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A Reconstruction of the Biodiversity of the Connecticut River Valley Using Fossil and Geological History Evidence

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Geologists have used the fossil and geologic record of the Connecticut River Valley to reconstruct the biological, and ecological, state of the region as it existed between 135 and 225 million years ago. Fossilized remains of fish, microbes, mollusks, plants, invertebrates, and pollen have been found throughout the Connecticut River Valley. Plant fossils such as conifers, cycads, ferns, and mosses suggest that the climate was tropical during the Mesozoic era. Fossilized relatives of modern day river dwelling fish are used to affirm that rivers meandered across the valley surface. Plant pollen discovered black shale shows that deep lakes existed in the region. The diversity and amount of fossils indicate that the past tropical environment of the Connecticut River Valley was biologically diverse.

Fossils allow humans a glimpse into the past biological history of the planet. The first recognition of fossils as a marked recording of the past occurred in 450 B.C.E. by a Greek historian Herodotus. He hypothesized that the imprints of shells found on rocks were evidence of ancient sea creatures living when the land was covered by ocean. The study of fossils has continued to advance throughout the ages and is now referred to as paleontology (Marshak 2001). Biologists use fossil records as evidence of evolution and are able to construct a biological history of the earth. Using the law of superposition, geologists help biologists to determine how species evolved. Knowledge of the origin of life, and the geological history of the Earth, has been greatly enhanced through the study of fossils.

Unfortunately, there is not a complete history of the planet recorded in fossils, because fossils can only be formed under very particular conditions. Normally, when an organism dies, scavengers and bacteria devour its parts in a number of days or weeks; so for specimen preservation to occur, the remains must settle into conditions devoid of these two factors. Most often only part of the specimen remains. Soft tissue may be preserved in one of three ways. The specimen may dry out completely and then be covered before it has time to decay, as in a dry, sandy environment in high winds. Another way to preserve tissue is for the specimen to be rapidly covered in sediment, often times while still alive. This can occur during a volcanic explosion where ash may be spread in great quantities over large distances. Finally, the carcass can fall to the bottom of a deep lake, swamp, or ocean. This is the case for the fish and plant remains found in the Connecticut River Valley (Paul 1980). The specimens were most likely buried under sediments at the bottom of a deep lake. Parts of the specimens remain intact while some of the fish remain as imprints in the petrified debris they died in (Alter 1995).

When organisms die in environments where they only partially decay before being covered by sediments it is the resistant parts of the specimen, such as teeth and bones, which are preserved. For instance, fossilized shark teeth are much more plentiful than the cartilage of the shark. The resistant parts of animals are generally composed of calcium phosphate, calcium carbonate and silica. For plants the resistant parts are the leaves, pollen, and spore cuticles that are formed from organic compounds containing cutin and sporopollenin. These substances are not necessarily hard but are resistant to decay (Paul 1980). However, if decay-resistant organism remnants are exposed to anoxic mineralized water the original minerals may leach out and secondary minerals may take their place. In a process known as petrification, porous remnants such as bone or wood are impregnated by secondary minerals, effectively turning the remnants into stone. Aragonite, a form of calcium carbonate, often changes to calcite, a more stable form of $CaCO_3$. Phosphate compounds often remain almost the same with minimal change to the compound (i.e. $Ca_5(PO_4)_3OH \rightarrow Ca_5(PO_4)_3F$) (Simpson 1983). The newly formed object has a different chemical composition, but the same shape and size as the original. This process occurred in the Connecticut River Valley in Portland, Connecticut where the remnants of Jurassic tree trunks were found in a brownstone quarry (Dinosaur State Park 2002).

Very rarely whole specimens are discovered. In arctic regions, perfectly preserved specimens of organisms have been found frozen in the earth. Geologists theorize that these organisms died and became trapped in mud pockets resulting from a spring thaw. These pockets remained continuously frozen so the organism may be found completely intact. The ages of organisms preserved in this manner range in the thousands rather than the millions of years old because the organism must remain undisturbed (Simpson 1983). Similarly well-preserved insect specimens have been found in tree sap that has hardened to form amber (Paul 1980). Bacteria do not destroy the insects because there is no oxygen present. While both of these sources for fossilization have been useful to scientists, these conditions are very rare and did not contribute to the preservation of specimens in the Connecticut River Valley.

The geologic and climatic conditions present dictate if and how an organism is preserved, therefore, an understanding of the history of land formation in the Connecticut River Valley is necessary to explain the types of fossils discovered there. Presently, three distinct topographical regions exist in Connecticut, named the Eastern Highlands, the Western Highlands and the Central Lowlands that define the Connecticut River Valley in Connecticut.

Over the past 4.6 billion years many changes have occurred to the land that is now known as Connecticut. The oldest rocks in Connecticut date from the Archeozoic era that occurred from 3.8 to 2.5 billion years ago; the Beckett gneiss that is found in pockets along the northern border of the Western highlands. However, most of the rocks in Connecticut were formed during the Paleozoic Era, 225 Ma to 570 Ma years ago. During the Cambrian period, 500 Ma to 570 ma years ago, the Atlantic Ocean intruded over what is now the Eastern portion of Connecticut. A shallow bay extended north along the western portion of the state into eastern New York and Massachusetts. Deposition of aquatic creatures left limestone while sand deposits formed into quartz. In the Ordovician period, 430 Ma to 500 Ma years ago, the tectonic plates that compose the Earth's crust shifted, forcing movement of the land along the edge of the North American continent. The movement caused mountains to rise and the pressure accompanying this changed the quartz and other deposits into schist and metamorphosed the limestone into marble (Paul 1980).

In the Silurian period, 395 Ma to 430 Ma, these mountains eroded, depositing hundreds of feet of sediments on the surrounding area. The land mass continued to shift creating more schist and gneiss. This process of land rising and eroding continued until the end of the Paleozoic era, when the present day Appalachian Mountains rose to an estimated elevation of greater than 10,000 feet (Cook 1933). As the landscape changed the ocean and bay along the borders of the state were pushed south. Most of the igneous and sedimentary rocks were compressed in folds of the land into slates, marbles, gneisses and schists. At the end of the Paleozoic era, the Appalachian Mountains had formed the basis for the Highlands and Central Lowland of Connecticut. During this period the first vertebrates, plants, forests, amphibians, and reptiles were seen on earth. When these mountains formed, however, the sedimentary rocks that may have contained fossils were subjected to large amounts of pressure as they were changed into metamorphic rocks. Almost no fossils are capable of withstanding metamorphism so all of the fossils in the Connecticut Highlands from this period were destroyed.

The Mesozoic Era that followed began with the Triassic Period (190 Ma to 225 Ma). During this period the Atlantic coast was farther out to sea than today, so there are no marine deposits during this period. Large mountains rose out of the eastern and western sides of the state. Rain and melt water running down these mountains distributed deposits in the center of the state through slow running streams. Continued tectonic plate movement caused a fault to run north-south through the center of Connecticut. As the fault grew a large section of earth fell significantly, forming the beginnings of what is presently the Connecticut River Valley (Montagna 1990). Lava flowed through the fault and is presently intermingled with sedimentary remains from the highlands.

The base of the valley was nearly flat so the streams changed their course often having a large impact on the geology of that time. Lakes and ponds formed, then drained and reformed. In areas were sediment was exposed to oxygen, either because water was shallow and oxygenated or because water was intermittently present, red sandstones formed (Hubert 1978). In areas were sediment was not exposed to oxygen black shale formed. There were deep lakes where vertical water movement was not sufficient to oxygenate the bottom. There were also marshy areas where the amount of organic material accrued and the stagnant state of the water prevented oxygen from reaching sedimentary layers. It is in these layers that fossilized fish and their imprints, as well as plant matter, such as spores, pollen, and tree remnants, as well as mollusks, were found (Colbert 1970).

In the Tertiary period (65 Ma to 2.5 Ma), a shift in the general pitch of the area gave it a slight slope down to the southeast. The incline caused rivers to wear away the soft sandstones that were the effect of sedimentation during the Cretaceous Period. In the time that followed ice sheets moved over the area four or five times, causing hills and valleys to riddle the surface of the landscape. The glaciers were the last geologic phenomenon to have a significant impact on the geologic landscape of the Connecticut River Valley (Cook 1933).

. The unique geology of the Connecticut River Valley has resulted in both impressions or tracks and actual fossils found in sedimentary rock. The changes evident in the biodiversity of the Valley over geologic time can be attributed to both intrinsic factors such as small scale changes and pressures on particular species and the extrinsic factors which are larger scale changes in the environment such as climate and sea-level changes and plate tectonics (Smith 1994). Using fossil and imprint evidence left from past geologic events it is possible to reconstruct the environment and organisms present in the Connecticut River Valley during past eras.

The beginnings of studying fossils in the Connecticut River Valley date back to 1800 when Pliny Moody discovered footprints on a rock that resembled bird tracks. He and others believed that these footprints had a religious origin. However, it was not until 1985 that fossils in the area were recognized as such and studied for scientific purposes. Edward Hitchcock, a geologist and college president, paved the way studying and collecting fossil samples in the Connecticut River Valley. He collected a great deal of data and published much of his work. During this time it was believed that the tracks discovered were left from birds (Klekowski 1997). Although this assumption was later disproved, Hitchcock made significant contributions to this field.

Since then scientists have continued to unearth new fossils and imprints. Little by little, these clues have been used to model what the environment of the Connecticut River Valley was like during the Mesozoic era. The Mesozoic era, also known as the "Age of the Dinosaurs," began after the greatest extinction of organisms occurred on the planet at the end of the Paleozoic era.

The tropical climate of the Connecticut River Valley during the Mesozoic dictated the nature of the flora and fauna present. The Connecticut River Valley was part of the then breaking up super-continent Pangea. It was located ten degrees north of the equator (Alter 1995). Connecticut was also deeply inland at this time and most likely just above sea level (Klekowski 1997). Long dry seasons were interrupted by short rainy periods (Klekowski 1997). This area was also a very wet region. Rivers, seasonal lakes, mud flats, and ponds were present.

The plant fossils of the Connecticut River Valley demonstrate evidence for a tropical climate. Coniferous trees most likely dominated the landscape. They are most closely related to modern *Araucaria*, examples of which include Brazilian pine and other conifers found in the Southern hemisphere. Other trees present were species closely related to modern day gingkos. Below these trees in the jungle strata there were cycads that have palm like fronds. Horsetails and club mosses, which still exist in Connecticut today were present, but as a much larger version. Covering the bottom jungle strata were a large number of ferns (Alter 1995). Although the forest was green year round, the diversity of color that is now found in tropical forests and jungles did not exist. This is because there were not any deciduous trees or flowering plants present. In addition, grasses did not exist in this region (Colbert 1970).

Another way in which vegetation has been studied is by identifying preserved spores and pollen of the various plant species. The shale from the Mesozoic era can be dissolved in acid in order to study these small structures. The field of paleopalynology has revealed that about fifty species of twenty-six genera of plants were present in what is now the Northeast region of the United States. For example, at a North Guilford, Connecticut, site, spores have been found in black shale which represent the ancient lake beds (McDonald 1973).

From fossil records it can be concluded that there was also a great deal of animal diversity that existed during the Mesozoic era. Insects that were present have left small imprints, tracks and burrows in the rock that make it possible to identify their presence (Geological 2002). An insect larva of the genus *Mormolucoides* has been preserved in a fossil (Colbert 1970). Fossil evidence also suggests that beetles, dragonflies, cockroaches, flying insects and crickets were also common (Dinosaur 2002). Other invertebrate species in existence were clams. They retain much similarity to their relatives today (Colbert 1970).

The streams, rivers, and ponds of the Connecticut River Valley in the Mesozoic era were teaming with life. Based on carbonized fish fossils and fish coprolites, or fossil feces, it can be determined that various types of fish were found at this time (Alter 1995). A considerable number of well-preserved, flattened body outlines with scales intact have been found in Connecticut and Massachusetts. They were deposited into the layers of black shales that were at the bottom of the waters (Colbert 1970).

The main groups of fish that have been found are coelacanth, chondrostean and holostean. Both chondrostean and holostean fish have "elongated, fusiform bodies, heavily boned skulls, and a covering of heavy, rhomboid or diamond-shaped scales"(Colbert 1970). The scales interlock and cover nearly the entire body. They had a pectoral fin at the back of the head, pelvic fins further back, a dorsal fin and an anal fin. They also have a tail fin consisting of equally sized lobes. Chondrostean fish were of the *Redfieldia* and *Ptycholepis* genera (Dinosaur 2002). Modern day relatives are sturgeon and Mississippi River fish. Holostean fish were from the genus *Semionotus*, which is related to the bowfin of today (Colbert 1970).

The third group of fish is coelacanth, or from the genus *Diplurus*, which has been found in Durham and Westfield, Connecticut. Due to its different body type, much has been learned about *Diplurus*. Unlike the other two groups, the bones from the postcranial skeleton have remained intact. The scales of *Diplurus* have been preserved, but they do not have as many as the other fish. The scales are thinner with longitudinal ridges. The bone structure is also unique. The lateral teeth of the fish are much smaller and only present on the frontal tips of the skull and lower jaws. Although the notochord has not been preserved, its place during the animal's life occurred between the vertebrae and the rib bones. Other differences occur among the fish's fins. The overall structure of the fins is more fan like in *Diplurus*. *Diplurus* also has two dorsal fins and its other fins are attached to the body through muscles attached to bony plates and surrounded by fleshy lobes (Colbert 1970).

Diplurus have been found in great numbers in the Newark beds in New Jersey. Called *Diplurus newarki*, these fish averaged four to six inches in length. However, the *Diplurus longicaudtus*, which measured greater than two feet in length, have been found in the Connecticut River Valley. This large size enabled them to prey upon the other two groups of fish (Dinosaur 2002). Another interesting fact about *Diplurus* is that it is related to the genus *Latimeria*. *Latimeria* has been found off the African coast and is considered a living fossil. It was discovered that these fish are related to "ancient air-breathing fishes that were the direct ancestors of the first land-living backboned animals"(Colbert 1970).

A large amphibian, metoposaurs that has been traced in other places as a common inhabitant has not been found in the Connecticut River Valley. It remains unknown whether they did not occur or whether geological conditions did not allow evidence of their existence to be preserved (Colbert 1970). Dinosaurs are the largest type of organism that has left clues to their presence during the Mesozoic era. There are a few bones that have recovered, but most evidence is in the form of tracks. Some of the dinosaurs roaming the Connecticut River Valley were *Coelophysis, Eubrontes, Anchisaurus, Rutidon,* and *Grallator* (Dinosaur 2002).

The Connecticut River Valley has a unique geological history. Certain periods and conditions that occurred allowed for various types of fossils to form. By interpreting the geology correctly, these fossils can be dated. In turn this information can be used to model the biodiversity of the Connecticut River Valley in the past. This can be very valuable information when studying the origins of live and evolutionary processes. By using interdisciplinary scientific analysis humans are given an opportunity to discover the types of habitat and variety of fantastic creatures have shared the land of the Connecticut River Valley.

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