

# Map Unit Properties Table: John Day Fossil Beds National Monument

Gray units are not mapped within John Day Fossil Beds National Monument.

Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
QUATERNARY (Holocene)	Alluvium (Qal)	<u>Clarno and Painted Hills unit maps</u> : Unconsolidated material deposited by running water (alluvium). <u>Sheep Rock Unit map</u> : Silt- to gravel-sized sediment deposited by rivers or streams.  Mapped in Clarno and Painted Hills units.	<b>Fluvial Geomorphic Features</b> —Floodplains, point bars, cutbanks, natural levees.	<b>Flooding and Subsequent Erosion</b> —Intense cloudbursts and scarce vegetation on badlands topography may trigger flash flooding, which may increase erosion. Erosion may expose or remove fossils.	<b>The Hot House: Holocene Epoch</b> —Since the end of the Pleistocene, the Oregon Cascades have remained relatively quiet with the exception of Mount Mazama, which erupted about 7,700 years ago and produced the caldera that currently contains Crater Lake. Smaller volcanic eruptions have occurred in the Cascades as recently as 1,000 years ago, depositing ash within what is now the monument. Early in the Holocene, basalt erupted from vents associated with the Brothers fault zone on the High Lava Plains Province.  The resources in John Day Fossil Beds National Monument may be impacted by global climate change. Changes in the timing, intensity, duration, and amount of precipitation may affect water quantity, riparian habitats, incision rates, and cliff erosion in the monument.
	Alluvium; aeolian/fluvial (Qae)	<u>Sheep Rock Unit map</u> : Silt, sand, pebbles, and boulders deposited by rivers. Clasts include a variety of igneous and sedimentary rocks. Gravel deposits up to 3 m (10 ft) thick. Volcanic ash deposits up to 2.7 m (9 ft) thick.  Mapped in Sheep Rock Unit.			
	Pediments (Qp)	<b>Qp1</b> . Lower surface. <b>Qp2</b> . Upper surface.  Mapped in Painted Hills Unit.	None reported.	None reported.	
	Terrace alluvium (Qt)	<u>Painted Hills Unit map</u> : Unconsolidated cobble conglomerate.  Mapped in Painted Hills Unit.	<b>Fluvial Geomorphic Features</b> —Floodplains, point bars, cutbanks, natural levees.	None reported.	
	Landslides (Qls)	<u>Sheep Rock Unit map</u> : Landslides. <u>Clarno Unit map</u> : Most mapped landslides occur where thick exposures of Claystones of Red Hill ( <b>Tcrh</b> ) are overlain by the welded tuff of Member A of the basal John Day Formation ( <b>Tja</b> ).  Mapped in Sheep Rock and Clarno units.	None reported.	<b>Slope Movements</b> —Landslides occur in John Day Formation ( <b>Tjd</b> ) claystones (Sheep Rock Unit) and in the claystones of Red Hill ( <b>Tcrh</b> , Clarno Unit), especially where overlain by <b>Tja</b> .	
NEOGENE (Miocene)	Rattlesnake Formation (QTr)	<u>Sheep Rock Unit map</u> : The formation consists of densely welded tuff, ignimbrite (pyroclastic flow), siltstone, fine- to medium-grained sandstone, and conglomerates, which are conglomerates that usually form on the upper end of an alluvial fan. The conglomerates consist of well-rounded, poorly-indurated pebbles to boulders in poorly-sorted, fine- to coarse-grained volcanic sandstone, basalt, quartz diorite, green chert, and white quartzite.  Mapped in Sheep Rock Unit.	<b>Stratigraphic Features and Paleontological Resources</b> —Alluvial fans, conglomerate, and the Rattlesnake Ash Flow Tuff (RAFT), which is the most distinctive unit in <b>QTr</b> . RAFT is 7.05 ± 0.01 million years old.  Contains primarily vertebrate fossils (table 21), including mammals, reptiles, and amphibians. Plant fossils (table 22; not found in the park) include sycamore, elm, and willow. Mammal fossils are reference fauna for Hemphillian North American Land Mammal Age (NALMA). The presence of the ground sloth <i>Megalonyx</i> suggests that North America was connected to South America.  <b>Paleosols</b> —Kalas, Skwiskwi, Tatas, Tnana, Xaus, and Cmti paleosols suggest woodlands, shrublands, and grasslands (table 23).  <b>Faults and Folds</b> —In the Picture Gorge area, the Rattlesnake Formation lies in angular unconformity above the Mascall Formation.	<b>Paleontological Resource Inventory, Monitoring, and Protection</b> —Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.	<b>The Cool Down: Late Miocene and Pliocene Epochs</b> —Open tall grassland and shrubland habitats with forest environments along river systems. About 7.1 million years ago, the RAFT erupted and deposited about 290 km <sup>3</sup> (70 mi <sup>3</sup> ) of ash in less than 1 week. In contrast to <b>Tm</b> , <b>QTr</b> was deposited in an active tectonic zone. Volcanic eruptions along the Brothers fault zone produced isolated peaks, and in the Cascades, low and volatile volcanoes continued to erupt. At the end of the Pliocene, glaciers began to expand, polar ice caps began reflecting more solar heat away from Earth, ocean currents changed, and temperatures became increasingly unstable.

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NEOGENE (Miocene)	Mascall Formation (Tm)	<p><u>Sheep Rock Unit map</u>: Volcanic sandstone and siltstone, volcanic ash, welded rhyolite tuff, minor lignite, conglomerate, bentonitic clay and shale, and traces of sand and gravel. The volcanic sandstone and siltstone are white, fine-grained, poorly indurated, and porous, with black manganese oxidation and fragments of pumice.</p> <p>Mapped in Sheep Rock Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Diatom-rich claystones, lignite, conglomerate beds, and volcanic tuff.</p> <p>Ages determined from volcanic layers include 15.8 million years (ash bed below Mascall Tuff); 17.619 million and 15.297 million years (Mascall Tuff); and 13.564 million years (Kangaroo Tuff).</p> <p>Complete lists of animal and plant fossils are available in tables 18–20. Most fossils come from the Sheep Rock Unit. Cypress and oak are the most abundant plant fossils. Larger mammals, mainly equids and palaeomerycids, dominate the <b>Tm</b> fauna, but several smaller taxa are relatively abundant. The proboscideans <i>Gomphotherium</i> and <i>Zygodon</i> are among the earliest records of “elephants” in North America and helped define the Barstovian NALMA. <i>Pseudaelurus</i> is the earliest known true cat (Felidae) in the Pacific Northwest. Open grassland habitats are represented by grazing-adapted mammals, such as camels and horses (<i>Merychippus</i>), rabbits (<i>Hypolagus</i> spp.), ground squirrels (<i>Protospermophilus</i>), and horned gophers.</p> <p><b>Paleosols</b>—Maqas, Patu, Skwiskwi, Luca, Wawcak, and Walasx are primary pedotypes (table 23) Paleosols characteristic of open, grassy habitats.</p> <p><b>Folds and Faults</b>—In the Sheep Rock Unit, northwest–southeast-trending faults juxtapose <b>Tcrbp</b> with <b>Tjd</b> and <b>Tm</b>.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p> <p><b>Flooding and Subsequent Erosion</b>—Intense cloudbursts and scarce vegetation on badlands topography may trigger flash flooding, which may increase erosion. Erosion may expose or remove fossils.</p> <p><b>Disturbed Lands</b>—Bentonite in <b>Tm</b> is mined in Crook County, south of Wheeler County.</p>	<p><b>Global Warming and Flood Basalts: Middle Miocene Epoch</b>—Paleosols that developed between basalt flows indicate open grass-dominated habitats. Swamp cypress grew along bodies of water. Modern representatives of the <b>Tm</b> flora suggest mean annual temperature of 8°C to 16°C (46°–61°F) and mean annual precipitation of 50 to 90 cm (20–35 in). Volcaniclastic sediments were derived from eruptions to the west, south, and east and deposited in floodplains. <b>Tm</b> was deposited in a low-relief, tectonically inactive area.</p>
	Columbia River Basalt Group; undivided (Tcrb, Tcrbu)	<p><u>Painted Hills and Clarno Unit maps</u>: <b>Tcrb</b>. Blocky, fine-grained basalt.</p> <p><u>Sheep Rock Unit map</u>: <b>Tcrbu</b>. Basalt flows, with andesite to rhyolite.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Many basalt flows ranging from fine-grained flows to flows with phenocrysts of plagioclase and augite, as well as zones of scoriaceous basalt. Flows tilt to the south-southwest in the vicinity of Picture Gorge.</p> <p><b>Cave and Karst Features</b>—Lava tubes, some of which are 15 m (50 ft) deep.</p>	<p><b>Slope Movements</b>—Potential for rockslides or rockfall.</p>	
	Columbia River Basalt Group	<p><u>Sheep Rock Unit map</u>: Basalt flows, flow breccia, tuff, volcanic siltstone, sandstone, and basalt talus. The basalt flows are up to 412 m (1,353 ft) thick and contain phenocrysts of feldspar, plagioclase, augite, and olivine. Vesicles (gas holes) are filled with zeolite and calcite. The basalts are a portion of the larger Steens–Columbia River flood basalts of the Pacific Northwest.</p> <p>Mapped in Sheep Rock Unit.</p> <p><b>Tcrbpi</b>. Very fine-grained basalt dikes with vesicles filled with calcite and veins of calcite. Not mapped in the monument.</p> <p><b>Tcrbpii</b>. Irregular basaltic intrusion that has a crumbly appearance and contains stringers of calcite and nodules of violet-zoned calcite or reddish baked tuff. Not mapped in the monument.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Many basalt flows ranging from fine-grained flows to flows with phenocrysts of plagioclase and augite, as well as zones of scoriaceous basalt. Flows tilt to the south-southwest in the vicinity of Picture Gorge. Ages determined from basalt include 16.0 ± 0.2 million years; 15.6–16.5 million years and 16.5 to 16.3 million years for Dayville Basalt Formation.</p> <p><b>Cave and Karst Features</b>—Lava tubes, some of which are 15 m (50 ft) deep.</p> <p><b>Paleosols</b>—Monana, Ilukas, Kwalk, Skaw, Nuqwas paleosols suggest peat swamps, forest, woodlands, and shrublands (table 23).</p> <p><b>Exceptional Geologic Landscape Features</b>—Sheep Rock is capped by <b>Tcrbp</b>. Picture Gorge is type area for <b>Tcrbp</b>.</p>	<p><b>Slope Movements</b>—Large blocks of <b>Tcrbp</b> have dislodged in the Sheep Rock Unit. The road through Picture Gorge is periodically closed to remove rockfall and landslide debris.</p> <p><b>Cave and Karst Inventory and Monitoring</b>—No systematic cave inventory or monitoring program exists for the monument.</p>	<p><b>Global Warming and Flood Basalts: Middle Miocene Epoch</b>—A warming event, known as the Middle Miocene Climatic Optimum, occurred approximately 16 million years ago. Between 17 million and 6 million years ago, basalts flooded the Columbia Basin and much of the region of present-day southeastern Oregon. The Picture Gorge Basalt (<b>Tcrbp</b>) erupted from fissures associated with the Monument dike swarm and covered 10,680 km<sup>2</sup> (4,124 mi<sup>2</sup>) of present-day central Oregon.</p>

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<p style="writing-mode: vertical-rl; transform: rotate(180deg);">PALEOGENE-NEOGENE (Oligocene-Miocene)</p>	<p style="writing-mode: vertical-rl; transform: rotate(180deg);">John Day Formation</p> <p>Undivided (Tjd)</p>	<p><u>Sheep Rock Unit map:</u> Ignimbrites, welded and non-welded tuff, lava flows of rhyolite and basalt, tuffaceous siltstone and mudstone, minor coarse-grained sandstone, and conglomerate. The extremely hard welded tuff is 15 m (50ft) thick and contains a variety of rock fragments. The non-welded tuff is 2–8 m (5–25 ft) thick. The thin basalt flows have vesicles filled with calcite, chlorite, chalcedony, and zeolite. The conglomerate is composed of very coarse pebbles to well-rounded boulders.</p> <p>Mapped in Sheep Rock Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Complex stratigraphy consisting of sedimentary and volcanic features (see individual units below).</p> <p>Plethora of fossil plants and animals (see individual units below and tables 10–17).</p> <p><b>Paleosols</b>—Diverse paleosols (see individual units below and table 23).</p> <p><b>Volcanic Features in the John Day Formation</b>—Tuffs are important marker beds throughout the formation (see individual units below).</p> <p><b>Folds and Faults</b>—Minor normal and thrust faults throughout the unit. A prominent north–south-trending normal fault cuts Carroll Rim and Painted Ridge, and a small reverse fault is visible from the Overlook Trail. In the Sheep Rock Unit, an east–west fault juxtaposes <b>Tjd</b> with <b>Kc</b>, and northwest–southeast-trending faults juxtapose <b>Tcrbp</b> with <b>Tjd</b> and <b>Tm</b>.</p> <p><b>Exceptional Geologic Landscape Features</b>—In Sheep Rock Unit, Sheep Rock, Foree, Blue Basin, Cathedral Rock are comprised of <b>Tjd</b>.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p> <p><b>Flooding and Subsequent Erosion</b>—Intense cloudbursts and scarce vegetation on badlands topography may trigger flash flooding, which may increase erosion. Erosion may expose or remove fossils.</p> <p><b>Slope Movements</b>—Landslides occur in <b>Tjd</b> claystones (Sheep Rock Unit). Undercutting of less resistant units may cause the overlying cliff of <b>Tji</b> to collapse.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—See individual units below.</p>
	<p>Haystack Valley Member (Tjh)</p>	<p><u>Painted Hills Unit map:</u> Pale-brown, nodular, tuffaceous siltstones and conglomerates. In Hatch’s Gulch, outside the monument boundaries, <b>Tjh</b> is 14 m (46 ft) thick and consists of resistant nodular tuffaceous siltstones and coarse clastic and conglomeratic deposits containing rounded and welded tuff fragments, and, more rarely, reworked bone fragments. Much of the conglomeratic material consists of reworked clasts of silica-cemented paleosols (fossil soils). Some brecciated nodular paleosol horizons contain abundant silica-cemented rhizoconcretions (branching, cylindrical structures resembling plant or tree roots).</p> <p>Balm Creek, Johnson Canyon, and Rose Creek members are now differentiated from Haystack Valley. This nomenclature is not reflected on GRI source maps that preceded the differentiation.</p> <p>Only the Rose Creek member is present in the monument, although not differentiated on source map.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Sandstone and conglomerates record stream incision into the underlying Kimberly Member. Air-fall tuff serves as a regional marker bed separating <b>Tjh</b> from overlying Balm Creek, Johnson Canyon, and Rose Creek members. JD-BC-3 tuff at contact with Balm Creek Member yielded an age of 23.79 ± 0.18 million years.</p> <p>No fossil material has been recovered in John Day Fossil Beds National Monument (Joshua Samuels, NPS, written communication, 11 April 2013). Fossils (table 14) beyond the monument boundaries indicate hardwood forest habitats and include massive rhinoceroses, chalicotheres (horse-like animals with claws), and smaller grazers, such as camels and horses. Fossils from Balm Creek, Johnson Canyon, and Rose Creek members are listed on tables 15–17.</p> <p><b>Paleosols</b>—Abiayi, Iscit, Plas, Plaspa, Tima, and Yapaspa paleosols are present in the “upper John Day Formation” and represent scrub, shrubland, and woodland (table 23).</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p> <p><b>Slope Movements</b>—Potential for landslides.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—The mammalian fauna of the Rose Creek Member suggest an age of 18.8–18.2 million years. Prior to deposition of the Rose Creek Member and following deposition of <b>Tjh</b>, the region was folded and faulted by northwest–southeast-directed compression, which produced anticlines and synclines, such as the Balm Creek syncline, and low-angle reverse faults. Normal faulting offset the Johnson Canyon Member following its deposition 22.6–19.2 million years ago.</p> <p>The abundance of gophers, burrowing beavers, running-adapted herbivores, such as camels and “stilt-legged” horses, and fossils from hardwood trees suggest open grassy habitats and forest environments similar to those in today’s eastern United States. Ages determined from volcanic layers indicate that <b>Tjh</b> is approximately 24 million years old.</p>

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PALEOGENE (Oligocene)	John Day Formation Kimberly Member (Tjk)	<p><u>Painted Hills Unit map:</u> Volcanic tuffs and tuffaceous siltstones. Although similar to <b>Tjut</b>, <b>Tjk</b> tuffs are generally thicker, fresher, and form bulbous jointed cliffs that are commonly crumbly, dangerous, and overhanging in places. The abundance of weather-resistant non-calcareous nodules, root traces, and rhizoconcretions increases toward the top of the formation.</p> <p>Although not differentiated on the source map, Kimberly Member strata are present in the Sheep Rock Unit (as <b>Tjd</b>).</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Erosion-resistant nodules. Ash-flow tuff. Cliff-forming tuffaceous siltstones.</p> <p>A complete list of animal fossils is available in table 13. Dominated by small mammals, including massive samples of gophers, such as <i>Entoptychus</i> and <i>Meniscomys</i>, but also includes new predators (i.e., first true dogs) and some of the largest John Day Formation mammals, such as the entelodonts <i>Archaeotherium calkinsi</i> and <i>Daeodon</i>, and the large oreodont <i>Promerychochoerus</i>. <i>Moropus</i>, <i>Daphoenodon</i>, and <i>Kalobatippus</i> appear in Oregon for the first time. Fossilized oak, elm, birch, maple, fir, spruce, and pine.</p> <p><b>Paleosols</b>—Succession of paleosols present in <b>Tjk</b>.</p> <p><b>Exceptional Geologic Landscape Features</b>—Kimberly Member layers exposed on and near Sheep Rock.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p> <p><b>Slope Movements</b>—Cliffs of tuffaceous siltstones are jointed. Overhangs may be unstable and susceptible to rockfall.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—The abundance of gophers, burrowing beavers, running-adapted herbivores, such as camels and “stilt-legged” horses, and fossils from hardwood trees suggest open grassy habitats and forest environments similar to those in today’s eastern United States.</p>
	John Day Formation Turtle Cove Member Upper Member (Tjut)	<p><u>Painted Hills Unit map:</u> Alternating clayey siltstones and tuffaceous siltstones that form densely dissected steep badlands. Tuffaceous layers are more resistant and weather to a darker shade of pale olive, whereas the more clayey layers weather to form lower-angle slopes of very pale olive with popcorn-textured surfaces. Most of the section consists of weakly developed paleosols. Thickness ranges from 0 to 63.5 m (0–208 ft).</p> <p>A <i>Promerychochoerus</i> skull was found <i>in situ</i> toward the top of the unit in a resistant, massive horizon of tuffaceous siltstone. The entombing siltstone is interpreted as an ashy flood deposit that was subjected to only minimal soil-forming processes and bioturbation.</p> <p>Mapped in Painted Hills Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Erosion-resistant tuffaceous siltstones and erodible clay-rich siltstones form a stair-step landscape of badlands topography. Ages of <b>Tjut</b> determined from volcanic layers include 27.89 million years (Deep Creek Tuff), 27.14 million years (biotite tuff), and 25.9 million and 25.3 million years (Tin Roof Tuff).</p> <p>A complete list of animal fossils for the entire Turtle Cove Member is available in table 12. The most abundant mammals are three species of hypertragulid (“mouse deer”) and many species of oreodonts. Among the most notable and significant mammals are: 1) the three-toed horse <i>Miohippus</i>, a key species in understanding horse evolution; 2) five species of saber-toothed nimravids, ranging in size from bobcat to jaguar; 3) the last primate known from North America, until the arrival of humans more than 25 million years later; and 4) an incredible diversity of dogs, with as many as 10 co-occurring species, making this the most diverse canid fauna in the history of Earth. Unusual fossils from <b>Tjut</b> include three-toed horses, mouse-deer, beavers, oreodonts, and carnivores, such as bear-dogs, cat-like nimravids, and giant pig-like entelodonts.</p> <p><b>Paleosols</b>—Most of <b>Tjut</b> consists of non-distinct paleosols (see table 23).</p> <p><b>Volcanic Features in the John Day Formation</b>—Tuffs may have originated from eruptions that produced the Crooked River Caldera (30.4–22.6 million years ago).</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—In the Oligocene, temperate conditions replaced a subtropical climate. Seasonal precipitation became more pronounced and the regional climate became 3–6°C (5–10°F) cooler. The landscape not only included wooded grasslands, but also featured towering stratovolcanoes. The 29.56-million-year-old Crooked River Caldera and 29.8–28.1-million-year-old Tower Mountain Caldera contributed abundant tuffaceous deposits and ash-flow tuffs to the Turtle Cove Member.</p> <p>Fauna and flora of <b>Tjut</b> indicate an environment of mixed wooded and open areas.</p>

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PALEOGENE (Oligocene)	John Day Formation	Picture Gorge Ignimbrite (Tji)	<p><u>Painted Hills Unit map:</u> The most widespread ash-flow tuff sheet in the John Day Formation and the middle unit of the Turtle Cove Member. It forms the crest of Carroll Rim. In places, as at Carroll Rim, the unit has two cooling units, indicating multiple eruptions and emplacement over some period of time. <b>Tji1:</b> Lower cooling unit. <b>Tji2:</b> Upper cooling unit.</p> <p>Mapped in Painted Hills Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Welded tuff formed from superheated gases, volcanic ash, and pulverized rock. Two distinctive cooling units (<b>Tji1, Tji2</b>). <b>Tji</b> yielded an age of 28.7 million years ago.</p> <p><b>Volcanic Features in the John Day Formation</b>—Forms a prominent marker bed. Equivalent to the Member H tuff. Crooked River Caldera eruption may have produced <b>Tji</b>.</p> <p><b>Exceptional Geologic Landscape Features</b>—<b>Tji</b> is a prominent marker bed on Sheep Rock. Caps cliffs in Foree and Carroll Rim.</p>	<p><b>Slope Movements</b>—Undercutting of less resistant units may cause overlying <b>Tji</b> to collapse.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—Approximately 28.7 million years ago, volcanic activity produced the Picture Gorge Ignimbrite, which is about 30 m (100 ft) thick in the Painted Hills Unit.</p>
		Lower Member (Tjlt)	<p><u>Painted Hills Unit map:</u> Pale-brown and olive siltstones and tuffaceous siltstones. The boundary between <b>Tjub</b> and <b>Tjlt</b> is well exposed in the lower slopes of Carroll Rim and is marked by a change from brown (<b>Tjub</b>) to pale-olive and pale-yellow (<b>Tjlt</b>; primarily Maqas and Yapas paleosols) paleosol types, which signals a change in paleoenvironment. Carbonate nodules appear for the first time in the Painted Hills section. This calcareous material is probably one reason for the preservation of vertebrate fossils at this level.</p> <p><b>Tjltst.</b> Sanidine tuff (Member G).</p> <p>Mapped in Painted Hills Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Clay-rich and tuffaceous siltstones and ash-flow tuff. Ages of <b>Tjl</b> determined from volcanic layers include 29.75 million years (A/B Tuff), 28.9 million years (Blue Basin Tuff), and 28.7 million years (white tuff).</p> <p>Because the Turtle Cove Member preserves about 5 million years of the Oligocene Epoch, the diverse fauna (table 12) document significant faunal and evolutionary changes due to changes in the regional environment.</p> <p><b>Paleosols</b>—Grassy woodland (Yapas, Maqas, Micay), waterlogged bottomland forest (Lakim), and lightly wooded, seasonally wet meadow (Xaxus) pedotypes.</p> <p><b>Volcanic Features in the John Day Formation</b>—Tuffs may have originated from eruptions that produced the Crooked River Caldera (30.4–22.6 million years ago).</p> <p><b>Exceptional Geologic Landscape Features</b>—Turtle Cove strata are exposed at Sheep Rock, Blue Basin, Foree, and Cathedral Rock, as well as Carroll Rim.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—Paleosols, which differ markedly from those of the Big Basin Member, signal a change in paleoenvironment from woodlands to more grassy habitats.</p>

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PALEOGENE (Oligocene)	John Day Formation	Upper Member (Tjub)	<p><b>Stratigraphic Features and Paleontological Resources</b>—Complete lists of animal and plant fossils from the Big Basin Member are available in tables 10 and 11. Fragments of horses, rhinoceroses, and entelodonts have been recovered from <b>Tjub</b>.</p> <p><b>Paleosols</b>—Variety of woodland paleosols (Skwiskwi, Micay, Kskus, Ticam, Lakim, and Luca; see table 23).</p> <p><b>Folds and Faults</b>—<b>Tjub</b> and <b>Tjmb</b> contain two small domes and a short plunging fold in the Painted Hills.</p> <p><b>Exceptional Geologic Landscape Features</b>—<b>Tjub</b> forms the iconic Painted Hills.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p>	<p><b>Global Icehouse: Oligocene–Miocene Epochs</b>—The temperate, 33-million-year-old Bridge Creek flora (<b>Tjmb</b>) contrast sharply with the tropical to subtropical flora of the Eocene Clarno Nut Beds (<b>Tcch</b>). Climate was cooler and more seasonal than in the Eocene. Seasonal precipitation became more pronounced and the regional climate became 3–6°C (5–10°F) cooler.</p> <p>The Overlook Tuff (<b>Tjmbot</b>), deposited near the Eocene–Oligocene boundary, buried an ancient landscape that consisted of swamps (lignite), poorly drained marsh, and well-drained, forested soils.</p>
		Middle Member (Tjmb)	<p><b>Tjmb</b>. <u>Painted Hills Unit map</u>: Pale-olive and pale-yellow, smectite-rich, silty claystones and several distinctive tuff beds, such as the lowermost Biotite Tuff, the 1.5-m- (5-ft) thick Charcoal-Pumice Tuff, and the thick Overlook Tuff (<b>Tjmbot</b>). Approximately 91 m (300 ft) thick. A titania-rich basalt flow exposed along the Painted Hills access road is interbedded with the claystones and tuffs. Several subdivisions of <b>Tjmb</b> were mapped in the Painted Hills Unit and are described below.</p> <p><u>Clarno Unit map</u>: Red-brown silty claystones, tuffs, and lacustrine shales with leaf impressions.</p> <p>Mapped in Painted Hills and Clarno units.</p> <p><b>Middle–upper Big Basin Member boundary and marker beds</b>. A Rainbow Hill Truncation Surface correlates with the Red Cap beds (<b>Tjmbrc</b>) and cuts out paleosols in the area.</p> <p><b>Red Cap beds (Tjmbrc)</b>. A double set of paleosols. The upper set consists of two or three thick, closely-spaced, deep-red Luca paleosols and is more laterally persistent than the lower set of less well-developed paleosols, which tend to grade laterally into dark-gray Lakim paleosols and thin, reddish-brown Ticam paleosols. Mapped in Painted Hills Unit.</p> <p><b>Overlook Tuff (Tjmbot)</b>. Tuff. A stratigraphic marker overlying red paleosols in Ruby Basin and <b>Tjmblg</b> in the Rainbow Hill–Yellow Basin area. Type locality is west of the visitor overlook. Mapped in Painted Hills Unit.</p> <p><b>Lignite beds (Tjmblg)</b>. Occur below <b>Tjmbot</b> and pinch out into yellow cracked beds in the Rainbow Hill–Yellow Basin area. Mapped in Painted Hills Unit.</p> <p><b>Member F basalts (Tjfb)</b>. Very dark-gray basalt. Mapped in Clarno Unit.</p> <p><b>Basalt (Tjb)</b>. Dark-gray, fine-grained olivine basalt.</p>		

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
PALEOGENE (Eocene)	John Day Formation Big Basin Member  Lower Member claystones (Tjlb)	<p><b>Tjlb. Painted Hills Unit map:</b> Red and ochre-colored claystones exposed between <b>Tjan</b> and <b>Tjmb</b>. Detailed mapping shows the claystones on-lapping the northern margin of <b>Tjan</b>.</p> <p><b>Clarno Unit map:</b> Widespread, thick, clayey red beds. Subdivisions from the Painted Hills area are also recognized in the Clarno Unit.</p> <p>Mapped in Painted Hills and Clarno units.</p> <p><b>Andesite saprolite breccia (Tjanb). Painted Hills Unit map:</b> Bleached boulder horizon interbedded with deep-red claystones. Mapped in Painted Hills Unit.</p> <p><b>Andesite of Sand Mountain (Tjan). Painted Hills Unit map:</b> Dark-gray, fine-grained, non-porphyrific, blocky-jointed, extensive andesite flow unit up to 100 m (330 ft) thick. A discontinuous red claystone separates <b>Tjan</b> from <b>Tja</b> locally. Mapped in Painted Hills Unit.</p> <p><b>Member F tuff (Tjft). Clarno Unit map:</b> Massive, white, weakly-welded, vitric tuff that is widespread but poorly exposed. Approximately 1–3 m (3–10 ft) thick. Mapped in Clarno Unit.</p> <p><b>Volcaniclastic deposits (Tjbs). Clarno Unit map:</b> Conglomerates with basalt clasts and sandstones.</p> <p><b>Member B basalts (Tjlb). Clarno Unit map:</b> Distinctive fine-grained basaltic andesite flows that overlie <b>Tja</b>. The flows weather into cobble-sized blocks. A 21-m- (69-ft-) thick columnar-jointed lava flow crops out at the head of Indian Canyon and is the thickest occurrence of <b>Tjlb</b> in the area. Mapped in the Clarno Unit.</p> <p><b>Welded tuff of Member A (Tja). Clarno Unit map:</b> Widespread ash-flow tuff that is useful for delineating the Clarno surface at the onset of John Day volcanism. A lower, red-purple, densely welded tuff forms prominent outcrops and is approximately 30 m (100 ft) thick. Unwelded tuff deposits are at the very base of the unit and also form the approximately 25-m- (82-ft-) thick slope on the Member A cuesta. <b>Tja-1.</b> Upper Member A. Poorly welded white tuff. <b>Tja-2.</b> Lower Member A. Welded tuff. Mapped in the Clarno Unit.</p> <p><b>Painted Hills Unit map:</b> Welded tuff that occurs in many small white mounds above Clarno Formation red beds in the southern part of the unit. Up to 8 m (26 ft) thick. Mapped in Painted Hills Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Columnar-jointed lava flow (<b>Tjb</b>). Welded tuff (<b>Tja</b>). Ages of <b>Tjlb</b> determined from volcanic layers include 37 million years (andesite of Sand Mountain [<b>Tjan</b>]) and 39.72 million years (Member A welded tuff [<b>Tja</b>]) at the base of the John Day Formation).</p> <p>Late Eocene flora (<b>Tjlb</b>) are approximately 38–36 million years old, several million years younger than the Middle Eocene Clarno flora.</p> <p><b>Paleosols</b>—Between the base of <b>Tjmb</b> and <b>Tjan</b>: tropical forest paleosols (Acas, Apax, Tuksay, and Sak; see table 23).</p> <p>Between <b>Tjan</b> and <b>Tja</b>: transition from tropical forest to early successional woodland (Tuksay, Lakim, Kskus, and Micay).</p> <p><b>Volcanic Features in the John Day Formation—Tja:</b> welded tuff from the eruption that produced the Wildcat Mountain Caldera.</p> <p><b>Folds and Faults</b>—Sand Mountain Fault, which offsets <b>Tjan</b> by as much as 60 m (200 ft).</p> <p><b>Exceptional Geologic Landscape Features—Tjlb</b> exposed at Red Scar Knoll.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p>	<p><b>Global Greenhouse: Eocene Epoch</b>—Greenhouse conditions increased as the Paleocene–Eocene Thermal Maximum event caused global temperatures to rise. Average annual temperatures in the region of present-day western United States were 20–25°C (68–77°F) and Arctic Ocean temperatures were 23°C (74°F). Fossil plants in <b>Tjlb</b> indicate a warm, temperate climate similar to the upper Clarno Formation climate.</p>
	Clarno Formation— Sheep Rock Unit map	Undivided (Tcl)	<p>Rock units include: 1) andesite breccia; 2) very hard aphanitic andesite flows; 3) basalt breccia with silicified wood fragments; 4) poorly-sorted, greenish basalt conglomerate; 5) basalt flows; 6) basaltic tuff; 7) dacite; 8) rhyolite flows, rhyolite tuff, and rhyolite breccia with silicified wood fragments; 9) fine ash; 10) volcanic boulder conglomerate; and 11) hard, well-rounded pebble conglomerate. Also includes veins of yellow limonite, thin layers of claystone, and soft hematite.</p> <p>Although not differentiated on the source map, Clarno Formation (undivided) strata are present in the Sheep Rock Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Sedimentary rock features include conglomerates, claystones, and accumulations of bones. Volcanic rock features include lahars, lava flows, and welded volcanic ash (tuff).</p> <p>Few exposures of the Clarno Formation are within the Sheep Rock Unit, and no fossils are known from them.</p>	None reported.

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History		
PALEOGENE (Eocene)	Clarno Formation—Painted Hills Unit map	Claystones of Brown Grotto (Tcg)	Red claystones and ocher-colored claystone breccia that lie between <b>Tcr</b> and <b>Tja</b> . Hardpans are present locally and cover the underlying <b>Tcr</b> . Named for exposures in the Brown Grotto area.  Mapped in Painted Hills Unit.	<b>Stratigraphic Features and Paleontological Resources</b> —Claystones, claystone breccia, and iron-bearing hardpan. Indistinguishable from the Big Basin Member of the John Day Formation without the presence of <b>Tja</b> .  <b>Exceptional Geologic Landscape Features</b> — <b>Tcg</b> named for Brown Grotto exposures.	None reported.	<b>Global Greenhouse: Eocene Epoch</b> —Greenhouse conditions increased as the Paleocene–Eocene Thermal Maximum event caused global temperatures to rise. Average annual temperatures in the region of present-day western United States were 20° to 25°C (68°–77°F) and Arctic Ocean temperatures were 23°C (74°F). The fossil remains from <b>Tcl</b> represent three major pulses of global warming that resulted in significant mammalian reorganization, floral diversity, and habitat complexity in the Eocene. The Nut Beds ( <b>Tcch</b> ) and Mammal Quarry ( <b>Tcq</b> ) attest to the extensive variety of plants and animals that inhabited subtropical jungles in the region of present-day central Oregon. Fruits and seeds collected from the Nut Beds record a broad-leaved evergreen subtropical forest habitat. The flora and fauna suggest frost-free conditions.  The angle of subduction of the Farallon tectonic plate beneath North America decreased, marking a dramatic eastward shift in tectonic activity. The Western Interior Seaway receded from the continent and the Rocky Mountains formed. A broad arc of volcanoes formed in the region of present-day Oregon, producing lava flows, lahars, and ash-fall tuff.	
		Andesite flows (Tcan)	Dark greenish-gray andesite.	<b>Stratigraphic Features and Paleontological Resources</b> —Rhyolite flows ( <b>Tcr</b> ), some of which have altered to a pebbly gravel ( <b>Tcsr</b> ). Andesite flows ( <b>Tcan</b> ) cap the sequence and contain phenocrysts of plagioclase and pyroxene.			
		Rhyolite saprolite (Tcsr)	White, red, and purple rhyolite saprolite with clay infilling. <b>Tcsrrg</b> . Rhyolite cobble conglomerate. Mapped in Painted Hills Unit.	<b>Exceptional Geologic Landscape Features</b> —Margin of <b>Tcsr</b> exposed at Painted Cove. <b>Tcr</b> is exposed at Brown Grotto.			
		Rhyolite of Bear Creek (Tcr)	Platy to blocky, gray rhyodacite that weathers into grayish-purple to grayish-yellow pebbly gravel. Traced to the large rhyolite dome complex of Sheep Mountain. Mapped in Painted Hills Unit.	None reported.			
		Claystones of Sand Mountain (Tcs)	Red and white claystones.	<b>Stratigraphic Features and Paleontological Resources</b> —Three andesite flows with plagioclase phenocrysts.			
		Andesite of Bridge Creek Canyon (Tca)	At least three andesite flows in the canyon narrows. The upper flow contains white plagioclase crystals in a dark-gray groundmass. The entire section of weathered andesite and overlying claystones is up to 40 m (130 ft) thick.	<b>Stratigraphic Features and Paleontological Resources</b> —Well-developed paleosol structure.  <b>Paleosols</b> —Rainforest paleosols (Lakayx) in the Painted Hills area (table 23).			
		Claystones of Meyers Canyon (Tcm)	Red claystones that are well exposed on the south-facing hill slope in Meyers Canyon just east of Bridge Creek. Approximately 20 m (70 ft) red claystone lies between resistant andesite lava flows ( <b>Tca</b> and <b>Tcla</b> ).	<b>Stratigraphic Features and Paleontological Resources</b> —Platy to blocky-jointed andesite separated from <b>Tca</b> by the thick paleosols of <b>Tcm</b> .			
	Lower Clarno andesite (Tcla)	Dark grayish-blue andesite lava flows. The flows are extensively exposed, dip to the northwest, and have a southwest–northeast-trending outcrop pattern. Correlation of the units in Bridge Creek Canyon with Clarno Formation units south of the canyon is not currently possible. Mapped in Painted Hills Unit.					
	Clarno Formation—Clarno Unit map	Siltstone of the Mammal Quarry (Tcq)	Tan, clayey siltstones and cobble conglomerates. A diverse accumulation of vertebrate fossils make <b>Tcq</b> paleontologically important. Several taxa have close affinities with Asiatic fauna and the early Duchesnean North American Land Mammal Age. East of the Mammal Quarry, siltstones of <b>Tcq</b> overlie Acas paleosols that cap the andesite breccia of <b>Tcah</b> , which overlies the red claystones of <b>Tcrh</b> .  Mapped in Clarno Unit.	<b>Stratigraphic Features and Paleontological Resources</b> —Fossils and sediments that accumulated on a fluvial point bar.  Hancock Mammal Quarry: leaves, fish, and amphibian fossils; disarticulated large mammal skeletons (tables 7 and 8). <b>Paleosols</b> —Tropical forest (Acas) pedotypes at the base of the unit (table 23).  <b>Exceptional Geologic Landscape Features</b> —Hancock Mammal Quarry.	<b>Paleontological Resource Inventory, Monitoring, and Protection</b> —Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.		Approximately 41.50–39.35 million years ago, the Wildcat Mountain Caldera formed, producing voluminous ash-flow tuff and pyroclastic material. <b>Tcrh</b> records a hiatus in volcanic activity 44–40 million years ago. <b>Tcah</b> records renewed volcanism that rejuvenated the alluvial system that deposited the Mammal Quarry beds ( <b>Tcq</b> ).  Ages of the Clarno Formation determined from volcanic layers include 42.7 million years (stony tuff), 43.8 million years ( <b>Tcab</b> ), and 51.2 million years ( <b>Tcap</b> ).
		Andesite of Horse Mountain (Tcah)	Platy to blocky andesite with abundant plagioclase phenocrysts. Caps much of Horse Mountain and overlies a thick red saprolite developed on <b>Tcab</b> . Ramp-like flow structures are common in lava flows exposed in the West Face Cliffs. Mapped in Clarno Unit.	<b>Stratigraphic Features and Paleontological Resources</b> —Lava flows. Plagioclase phenocrysts.	None reported.		
<b>Tcau</b> . Upper andesite. Dark-gray basaltic andesite flow. Exposed on the top of the west part of Horse Mountain. Mapped in Clarno Unit.							
		<b>Tcrc</b> . Red claystones. Underlies <b>Tcau</b> .					

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History		
PALEOGENE (Eocene)	Clarno Formation—Clarno Unit map	Claystones of Red Hill (Tcrh)	<p><b>Stratigraphic Features and Paleontological Resources</b>—Primarily claystones with local conglomerates (Tcrg) containing rounded clasts of andesite and basalt. Conglomerates represent channels incised into Tcch. Claystones represent floodplain deposits.</p> <p><b>Paleosols</b>—Rainforest (Lakayx) and forest (Luca) pedotypes (table 23).</p> <p><b>Exceptional Geologic Landscape Features</b>—Red Hill.</p>	<p><b>Slope Movements</b>—Claystones are prone to landslides (Qls), especially on the eastern side of Indian Canyon. Most landslides occur where thick exposures of claystones are overlain by Tja. The coherent blocks of Tja form shallow, rocky slides and do not appear to be deeply seated.</p>	<p><b>Global Greenhouse: Eocene Epoch</b>—Greenhouse conditions increased as the Paleocene–Eocene Thermal Maximum event caused global temperatures to rise. Average annual temperatures in the region of present-day western United States were 20° to 25°C (68°–77°F) and Arctic Ocean temperatures were 23°C (74°F). The fossil remains from Tcl represent three major pulses of global warming that resulted in significant mammalian reorganization, floral diversity, and habitat complexity in the Eocene. The Nut Beds (Tcch) and Mammal Quarry (Tcq) attest to the extensive variety of plants and animals that inhabited subtropical jungles in the region of present-day central Oregon. Fruits and seeds collected from the Nut Beds record a broad-leaved evergreen subtropical forest habitat. The flora and fauna suggest frost-free conditions.</p> <p>The angle of subduction of the Farallon tectonic plate beneath North America decreased, marking a dramatic eastward shift in tectonic activity. The Western Interior Seaway receded from the continent and the Rocky Mountains formed. A broad arc of volcanoes formed in the region of present-day Oregon, producing lava flows, lahars, and ash-fall tuff.</p>		
		Conglomerates of Hancock Canyon (Tcch)	<p>Conglomerates with mostly andesite clasts. Dominated by matrix-supported boulder debris flows, but includes tuffaceous beds and a distinctive basalt flow. Contains the Nut Beds fossil site. A prominent bench of red claystone separates Tcch from the underlying Tccp. Fine-grained tuffs and medium-grained lahar deposits are common in Hancock Canyon. On-laps the Hancock dacite dome (Tcd) and the middle andesite unit (Tcam). Mapped in Clarno Unit.</p> <p><b>Tct.</b> White pumice lapilli welded tuff.</p> <p><b>Tclh.</b> Lavender lahar with abundant hornblende and andesite clasts. Light-colored boulders weather out of the matrix. Mapped in Clarno Unit.</p> <p><b>Tcab.</b> Amygdaloidal basalt. A distinctive and widespread dark-grey vesicular amygdaloidal basalt flow that displays pahoehoe flow structures and local jointing. Mapped in Clarno Unit.</p> <p><b>Tcam.</b> Middle andesite. Blocky, dark, pyroxene-plagioclase andesite. Locally present south of Clarno along the John Day River. On-lapped by Tcch. Fills a paleovalley cut into Tccp in the southern part of the area.</p>			<p><b>Stratigraphic Features and Paleontological Resources</b>—Features associated with debris-flow, deltaic, and floodplain deposits. Lahars and lava flows. Paleosols.</p> <p><u>Clarno Nut Beds</u>: diverse flora including nuts, seeds, and petrified wood representing at least 173 plant species (table 4); fungi (table 5); mammal and reptile fossils (table 6).</p> <p><u>Hancock Tree</u> (<i>Exbucklandia</i> sp.): pipili tree that may be preserved in growth position.</p> <p><b>Exceptional Geologic Landscape Features</b>—Nut Beds, Hancock Canyon.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p>
		Conglomerates of the Palisades (Tccp)	<p>Matrix-supported, laterally continuous conglomerates with abundant andesite clasts that form the Palisades Cliffs. Interpreted as floodplain debris-flows that on-lap the irregular surface of Tcap. Form the spectacular hoodoos along Pine Creek and in the lower part of the West Face Cliffs along the John Day River. Several thin, green, clayey paleosols with wood fragments and leaf impressions are exposed near the middle of the unit. Overlying the green paleosols is a massive debris flow that weathers brown-orange and crops out prominently along the West Face Cliffs.</p> <p><b>Tcrp.</b> Red claystones. A continuous stratigraphic section exposed in the southern part of Cove Creek contains, in stratigraphic order from oldest to youngest: Tccp, Tcrp, Tcch, Tcrh, and Tja.</p> <p>Mapped in Clarno Unit.</p>			<p><b>Stratigraphic Features and Paleontological Resources</b>—Conglomerates from debris flows form the cliffs and hoodoos of the Palisades.</p> <p>Fossil leaves and petrified wood are found in Tccp. The Clarno Fern Quarry preserves leaf impressions, including those of ferns and angiosperms.</p> <p><b>Paleosols</b>—Paleosols represent humid woodland (Scat) and waterlogged lowland forest (Sitaxs) environments (table 23).</p> <p><b>Exceptional Geologic Landscape Features</b>—Clarno Palisades.</p>	

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
PALEOGENE (Eocene)	Clarno Formation—Clarno Unit map	<p>Andesite of Pine Creek (Tcap)</p> <p>Thick lava flows of dark andesite. Extensively exposed to the east of Cove Creek. The flows have very irregular upper surfaces. Paleorelief of this unit is best exposed in cliffs along Pine Creek between the Palisades Cliffs and the entrance to Hancock Field Station, where more than 40 m (130 ft) of andesite are on-lapped by debris flows over a lateral distance of 200 m (660 ft).</p> <p><b>Tcrw.</b> Red and white claystones that occur at the top of the unit.</p> <p>Mapped in Clarno Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Andesite lava flows with phenocrysts of pyroxene and plagioclase.</p> <p><b>Paleosols</b>—Paleosols (<b>Tcrw</b>) are preserved between <b>Tcap</b> and <b>Tccp</b>.</p>	<p><b>Slope Movements</b>—Potential cliff collapse along Pine Creek.</p> <p><b>Flooding and Subsequent Erosion</b>—<b>Tcrw</b>: The clayey saprolite and claystones erode to form an erosional bench, which is occupied in part by the modern Pine Creek floodplain. Erosion of cliffs along Pine Creek is in part due to the erodability of these claystones.</p>	<p><b>Global Greenhouse: Eocene Epoch</b>—Greenhouse conditions increased as the Paleocene–Eocene Thermal Maximum event caused global temperatures to rise. Average annual temperatures in the region of present-day western United States were 20° to 25°C (68°–77°F) and Arctic Ocean temperatures were 23°C (74°F). The fossil remains from <b>Tcl</b> represent three major pulses of global warming that resulted in significant mammalian reorganization, floral diversity, and habitat complexity in the Eocene. The Nut Beds (<b>Tch</b>) and Mammal Quarry (<b>Tcq</b>) attest to the extensive variety of plants and animals that inhabited subtropical jungles in the region of present-day central Oregon. Fruits and seeds collected from the Nut Beds record a broad-leaved evergreen subtropical forest habitat. The flora and fauna suggest frost-free conditions.</p> <p>The angle of subduction of the Farallon tectonic plate beneath North America decreased, marking a dramatic eastward shift in tectonic activity. The Western Interior Seaway receded from the continent and the Rocky Mountains formed. A broad arc of volcanoes formed in the region of present-day Oregon, producing lava flows, lahars, and ash-fall tuff.</p> <p>Approximately 41.50–39.35 million years ago, the Wildcat Mountain Caldera formed, producing voluminous ash-flow tuff and pyroclastic material. <b>Tcrh</b> records a hiatus in volcanic activity 44–40 million years ago. <b>Tcah</b> records renewed volcanism that rejuvenated the alluvial system that deposited the Mammal Quarry beds (<b>Tcq</b>).</p> <p>Ages of the Clarno Formation determined from volcanic layers include 42.7 million years (stony tuff), 43.8 million years (<b>Tcab</b>), and 51.2 million years (<b>Tcap</b>).</p>
		<p>Hancock dacite dome (Tcd)</p> <p>Dacite intrusion that is overlain by claystone beds (Pswa paleosols). Exposed in the hills and gullies northeast of Hancock Field Station. Formed an erosional, topographic feature. Extensive alteration probably took place in the Eocene.</p> <p>Mapped in Clarno Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Igneous intrusion of dacite with plagioclase and hornblende phenocrysts. The dacite intruded into <b>Tclc</b> and was mantled by colluvium and soils of <b>Tch</b> and <b>Tccp</b>.</p>	None reported.	
		<p>Lower Clarno conglomerates (Tclc)</p> <p>Matrix-supported conglomerates with boulder- and cobble-sized clasts of andesite exposed just west of Hancock Canyon. Oldest and most deformed unit in the map area. The unit lacks tuff beds and paleosols. Stratigraphic relationships with overlying strata are not clear.</p> <p>Mapped in Clarno Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Boulders trapped within a fine-grained matrix (debris flows).</p> <p><b>Folds and Faults</b>—<b>Tclc</b> was folded and then intruded by the Hancock dacite dome (<b>Tcd</b>) before subsequent deformation.</p>		
CRETACEOUS	Cretaceous rocks (Krx)	<p><u>Painted Hills Unit map</u>: Iron-stained conglomerates and sandstone.</p>	None reported.	None reported.	<p><b>Preamble to the Age of Mammals and the Emergence of Central Oregon: Cretaceous Period</b>—Units were deformed and accreted to the North American continent during the Cretaceous.</p> <p><b>Preamble to the Age of Mammals and the Emergence of Central Oregon: Cretaceous Period</b>—Turbidite (density-flow) deposits in a submarine fan system off the coast of present-day Oregon in the Cretaceous. Units were deformed and accreted to the North American continent.</p>
	Mitchell Group	<p>Conglomerate with intercalated sandstone lenses (Kc)</p> <p><u>Sheep Rock Unit map</u>: Conglomerate and sandstone. Clasts consist of a wide variety of rock types and are as large as cobbles. Conglomerate has very low porosity. The sandstone is about 2 m (6 ft) thick and includes pebbles. It has poor-to-excellent porosity and permeability.</p> <p>Mapped in Sheep Rock Unit.</p>	<p><b>Stratigraphic Features and Paleontological Resources</b>—Gable Creek Formation at Goose Rock contains sedimentary features associated with a submarine fan system.</p> <p><b>Exceptional Geologic Landscape Features</b>—Goose Rock.</p>	<p><b>Paleontological Resource Inventory, Monitoring, and Protection</b>—Management of paleontological resources includes inventory and monitoring, field recovery and excavation, stabilization, preparation, identification, cataloging of specimens, and cyclic prospecting of fossil localities, with more erodible strata visited more frequently. The monument manages John Day Basin paleontological resources cooperatively with Bureau of Land Management and Forest Service.</p> <p><b>Flooding and Subsequent Erosion</b>—Intense cloudbursts and scarce vegetation on badlands topography may trigger flash flooding, which may increase erosion. Erosion may expose or remove fossils.</p>	

Gray units are not mapped within John Day Fossil Beds National Monument.

Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
CRETACEOUS	Mitchell Group Sedimentary rocks (Ks)	<u>Sheep Rock Unit map</u> : Fossiliferous conglomerate and sandstone.	None reported.	None reported.	<p><b>Preamble to the Age of Mammals and the Emergence of Central Oregon: Cretaceous Period</b>—Subduction-related intrusions (<b>Kil</b>) and submarine fan deposits (<b>Ks</b>). Units were deformed and accreted to the North American continent during the Cretaceous.</p>
	Nevadan intrusives (Kil)	<u>Sheep Rock Unit map</u> : Diorite with quartz and biotite, porphyritic granodiorite, norite, and quartz monzonite.			
TRIASSIC	Olds Ferry Terrane Vester Formation (TRv)	<u>Sheep Rock Unit map</u> : Mostly volcanic sandstone, conglomerate, graywacke, and shale with minor breccia and basalt flows.			<p><b>Preamble to the Age of Mammals and the Emergence of Central Oregon: Cretaceous Period</b>—TRv and TRsp form the foundation of the Blue Mountains. Each terrane originated as a separate fault-bounded block containing strata of different ages that formed primarily in volcanic island-arc, tropical settings well south of their present latitude.</p>
	Igneous and metamorphic rocks (TRsp)	<u>Sheep Rock Unit map</u> : Igneous and metamorphic rocks. Serpentinite.			
PALEOZOIC and MESOZOIC ERAS	Baker Terrane Metamorphic rocks (MZPZm)	<u>Sheep Rock Unit map</u> : Metamorphosed limestone, 270 m (900 ft) thick, with stringers of white secondary calcite. Serpentinite fills cavities and fractures.			
PALEOZOIC ERA	Sedimentary, volcanic, and metamorphic rocks (PZu1)	<u>Sheep Rock Unit map</u> : Unspecified Paleozoic rocks; granite; quartz diorite.			