World Heritage Sites

Protected Areas and World Heritage

JOGGINS FOSSIL CLIFFS
CANADA

The Joggins Fossil Cliffs reveal one of the most significant events in the history of life on Earth. They contain the world's most complete fossil record of terrestrial life in the Pennsylvanian 'Coal Age' including an intact record of the first reptiles and amniotes - the first vertebrates able to reproduce on land - and the 'coal swamp' forests in which they lived. The cliffs, which are continually exposed by the world's highest tides, reveal their fossil record in its ecological context which became, and continues to be, a conclusive part of our understanding of the evolution of life and the history of the Earth.

COUNTRY
Canada

NAME
Joggins Fossil Cliffs

NATURAL WORLD HERITAGE SITE
2008: Inscribed on the World Heritage List under Natural Criterion viii.

STATEMENT OF OUTSTANDING UNIVERSAL VALUE
The UNESCO World Heritage Committee issued the following Statement of Outstanding Universal Value at the time of inscription:

Values
The Joggins Fossil Cliffs have been termed the "coal age Galápagos" and are the world reference site for the "Coal Age". Their complete and accessible fossil-bearing rock exposures provide the best evidence known of the iconic features of the Pennsylvanian (or Carboniferous) period of Earth History.

Criterion (viii): Earth's history, geological and geomorphic features and processes: The "grand exposure" of rocks at Joggins Fossil Cliffs contains the best and most complete known fossil record of terrestrial life in the iconic "Coal Age": the Pennsylvanian (or Carboniferous) period in Earth's history. The site bears witness to the first reptiles in Earth history, which are the earliest representatives of the amniotes, a group of animals that includes reptiles, dinosaurs, birds, and mammals. Upright fossil trees are preserved at a series of levels in the cliffs together with animal, plant and trace fossils that provide environmental context and enable a complete reconstruction to be made of the extensive fossil forests that dominated land at this time, and are now the source of most of the world's coal deposits. The property has played a vital role in the development of seminal geological and evolutionary principles, including through the work of Sir Charles Lyell and Charles Darwin, for which the site has been referred to as the "coal age Galápagos".

Integrity
The boundaries of the property are clearly defined in relation to logical stratigraphic criteria and include all of the areas necessary to fully display the fossil record of Joggins including the cliff face and foreshore rock exposures, and include both the most fossiliferous strata and younger and older rocks that provide geological context. The inland extent of the property is defined based on the eroding top of the cliffs and this is a fully justifiable and logical basis to cope with the dynamic nature of this coastal property. A relatively narrow buffer zone is defined, which is not part of the inscribed property, but is sufficient to control coastal development which could otherwise threaten the values of the property.

Protection and Management Requirements
The property has effective legal protection and has the strong support of all levels of government, including in relation to the provision of funding. Some aspects of the legislation, such as for the licensing of fossil collection are cumbersome and would benefit from review, although can be better implemented if site managers are empowered to do so. The site is well resourced, including through the provision of a new visitor centre, and is managed in a way that can be considered to set international standards. The effective process of community involvement and

partnerships between scientists, museums and economic interests are also noted, and the biggest challenge of the property will be to maintain the level of performance and resources required in the future.

IUCN MANAGEMENT CATEGORY

Joggins Fossil Cliffs Heritage Area: III Natural Monument

BIOGEOGRAPHICAL PROVINCE

Canadian Taiga (1.4.3)

GEOGRAPHICAL LOCATION

In northwest Nova Scotia on the shores of the Cumberland Basin of Chignecto Bay, the northern extension of the Bay of Fundy, between Downing Head 45°45'07"N x 64°25'05"W and Ragged Reef Point at 45°40'24"N by 64°23'09"W; centrepoint 45°42'35"N by 64°26'09"W.

DATES AND HISTORY OF ESTABLISHMENT

1970: The provincial Historical Objects Protection Act is adopted;

1972: Joggins Fossil Cliffs (7ha) was the first protected site designated under provincial legislation through the Historical Objects Protection Act;

1980: Special Places Protection Act of Nova Scotia passed, replacing the Historical Objects Protection Act: protection is strengthened; Joggins Fossil Cliffs designated a Special Place;

1989: A Protected Beach under the Beaches Act and Regulations (1989) covering 8.5 km of the northern most scientifically important half of the site from mean low to mean high water marks plus a 30.48m (100ft.) landward buffer;

2006: Entire property is closed to mineral exploration under the Mineral Resources Act of 1990;

2006: The Protected Site buffered by a 20m restrictive setback by the Secondary Municipal Planning Strategy and Land Use Bylaw for the Joggins Planning Area of Cumberland County;

2007: The Protected Site (1972) is expanded under the Special Places Protection Act from the top of the cliff-face or back of beach to 500m parallel out to sea over 14.7 km of coastline.

LAND TENURE

The Province of Nova Scotia owns approximately 95% of the area. The buffer area is approximately one third provincially owned and two thirds private land with a small municipally owned area in Joggins around the Fossil Centre.

AREA

Core nominated area 689 ha. Buffer area: 55.3 ha, comprising 29.4 ha along the 14.7 km length of the site, plus 25.9 ha along 8.5 km which includes the 'Classic Section'.

ALTITUDE

Mean low water mark to 300m+

PHYSICAL FEATURES

The site is a 14.7 km stretch of cliffs, low bluffs and wave-cut platforms on the eastern shore of Cumberland Basin, a branch of Chignecto Bay, the most northerly arm of the Bay of Fundy, The rocks are layers of ochreous sandstone up to 30 m high, forming headlands, with bays in grey-green mudrock between them, and a wide intertidal bedrock platform with serried reefs running into the sea. The southern half is capped by glacial till of boulders in reddish clay which sits on a clearly defined earlier wave-cut platform and preserves a record of past glacial movements. The cliffs are the world's thickest and most comprehensive record of Pennsylvanian coal-bearing strata (318 - 303 million years ago) with the most complete fossil record of Upper Carboniferous terrestrial life in existence. This includes the remains and tracks of very early animals and the rainforest in which they lived, revealed in situ, in an undisturbed geological context, and intact. The cliffs have been mined in the past for a low grade coal which occurs in thin seams associated with bivalve-bearing limestone and black shale, and for fossils, but the lower cliff faces are renewed twice daily by erosion from the 16.8 m tides of the Bay of Fundy,

the highest in the world. The site's landward boundary is the top of the cliff-face or back of beach; the seaward boundary is 500 m parallel to this.

The Joggins Formation lies in the Athol syncline of the Carboniferous Cumberland Basin, which covers much of northern Nova Scotia, part of a complex of northeast-trending basins formed over 310 million years ago. The site's coast displays in horizontal section a 15 million year succession of sedimentary layers in the Pennyslvanian Cumberland Group one after the other. The 915.5 m thick, 2.8 km long 'Classic Section' of the Joggins Formation, with thin coal-bearing seams of varying thickness, is shown between the younger Springhill Mines and Ragged Reef Formations deposited above it (now to its south), and the red beds of the Little River and Boss Point Formations originally below it (to its north), all tilted at an angle of 21$_{o}$ from the horizontal and running back inland many kilometres. Beyond these at the north end of the section, lying unconformably, are the older Claremont and Shepody Formations of the very different Mississippian Mabou Group, which has been used to establish the global timescale of polar reversals in the earth's magnetic field, central to reconstructing earlier global positions of the continents. The unconformity dates from the time when the archaic land masses of Laurentia and Gondwana collided near the equator, producing mountains from which large rivers flowed to the sea through estuarine rain forests. The decay and burial of these forests, as the area subsided, created the vast deposits of peat which became coal. At the time of deposition of the Cumberland Basin coal seams there is evidence of rhythmic successions of vegetation adapted to alternate periods of flooding and drying, when a thickness of 4 kilometres of strata subsided over the geologically rapid period of four million years caused by faulting and the withdrawal of deep underground layers of salt. This was followed by later wet/dry periods due probably to glacial-interglacial climatic fluctuations, analogous to those of recent Earth history.

CLIMATE

The present climate of the site is maritime, having cool wet winters with storms from the northeast and very warm humid summers. The slightly more continental climate of nearby Moncton has a mean temperature range of -8°C to 36°C and annual rainfall of 1144mm. The climate of the coal-age forests was equatorial, hot and humid with a seasonal precipitation flux, subject to storms resulting in flash floods bearing sediment loads heavy enough to half-bury forests. The forests were also drowned by rising ground or seawater during periods of subsidence. But fossilised charcoal reveals that the alluvial plains could be subject to droughts when lightning-caused forest fires became a hazard. The Pennsylvanian 'Coal Age' (Pennsylvanian) was the last period of Earth history before the present to experience polar ice caps that eventually receded in the face of global warming in the Permian Period.

VEGETATION

The existing setting is boreal forest and wooded cliff-edge farmland. The exposed fossil assemblages form a remarkable paleoecological archive of a coastal rainforest of 310,000 million years ago where the fossils remain in situ, grouped in a combination unusually valuable to science of three neighbouring ecosystems, brackish estuarine bay, peat-forming floodplain rainforest and fire-prone forested alluvial plain with freshwater pools, a far rarer source of fossils. The seams preserve, mostly as casts, the upright fossilized trunks of trees up to 7.6m high, which grew in a poorly drained disturbance-prone deltaic plain. There they were preserved by burial 3-4 m deep in flood-deposited alluvial sands and mud during a period of geologically rapid subsidence. Within this area, 195 fossil species have been discovered, composed of rainforest and seasonally dry land vegetation, with its vertebrate and invertebrate inhabitants both terrestrial and aquatic. There are 95 species of plant life and at least 187 plant microfossils, from massive trees to delicate ferns. Darwin wrote of the 68 coal-bed horizons with standing trees when citing the discoveries of tetrapods (amphibians and reptiles) and the earliest land snail in *The Origin of Species.*

The fossils are the buried relics of a wetland forest found still standing upright: over 100 large lycopsid clubmoss-like trees with liana-like ferns, ferns, seed-bearing pteridosperms, smaller riverine mangrove-like cordaite trees, and calamitean horsetail-like shrubs growing in the most flood-prone land. The *Lepidodendron* spp. with scaly trunks of 45cm or more in diameter growing in a rich organic substrate of peat were dominant within mires, with smaller *Sigillaria* trees in more disturbed habitats. Where not preserved entire, their hollow stumps attracted a fauna, which was buried with them along with leaves and rootlets. The *Sigillaria* proved more resilient and successful than the larger trees and were themselves succeeded by flood-tolerant *Calamites* spp. The decay and intermittent periods of burial of this rich vegetation contributed to the many layers of peaty debris that became coal.

FAUNA

Evidence of the entire food chain of a primeval terrestrial ecosystem is present, from the primary producer plants to invertebrate detrivores and tetrapod carnivores. The forests were inhabited by molluscs, land snails, spiders and scorpionids, flying insects, millipedes, amphibian tetrapods and the earliest known reptiles. Many animal trackways were preserved including those of one of the largest millipede-like creatures ever recorded, 2 metres long. The sea was brackish, populated by an extensive aquatic fauna of annelid shells, bivalves, crustaceans, horseshoe crab-like forms, sharks, ray-like fishes and several species of bony fish. In 1852 C. Lyell and W. Dawson found the first tetrapod amphibian and land snails trapped within a buried hollow Lepidodendrid tree stump. They were named respectively *Dendrerpeton acadianum* and *Dendropupa vetusta*. These discoveries, incorporated into his theories by Darwin, led to acclaim for the Joggins Cliffs as 'the Galapagos of the Coal Age'. In 1859 Dawson discovered the earliest known reptile, *Hylonomus lyelli,* the ancestor of dinosaurs, birds and lizards, and in 1882, he discovered 25 fossil trees with over two hundred tetrapods of five taxa and more reptiles. Many skeleton remains were found grouped in hollow tree stump-pits, perhaps buried while the animals were escaping forest fires (or while denning). Remains were also found in waterholes in the seasonally dry alluvial plains. Of 66 species of terrestrial fauna and trackways, over half are type specimens first or only found at Joggins. Nineteen of these are amphibian and reptile tetrapods, including the earliest known reptile, and the oldest amniote known. These were the first vertebrates able to reproduce on land by laying eggs in an amniotic sac, a group that eventually developed into the dinosaurs, birds and mammals. 96 genera, some 148 species of protists, animal and plant body fossils plus 20 footprint groups *(ichnogenera)*, have been found on the site, forming the most comprehensive assemblage known of the fossil life of three distinct paleoecosystems.

CONSERVATION VALUE

This classic paleo-ecological site provides outstanding evidence of a major stage of earth's history, including a remarkably intact and wide record of great biodiversity including amniotes, the first vertebrates able to reproduce on land, the first reptiles, the coal swamps in which they lived and the sedimentary layers surrounding them. The discovery of standing trees and their contained fossil fauna became through Lyell and Darwin a conclusive part of the support for the theory of gradual evolution, leading to the site becoming known as the 'Galapagos of the Coal Age'. Research will continue as more of the section is revealed by erosion. The site lies within a WWF Global 200 Eco-region.

CULTURAL HERITAGE

The name comes from Chegoggin, a Mi'kmaq Indian word for a 'place of fish weirs'. Coal was mined in the 17th and 18th centuries by the first French colonists and continued in the Joggins Formation (beside and underlying Joggins village) intermittently from 1847 on, some galleries running underwater into the bay. The gritstone of Boss Point was used for a successful grindstone business in the 19th century. The site's internationally acclaimed scientific heritage is its historic proof of the origin of coal, as the most complete source of terrestrial life in the Pennsylvanian, including fossil 'Coal Age' swamp forests, amphibians and first known reptiles, and its contribution through the work of Lyell and Darwin to the theory of evolution.

LOCAL HUMAN POPULATION

The village of Joggins immediately above the cliffs has always been dependent on coal mining, which ended there only in 1961, leading to local economic decline. Company men and local enthusiasts had long assisted geologists by reporting and saving palaeontological finds and the community remains dedicated to stewardship of the cliffs. Only five people lived in the two houses in the buffer zone in 2006.The local people use the area for walking, fishing, swimming and parasailing. Preparation for the nomination began 28 years ago and the local community has been continually consulted and brought into collaboration with the process.

VISITORS AND VISITOR FACILITIES

Exact past figures for past visitors were not taken but they have included people from 43 countries, among them many field trips by international groups, and from universities and high schools despite the out of the way location and lack of facilities. For the year 2007-8, visitation of 38,440 is projected; and for 2011-12, 48,600. There is limited present public access but a new entry point will be part of the Joggins Fossil Centre, opening in 2007. This will have a large exhibition and information gallery on the fossils and cliffs, the Bay of Fundy ecosystem and the coal village of Joggins. It will also have a café, shop, meeting room, first aid facilities and an office, laboratory and curated fossil collection for use by scientists. Information on tides will be given, and a shuttle bus, guided tours and beach attendants will be provided. A range of brochures, field guides and web sites already exists.

SCIENTIFIC RESEARCH AND FACILITIES

This site was discovered by the engineers R. Brown in 1826 and A. Gesner in 1836 and was visited by the geologist Charles Lyell in 1842. In 1843, 4,441 m of the cliffs – the 'Classic Section'- were measured in detail by William Logan of the Canadian Geological Survey, a description which stood for 140 years until a partial remeasurement in the 1980s and a total one in 2002. Lyell was one of the founders of modern geology whose 1830 *Principles of Geology* text vitally influenced Darwin. On seeing large fossil trees rooted in a layer of coal he was convinced that coal formed from the soil of ancient forests - at a time when coal was the main source of industrial power. In 1852 Lyell and William Dawson found the first tetrapod amphibian and land snails, which received their scientific names from Owen, who also named the *Dinosauria.* The seams and their fossils became a conclusive part of the support for the theory of uniformitarianism, or gradual evolution in the argument against catastrophism, and was incorporated by Darwin in *The Origin of Species.*

From 1859, when he discovered the earliest known reptile, Dawson continued to research the site until the 1890s, discovering many more trees, tetrapods and reptiles on which he published 19 papers in all. The site has perennial international interest and scientists have continued to work on it up to the present day. A unique reason for this that tidal erosion of the cliffs constantly reveals new facies; in fact much material must be washed away during storms without being studied. Among leading researchers were G.F. Matthews on tetrapod footprints in the early 20th century, W.A. Bell on macroflora from 1911, R.C. Carroll on the earliest reptiles in the 1960s and 70s, M.R.Gibling and S.J. Davies on the sedimentary record in the 1980s through 2000s, J.H. Calder on palaeoecology in the 1980 through 2000s, H.J. Falcon-Lang and R.H. Wagner on the fossil flora today. Subjects researched include sequential stratigraphy, salt tectonics, paleosoils, vegetation-sediment interactions, fossil fires, terrestrial vertebrate paleoecology and evolution, the effects of global climate change on vegetation and even its relevance to a revived theory of partial catastrophism. Over the years the site has yielded 96 genera, some 148 fossil species and about 20 footprint groups from three paleoecosystems, in a record that, after years of fieldwork, has proved relatively complete. But reinterpretations of this paleoenvironment will continue as long as the tides continue to uncover new evidence.

The Joggins Fossil Institute, set up in 2006, will be advised by a Scientific Advisory Committee. Because of the clarity and continued tidal renewal of the exposure, the site continues to be important for scientific research and education. Relationships with local, national and international museums and institutions will be fostered. Over 900 books and papers have been produced on the site, 15 of which were included to support the nomination as well as a separate annotated bibliography.

MANAGEMENT

Between 1972 and 2006 several laws have been passed to ensure protection of the site. The most important are the provincial Special Places Protection Act covering from the cliff top or back of beach to 500m parallel out in the bay; the Beaches Act and Regulations (1989) from mean low to mean high water marks for 8.5 km of the most scientifically important half of the site plus a landward buffer of 30.48m; the Mineral Resources Act which prohibited mining, and a 20m restrictive setback in the Land Use Bylaw for the area by Cumberland County. These Acts and municipal policies require any proposals for fossil collection or for structural work within the coastal area to gain prior official permission. Relations with local landowners are good and beach access has been agreed with them. The site is in excellent condition since even the remnants of the former mines have become fairly unobtrusive. This is because constant tidal erosion has scattered the old flotsam and eroded previously damaged cliffs, even those dynamited by Dawson in the 1870s and by another academic in the 1960s (which led to provincial laws limiting fossil collection and the present requirement for a Heritage research permit). Moreover, very few fossils existed in the mined seams. The current Management Plan sets out the program for protecting and operating the site, plus a comprehensive visitor-monitoring program. In addition it emphasises the needs to provide for world-class sustainable tourism, to publicise its scientific and educational values and to involve the local community.

The Joggins Fossil Institute, established in 2006, will become the centre for well-organised conservation of the site. It is governed by a 12-member Board of Directors: six from Cumberland municipality, one a Councillor and one from the Regional Economic Development Association plus one federal and two provincial representatives, one scientist and three others. It is advised by a Scientific Advisory Committee and supported by an Emergency Response Planning Group to coordinate with local health and safety, fire and police authorities. Indicators of conservation success to be monitored monthly are fossil bed erosion and occurrences, and illegal collection. Annual monitoring will be carried out of

human impacts in the buffer zone, stakeholder engagement, numbers of reviewed papers, scientific workshops, research projects, reports and research permits issued, specimens sent to museums and the status of type specimens transferred to international collections.

MANAGEMENT CONSTRAINTS

The extreme tides and cliff erosion have not encouraged development and the village is too small to contaminate the area. The Bay's water level has risen 40 cm during the past century, and climate change may accelerate the wave action, but earthquakes, hurricanes and tidal waves are almost unknown. The greatest potential threat to the fossils is illegal collection and, from the cliffs, falling and slippery rock.

COMPARISON WITH SIMILAR SITES

The main bases for comparison with existing World Heritage sites of similar quality are:

a) An outstandingly complete and intact assemblage of the fossil plants, invertebrates and vertebrates of three distinct palaeo-ecosystems: brackish bay, wetland rainforest and inland dry land of the Pennsylvanian Period, found in situ in their stratigraphic context.
b). The world's most diverse and significant examples of Pennsylvanian Period fossils: upright petrified trees rooted in a 'coal' soil, the first amniote tetrapods and reptiles, a wide range of terrestrial plant and animal species.
c). A classic research site, which supplied conclusive evidence supporting the theory of gradual evolution, and which because of continuous tidal renewal continues to be important for scientific research and education.

The quality of the Joggins site is relevant as the record of a major terrestrial evolutionary event and period contained within a *lagerstëtten* or fossil mother lode not so well shown elsewhere Ten non-World Heritage Carboniferous fossil tetrapod exposures are compared in the nomination to demonstrate the relative excellence of the Joggins cliffs. Of the eight most significant, Joggins is the only one still capable of revealing new information and supporting productive research into the development of the terrestrial ecosystems of the time, terrestrial tetrapods and invertebrates, plants and trace-fossils together in one place. Its trackways and footprint assemblages are the most extensive and most studied of their period, yielding information not revealed in bones alone. Most of the sites have been destroyed, two are spoil-heaps: one, at Mazon Creek in Illinois typifies many fossil sites in having had a far richer well preserved range of fossils, especially of plants but, being first swept from its original site then salvaged from mining spoil, was without ecological context, and was then dispersed and obliterated; another, at East Kirkton in Sotland, discovered in the 1980s, is earlier but similar.

There is a sea cliff site at Sydney coalfield in nearby Cape Breton which has similarities and is protected by the province. . Fossils of major importance are protected in a dozen World Heritage sites and there are lesser occurrences in several more. Several sites are of comparable quality but represent a range of differing periods and features along the geological timescale.

STAFF

This will comprise a Director with an Administrative Assistant, and Property & Maintenance Manager, a Science and Education Coordinator, with a seasonal interpretive staff of 6, and an Operations Coordinator with two seasonal customer service assistants. Staff could potentially be shared with the nearby Cape Chignecto Provincial Park. A 5-year program for 2007-2012 for funding the staffing and training of staff is given.

BUDGET

The projected annual staffing and operating budget of the Joggins Fossil Institute is estimated at approximately $500,000, from the Province, Cumberland County, admissions, shop and donations.

LOCAL ADDRESS

The Joggins Fossil Institute, 35 Church St. P.O. Box 546, Amherst, Nova Scotia, Canada.

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DATE

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