GEOLOGIC, PALEONTOLOGIC, AND CONTEMPORARY INTRODUCTION

John Day Fossil Beds National Monument

Among the valleys and bluffs of the John Day Country is buried a spectacular fossil record, an archive of ancient life. Here scientists have unearthed priceless chapters of this record of land plants and animals extending back from 6 to 54 million years. Back to ancient days when strange beasts roamed in lush, near-tropical forests.

A visit here can awaken a sense of time's awesome duration, of prehistoric animals and plants, and of Oregon's complex geologic development. It can also introduce visitors to scenic beauty, to regional wildlife and vegetation, and to the romantic flavor of the Old West.

The park consists of three widely separated units, located in the John Day River basin within Oregon's "Blue Mountains" province. Although some rocks of this province date from more about 400 million years ago, the fossil record discovered in the fossil beds begin with sea life of the Cretaceous Period, roughly 100 million years ago. Thereafter, the Eocene, Oligocene, Miocene, and Pliocene epochs have been marked by distinctive earth deposits that contain an outstanding fossil record.

The Clarno Formation: Near-tropical forests mantled Clarno's near-coast terrain 54 to 37 million years ago. We know of these forests because of a splendid sample of fossil seeds, nuts, fruits, leaves, branches, and roots. The Clarno Nutbeds are among the finest fossil plant localities on the planet, with hundreds of species, many new to science, preserved. Conspicuous among mammals because of their great size and ungainly appearance were the browsing brontotheres and amynodonts. Impressive too, were the large-jawed scavengers such as *Hemipsalodon*, and the ruggedly framed predator, *Patriofelis*. Although a few of these lineages continue into the early Oligocene--34 million years ago--they have left no modern descendants.

However, some of their contemporaries--the equids, rhinos, tapirs, and cats were types known elsewhere in North America, and have present day descendants.

John Day Formation: The John Day Formation spans an great amount of time, from 39 to 20 million years ago. Even a cursory examination reveals that many different climates dominated this landscape. Over time the near-tropical forests were replaced by temperate, deciduous forests, and in turn grasslands began to make an appearance.

A mixture of habitats paralleled a rich diversity in animal types. More than 100 species of mammals have been found in this formation, including dogs, cats,

swine, oreodonts, horses, camels, rhinoceroses, and rodents. Numerous fossil plant localities also indicate the great botanical diversity of this period. By the beginning of the Miocene, mammals had attained their maximum generic diversity on this continent. Thereafter the number of genera began to decline.

The Mascall Formation: The interval between deposition of the John Day Formation and the Mascall Formation was marked by intermittent flows of basaltic lava that repeatedly flooded and denuded the region. By 15 million years ago these eruptions had ceased in this area (though they continued to the north for several million more years adding to what we now call the Columbia River Flood Basalts). At about the same time a number of volcanoes to the south and east, now called the Strawberry Volcanics, were building high volcanic cones similar in structure to major mountains of the modern Cascade Range.

These ancient volcanoes provided the fine ash deposits and erosional outwash materials that became the Mascall Formation, forming 15 to 12 million years ago. A moderate climate, sufficient precipitation, and periodic deposits of volcanic ash, combined to produce highly fertile soils, and from these soils arose lush, nutritious grasses and mixed hardwood forests--much like those found today in the eastern United States.

The Mascall (woodland-grassland) savanna was home to a great variety of animals that we might recognize as horses, camels, and deer, as well as bears, weasels, dogs, and cats. Some dwelt in the woodlands, while others adapted to the growing grasslands. At the same time large mammals immigrated from Asia. Among them were the gomphotheres (early elephants), and some sizable bear-dogs.

The Rattlesnake Formation: Tectonic pressures from the south and north folded and buckled the rock beneath and around the base of the Strawberry Volcanics, eventually thrusting the modern Strawberry-Aldrich mountains upward as much as 1.5 miles above the John Day Valley. As the mountains rose and eroded the valley was slowly filled with deposits.

The interface between the Mascall and the Rattlesnake Formations is easily distinguishable to geologists and paleontologists because the nature of the materials in the two sequences are quite different. It is somewhat subtle to the untrained eye. The most spectacular clue is best seen from the geologic exhibit on Route 26, south of Picture Gorge, where a 5% angular unconformity between the formations can be clearly seen. The underlying Mascall beds are tilted at a different, steeper angle than the younger Rattlesnake deposits (formed after a major tilting of the Mascall Formation and lower layers).

Named for a nearby creek, the Rattlesnake Formation, 8 to 6 million years old, is the least durable. The rocks were deposited in a series of fanglomerates (coarse materials laid down in alluvial fans, with the pieces relatively unworn), and as volcanic ashes. Within this sequence some interesting plant and animal fossils can be found, though less abundant than the lower formations.

Within the Rattlesnake Formation is a large, blocky, welded tuff layer. It was formed from a fiery tidal-wave of super-heated volcanic gases and particles from an explosive volcanic source far to the south (perhaps Harney Lake) -- an ignimbrite. This rimrock layer can be seen above Picture Gorge and eastward along the John Day Valley -- relics of this massive volcanic event. This tuff averages 90 feet thick, and yields no fossils. Above this ignimbrite layer are more Rattlesnake Formation erosional deposits. However, here, as deposition from the Strawberry-Aldrich mountains continued, the character of the deposits graded toward finer particles as the nearby mountains wore down.

The fossil-bearing strata in the Rattlesnake are often so poorly consolidated that extracting a fossil frequently requires artificial stabilization of the rock to keep it in one piece. The Rattlesnake Formation is of great importance as one of four correlative localities on which the Hemphillian North American Land Mammal Age is based.

The fossils from this formation suggest populations that were adjusted to a significantly dryer, cooler climate than that found in older formations. There is a relative abundance of grazing species as opposed to browsers. Among the horse group there was one genus, *Pliohippus*, that was near the lineage of the modern horse. Other grazers were pronghorns, deer, rabbits, squirrels, and camels. Predators included bear, bear-like dogs, an early coyote, and mustelids -- low slung long-bodied animals most like weasels, minks, badgers, etc. Also, a fossil bear found in northern India has been shown to be virtually identical with Rattlesnake Formation specimens, tending to reinforce evidence from the Mascall Formation that an Asian land bridge did exist.

Fossil beds that span even 5 million years are rare, yet in this valley the fossil record shows more than 40 million years of the diverse plant and animal life that existed here 54 million to 6 million years ago. Fossils are common components of the earth's crust. Typically they are tantalizingly incomplete, or may occasionally represent only a momentary environmental catastrophe. In only a few areas on the planet have earthly processes, events, and chance combined to produce such a generous array of information as is found in the John Day Fossil Basin.

The fossils found here are generally very well preserved specimens. The Clarno Nutbeds yield fossilized material with cellular structure clearly visible. The John Day vertebrates are among the best preserved of their type. The fossils also occur

in large numbers. The Bridge Creek site yielded 22,000 plant specimens in a single early collection event. The Mascall Formation has provided billions of small invertebrates (mostly small diatoms). Also remarkable is the great diversity of fossilized materials: whole communities, not just individuals are preserved, reflecting rich ecosystems.

All these features are arranged in an unusually ordered sequence. They were deposited during a momentous and interesting time in earth's history, recording an amazing array of evolutionary activities that reveal mammalian adaptive radiation, shifting climates, global cooling, and other nuances of earth's history only sparsely hinted at most localities in the world. The John Day Fossil Beds contain vestiges of the actual soil, rivers, ponds, watering holes, mudslides, ashfalls, floodplains, middens, trackways, prairies, and forests - in short, entire landscapes.

Perhaps best of all, the absorbing time sequence of these fossils is recorded by their interbedment with ashes and other volcaniclastics that serve as time markers. The many datable layers allow correlation with other formations throughout the world. The result, earth historians can receive detailed corroboration or falsification of hypotheses about transformation of climates, life-form lineages, and ecosystems throughout broad spans of time.

Exploration and study of the John Day fossil beds continues today. In many of the beds, the fossils are widely scattered, and their occurrence cannot be predicted. Fossils deteriorate rapidly once erosion exposes them to the elements. Thus the fossil beds are continually canvassed according to cyclic prospecting schedules. Sites that weather rapidly are revisited more frequently.

Prospecting conducted by the monument's staff results in the collection of hundreds of specimens each year. Many are mere fragments - a few teeth, for instance, but each specimen is accompanied by a wealth of field data: coordinates that pinpoint both its geographical location and the stratigraphic position, descriptions of where it was deposited, and data about its recovery. This information, as well as that gained as the fossil is stabilized, prepared, and studied, is entered into national museum files.

Such comprehensive collection efforts provide researchers with scientifically significant samples, which open up intriguing avenues for research. Paleontologists can now detect subtle shifts in the composition of the ecosystems through time. Researchers have identified and studied some ancient soils preserved in the John Day Basin and, from a distance of millions of years, are able to gauge former climatic conditions in significant detail. Sedimentologists map the orientation of bones in a Clarno Formation quarry, and thereby plot the eddies, backwaters, and gravel bars of a river that flowed 37 million years ago. Paleobotanists determine the rate at which plant communities evolved. A biostratigrapher dates the last

known occurrence of a fossil primate in North America. Studies such as these, representing many scientific disciplines, combine to give us richly detailed pictures of the past. These, however, are constantly changing as new data come to light.

As It Is Today

American Indians were the first human inhabitants here, but little of their story is known. Archaeologists have uncovered and studied only a few of the Indians' campsites. Apparently their arrival here was many thousands of years before the first white settlement.

John Day, a Virginian, came to Oregon in 1812 with the Overland Expedition of the Pacific Fur Company (Astorians). John Day traveled primarily in Northern Oregon, and a river was named for him due to an incident near the mouth (along the Columbia River), where John Day was robbed by American Indians.

Other pioneers and settlers came to farm, to mine and to cut timber. Gold was discovered in the John Day country in the 1860's and a brief gold rush followed. Today, cattle ranching, farming, lumbering, and tourism sustain the economy of this out-of-the-way, uncrowded region.

The John Day Basin was first recognized as an important paleontological site in the 1860's, thanks to the ability of a young frontier minister, Thomas Condon, who recognized the fossil beds as a scientific treasure. Soon after the gold-rush, a fossil-rush was to follow. At the time, paleontology was still a new science. However, discoveries such as Condon's galvanized scientific interest. By the late-19th century, researchers at Yale, Princeton and the Smithsonian Institution had received hundreds of specimens from the John Day Basin. They were then classified and described in the scientific literature. This early work set the stage for field geologists such as John C. Merriam who, in 1899, began the task of placing the John Day fossils in their geological, chronological, and paleoecological context. The Blue Mountain Eagle (John Day, Oregon newspaper) Dec. 1, 1916 ... "The famous fossil beds of the John Day valley will be an objective point of interest to tourists ... These beds are among the most prolific in rare relics of pre-historic days ... It might be well for the government to withhold the lands from entry and establish here a national park ... As time goes on the value of these beds will be recognized."

Concern for the protection of these fossil resources continued to build, and found expression in the establishment of a 1.5, acre Thomas Condon - John Day Fossil Beds State Park, at the end of January, 1930. Additions continued until it contained slightly more than 2,681 acres by 1956. Painted Hills State Park, containing 13.2 acres, was purchased in 1947. Clarno State Park was established with 100 acres in 1964-5. Today the Sheep Rock Unit, including the former

Thomas Condon - John Day Fossil Beds State Park, contains about 8,534 acres. The Painted Hills Unit has approximately 3,289 acres, and the Clarno Unit about 2,051 acres.

An archeological survey of the monument was conducted in 1976 by Oregon State University under National Park Service contract. The results of the survey are reported in a manuscript entitled "Final Report, Survey of Historic and Prehistoric Resources in the John Day Fossil Beds National Monument," by Wilbur A. Davis. The survey generally covered the areas of the monument judged most likely to yield remains, and areas where visitor or administrative facilities might be developed. In 1993, a preliminary survey of the monument by contract archeologists revealed over a dozen new sites. These suggest more aboriginal inhabitants, over a longer time, than had been considered; sufficient to fund a major reopening of the research in 1994.

All three units of the monument support similar plant communities, though species of these communities do vary from unit to unit. The basic plant communities include the greasewood/cheatgrass, the shadescale/Sandberg's bluegrass, the sagebrush/Sandberg's bluegrass, the big sagebrush/bluebunch wheatgrass, and the western juniper/big sagebrush communities.

A drastic change in faunal composition of the region has evolved in the past hundred or so years because of intensive settlement and agriculture. Deer and coyotes survive and flourish in all three units. Rabbits, squirrels, gophers, and rodents are common residents throughout the monument; and bobcats inhabit all three units. Mink, beaver, muskrat, and raccoons are occasional residents within the Sheep Rock Unit. Partial bird lists have been compiled; but comprehensive lists of reptiles, amphibians and arthropods have not.

Chukar partridge and pheasant are exotics that have become established in all units. No threatened or endangered wildlife species are known to inhabit the monument, save possibly one bat species.

Fish such as steelhead use the John Day River and tributaries for spawning. Other species of fish include redband trout and spring chinook salmon (native); rainbow trout, Montana whitefish, small-mouth bass, channel catfish, black bullhead, and brown bullhead (introduced). Freshwater sculpin and miscellaneous minnows, carp, suckers, and lamprey are also present. Fishing is regulated by the Oregon Department of Fish and Wildlife.

Extensive wildlife habitat modifications exist because of intensive human impact; particularly obvious disruptions are livestock grazing, fence barriers, and stream channelization. The John Day River has been channeled along much of its length to "reclaim" bottomland and to facilitate irrigation.

The sensitivity of the resources and the fragility of the land--especially in the Painted Hills Unit--influences development, visitor services, and use considerations. Of the 14,014 acres designated for the monument, about 10,448 are in Federal ownership. Several large parcels of private lands are within the Sheep Rock Unit. These private lands are active ranchlands, typical of many that are situated in a agricultural belt along the John Day River valley.

The most prominent, former ranch within the park boundary is one that until recently belonged to the James Cant family. In 1975, 849 acres of the Cant Ranch (one of the most prominent local ranches) was purchased by the National Park Service. Two hundred acres of this purchase has been designated the James Cant Ranch historic district. The 1917 ranch house, part of the district, is now the monument's visitor center and employee office building. Surrounding the ranch, the opportunity exists for dramatic viewpoints along the river. The flanks of surrounding hills are sparsely covered with sagebrush, grasses and juniper. Upper slopes expose striking weathered cliffs and spires of red, green and buff colored clay formations.

Grazing is eliminated on those private lands acquired in fee title by the Federal Government; however river bottom lands of the Cant Ranch may continue to be leased for hay and for grazing by livestock in compliance with the National Park Service Historic Property Leasing Guideline (NPS-38). The ranch was listed on the "National Register of Historic Places" on June 21, 1984. An agricultural use plan has been approved.

The Mascall Overlook is at the southern portion of the Sheep Rock Unit about one quarter mile south of Picture Gorge (this overlook is not yet open to the public). When developed, these circumstances will make it the first contact with John Day Fossil Beds National Monument for travelers going west, and the last for eastbound travelers. From the overlook a 240 degree panorama centers on Picture Gorge. The Rattlesnake and Mascall formations, and the Picture Gorge basalt are the major geologic elements in the landscape. At this time, visitors are not referred to this area due to poor traffic conditions on a dirt access road, and concern for visitor safety.

About 16 million years ago the massive eruptions of what are now called the Picture Gorge Basalts occurred. During this period, all of the habitat of much of Oregon, Washington and Idaho were destroyed, marking the end of the John Day Formation record.

Approaching the Sheep Rock Unit from the south, along U.S. 26, features the river-cut basalt gateway, Picture Gorge. The John Day River meanders north through the gorge and traverses the length of the unit, paralleled by Oregon State Route 19. The river is tranquil as it eases across the foot of surrounding hills,

obviously a precious resource in a setting noticeably low in moisture. The opportunity exists for spectacular viewpoints along the river. The flanks of these hills are sparsely decorated with sagebrush, grasses, and juniper, accustomed to waiting long periods for the summer showers that bring most of the 12 inches of annual precipitation. Upper slopes expose raw cliffs and spires that lay bare the color-coded chapters of geologic upheavals that altered the face of the earth, time after time, through millions of years.

The Thomas Condon Visitor and Research Center site was selected on January 9, 1990. The site on which this proposed visitor center, parking and access roads would be located was once a fenced pasture. It is 1 3/4 miles north of the junction of Highways 26 and 19. The area lies on the western edge of the John Day River Valley, across the roadway from the Sheep Rock Overlook. Hills delineate the site on its west, south, and north sides; the highway is its eastern boundary. The visitor center site slopes gently up and away from the highway. It has dynamic landmark views of the fossil resource, Sheep Rock, and good views of the river valley to the north. The Cant Ranch is not visible from here, thus providing the essential separation of a visually and emotionally compelling cultural artifact from the paleontological resources which are the driving force for management and interpretation.

Blue Basin is administered as part of the Sheep Rock Unit, but is physically isolated by intervening private lands. Along State Route 19, 3 miles north of the visitor center, a parking area accesses trailheads. **Off-trail use of this area is prohibited to protect fossil resources.** The visitor may enter the spectacular erosional displays of the John Day Formation, famous for its ever-changing blue-green color tints, and see at close range the complex strata of one of the finest paleontological deposits in the park. The scenic views at this location include lands outside the park.

At Blue Basin and the Foree Deposits, which are in the John Day Formation, one is at once aware of the striking, almost ethereal appearance of the pervasive blue-green color of the dominant deposits. The reason for this unique coloration remains obscure; the chemistry that occurred here is the product of millions of years of complex temperatures, pressures and processes, and ingredients. What is known is interesting. The colorful layers are primarily a "zeolitized, tuffaceous claystone" containing former clays (created from ash-fall deposits) with many crystal types of differing colors. The green layers are primarily a blending of two dominant clay crystals, one blue and the other a yellow.

The John Day Formation is composed primarily of rhyolitic ash deposits blown eastward into the John Day Basin from former volcanos just to the west of the present (and recent) Cascade Range. These former volcanics are known as the Ancestral Cascade range, and only foothills remain. Rhyolite is the volcanic equivalent of granite, which is composed chiefly of orthoclase and albite feldspars,

quartz, mica and hornblende or augite. The name "feldspar" is a generic term for a group of silicate minerals that make up about 60% of the outer nine miles of the earth's crust. They are aluminum silicates that also contain metallic ions. There may be potassium, sodium, calcium and, rarely, barium in the molecule. Orthoclase feldspar contains potassium and aluminum. Albite, a plagioclase feldspar, contains sodium and aluminum. None of these chemicals normally display the colors seen at Blue Basin, singly or in combination. Both hornblende and augite contain magnesium, iron and fluorine in addition to the feldspar atoms, and are dark green to black. They usually appear as small inclusions in granite rock. It does not appear that they could be associated directly with the colors or tints observed.

Zeolites will come up again in a discussion of the Painted Hills Unit. These minerals are chemically very similar to the feldspars, but they exhibit an aluminosilicate molecular structure in which the oxygen atoms form a tetrahedral framework. Zeolites have ion-exchangeable large cations and loosely held water molecules that are surrendered when dry conditions prevail, then they re-hydrate when water is again plentiful. Zeolites are common secondary minerals in cavities in lava, often filling microscopic spaces in the original ash particles as consolidation takes place.

In the middle of the Turtle Cove member of the John Day Formation is the remaining product of what was a heavy, flowing cloud of incandescent volcanic materials and gasses (ignimbrite) that moved very rapidly across the surface of the John Day Basin, covering about 12,000 square miles. The volcanic source of this fiery, tidal-wave-like cloud was somewhere just to the west of Mitchell, Oregon. The heat was so intense and cooling so rapid upon contact with the ground that a glass-like rock formed. At over 1,000 degrees F. and moving at over 100 miles per hour, it no doubt incinerated all life forms in its path. A specimen portion of this Picture Gorge ignimbrite is the caprock on Cathedral Rock, where all the later depositions once covering this feature have eroded away.

Cathedral Rock is located on State Route 19, north of Blue Basin - a scenic anomaly resulting from a geologically recent landslide. The slump brought a fine example of the Picture Gorge ignimbrite down the west side of John Day River valley, perched upon a spectacular piece of the John Day Formation. This event rerouted the river. At present, Oregon State Route 19 closely circumscribes the base of the rock east of the river. There are prospects that Oregon 19 may be realigned and improved farther east of Cathedral Rock. The current roadway may then become available to provide an excellent interpretive site safely out of the now dangerous traffic.

The Foree Area and picnic area is also along Route 19, 2 miles north of Cathedral Rock, made accessible via a short spur road. In a manner similar to Blue Basin, "badlands" type erosion has revealed a large surface area of the John Day

Formation. The high, steep face of a basalt cliff built by a series of extensive lava flows overlays softer rock formations formed from ash. To the untrained eye, there are many similarities between the Foree exposures and those at Blue Basin. There are some important paleontologic differences, however.

The Painted Hills Unit is few miles off of State Route 26 northwest of Mitchell, Oregon. In this small area is a series of smoothly sculptured hills and ridges, rounded and folded and startlingly colored in deep pastel reds, greens, and buffs. Long, colored striations run laterally from hill to hill. The hills are virtually devoid of vegetation except for specially adapted flowering plants that furtively cling to narrow creases in drape-like folds, indicating the presence of moisture.

A scenic intrusion exists at the Painted Hills: A county road passes through the middle of the unit, where the highest scenic values exist. The land forms are too fragile to permit any vehicular traffic off this road, but no natural barriers exist. A visually acceptable control solution has yet to be devised.

The Painted Hills include the oldest part of the John Day Formation - an intermediate age in the John Day Fossil Beds story. Some units contain rich fossil deposits. However, travelers encountering these hills for the first time are most amazed by the intense pastel colors and the way the beautiful scene changes with every nuance of light direction and intensity, and every variation in humidity. These visual delights result from the way the original volcanic ash depositions (essentially glass particles) were metamorphosed over time by physical and chemical interactions. The clays that now predominate here are rich in bentonite, which is a complex hydrous silicate molecule that contains magnesium and aluminum. It has an extraordinary ability to absorb water when it is freely available, and release it during dry times. Bentonite, sometimes called Montmorillonite, is chemically active in forming bonds with bases that contain hydrous aluminum silicate, with a considerable capacity for exchanging part of the aluminum for magnesium, alkalies and other bases. Another closely related molecule has essentially the same structure except for the presence of lithium. Thus, Montmorillonite is a family name for an interesting cluster of chemical substances that change their composition over an unusually wide and reversible spectrum of temporary environmental changes. These changes cause the eyes to notice subtle differences in the colors, and sometimes dramatic changes in their intensity. The landscape contains other colors due to the presence of more stable ingredients like kaolin clay and ores of iron and other metals. Also, zeolites occur. These are hydrous silicates analogous in composition to feldspars. Zeolites are usually present as secondary minerals in cavities of lavas - in this case, as tiny fillings in the remaining glass shards of the original ash.

The Bridge Creek Flora is exposed in the southwestern corner of the Painted Hills Unit in two low hills (called Leaf Hill) composed of shales created in shallow lakes

and ponds. The grasses, sagebrush and a few junipers only partially conceal the outcroppings of alternating shales and clays that occur over an interval of about twenty-five feet. The shales are the fossil-bearing members.

From the standpoint of interpreting the geologic history and environments of the John Day region, the Bridge Creek flora is world famous as the most important source of information about plant life and climatic conditions in the John Day Formation. The excellence of fossil remains here is difficult to overstate: every morphological and botanical feature of roots, leaves, stems, twigs and vines can be seen, including even the parasites upon them! The Bridge Creek Flora is also one of the important Tertiary leaf assemblages on the Pacific Coast, because of its similarity to the modern redwood assemblage now occurring in more humid areas near the Pacific Ocean, its wealth of fossil specimens, and its importance to regional correlations of ancient climatic changes along the Pacific Coast.

Like the rest of the Painted Hills Unit, this rich site is physically vulnerable, and requires restraint in permitting access.

The Clarno Unit is on State Route 218 18 miles west of the town of Fossil. It lies on high ground on the east side of the John Day River. The most prominent feature is the towering palisades, rising sharply from the valley floor and forming craggy pinnacles.

The palisades are a series of sharp cliffs up to 150 feet high, formed from a series of volcanic ash-laden mud-flows (called lahars), with erosional features along the face and horizon view from the parking lot. Understanding their origin is central to the paleohistory of the Clarno Unit. Almost a thousand yards long, they form part of the west wall of Indian Canyon, a box canyon which is one of many similar canyons eroded into the Clarno deposits. The ground cover in this areas is dominated by big sagebrush, scattered pinions and sparse grasses. About 44 million years ago this area was a warm, moist, heavily vegetated forest. There is evidence for the close association of parts of this landscape with fumaroles or hot springs. The nut beds, a very important paleontological resource in the Clarno, grew in this kind of environment and were silicified before later volcanic events intervened. The fossils associated with this phenomenon include such fragile species as Equisetum, preserved in actual growth positions. Tissue replacement by silicates (permineralization) is so precise that cell structures within many nuts, seeds and associated fossils can be seen, with proper preparation.

Later, extensive volcanic episodes occurred west of this lush, moist coastal environment: Lahars are common volcanic events. Very hot pyroclastic material pouring down the flanks of volcanoes encounters water and produces heavy mudflows. These may travel for many miles, engulfing and transporting surface

materials. At Clarno there is evidence that very large lahars swept through the land again and again, over geologic time. The palisades are the eroded faces of many separate lahars that were extraordinarily large and long. Single-episode deposits are on the order of twenty to thirty feet deep. Within these mudstones and the land beyond are the fossil remains of whole tree trunks and a rich mixture of other petrified detritus from the inhabitants of denuded landscapes buried and left behind.

Erosion and deposition events at Clarno, as elsewhere in the park, have provided exceptional insights: Nut beds as old as 44 million years are exposed. Younger deposits are sandwiched between paleosols - ancient soils - that permit accurate dating. The deposits are extensive and rich - in a single place hundreds of species have been identified.

The Clarno beds are an important occurrence for two reasons. The plant remains are permineralized seeds and nuts, while most fossil floras yield only or mainly impressions of leaves. Furthermore, it was one of the first occurrences of terrestrial fossils for which a radiometrically derived age has been determined. The locality provides an important reference in regional reconstructions of *paleoclimatology and *paleoecology, and in worldwide correlations.

The Clarno Mammal Quarry yields the most complete vertebrate remains that have been found thus far in the Clarno Formation. A thorough biostratigraphic study of this fauna has not yet been published. Preliminary analysis suggests that this is the best early Oligocene vertebrate fauna of the northwestern United States and western Canada. The quarry contains a good representation of large mammals. Because it is the only source of abundant vertebrate fossils from early Oligocene time, it is of great importance to our knowledge of the early Tertiary. The outcrops of the Big Basin Member of the John Day Formation exposed in the Clarno Unit contain a freshwater fauna that is also unique, in addition to a terrestrial fauna related to one represented within the Sheep Rock Unit.

The mammal quarry is about 5 million years younger than the Clarno Nut Beds. The flora of the Mammal Quarry may also become important because it occurs stratigraphically above the Clarno Nut Beds and is directly associated with the fossil vertebrate assemblage, thus establishing a means of interpreting the environment of the latter. The flora of the Mammal Quarry is similar to that of the Clarno Nut Beds, and has yet to listed completely.

A ten-acre inholding in the Clarno Unit is Camp Hancock, which is owned by the Oregon Museum of Science and Industry. Some of the most significant paleontological resources within the authorized Congressional boundary of the park are still in private ownership.