Map Unit Properties Table: Hot Springs National Park

Colored cells indicate units mapped within Hot Springs National Park. Italicized text refers to report sections.
Detailed descriptions of the units and additional information are available in the GRI GIS data (hosp_geology.pdf). Geologic units and descriptions derived from the source map by Johnson and Hanson (2011; Arkansas Geological Survey).

Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Issues	Geologic History
QUATERNARY (Holocene and Pleistocene)	Tufa (Qtufa)	**Qtufa** is mapped where hot spring waters emerge. The unit has a distinctive banded appearance with alternating dark gray and white layers, and fibrous to porous texture. Locally, **Qtufa** contains layers of conglomerate and colluvium. Individual deposits are 2 to 3 m (6 to 8 ft) thick.	*Geothermal Hot Springs*—**Qtufa** is deposited as mineral precipitates settle out of solution when calcium carbonate-saturated hot springs water reaches the surface *Connections with Park Stories*— Much of the tufa "blanket" was removed during development of the hot springs. **Qtufa** contains physical biomarkers of microbial activity and may serve as an analog for Martian conditions.	*Geothermal Water Quality and Quantity*—Dating the **Qtufa** deposits in the park area would help determine the timing of spring emergence and the history of spring discharge. Precipitates clog hot spring flow systems. *Radon Exposure*—Radium carbonate naturally occurs in **Qtufa**. *Slope Movements*—Cliffs of weathered and fractured **Qtufa** failed periodically in an area above the park's water cooling facility. Bolts and nets were installed to protect the facility and human safety. The site is monitored.	*Ouachita Mountains Erosion and Surface Processes*—**Qtufa** is still forming in association with hot spring activity.
	Alluvium (Qal)	**Qal** consists of unconsolidated (not solidified) recent fluvial deposits of (by increasing grainsize) clay, silt, sand, and gravel. **Qal** is mapped along rivers and streams.	None reported.	*Flooding*—Runoff following intense precipitation events can flood local waterways. Hot Springs Creek flows through "creek arch" below Central Avenue and Bathhouse Row and is particularly susceptible to flooding.	*Ouachita Mountains Erosion and Surface Processes*—**Qal** is currently accumulating along local waterways as part of the modern floodplain.
	Terrace deposit (Qt)	**Qt** comprises unconsolidated, sorted gravel that grades upward to silt and clay. Topographically, terraces occur at elevation above the active floodplain of streams and/or rivers. **Qt** records the former floodplains of associated streams now perched above the modern fluvial system.	None reported.	None reported.	*Ouachita Mountains Erosion and Surface Processes*—**Qt** records former river levels, perched above the active floodplain.
No rocks from the Paleogene or Neogene periods were mapped by Johnson and Hanson (2011). Rocks of those ages were either never deposited or eroded away.					
CRETACEOUS (Early to Late)	Metasedimentary rocks, undivided (Kms)	**Kms** consists of irregular zones of metaquartzite and hornfels, formed when **Ki** intruded layers of **MDa** and **Ms**, respectively. Irregularities stem from changing parent rock types, the presence of faults, and a decreasing grade of metamorphism away from the igneous intrusions.	*Geothermal Hot Springs*—Thermal water is heated by the normal geothermal gradient and is not associated with igneous activity.	None reported.	*Pangaea Separation, Ouachita Mountains Erosion, and Igneous Intrusion*—**Kms** formed through contact metamorphism during the intrusion of **Ki**. The metamorphosed contact aureole (zone of altered rock) exists for 760 m (2,500 ft) at Magnet Cove and 670 m (2,200 ft) at Potash Sulphur Springs.
	Igneous rocks, undivided (Ki): Alkalic dikes (Kia)	**Ki** consists of nepheline syenite plutons, and alkalic to lamprophyric (or undifferentiated) dikes and sills. Nepheline syenite is a quartz-poor intrusive igneous rock rich in nepheline and alkali feldspar minerals. Dikes cut across preexisting planar structures such as sedimentary layering, whereas sills are injected parallel to or along such structures. Dikes of **Kid** are present within park boundaries. The plutons of **Ki** are located at Magnet Cove, Potash Sulphur Springs, and the V-Intrusive near Lake Catherine.	*Geothermal Hot Springs*—Thermal water is heated by the normal geothermal gradient and is not associated with igneous activity.	None reported.	*Pangaea Separation, Ouachita Mountains Erosion, and Igneous Intrusion*—Lamprophyric dikes (**Kil**) were the first to intrude and are widespread. Alkalic intrusions occurred later. The intrusions at Potash Sulphur Springs occurred 101 million years ago, whereas those at Magnet Cove occurred between 100 and 89 million years ago. All igneous intrusions ended by approximately 80 million years ago.
	Lamprophyric dikes (Kil)				
	Undifferentiated dikes (Kid)				
	Undifferentiated sill (Kis)				
No rocks from the Pennsylvanian, Permian, Triassic, or Jurassic periods were mapped by Johnson and Hanson (2011). Rocks of those ages were either never deposited or eroded away.					

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Age	Map Unit (Symbol)	Geologic Description	Geologic Features and Processes	Geologic Issues	Geologic History
MISSISSIPPIAN (Early)	Stanley Shale (Ms) Stanley Shale, Hot Springs Sandstone Member (Mshs)	**Ms** consists of grayish-black to brownish-gray shale with interbeds of fine-grained, gray to brownish-gray, micaceous and feldspathic sandstone, dark-green to black tuff, and black chert. Weathered exposures of **Ms** are olive-gray (shale) and brown (sandstone). Locally, **Ms** is 460 m (1,500 ft) thick, but can be as much as 3,000 m (10,000 ft) thick. **Ms** is conformable with **Mshs**, separated by a conglomerate layer. **Mshs**, located at the base of **Ms**, contains medium- to fine-grained, massive- to thin-bedded quartz arenite. Weathered surfaces of **Mshs** are light-gray to light-tan, whereas fresh surfaces are white and gray. Thin quartz veins are common in **Mshs**. Unit thickness ranges from 0 to 140 m (0 to 450 ft), eventually "pinching out" to the south. The contact with underlying **MDa** is unconformable often marked by a basal conglomerate that contains novaculite. Stanley Shale was named after the village of Stanley, Oklahoma. **Mshs** crops out on the northern flank of Sugarloaf Mountain, and on the south to southeast face of North, West, and Indian mountains. **Mshs** was named after the hot springs in the area.	*Geothermal Hot Springs*—Deformed, fractured bedrock of **Mshs**, **MDa**, and **Obf** north and northeast of Hot Springs creates the pathways for the geothermal and groundwater systems The geothermal water emerges as hot springs exclusively within **Mshs**. *Folds, fractures, and faults of the Ouachita Mountains*—These structures are the "plumbing" for the springs and were formed during the Ouachita Orogeny. **Mshs** and **MDa** compose the ridges in the Zigzag Mountains in the Hot Springs area. **Ms** underlies the valleys. *Paleontological Resources*—fragmentary fossils of plants, vertebrates, and invertebrates.	*Geothermal Water Quantity and Quality*—**Ms** forms a less permeable, local hydrologic barrier to groundwater flow. *Slope Movements*—Fractured exposures of **Mshs** may be prone to rockfall on steep slopes. **Ms** may be prone to slumping.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—**Ms** and **Mshs** were deposited by turbidity currents. **Ms** collected in a rapidly subsiding basin as the Ouachita Orogeny was beginning. Metamorphosed during the Ouachita Orogeny. *Ouachita Mountains Erosion and Surface Processes*—Differential weathering has lowered areas underlain by **Ms** relative to more resistant rocks such as **Mshs**, **MDa**, or **Obf**.
DEVONIAN (Late) to MISSISSIPPIAN (Early)	Arkansas Novaculite (MDa)	Novaculite is a highly siliceous (silica-rich), erosion-resistant, dense, rock resulting from metamorphism of chert. In the Hot Springs area, **MDa** is more than 99% silica with some pyrite (iron sulfide) and/or iron and manganese-bearing calcite minerals. Grainsizes average approximately 5 microns. The name was first applied by H. R. Schoolcraft in 1819. **MDa** is informally grouped into three divisions: upper, middle, and lower. The upper division contains white, thin-bedded novaculite interlayered with soft, white shale. It locally resembles **Obf** as it weathers. Individual beds may be over 1 m (4 ft) thick and total local thickness can reach 50 m (160 ft). The middle division contains dark-gray to black, siliceous shale interlayered with thin beds of dark novaculite and chert. Thickness of the middle division is locally as much as 24 m (80 ft). The lower division contains white to dark-gray cryptocrystalline quartz. Bedding is massive, up to 9.1 m (30ft) thick. Some gray shales, sandstone, and conglomerate are interbedded near the base. Bedding planes are very flat and easily confused with regional joint structures. The lower division is locally 84 m (275 ft) thick. Contacts between the divisions are frequently marked by conglomerates. **MDa** is the dominant formation within park boundaries. Along with **Mshs**, it forms the backbone of Hot Springs, Sugarloaf, West, North, and Indian mountains. Arkansas Novaculite occurs only in the Ouachita Mountains of Arkansas and Oklahoma and the Marathon Uplift in Texas.	*Geothermal Hot Springs*—Deformed, fractured bedrock of **Mshs**, **MDa**, and **Obf** north and northeast of Hot Springs creates the pathways for the geothermal and groundwater systems. Fractured exposures of **MDa** compose much of the recharge area for the thermal groundwater. *Folds, fractures, and faults of the Ouachita Mountains* — **Mshs** and **MDa** compose the ridges in the Zigzag Mountains in the Hot Springs area. *Connections with Park Stories*—For hundreds or thousands of years, and continuing today, novaculite has been used for tool making and whetstones. American Indian quarries occur across Garland County as part of one of the largest archeological sites in Arkansas. Novaculite tools were widely traded. *Paleontological Resources*—sponge spicules, radiolarians, conodonts, and spores.	*Geothermal Water Quantity and Quality*—The lower member of **MDa** is the dominant unit on Hot Springs Mountain, likely forming much of the shallow groundwater aquifer. Fractures in **MDa** may provide conduits for rapid transportation of contaminants from surface pollution. *Slope Movements*—Fractured exposures of **MDa** may be prone to rockfall when exposed on steep slopes.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—Flow indicators include ripple marks and distributary channel features. Unit thickens to the south indicating an ancient direction of transport. **MDa** collected in a "starved basin" depositional environment with little sedimentary input besides siliceous material. Metamorphosed during the Ouachita Orogeny. *Ouachita Mountains Erosion and Surface Processes*—Differential weathering has lowered areas underlain by **Ms** relative to more resistant rocks such as **Mshs**, **MDa**, or **Obf**.
SILURIAN (Late)	Missouri Mountain Shale (Sm)	**Sm** consists of dark gray shale with minor conglomeratic, novaculite, sandstone, or quartzite layers. Weathered shale outcrops appear green to maroon. One to four distinctive, thin quartzite beds occur near the top of the unit. Unit is 23 to 38 m (75 to 125 ft) thick locally. Lower contact with **Sb** is conformable, locally marked by shale clasts within the basal sandstone. **Sm** was metamorphosed into slate in some localities. Missouri Mountain Shale was named after the Missouri Mountains.	*Paleontological Resources*—Contains few identifiable fossils of conodonts and other fragments.	*Slope Movements*—Weathered exposures of **Sm** may be prone to slumping.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—**Sm** was deposited in a deep marine environment. Marine transgressions occurred during the deposition of **SOu** and **Sm**. Metamorphosed during the Ouachita Orogeny.

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SILURIAN (Early to Late)	Blaylock Sandstone (Sb)	**Sb** contains tan to gray, fine- to medium-grained sandstone and siltstone interlayered with black, fissile (breaks into shards) shale. **Sb** ranges in thickness from 90 to 180 m (300 to 600 ft). The contact with **Opc** is unconformable. Blaylock Sandstone is named after Blaylock Mountain.	*Paleontological Resources*—Graptolites and trace fossils are rare.	None reported.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—Metamorphosed during the Ouachita Orogeny.
ORDOVICIAN to SILURIAN	Missouri Mountain Shale-Polk Creek Shale (SOu)	The Missouri Mountain Shale within **SOu** contains dark-gray shale with a few thin beds of quartzite near the top. Weathered surfaces appear green to maroon. The Polk Creek Shale of **SOu** is black, sooty, fissile (breaks into shards) shale that appears light-gray to buff when weathered. Thickness of **SOu** ranges from 60 to 75 m (200 to 250 ft). Where **Sb** is not present in the Zigzag Mountains, the Missouri Mountain Shale and Polk Creek Shale are mapped together as **SOu** even though the units are not conformable. **SOu** is well-exposed in the Whittington Creek bed in Hot Springs National Park.	*Paleontological Resources*—Graptolite fossils from the Polk Creek Shale are catalogued in the Hot Springs National Park museum collection. Fossil conodonts and other fragments occur within the Missouri Mountain Shale.	*Slope Movements*—Weathered exposures of **SOu** may be prone to slumping.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—Marine transgressions occurred during the deposition of **SOu** and **Sm**. Metamorphosed during the Ouachita Orogeny. *Ouachita Mountains Erosion and Surface Processes*—Differential weathering has lowered areas underlain by **SOu** relative to more resistant rocks such as **Mshs**, **MDa**, or **Obf**.
ORDOVICIAN (Late)	Polk Creek Shale (Opc)	**Opc** is black, sooty, fissile (breaks into shards) shale with minor beds of black chert and gray quartzite. Unit appears light-gray to white when weathered and very soft. Unit thickness ranges from 15 to 30 m (50 to 100 ft). **Opc** is conformable with underlying **Obf** grading quickly from shale downwards to chert. Polk Creek Shale is named after Polk Creek near Caddo Gap.	*Paleontological Resources*—Graptolites are common in **Opc**.	*Slope Movements*—Weathered exposures of **Opc** may be prone to slumping.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—Metamorphosed during the Ouachita Orogeny.
ORDOVICIAN (Middle to Late)	Bigfork Chert (Obf)	**Obf** is thin-bedded, dark- to light-gray, cryptocrystalline (extremely fine-grained) chert with black siliceous (silica-rich), shale; calcareous siltstone; and dense, blue-gray limestone. Certain "tripolitic" intervals of chert weather to a chalky, porous, friable rock (an industrial mineral material called Tripoli) and the shale weathers to a soft texture and buff color. **Obf** varies in thickness up to 230 m (750 ft). Contact with underlying **Ow** is conformable. Bigfork Chert is named after Bigfork post office, Polk County, Arkansas. **Obf** is well-exposed at the center of a large anticline bound by Sugarloaf, West, North, and Indian mountains.	*Geothermal Hot Springs*—Deformed, fractured bedrock of **Mshs**, **MDa**, and **Obf** north and northeast of Hot Springs creates the pathways for the geothermal and groundwater systems. Fractured exposures of **Obf** compose some of the recharge area for the thermal groundwater. *Folds, fractures, and faults of the Ouachita Mountains*—**Obf** contains distinctive, thin interbeds and folding structures. **Obf** underlies the valley between Sugarloaf, Music, West, and North mountains. *Paleontological Resources*—rare, fragmentary radiolarians, trilobites, brachiopods, crinoids, sponges, conodonts, and graptolites.	*Geothermal Water Quantity and Quality*—Exposures of **Obf** serve as major recharge areas for the regional, shallow groundwater aquifer system. *Slope Movements*—Fractured exposures of **Obf** may be prone to rockfall when exposed on steep slopes. *Disturbed Lands*—Weathered **Obf** provided sand and gravel material at Graves Pit.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—Unit contains submarine debris flow deposits that include exotic clasts such as igneous pebbles and cobbles, and limestone fragments. Unit experienced low-grade metamorphism during the Late Paleozoic Ouachita Orogeny. *Ouachita Mountains Erosion and Surface Processes*—Differential weathering has lowered areas underlain by **SOu** or **Ms** relative to more resistant rocks such as **Mshs**, **MDa**, or **Obf**. However, within the park, **Obf** underlies a deeply weathered syncline.
ORDOVICIAN (Middle)	Womble Shale (Ow)	**Ow** contains dark gray to black shale with dark gray limy siltstone and a few beds of gray silty limestone. Shale is siliceous and hard. Milky quartz veins are common. **Ow** ranges from 150 to 370 m (500 to 1,200 ft) thick. Contact with underlying **Ob** is conformable. Womble Shale is named after the town of Womble, Arkansas.	*Paleontological Resources*—trilobites, graptolites, and conodonts.	None reported.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—**Ow** was deposited in deep water and later metamorphosed during the Ouachita Orogeny.
ORDOVICIAN (Middle)	Blakely Sandstone (Ob)	**Ob** contains black and green shale layers alternating with hard gray to blue, medium-grained sandstone and some blue-gray limestone. The thick sandstone sequences appear most prominently in outcrop due to their higher resistance to erosion, but the shales are more abundant, making up more than half of the unit. Shales have a "ribboned" appearance similar to those in **Om**. **Ob** ranges from 150 to 230 m (500 to 750 ft) thick. Contact with underlying **Om** is conformable. Blakely Sandstone is named after Blakely Mountain.	*Paleontological Resources*—graptolites and conodonts.	None reported.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—**Ob** was formed as submarine fan channel deposits in deep water and later metamorphosed during the Ouachita Orogeny.

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ORDOVICIAN (Early)	Mazarn Shale (Om)	**Om** contains gray to black shale interlayered with lesser amounts of siltstone; silty to conglomeratic, quartzose sandstone; blue-gray, dense limestone; and glossy black chert. Chert is concentrated in the upper part of the formation. Milky quartz veins are locally common. **Om** characteristically displays a "ribboned" surface when broken at an angle to the bedding direction. Thickness ranges from 305 to more than 762 m (1,000 to over 2,500 ft). Lower contact of **Om** is conformable with underlying unit. Mazarn Shale is named after Mazarn Creek.	*Paleontological Resources*—sparse graptolite fossils.	None reported.	*Building the Ouachita Mountains, Assembling Pangaea, Developing the Geothermal System*—**Om** was deposited in deep water and later metamorphosed during the Ouachita Orogeny.