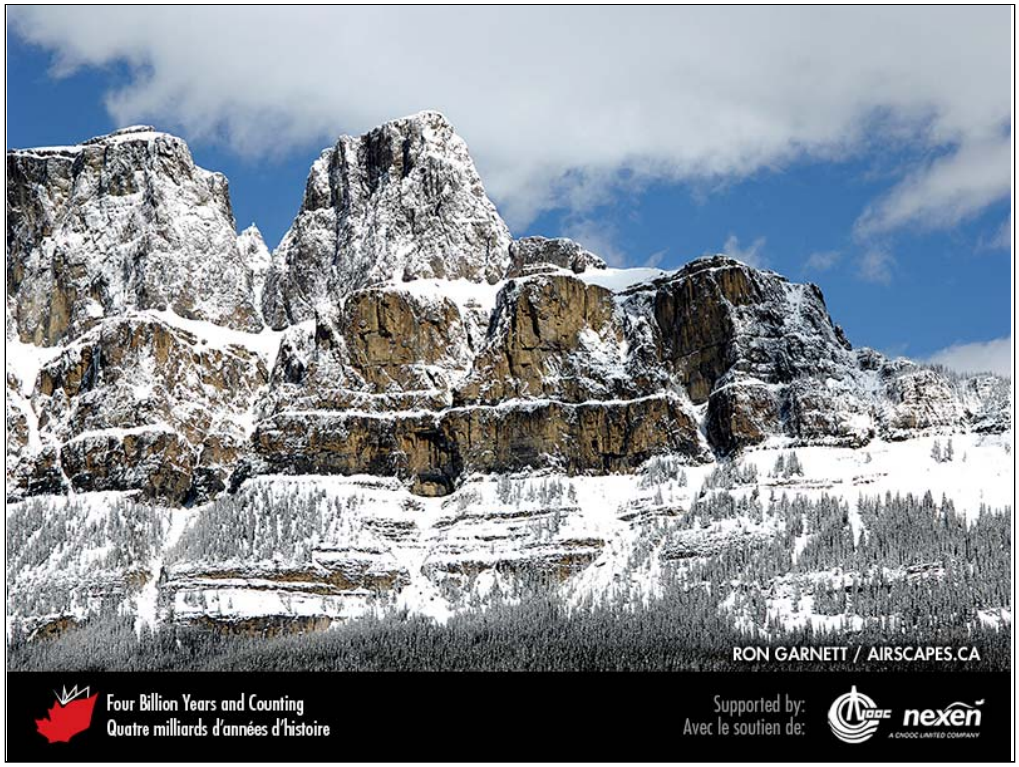


Section from north to south through the Neoproterozoic to Ordovician rocks of Ellesmere Island, reconstructed to show how they would have appeared at the end of the Ordovician. Notice that older rocks were deposited in less extensive, fault-bounded rift basins and younger rocks are distributed more broadly over a passive margin, with strata thickening oceanward. This pattern is similar to that along the early Paleozoic Cordilleran margin and the Atlantic margin off eastern Canada today.



The modern geological structure of Canada in part reflects early Paleozoic geography, with a large part of the former continent of Laurentia central to the story. The white areas to the far west, far east, and at the tip of Ellesmere Island in the far north are the only parts of Canada not underlain by the former continent. These areas are largely composed of terranes that have accreted during the past 550 million years, crumpling the edges of the former Laurentian continent in the process, as shown by the dark green areas. Light green represents areas of relatively undeformed strata formed during the past 550 million years. Pink represents the Canadian Shield, the exposed core of Laurentia, which was once also covered by a blanket of Phanerozoic sediment. ADAPTED FROM VARIOUS SOURCES.

Ordovician strata overlying crystalline rocks of the Grenville Orogen, Trenton, Ontario. PIERRE JUTRAS.



Cambrian carbonates form the precipitous cliffs of Castle Mountain in Alberta. The snowclad, more thinly bedded sequence on the lower slopes is mainly composed of Cambrian quartz-rich sandstone. RON GARNETT / AIRSCAPES.CA.

This aerial view, 40 kilometres southeast of Mount Field, British Columbia, shows black and rusty-weathering Cambrian calcareous shale abutting Cambrian carbonate of the Cathedral Escarpment. Fault movements more than 500 million years ago created the escarpment and, in places, caused the edge of the paleonorthern continental shelf of Laurentia to collapse in huge underwater landslides. BRIAN PRATT.

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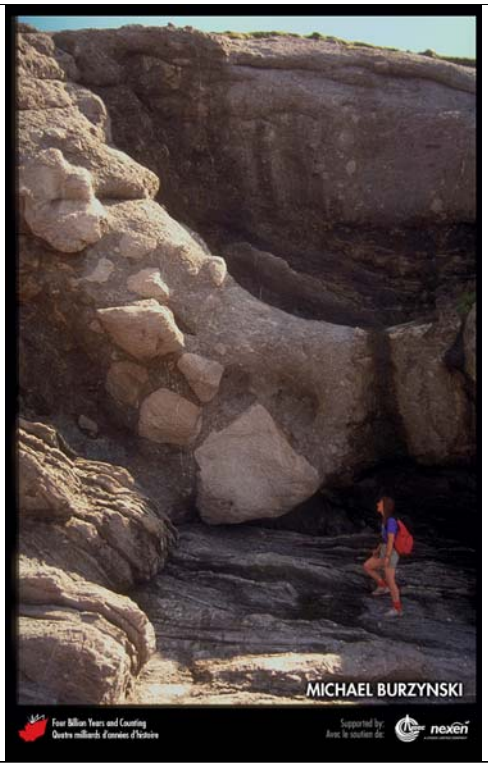
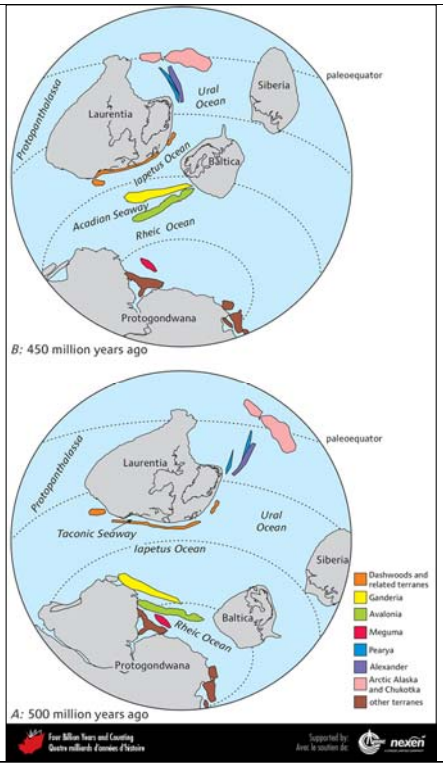
Part 4 of 4

Earliest Cambrian quartz-rich sandstone beds in a road cut on the Trans-Canada Highway west of Golden, British Columbia. These beds overlie the Purcell Thrust, which carried Neoproterozoic and mostly non-calcareous, deep-water early Paleozoic strata eastward over early Paleozoic calcareous shale and carbonate. JIM MONGER.

Folded Cambrian calcareous shale in the Solitude Range of the Columbia Mountains, about 100 kilometres northwest of Golden, British Columbia. LEN GAL.



Early Ordovician breccia at Cow Head, Newfoundland, originally a debris flow at the edge of a carbonate bank on the Laurentian margin. The debris flow may have been triggered by earthquakes associated with the Taconic Orogeny. MICHAEL BURZYNSKI.



Global paleogeography, from a paleosouthern perspective, of the late Cambrian, 500 million years ago (*A*), and of the late Ordovician, 450 million years ago (*B*). The northern part of Laurentia straddles the paleoequator in both figures. In *A*, the Dashwoods Microcontinent is immediately off southern Laurentia, but a narrow remnant of the Taconic Seaway remains. Ganderia and Avalonia lie immediately to the north of Protogondwana in high southern latitudes. The two terranes are separated from Laurentia by the broad Iapetus Ocean and from Protogondwana by the developing Rheic Ocean. Meguma and adjacent terranes are still close to or attached to Protogondwana. Protopanthalassa, the Ural Ocean, and Iapetus surround Laurentia. In *B*, the Taconic Seaway has closed and the Dashwoods Microcontinent has accreted to the southern margin of Laurentia. Fast approaching Laurentia from the south are Ganderia and Avalonia, reflecting the rapid closing of Iapetus and the widening Rheic Ocean. Meguma, which now forms part of Nova Scotia, and adjacent terranes, which now form parts of western Europe, are still close to or attached to Protogondwana. Also shown in *A* and *B* are the possible positions of Pearya and the Alexander Terrane. ADAPTED FROM VARIOUS SOURCES.

Tilted 550-million-year-old pillow lavas and overlying strata at Green Gardens, near Gros Morne National Park of Canada, western Newfoundland. The tilting occurred during the Taconic Orogeny. MICHAEL BURZYNSKI.

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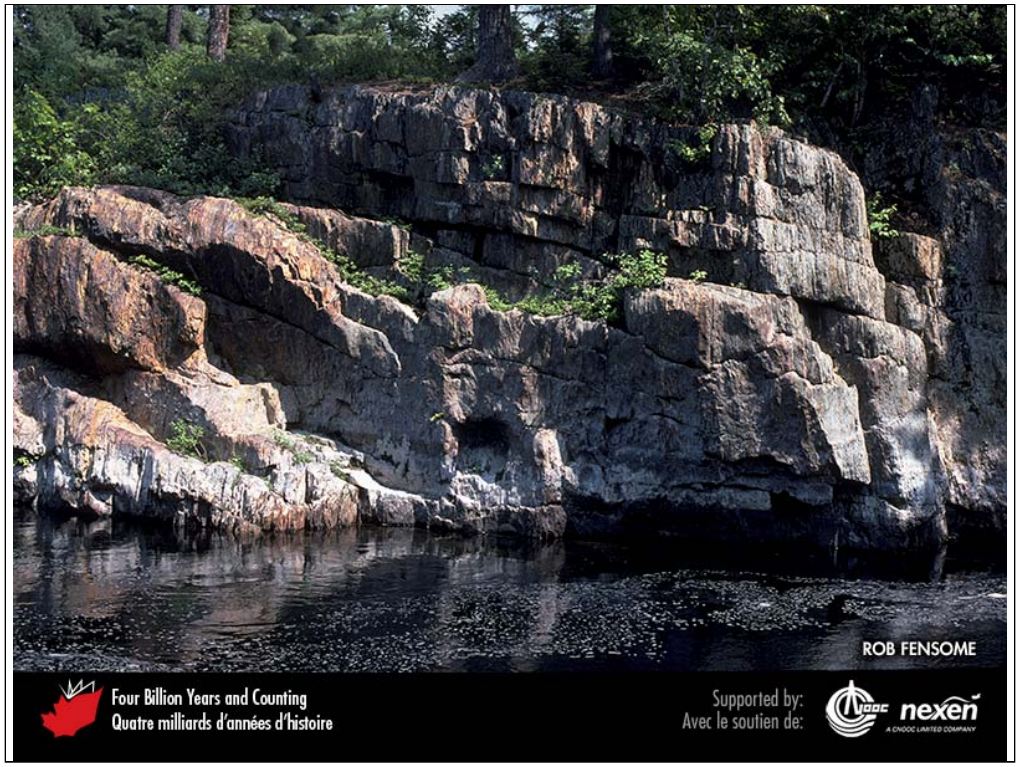
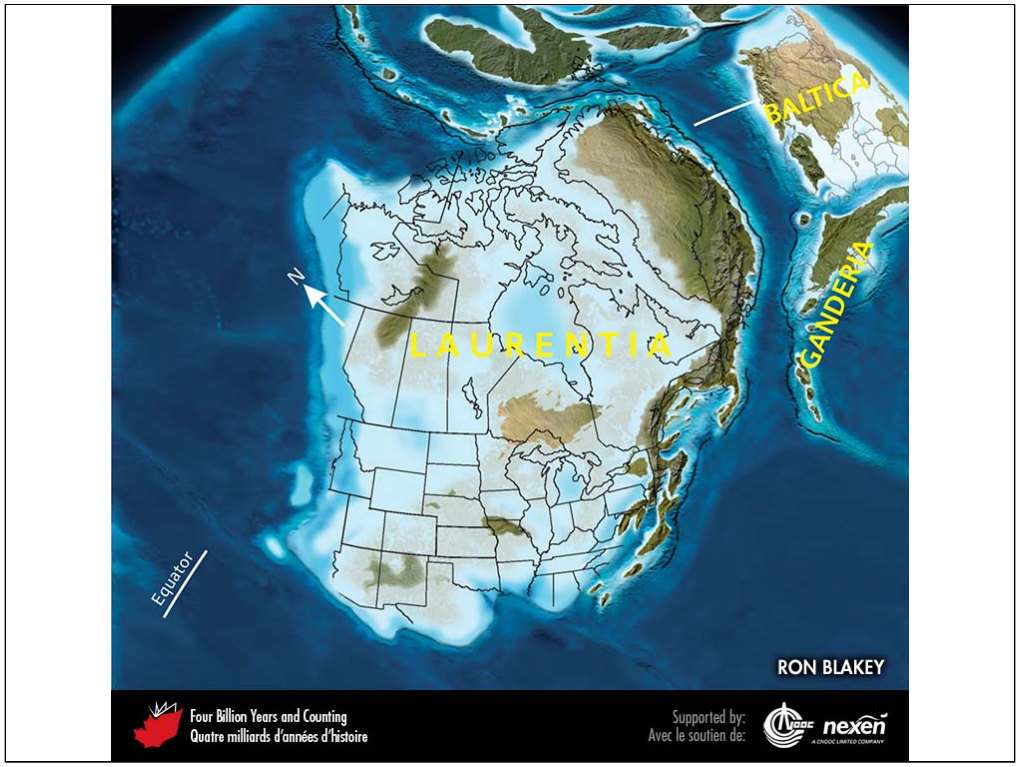
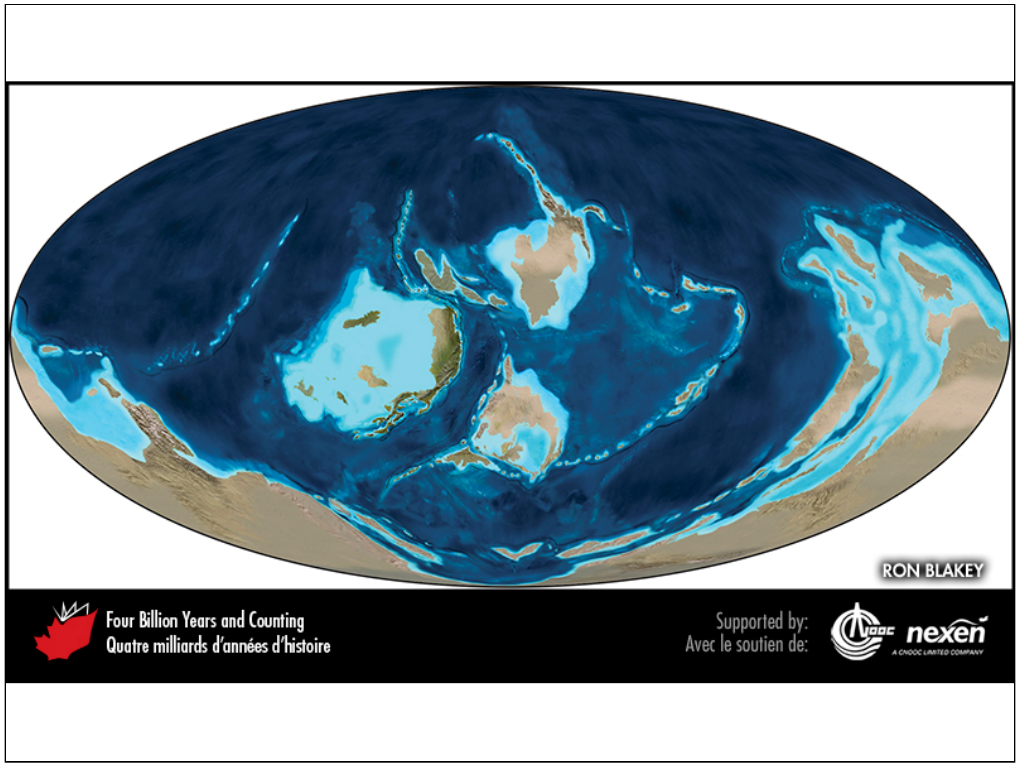
This sequence of early Cambrian turbidites, at chutes-de-la-Chaudière, Charny, Quebec, was deposited on the continental slope off Laurentia. Thin mudstone layers separate sandstone beds. The beds were thrust toward the continent and tilted during the Taconic Orogeny. Note the person at bottom left for scale. ROB FENSOME.



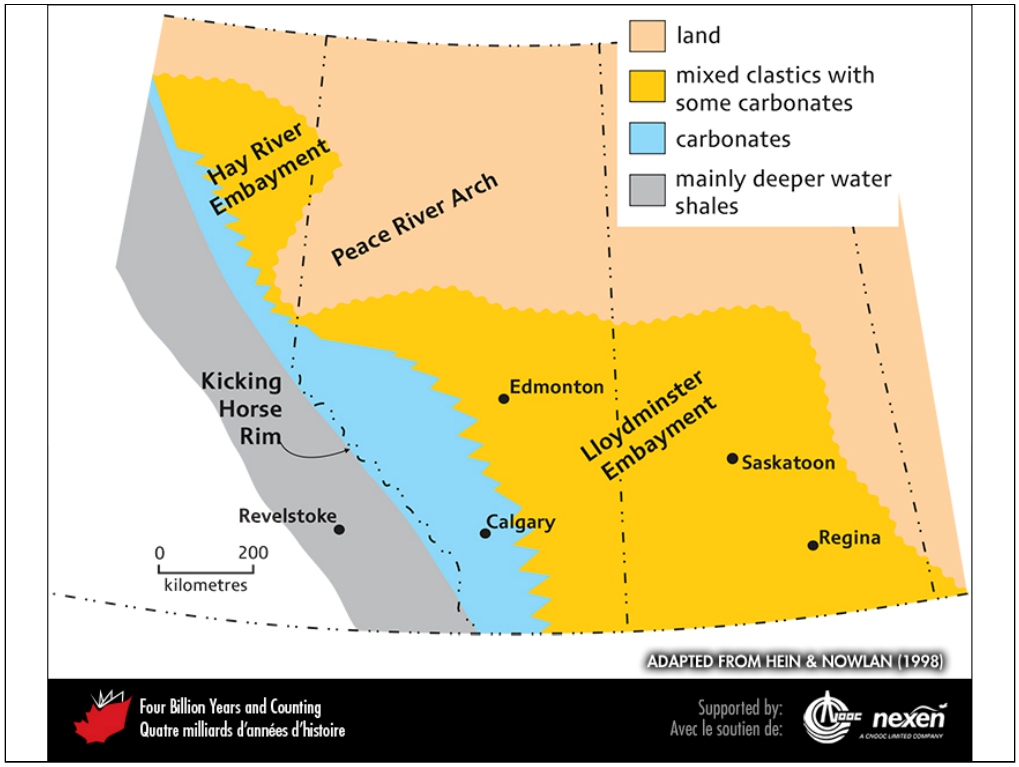
Early to middle Ordovician metavolcanic rocks of the Tetagouche-Exploits Basin, on the banks of the Nepisiguit River, south of Bathurst, New Brunswick. ROB FENSOME.



Paleogeography of what was to become North America and adjacent regions in the middle Ordovician, 450 million years ago. Land is shown in green and 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.

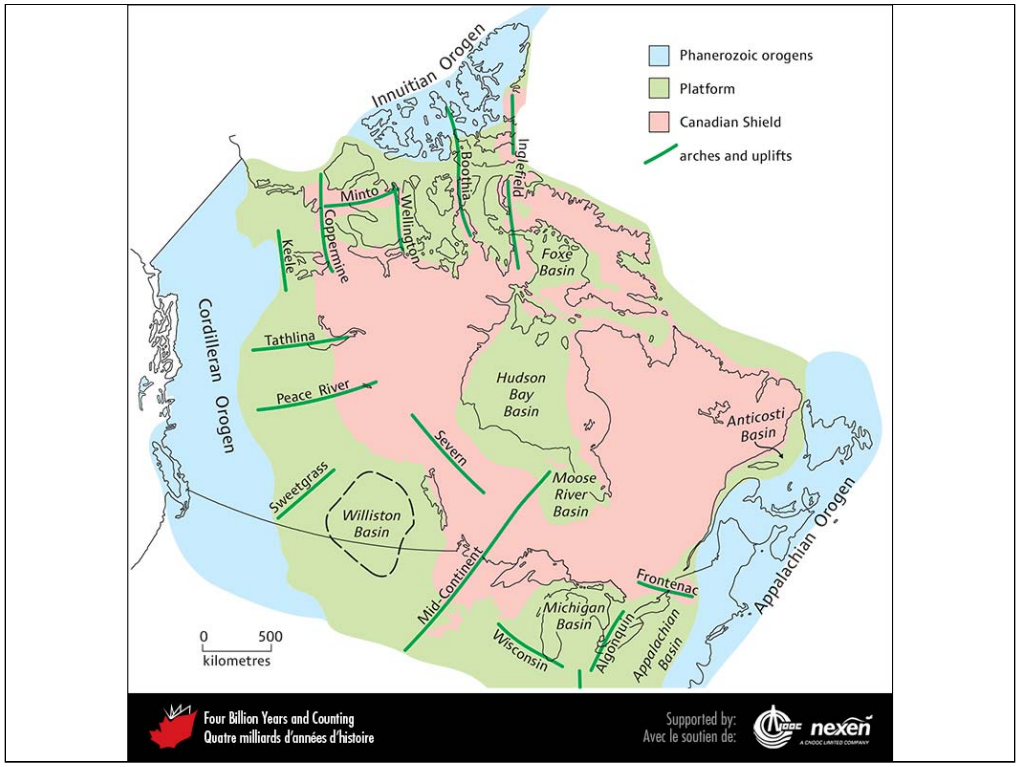


Global paleogeography 450 million years ago, during the late Ordovician. Colours as for previous figure.



Present distribution of Cambrian and Ordovician strata in the southern Canadian Western Interior and major features that influenced their deposition. Note that the rocks reflect a general trend from shallower to deeper water in a modern southwesterly direction. ADAPTED FROM HEIN AND NOWLAN (1998).

Specimens of the graptolite *Rhabdinopora flabelliforme* on an early Ordovician bedding surface in Meguma Terrane rocks near Wolfville, Nova Scotia. ROB FENSOME, SPECIMEN COURTESY OF CHRIS WHITE.



Major upward flexures (arches) and downward flexures (basins) in the lithosphere of the continental interior that persisted through much of the Paleozoic. ADAPTED FROM VARIOUS SOURCES.

Aerial view of the shoreline of Hudson Bay, near Churchill, Manitoba. The boulders are embedded in Ordovician carbonate and are remnants of the ancient shoreline of an island within the late Ordovician continental sea covering Laurentia. Paleoproterozoic metasandstone deposited in the Trans-Hudson Orogen was the source of the boulders. GRAHAM YOUNG.

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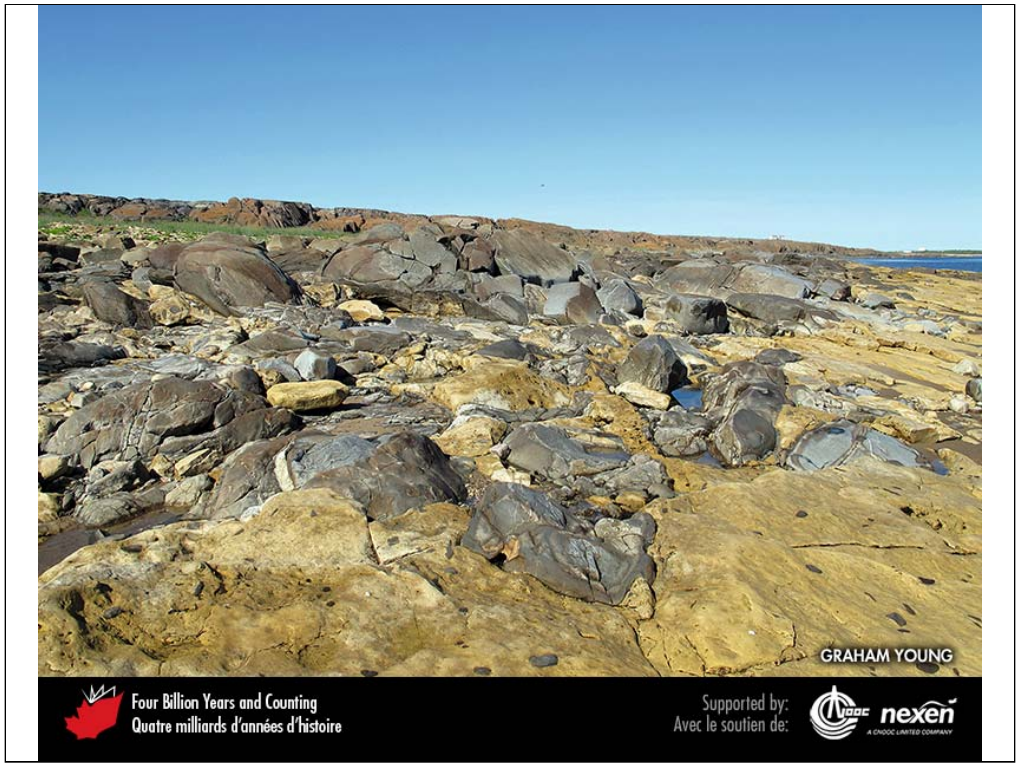

Close-up of the rocks shown in the previous photo. GRAHAM YOUNG.

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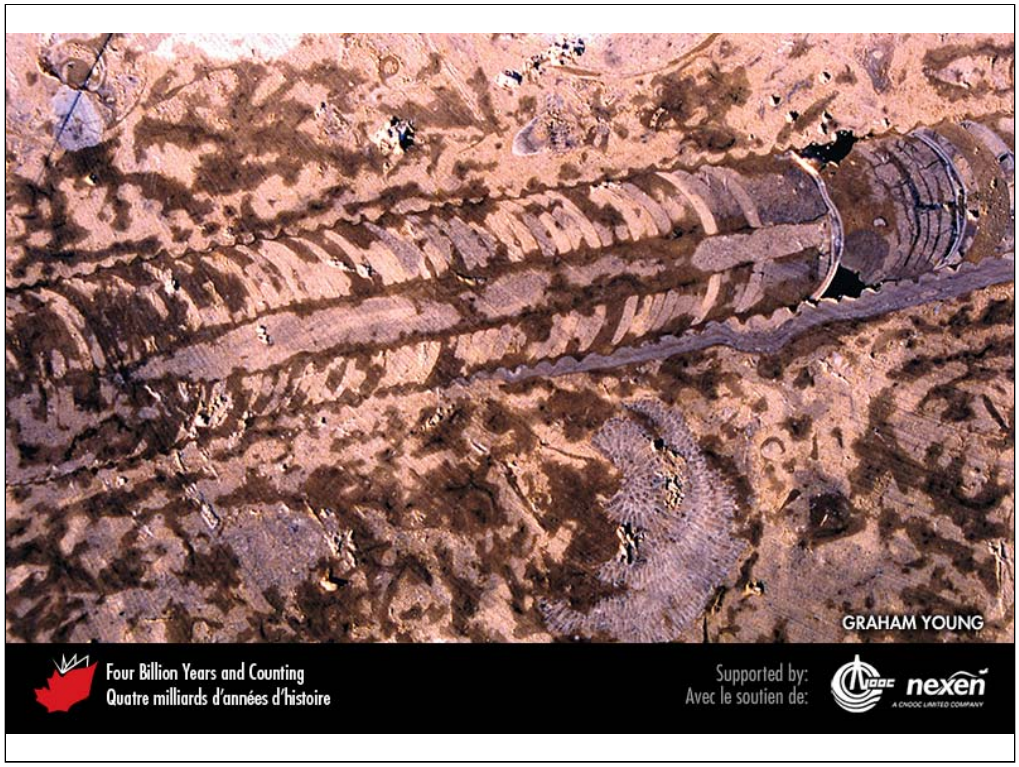
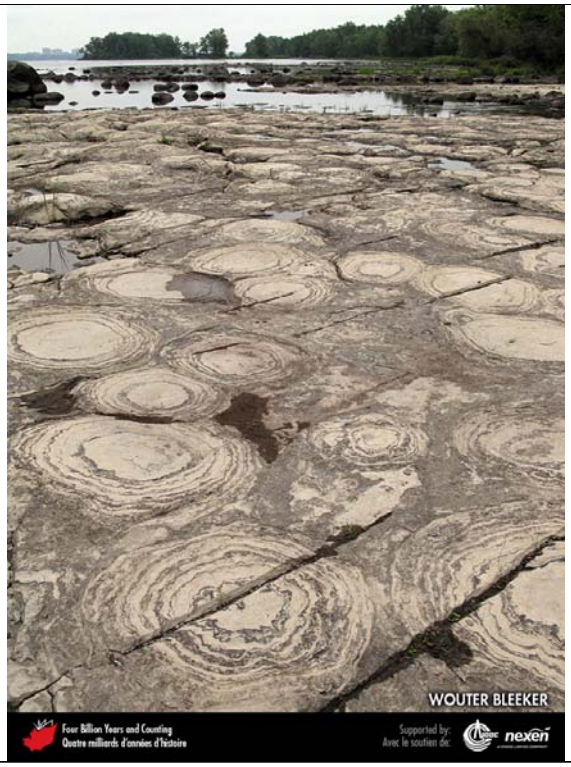


Nautiloid in a polished slab of Ordovician Tyndall Stone from Garson, Manitoba. GRAHAM YOUNG.



These late Ordovician carbonates with impressive stromatolites can be seen at low water levels near the Quebec shore of the Ottawa River, Gatineau, Quebec. Much of Laurentia was covered by a continental sea during the late Ordovician. WOUTER BLEEKER.

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Black shales within a sequence of clastics and carbonates marking the Ordovician-Silurian boundary on Ellesmere Island, Nunavut. The boundary is probably at the base of the thickest band of black shale. MIKE MELCHIN.

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