The site at Arkona, which forms part of the Onondaga Peninsula or Formation, has three exposed strata (particularly on both the south and north cliff faces. The strata are of the Hamilton Group (dated to the Middle Devonian, 397.5±2.7 to 385.3±2.8 Ma) - from top to bottom - the Widder Formation, the Hungry Hollow Formation, and the Arkona Shale.

Easiest to collect at Arkona is from the Hungry Hollow Formation.

1. *A guide to the fossil bearing areas of Arkona, Thedford and vicinity*, by Charles Southworth - almost impossible to get - it's a rare book.
   The following stacks call link for York University (don't know if you can borrow the book - but you should be able to view it at York (not a very convenient solution)).
   https://www.library.yorku.ca/find/Record/798425
   As it turns out, we actually have a copy in our archives - and we're planning on adding to our website.
   Southworth was an amateur fossil collector - but a huge number of Onondaga fossils have been named after him - because he found and identified so many - of which many were rare. Anything that's followed by "southworthii" will have been named after him. (Lots of Onondaga fossils are also named after Arkona and Thedford - 2 towns which are on located on the Onondaga fossils fields.) Additionally, Southworth knew all the top, top, top palaeontologists of the time - because of the Onondaga fossils.

2. Another article you may wish to read is *Charles Southworth, Fossil Collector of Thedford, Ontario, 1880-1968*, By Jean D Wright (who actually collected with Southworth) - the document is stored on the University of Michigan's website and can be accessed and downloaded at *http://deepblue.lib.umich.edu/bitstream/handle/2027.42/48440/ID288.pdf?sequence=2* .

3. Also try the UMMP photo archive at *http://michiganbasinfossils.org/search?fm=Arkona&page=1* for a tremendous amount of pictures that have bee taken of a tremendous amount of fossils collected at Hungry Hollow.

http://deepblue.lib.umich.edu/handle/2027.42/48514
Arkonaster, a New Multi-Armed Starfish from the Middle Devonian Arkona Shale of Ontario
Robert V Kesling; University of Michigan Papers on Paleontology; 1982

http://deepblue.lib.umich.edu/handle/2027.42/48513
Acinetaster Konieckii, A New Brittle-Star from the Middle Devonian Arkona Shale
Robert V Kesling; University of Michigan Papers on Paleontology; 1982

http://deepblue.lib.umich.edu/handle/2027.42/48446
Drepanaster wrighti, A New Species of Brittle-Star from the Middle Devonian Arkona Shale of Ontario
Robert V Kesling; University of Michigan Papers on Paleontology; 1970

http://deepblue.lib.umich.edu/handle/2027.42/48463
Proctothylacocrinus berryorum, A New Crinoid from the Middle Devonian Arkona Shale of Ontario
Robert V Kesling; University of Michigan Papers on Paleontology; 1971

Hungry Hollow Fossils
Pictures of crinoids, trilobites, rugosa corals, and mucrospirifers. University of Waterloo

Middle Devonian Arkona Shale of Ontario, Canada and Silica Shale of Ohio, USA
From a chapter extract:
The two related fossil assemblages discussed in this chapter occur in possibly age-equivalent Middle Devonian mudstones in southern Ontario and Ohio (Fig. 137). The Arkona Shale is exposed along the banks of the Ausable River and in its tributary streams in the vicinity of Arkona, Lambton County, Ontario, Canada. … These mudstones are considered to be in the lower part of the Hamilton or Traverse Group and are of Early Givetian age, approximately 385 million years before present.

Limestone Lenses with Bryozoans, Brachiopods, Trilobites and Complete Crinoids
The thin skeletal limestone lenses within the Arkona and Silica Shales (silica shale is in Ohio) carry a moderately diverse fauna of bryozoans, brachiopods, gastropods, bivalves and trilobites, as well as crinoids and blastoids. Approximately 40–50 species can be found with considerable effort. The Silica fossils are described in a richly illustrated volume compiled by Kesling and Chilman (1975). Among the most common fossils are the stick-like bryozoans, Sulcoretepora, as well as Fenestella. Brachiopods include abundant, small, concavo-convex chonetids and Mucrospirifer. The trilobite Phacops is also commonly associated and has been found in clumps of articulated individuals in the Silica Shale of Ohio; it has become the landmark of these strata and is a highly valued collector's item. The surrounding mudstones are quite sparsely fossiliferous, but do occasionally contain isolated specimens of chonetids, Mucrospirifer and other brachiopods. Scattered, pyritized specimens of small bivalves (nuculids), goniatites and bactritids also occur.
Cambridge University

Edaphophyllum irregularum, a new middle Devonian digonophyllid coral from the lower Arkona formation, Ontario, Canada
Wayne State University

A pyritized polychaete from the Devonian of Ontario
Polychaeta are marine worms. Yale University – you can access the complete article by clicking on “free text”.

Blog about Corals from Arkona
Typical pictures of what horn corals you would find.

Ostracods of the Family Aechminidae from the Arkona Shale of Southern Ontario
University of Michigan – you’ll need to click on the pdf link to see this article – pictures are at end.

Examples of Devonian Fossils
German fossil site – and is in German.

Hamilton (Middle Devonian) Chitinozoa from Rock Glen, Arkona, Ontario
Chitinozoa are marine microfossils produced by an as yet unknown animal.

Onondaga Formation

From Wikipedia, the free encyclopedia

Location of the Onondaga limestone outcrop in New York State, USA and Ontario, Canada.

The Onondaga Formation is a group of hard *limestones* and *dolostones* of *Devonian* age that form an important geographic feature in some areas in which it *outcrops*, in others; especially its *Southern Ontario* portion, the formation can be less prominent as a local surface feature.[*citation needed*]

In upstate *New York* and southern *Ontario* the sedimentary rocks tend to slope slightly to the southward, and the Onondaga outcrops in a line that usually forms an *escarpment* (the steep face of a *cuesta*), because of its resistance to erosion. The outcrop can be traced from the *Hudson River* valley westward along the southern rim of the *Mohawk River* valley, passing just south of *Syracuse*, and along the northern heads of the major *Finger Lakes* to *Buffalo, New York*. From *Fort Erie, Ontario* it runs to *Windsor* just north of the *Lake Erie* shoreline, becoming less prominent as one travels westward. It is not distinct west of Windsor, but begins to become noticeable as a steep hill just northwest of *Leamington*, as it forms a low ridge/escarpment along much of the *Lake Erie* shoreline.

In several spots it is breached by geologically young *streams* and spectacular waterfalls are formed, such as at *Chittenango Falls* just east of Syracuse, Buttermilk Falls at *Le Roy, New York* and *Indian Falls* west of *Batavia*.

A few other breaches occur in older valleys, which likely once had waterfalls, but *erosion* eventually obliterated them. Such breaches occur at the *Tully* valley, the *Genesee River* valley near *Avon, New York*, and at *Port Colborne, Ontario*, where the old valley forms a harbor on Lake Erie.

The formation is broken by the only major fault line in western New York, the *Linden Fault* just east of Batavia, where the eastern side of the fault has dropped down and the ledge moved southward relative to the western side. On the western side of the fault in *Genesee County* the escarpment achieves its greatest prominence. The *New York State Thruway* has a rock cut at Batavia which clearly shows the fault and is a popular point for geology class field trips. The *fault*, which runs from *Attica, New York* northward to Lake Ontario, is still active and periodically causes minor earthquakes in the area.

The Onondaga Formation also can be found in other areas where rocks of the same age outcrop, such as in western *Pennsylvania* and *Michigan* but they do not form prominent geographic features.

A similar and more prominent outcrop known as the *Niagara Escarpment* runs parallel and about 25 miles (40 kilometers) to the north through upstate New York, but curves northwestward in southern Ontario toward *Lake Huron* and eventually into Michigan's *Upper Peninsula* and Wisconsin's *Door Peninsula*.

Another smaller outcrop known as the *Portage Escarpment* lies about 35 miles to the south, running along the southern ends of the *Finger Lakes* and forming Cascadilla, Ithaca and Buttermilk Falls in *Ithaca*.

The Onondaga Escarpment contains significant outcrops of *flint* (a type of *chert*) which bears the escarpment's name. This variety of chert was of great importance to *First Nations* peoples throughout *Southern Ontario*, who used it to make stone tools (*lithics*) such as *projectile points* and hide scrapers. This variety of chert, which is of reasonably high-quality and which was highly-valued by First Nations peoples, is often a common variety of chert recovered archaeologically from sites relatively adjacent to outcrops; for example, Onondaga-variety chert comprises 95% of all of the flint material from some sites in *Milton, Ontario*. The material has also been found as well at some distance from its original source; Onondaga chert has been recovered at the *late archaic* Duck Lake archaeological site in northern Michigan, circa 400 kilometers from the nearest outcropping of the material. This wide distribution implies either a very large seasonal migration of ancient peoples or long-distance trade routes, with both likely being the case at different times throughout the prehistory of the *Great Lakes* region.

Age
Relative age dating of the Onondaga places its formation in the Eifelian to Givetian *stage* of the *Middle Devonian* period, or 391.9 to 383.7 *Ma*. Radiometric dating of a sample from the bentonite at the top of the Onondaga placed it at 390 ± 0.5 Ma.

What is "chert"?
The most prevalent type of artifact found on a prehistoric site is a chert flake. Chert is a coarse type of siliceous rock (a form of flint or chalcedony), which was the primary raw material used by the aboriginal inhabitants of southern Ontario for the manufacture of a wide variety of tools including projectile points (spear and arrowheads), drills, knives and scrapers. Chert occurs naturally under specific geological conditions in bedrock formations, where it can be "mined" or extracted in chunks or nodules. But glaciation wreaked havoc on the landscape, and nodules of various types of chert were distributed as glacial outwash and in moraines throughout southern Ontario. For example, nodules of Onondaga chert which originates in veins in the Onondaga Escarpment in the Fort Erie to Port Colbourne area of the Niagara Peninsula can be found today on the surface of fields around London. Chert nodules were hammered and flaked into the rough outline of a "biface" or preform, and then finely flaked into a finished tool such as an arrowhead. In the process of making a biface or a finished tool, hundreds of small waste flakes are removed and discarded. Archaeologists frequently first find a scatter of these chert waste flakes (debitage), an important clue towards documenting a site. The waste flakes themselves sometimes have razor-sharp edges which were simply an expedient tool for cutting or scraping, so it is important for the archaeologist to carefully examine the edges of each and every flake. Detailed archaeological excavation of a large camp site or an Iroquoian village site might result in the recovery of thousands of chert flakes.

Canadian Encyclopedia reference to the Onondaga Peninsula

The Niagara Peninsula lies between Lakes *Ontario* and *Erie* and the *Niagara River* in southwestern Ontario. As the river is also on the international boundary between Canada and the US, the peninsula has played a frontier role since 1783.

Physically, the peninsula comprises 2 contrasting plains separated by the *Niagara Escarpment*. The Ontario Plain, with fertile, sandy soils and a favourable climate, contains the Niagara Fruit Belt, where much of Canada's soft fruits and vines are grown. The wooded slopes of the escarpment, an abrupt rise of some 60 m, are etched deeply by gorges with falls at their heads, most notably at *Niagara Falls*, and are quarried for limestone. The Erie Plain, with bedrock closer to the surface, is less productive than its northern counterpart; the soils are poorly drained clay, and the climate is wetter, with shorter frost-free periods. The Onondaga Escarpment, inland from Lake Erie, is quarried for limestone.

Sub regions in the peninsula provide a rich variation of detail: shoreline bluffs along Lake Ontario, with ponded river estuaries behind sandbars; the shoreline of glacial Lake Iroquois across the Ontario Plain; the Short Hills embayment in the escarpment, with steep-sided slopes; a glacial kame of sand deposits at Fonthill, the highest point of the peninsula; the buried St David's Gorge, the plugged channel of an ancestral Niagara River; marsh areas, including peat bogs, on the southern plain; the slender Onondaga Escarpment; and limestone headlands alternating with sandy bays along Lake Erie, contrasting with the eroding clay and sand bluffs along Lake Ontario.

Niagara Frontier website reference to the Onondaga Escarpment
A smaller Onondaga Escarpment runs east - west is located along the northern shoreline of Lake Erie. Consisting of Onondaga limestone cap rock, this escarpment runs through Buffalo, New York and Fort Erie, Ontario. This escarpment is most noticeable east of Buffalo, however rarely rises more than 10 meters.

Substantial breaks in the Onondaga Escarpment have allowed Lake Erie waters to flow into the low lands of the Wainfleet Marsh 10,500 - 11,000 years ago and again 4,000 - 5,000 years ago during periods of time when the water level in the Erie Basin was much higher from the influx of waters from glacial Lake Agassiz.

Other physical breaks in this escarpment can be found at Lowbanks and Highway #58 in Port Colborne.

Between the Niagara Escarpment and the Onondaga Escarpment is a relatively flat and poorly drained lowland called the Tonawanda plain.

Devonian (Northern Mines and Development Ministry, Ontario)
The early Devonian in southern Ontario was characterized by an extended period of erosion.

Silurian strata is separated from the Oriskany Formation by a disconformable contact. In most areas, the Bois Blanc Formation is the oldest Devonian stratum. The Bois Blanc Formation is a cherty limestone in the Appalachian Basin and dolostone in the Michigan Basin.

The Bois Blanc Formation is overlain by Onondaga Formation limestone in the Niagara Peninsula and the Detroit River Group elsewhere in southwestern Ontario.

In ascending order, the Sylvania, Amherstburg and Lucas Formations are included in the Detroit River Group. The Sylvania sandstone is restricted to the subsurface in the Windsor area. The Amherstburg Formation is a relatively thick bituminous limestone. It is conformably overlain by the Lucas Formation of interbedded dolostone and limestone strata. In the Algonquin Arch area, the Lucas Formation consists of a high-purity limestone.

The overlying Dundee Formation is the subcrop strata for broad area between lakes Erie and Huron. The Dundee Formation is a fossiliferous, micitric limestone. In a small area north of Lake Erie, the Dundee Formation is overlain by the black, organic-rich shales of the Marcellus Formation.

A sharp change from carbonate to shale-dominated strata begins above the Dundee and Marcellus Formations. The overlying Hamilton Group consists of mudstones and shales with thin carbonate horizons. The formations constituting the Hamilton Group are, in ascending order, Bell, Rockport Quarry, Arkona, Hungry Hollow, Widder and Ipperwash.

An unconformity separates the Hamilton Group from the overlying Kettle Point Formation. The Kettle Point Formation consists of a siliciclastic organic-rich shale.

It is disconformably overlain by the Port Lambton Group. This group of clastic rocks consists mainly of grey and black shales and sandstones. In southern Ontario, Port Lambton Group strata are restricted to the subsurface in an area south of Sarnia.
Devonian
The Devonian is a *geologic period and system* of the *Paleozoic* Era spanning from 416 to 359.2 million years ago (*ICS*, *2004*, *chart*). It is named after *Devon*, *England*, where rocks from this period were first studied.

During the Devonian Period the pectoral and pelvic fins of *lobe-finned fish* evolved into *legs[6]* as they started to walk on *land* as *tetrapods* around 397 *Ma*. Various terrestrial *arthropods* also became well-established.

The first *seed-bearing plants* spread across dry land, forming huge *forests*. In the *oceans*, primitive *sharks* became more numerous than in the *Silurian* and the *late Ordovician*, and the first *ray finned* and *lobe-finned* *bony fish* evolved. The first *ammonite* *mollusks* appeared, and *trilobites*, the mollusc-like *brachiopods*, as well as great *coral reefs* were still common. The *Late Devonian extinction* severely affected marine life.

The *paleogeography* was dominated by the *supercontinent* of *Gondwana* to the south, the *continent* of *Siberia* to the north, and the early formation of the small supercontinent of *Euramerica* in between.

History
The period is named after *Devon*, a county in southwestern England, where Devonian outcrops are common. While the *rock beds* that define the start and end of the period are well identified, the exact dates are uncertain. According to the *International Commission on Stratigraphy* (*Ogg, 2004*), the Devonian extends from the end of the *Silurian* Period 416.0 ± 2.8 *Mya*, to the beginning of the *Carboniferous* Period 359.9 ± 2.5 Mya (in *North America*, the beginning of the *Mississippian* subperiod of the Carboniferous) (ICS 2004).

In nineteenth-century texts the Devonian has been called the "Old Red Age", after the red and brown terrestrial deposits known in the United Kingdom as the *Old Red Sandstone* in which early fossil discoveries were found. Another common term is "Age of the Fishes", referring to the evolution of several major groups of *fish* that took place during the period. Older literature on the Anglo-Welsh basin divides it into the Downtonian, Dittonian, Breconian and Farlovian stages, the latter three of which are place in the Devonian.*[8]*

The Devonian has also erroneously been characterized as a "greenhouse age", due to *sampling bias*: most of the early Devonian-age discoveries came from the *strata* of *western Europe* and eastern *North America*, which at the time straddled the *Equator* as part of the supercontinent of Euramerica where *fossil* signatures of widespread reefs indicate tropical *climates* that were warm and moderately humid but in fact the climate in the Devonian differed greatly between *epochs* and geographic regions. For example, during the *Early Devonian*, arid conditions were prevalent through much of the world including Siberia, Australia, North America, and China, but Africa and *South America* had a warm *temperate climate*. In the *Late Devonian*, by contrast, arid conditions were less prevalent across the world and *temperate* climates were more common.

Subdivisions
Preceded by the *Silurian*

The Devonian Period is formally broken into Early, Middle, and Late subdivisions. The rocks corresponding to these *epochs* are referred to as belonging to the Lower, Middle and Upper parts of the Devonian System.

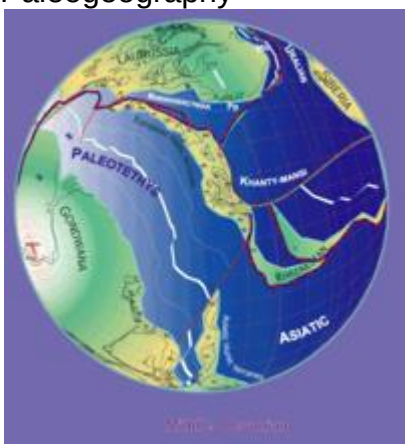
The Early Devonian lasts from *416* ±2.8 to *397.5* ±2.5 and begins with the Lochkovian stage, which lasts until the Pragian. This spans from *411.2* ±2.8 to *407* ±2.5, and is followed by the Emsian, which lasts until the Middle Devonian begins, *397.5*±2.7 million years ago.
Lochkovian
Pragian
Emsian
The Middle Devonian comprises two subdivisions, the Eifelian giving way to the Givetian *391.8*±2.7 million years ago. During this time the armoured jawless *ostracoderm* fish were declining in diversity; the jawed fish were thriving and increasing in diversity in both the oceans and freshwater. The shallow, warm, oxygen-depleted waters of Devonian inland lakes, surrounded by primitive plants, provided the environment necessary for certain early fish to develop essential characteristics such as well developed lungs, and the ability to crawl out of the water and onto the land for short periods of time.
Eifelian
Givetian
Finally, the Late Devonian starts with the Frasnian, *385.3* ±2.8 to *374.5* ±2.5, during which the first forests were taking shape on land. The first tetrapods appear in the fossil record in the ensuing Famennian subdivision, the beginning and end of which are marked with extinction events. This lasted until the end of the Devonian, *359.2*±2.5 million years ago.
Frasnian
Famennian

Followed by the *Carboniferous*

Climate

The Devonian was a relatively warm period, and probably lacked any glaciers. Reconstruction of tropical sea surface temperature from *conodont* *apatite* implies an average value of 30°C (86°F) in the Early Devonian. CO2 levels dropped steeply throughout the Devonian period as the burial of the newly-evolved forests drew carbon out of the atmosphere into sediments; this may be reflected by a Mid-Devonian cooling of around 5°C (9°F). The Late Devonian warmed to levels equivalent to the Early Devonian; while there is no corresponding increase in CO2 concentrations, continental weathering increases (as predicted by warmer temperatures); further, a range of evidence, such as plant distribution, points to Late Devonian warming. The climate would have affected the dominant organisms in *reefs*; *microbes* would have been the main reef-forming organisms in warm periods, with corals and *stromatoporoid* sponges taking the dominant role in cooler times. The warming at the end of the Devonian may even have contributed to the extinction of the stromatoporoids.

Paleogeography



The *Paleo-Tethys* Ocean opened during the Devonian
The Devonian period was a time of great *tectonic* activity, as *Euramerica* and *Gondwanaland* drew closer together.

The continent *Euramerica* (or Laurussia) was created in the early Devonian by the collision of *Laurentia* and *Baltica*, which rotated into the natural dry zone along the *Tropic of Capricorn*, which is formed as much in Paleozoic times as nowadays by the convergence of two great air-masses, the *Hadley cell* and the *Ferrel cell*. In these near-deserts, the *Old Red Sandstone* sedimentary beds formed made red by the oxidized iron (*hematite*) characteristic of drought conditions.

Near the *equator*, the *plate* of Euramerica and Gondwana were starting to meet, beginning the early stages of assembling *Pangaea*. This activity further raised the northern *Appalachian Mountains* and formed the *Caledonian Mountains* in *Great Britain* and *Scandinavia*.

The west coast of Devonian North America, by contrast, was a passive margin with deep silty embayments, river deltas and estuaries, in today's *Idaho* and *Nevada*; an approaching volcanic *island arc* reached the steep slope of the continental shelf in Late Devonian times and began to uplift deep water deposits, a collision that was the prelude to the mountain-building episode of Mississippian times called the *Antler orogeny*.*[12]*

Sea levels were high worldwide, and much of the land lay submerged under shallow seas, where tropical *reef* organisms lived. The deep, enormous *Panthalassa* (the "universal ocean") covered the rest of the *planet*. Other minor oceans were *Paleo-Tethys*, *Proto-Tethys*, *Rheic Ocean*, and *Ural Ocean* (which was closed during the collision with *Siberia* and Baltica).

Biota
Marine biota
Sea levels in the Devonian were generally high. Marine faunas continued to be dominated by *bryozoa*, diverse and abundant *brachiopods*, the enigmatic *hederelloids*, *microconchids* and *corals*. Lily-like *crinoids* were abundant, and *trilobites* were still fairly common. Among vertebrates, jaw-less armored fish (*ostracoderms*) declined in diversity, while the jawed fish (gnathostomes) simultaneously increased in both the sea and *fresh water*. Armored *placoderms* were numerous during the lower stages of the Devonian Period and became extinct in the Late Devonian, perhaps because of

competition for food against the other fish species. Early cartilaginous (*Chondrichthyes*) and bony fishes (*Osteichthyes*) also become diverse and played a large role within the Devonian seas. The first abundant genus of shark, *Cladoselache*, appeared in the oceans during the Devonian Period. The great diversity of fish around at the time, have led to the Devonian being given the name "The Age of Fish" in popular culture. The first *ammonites* also appeared during or slightly before the early Devonian Period around 400 *Mya*. *Dunkleosteus*, one of the largest armoured fishes to ever roam the planet, lived during the late Devonian.

Reefs
A now dry barrier reef, located in present day *Kimberley Basin* of northwest *Australia*, once extended a thousand kilometers, fringing a Devonian continent. Reefs in general are built by various *carbonate*-secreting organisms that have the ability to erect wave-resistant frameworks close to sea level. The main contributors of the Devonian reefs were unlike modern reefs, which are constructed mainly by corals and calcareous *algae*. They were composed of calcareous algae and coral-like *stromatoporoids*, and tabulate and *rugose corals*, in that order of importance.[*clarification needed*]

Terrestrial biota
By the Devonian Period, life was well underway in its colonization of the land. The *moss* forests and *bacterial* and algal mats of the *Silurian* were joined early in the period by primitive rooted *plants* that created the first stable *soils* and harbored arthropods like *mites*, *scorpions* and *myriapods* (although arthropods appeared on land much earlier than in the *Early Devonian* and the existence of fossils such as *Climactichnites* suggest that land arthropods may have appeared as early as the *Cambrian* period). Also the first possible fossils of *insects* appeared around 416 *Mya* in the Early Devonian. The first *tetrapods* evolving from *lobe-finned fish*, appeared in the coastal water no later than middle Devonian, and give rise to the first Amphibians.
[*edit*] The greening of land

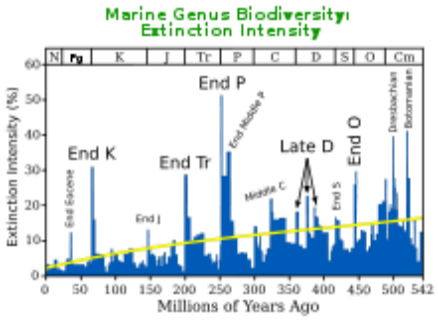
The Devonian period marks the beginning of extensive land colonization by *plants*. With large *herbivorous* land-animals not yet being present, large forests could grow and shape the landscape. *Early Devonian* plants did not have roots or leaves like the plants most common today, and many had no vascular tissue at all. They probably spread largely by vegetative growth, and did not grow much more than a few centimeters tall. By far the greatest land organism was *Prototaxites*, the fruiting body of an enormous fungus that stood more than 8 meters tall, towering over the low, carpet-like vegetation. By *Middle Devonian*, shrub-like forests of primitive plants existed: *lycophytes*, *horsetails*, *ferns*, and progymnosperms had *evolved*. Most of these plants had true roots and leaves, and many were quite tall. The earliest known trees, from the genus *Wattieza*, appeared in the Late Devonian around 380 *Ma*. In the *Late Devonian*, the tree-like ancestral fern *Archaeopteris* and the giant *cladoxylopsid* trees grew with true *wood*. (See also: *lignin*.) These are the oldest known trees of the world's first forests. By the end of the Devonian, the first seed-forming plants had appeared. This rapid appearance of so many plant groups and growth forms has been called the "Devonian Explosion".

The 'greening' of the continents[*citation needed*] acted as a *carbon dioxide sink*, and *atmospheric* levels of this *greenhouse gas* may have dropped. This may have cooled the climate and led to a massive *extinction event*. See *Late Devonian extinction*.

Animals and the first soils
Primitive arthropods co-evolved with this diversified terrestrial vegetation structure. The evolving co-dependence of insects and seed-plants that characterizes a recognizably modern world had its

genesis in the Late Devonian. The development of soils and plant root systems probably led to changes in the speed and pattern of *erosion* and sediment deposition. The rapid evolution of a terrestrial ecosystem containing copious animals opened the way for the first *vertebrates* to seek out a terrestrial living. By the end of the Devonian, arthropods were solidly established on the land.

Late Devonian extinction



The Late Devonian is characterized by three episodes of extinction ("Late D")

Main article: *Late Devonian extinction*
A major extinction occurred at the beginning of the last phase of the Devonian period, the Famennian faunal stage, (the Frasnian-Famennian boundary), about 364 Mya, when all the fossil *agnathan* fishes, save for the *psammosteid* *heterostracans*, suddenly disappeared. A second strong pulse closed the Devonian period. The Late Devonian extinction was one of five major extinction events in the history of the Earth's biota, more drastic than the familiar extinction event that closed the Cretaceous.

The Devonian extinction crisis primarily affected the marine community, and selectively affected shallow warm-water organisms rather than cool-water organisms. The most important group to be affected by this extinction event were the reef-builders of the great Devonian reef-systems .

Amongst the severely affected marine groups were the *brachiopods*, trilobites, *ammonites*, *conodonts*, and *acritarchs*, as well as jawless fish, and all placoderms. Land plants as well as freshwater species, such as our tetrapod ancestors, were relatively unaffected by the Late Devonian extinction event.
The reasons for the Late Devonian extinctions are still unknown, and all explanations remain speculative. *Canadian* *paleontologist* *Digby McLaren* suggested in 1969 that the Devonian extinction events were caused by an asteroid impact. However, while there were Late Devonian collision events (see the *Alamo bolide impact*), little evidence supports the existence of a Devonian crater large enough.