Arkansas Geological Survey
Bekki White, State Geologist and Director

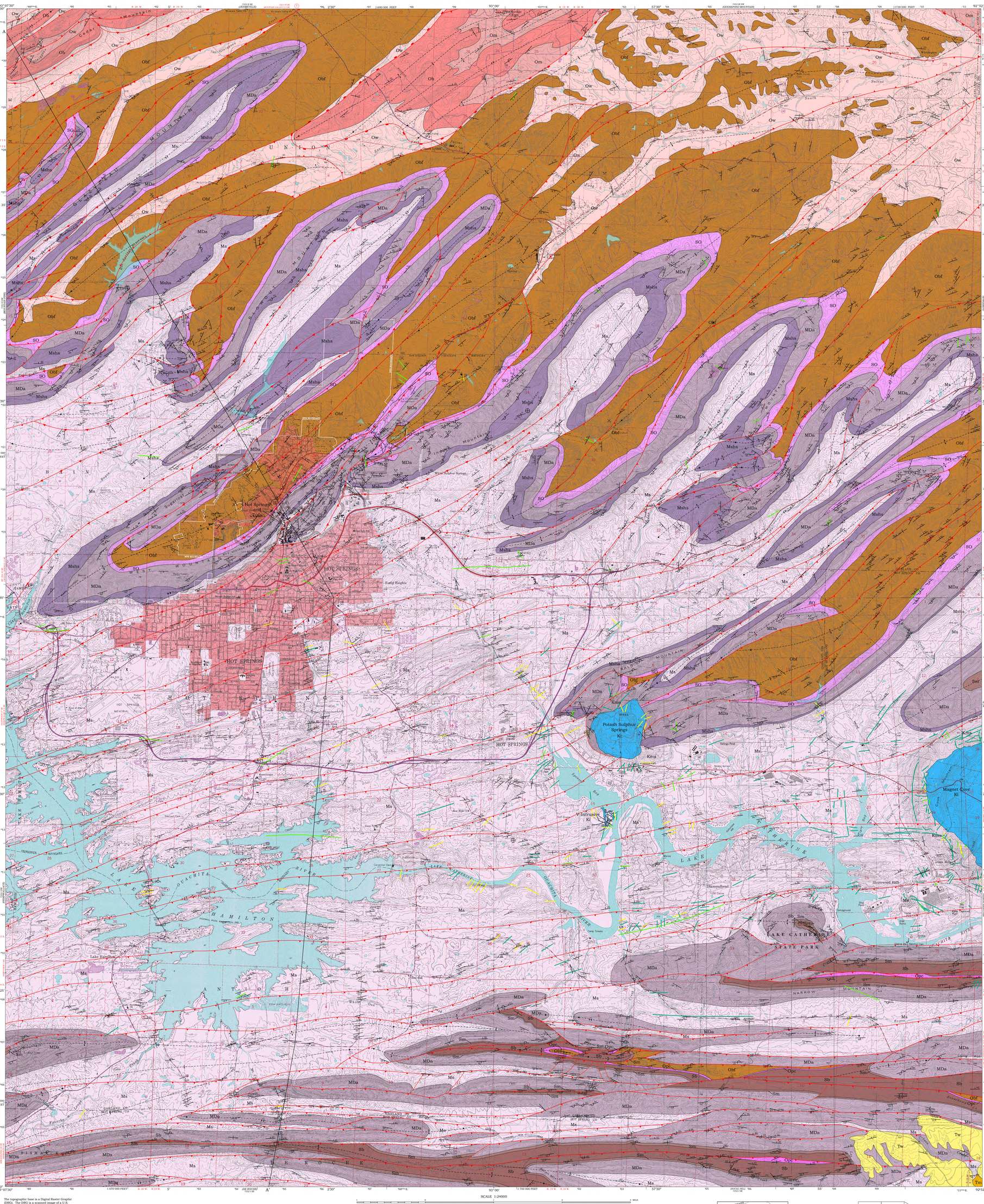
Geologic Map of the Hot Springs North, Hot Springs South, Fountain Lake and Lake Catherine Quadrangles Garland, Hot Spring and Saline Counties, Arkansas

Ty C. Johnson and William D. Hanson

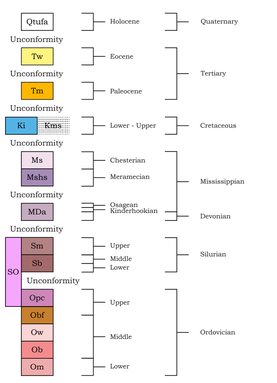
2011

After: Charles G. Stone and Boyd R. Haley, 1996

Digital Geologic Map
Hot Springs North, Hot Springs South,
Lake Catherine, Fountain Lake
DGM-HSR-003



Correlation of Map Units



Introduction

From 2009 through 2011 the Arkansas Geological Survey (AGS) undertook the geological mapping of four United States Geological Survey 7.5 minute quadrangles surrounding Hot Springs National Park in Arkansas. This was done in cooperation with the National Park Service (NPS) which is currently interested in compiling more detailed geologic map data of selected park lands and adjacent areas. This project area includes: Hot Springs North, Hot Springs South, Fountain Lake and Lake Catherine quadrangles. This area lies within the Ouachita Mountains Physiographic Province and overlaps parts of the Mazarn and Saline Basins which are separated by the Zigzag Mountains. The Trap Mountains are located on the southern edge of the Mazarn Basin. Rocks in this area are predominantly sedimentary and deposited in a deep marine environment. They primarily consist of shale, sandstone, siltstone, novaculite, chert and conglomerate. Paleozoic formations range in age from Ordovician to Mississippian and generally thicken to the south. Sparse plutonic igneous rocks were emplaced during the Cretaceous. Tertiary deposits along the Fall Line are often gravels. Tufa has precipitated recently where the hot springs flow over the surface and is Quaternary.

All Paleozoic units in this area have been subjected to low grade metamorphism. Temperatures are less than that of the zeolite facies, during the Ouachita Orogeny (Jackson, 1977). A thermal event occurred from the late Pennsylvanian into the early Permian resulting in quartz vein formation that may have been related to metamorphism (Arbenz, 2008). Degree of metamorphism increases toward the core of the mountain range with a maximum of 15 micrometer grain size in the core area to the north and 9-6 micrometers for the Zigzag Mountains (Stone, per. comm., 2011). Local stresses also control metamorphic effects.

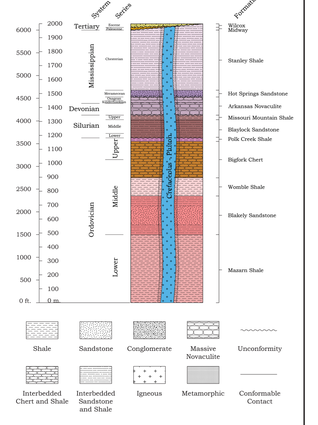
The igneous rocks consist of mostly nepheline syenite and were implaced during the mid-Cretaceous as plutons, dikes and sills. Major intrusions are located at Magnet Cove, Potash Sulphur Springs, and the V-Intrusive near Lake Catherine. There are numerous dikes and sills throughout the project area that are primarily composed of either lamprophyric or alkalic rock types. Contact metamorphism associated with the rocks at Magnet Cove, Potash Sulphur Springs, and minor amounts at the V-Intrusive has altered the surrounding sedimentary rocks primarily to hornfels and metaquartzite.

The Ouachita Orogeny occurred from the Meramacen Series of the Mississippian System to Early Permian. Thickening of the orogenic units occurred due to accelerated subsidence, as evidenced by flysh deposits in the Stanley Shale. Folding of the sedimentary units progressed until shortening resulted in over-thrusting. The Saline Basin, Zigzag Mountains and Crystal Mountains are part of the Central Uplifts. As uplifting occurred in the Central Uplifts during the last major tectonic event, the ductile middle Paleozoic rocks underwent simple shear as overlying younger and more competent strata resisted further northward movement. South vergent overturned folds and faults and some back thrusting from the north resulted in the Zigzag Mountains, the southern limb of the Central Uplifts. In contrast to this structure, the Trap Mountains and the Mazarn Basin folds and faults maintained their original north vergence (Arbenz, 2008). The narrow transition zone of overturning from the north to the south between the Zigzag Mountains and the Mazarn Basin suggest that the south vergence was produced during the uplift of the Central Uplifts (Arbenz, 2008). Thrust faults are disharmonic and exhibit varying amounts of displacement (Misch/Oles, 1956). They are commonly present along fold axes and are generally thrust from the south. Inclination of bedding and the number of joint sets increase near faults. A major sole thrust between older Ordovician sandstone and shale and younger Ordovician to Devonian chert and shale crops out in the northern part of the mapping area exposing a lower thrust sheet of more intensely deformed core-type strata. Folding in the Zigzag Mountains consists of northeast-southwest trending asymmetrical, overturned and cylindrical folds plunging to the southwest. The Trap Mountain folds are very tight, east-west trending and north vergent, and plunge east or west. Folding in the pre-orogenic strata is polyharmonic (Viele, 1995). Competent novaculite and sandstone form the framework of large folds and are more harmonic. Less competent shale and thin-bedded chert form tightly folded, disharmonic folds especially near faults and in the axes of larger folds. Faulting also responds to the rigidity of the rock units. Stresses were more focused in areas of thick, competent rock, resulting in more faults and tighter folds.

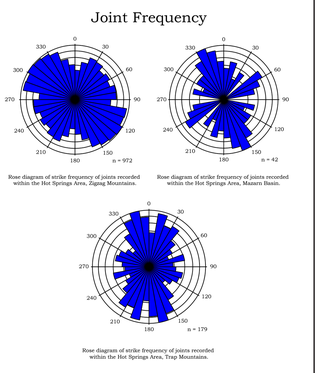
The Zigzag Mountains are accentuated by the erosionally resistant nature of the Arkansas Novaculite and the Hot Springs Sandstone while the Trap Mountains are accentuated by the Arkansas Novaculite. Erosion of the relatively thick sequences of shale between these harder rocks resulted in sharp, hogback ridgelines. Forty to fifty thousand feet (12,192-15,240 m) of rock has eroded from the Ouachita Mountains. Thick sequences of shale allowed extensive erosion. Erosion during orogenic rise through the present time is displayed by relatively young formations in structural lows. Calculated cooling and erosion rates of Cretaceous igneous intrusions suggest 1+/-0.5 km of material has been eroded since the time of emplacement (Howard, 1974).

The recharge area for the hot springs is likely north and northeast of their present location. In that area the Bigfork Chert, Arkansas Novaculite and the Hot Springs Sandstone Member of the Stanley Formation are present at the surface. Intense fracturing of these units has provided necessary secondary porosity. Indian Mountain and other areas to the north have sufficient elevation to provide the hydraulic head needed to drive the hydrothermal system. The flow paths of the water coalesce on faults, fractures and bedding planes along southwestward plunging structures to a depth at which it becomes heated by the geothermal gradient. The heated water is less dense and rises to the surface.

Stratigraphic Column



Joint Frequency



Rose diagram of strike frequency of joints recorded within the Hot Springs Area, Zigzag Mountains.

Rose diagram of strike frequency of joints recorded within the Hot Springs Area, Mazarn Basin.

Rose diagram of strike frequency of joints recorded within the Hot Springs Area, Trap Mountains.

Description of Map Units

Qtufa (Quaternary - Holocene) – Tufa is a rock formed by precipitation of the hot springs water flowing over the ground surface. The water is supersaturated with respect to calcium carbonate which degasses CO_2 when it reaches the surface and precipitates tufa. The rock has distinctly banded dark gray and white layers of calcite, and has a fibrous, porous texture. Colluvial material is incorporated in the tufa, as well as layers of conglomerate. Tufa deposits are six to eight feet thick (Purdue and Miser, 1923).

Tw (Wilcox Formation (Tw) (Tertiary - Eocene) – Coarse gravel deposits along the Fall Line are sourced directly from the Ouachita Mountains. Fluvial processes also reworked the coastal facies of the Midway Formation and represent a coarse facies of the coal seams, sands, silts and clays of the Wilcox Group. Grains are composed of subangular to subrounded chert, sandstone, and novaculite cobbles and pebbles with a silt and clay matrix.

Tm (Midway Formation (Tm) (Tertiary, Paleocene) – Up dip coarse gravel deposits are a coastal facies of the otherwise known limestones and marls of the Midway Group. Grains are composed of subangular to subrounded chert, sandstone, and novaculite cobbles and pebbles with a silt and clay matrix.

Kms (Metasedimentary Rocks (Kms) (Lower - Upper Cretaceous) – Contact metamorphism has altered the rocks surrounding the igneous intrusions for a distance of about 2500 feet (762 m) at Magnet Cove and at Potash Sulphur Springs about 2200 feet (671 m). The rocks are primarily metaquartzite where the Arkansas Novaculite, Hot Springs Sandstone are altered and to hornfels where the Stanley Shale is altered. The grade of metamorphism decreases with distance from intrusions and the zone is uneven due to faults and changing

Ki (Igneous rocks (Ki) (Lower - Upper Cretaceous) – Igneous rocks were emplaced during the mid-Cretaceous: Magnet Cove – 101-91 Ma (Eby, 1987), Potash Sulphur Springs – 101 Ma (Howard, 1974) and V-Intrusive – 102-97 Ma (Owens, 1967). The igneous bodies are in the form of plutons, dikes and sills.

The Magnet Cove pluton is a ring dike complex (Erickson and Blade, 1963) with an areal extent of 5.7 miles^2 (12.3 km^2). The western mapped portion is 0.97 miles^2 (2.5km^2). The outer ring consists of nepheline syenite, related syenites, roof pendants and partially melted country rock xenoliths are common. The middle ring is fine-grained syenites, trachyte and phonolite, and the core consists of more mafic rocks including ijolite and carbonatite (Morris, 1987).

The Potash Sulphur Springs pluton is crudely zoned with an areal extent 0.486 miles^2 (1.26 km^2). It is a differentiated in-situ body consisting principally of nepheline syenite and related syenites with piercing masses of other more mafic rocks, including ijolite and carbonatite (Howard, 1974).

The V-Intrusive is a dike swarm with an areal extent of 0.0154 miles^2 (0.04 km^2). It is a concentration of cross cutting dikes. Lithologies are similar to that of Magnet Cove (Morris, 1987).

Lamprophyric and alkalic dikes form in an east-west trending band mostly within the Mazarn Basin though lamprophyres have a much wider geographic extent than the alkalic dikes which are more concentrated near the igneous plutons. They mostly form along joints and for short distances will follow bedding; though some were formed in perimeter fracturing around Magnet Cove. They are up to 10 feet (3 m) wide and 1.6 miles (2.5 km) long. Most surface exposures have weathered to clay, although the remnant igneous textures can usually be observed. Alkalic dikes are typically porphyritic and green to cream in color, while most lamprophyres are dark, often brown, and display crystals of hexagonal biotite booklets.

Ms (Stanley Shale (Ms) (Mississippian, Chesterian) – The Stanley is composed predominantly of grayish-black to brownish-gray shale, with lesser amounts of thin- to massive-bedded, fine-grained, gray to brownish-gray, micaceous, feldspathic sandstone, dark-green to black tuff and black chert. Weathered shale is olive-gray, and weathered sandstone is generally brown and more porous. The formation was deposited by turbidity currents. This unit is 1500 feet (457 m) thick in the mapping area and has a total thickness of over 10,000 feet (3048 m) (McFarland, 2004). The contact is conformable with the Hot Springs Sandstone member. Near the contact, clean sandstones are interbedded with shale and sandstone in the Stanley. Sandstone on sandstone contact can also occur making the determination of the actual contact difficult to pick. Locally a conglomerate marks the contact.

Mshs (Hot Springs Sandstone Member (Mshs) (Mississippian, Meramecian) – The basal member of the Stanley Shale consists of medium- to fine-grained, sub-angularr to sub-rounded quartz arenite. Bedding is massive- to thin-bedded. In places, the unit is quartzite. Siltstone and shale is present at the top of this member locally. On weathered surfaces this sandstone is very light-gray to light-tan. On fresh surfaces the sandstone is light-gray to white and rarely medium-gray. Intraformational conglomerates also occur and range in thickness from one inch to five feet (2.5cm-1.5m). Thin, less than one inch, quartz veins are common in the sandstone. Thickness of this member is highly variable, reflecting a local morphology as a channel deposit. The unit is deposited by turbidity currents. Thicknesses range from 0 – 450 feet (0-137 m) pinching out to the south. The thickest parts of the formation occur in the noses of folds. This member is restricted to the Zigzag Mountains where it forms hogback ridgelines with the Arkansas Novaculite. The contact with the Arkansas Novaculite is unconformable. A conglomerate is commonly at its base. The matrix is sand or novaculite with novaculite clasts that range in size from very coarse sand to boulders. In places, the conglomerate is up to 60 feet (18 m) thick.

MDa (Arkansas Novaculite (MDa) (Mississippian-Devonian) – Three informal divisions of the Arkansas Novaculite are recognized. The lower division, Devonian age, is white to dark-gray cryptocrystalline quartz that has been metamorphosed to a coarse euhedral, polygonal, triple-point quartz crystals (Keller, 1984). Fine-grained novaculite is translucent on thin edges and is harder and denser than opaque coarse-grained novaculite. Bedding is massive, 4 to 30 feet (1.2-9.1 m) thick, with interbedded gray shales, minor amounts of sandstone and conglomerate near the base. Bedding planes are locally very flat and can be confused with joint planes. A hummocky surface was also common. On Glazypeau Mountain the lower novaculite pinches out, and when present, sandstone is encountered at the base. The lower division is a prominent ridge former, is approximately 275 feet (84 m) thick in Hot Springs and thickens in the Trap Mountains to 450 feet (137 m).

The middle division, Kinderhookian age, is typically dark-gray to black siliceous shale interbedded with numerous thin beds of dark novaculite. In the Zigzag Mountains the novaculite beds are generally less than two inches thick, but in the Trap Mountains they range from 2 to 4 inches (5-10 cm) thick. Thin- to thick- bedded quartz arenite sandstone resembling the Hot Springs Sandstone is present in the Trap Mountains in Lake Catherine State Park. This division reaches a maximum thickness of 80 feet (0-24 m) in the Zigzag Mountains and 100 to 300 feet (30-91 m) in the Trap Mountains. The contact with the lower division is sharp. Locally this division is totally or partially replaced by conglomerate.

The upper division, Osagean age, is white thin-bedded novaculite interbedded with soft white shale and is typically calcareous and tripolitic. Thicker beds of novaculite at the top of this division resemble the lower member with beds are up to 4 feet thick. This unit becomes thin-bedded in the Glazypeau Mountain area and resembles the Bigfork Chert. Thickness of the upper division reaches a maximum of 160 feet (0-49 m) in Hot Springs and 100 feet (0-30 m) in the Trap Mountains. The contact with the Stanley Shale and/or Hot Springs Sandstone is unconformable. Locally, the upper and/or middle divisions are eroded and replaced by conglomerate.

Grain size of the novaculite averages about 5 microns (Holbrook and Stone, 1978). Conglomerates with novaculite clasts occur at various intervals in the formation and are deposited by granular-grain flows that form beds several inches thick to boulder-clast flows several feet thick. The novaculites are 99 percent silica with the remaining one percent predominantly pyrite and/or FeMn-bearing calcite (J.M. Howard, per. comm., 2010). Many quartz veins occur within the novaculite, but are too small to observe in outcrop. This unit and the Hot Springs Sandstone compose the backbone of the Zigzag Mountains in the Hot Springs area. The estimated total thickness of the Arkansas Novaculite in the Hot Springs area is 400 feet (122 m) and reaches 600 feet (183 m) in the Trap Mountains. Flow indicators include ripples marks, distributary channel features and thickening to the south. The contact with the middle division of the Arkansas Novaculite is unconformable and often marked by a conglomerate or breccia.

Sm (Missouri Mountain Shale (Sm) (Upper Silurian) – The Missouri Mountain consists predominantly of shale with minor amounts of conglomerate, chert and sandstone or quartzite. Weathered shale is dull green to maroon in color. One to four thin quartzite beds occur near the top of this unit. These beds are commonly one to two inches but beds up to 8 inches (20 cm) thick are locally present. This formation is 75 to 125 feet (23-38 m) thick in the Trap Mountains and is mapped with the Polk Creek in the Zigzag Mountains. Few identifiable fossils have been recovered from this unit. The unit has a conformable contact with the Blaylock. Shale clasts are locally incorporated in the basal sandstone beds.

Sb (Blaylock Sandstone (Sb) (Middle - Lower Silurian) – The Blaylock consists of tan to gray, fine- to medium-grained sandstone, siltstone interbedded with black fissile shale. Graptolites and trace fossils are rare. This formation is 300 to 600 feet (91-183 m) thick in the Trap Mountains, and is not present in the Zigzag Mountains. The contact with the Polk Creek Shale is unconformable.

SO (Missouri Mountain Shale - Polk Creek Shale (SO) (Silurian - Ordovician) – Missouri Mountain Shale is dark gray on a fresh surface and weathers green to maroon. Locally there are a few thin beds of quartzite near the top of the formation. The Polk Creek is black, sooty, fissile, shale that weathers light-gray to buff. Thickness ranges from 200 to 250 feet (61-76 m). The Polk Creek and the Missouri Mountain are unconformable. In the Zigzag Mountains these two units are mapped together when the Blaylock Sandstone is not present.

Opc (Polk Creek Shale (Opc) (Upper Ordovician) – The Polk Creek consists of black, sooty, fissile shale with minor black chert and traces of gray quartzite. Weathered shales are light-gray to white and are very soft. Thickness ranges from 50 to 100 feet (15-30 m). Graptolites are common throughout the formation. The unit is conformable with the Bigfork Chert. This contact grades rapidly from chert beds to shale.

Obf (Bigfork Chert (Obf) (Upper - Middle Ordovician) – The Bigfork consists of thin-bedded, dark- to light-gray cryptocrystalline chert interbedded primarily with black siliceous shale and subordinate amounts of calcareous siltstone and dense blue-gray limestone. Some intervals are tripolitic. Shale weathers to a soft texture and buff color. Sandstone beds and chert with floating sand grains are locally present near the top of the unit. Fossils are rare but fragments of brachiopoda, crinoids, sponges, conodonts, and graptolites have been reported (McFarland, 2004). Debris flows deposited in this unit contain igneous pebbles and cobbles and limestone fragments. This unit is identifiable by its thin-interbedded nature and disharmonic folding. Dendritic drainage patterns are common to this unit. Thickness is up to 750 feet (229 m) (McFarland, 2004). The unit is conformable with the Womble Shale.

Ow (Womble Shale (Ow) (Middle Ordovician) – The Womble consists of dark gray to black shale and dark gray limy siltstone, with a few beds of dark gray silty limestone. Shale can be siliceous and hard at the top of the formation. Graptolites and conodonts are present. Milky quartz veins are common. The unit is conformable with the underlying Blakely Sandstone. Thickness ranges from 500 to 1200 feet (152-366 m) (McFarland, 2004).

Ob (Blakely Sandstone (Ob) (Middle Ordivician) – The Blakely Sandstone consists of black and green shale in alternating layers with hard gray sandstone and lesser amounts of blue-gray limestone. Although shale makes up locally 50% - 75% of the sequence, it is thick sandstone sequences that outcrop prominently. The sandstone is light-gray to blue, medium-grained, well-cemented and thin- to thick- bedded. The shale of the Blakely is sometimes ribboned much like the Mazarn Shale. Graptolites and conodonts have been reported from the formation. The unit is conformable with underlying Womble Shale, and the thickness ranges from 500 to 750 feet (152-229 m).

Om (Mazarn Shale (Om) (Lower Ordovician) – The Mazarn is predominantly shale with lesser amounts of siltstone, silty to conglomeratic sandstone, limestone and glossy black chert. The shale is mostly gray-black but thin layers of olive-gray silty shale or siltstone are interbedded with the darker shale in some sequences. When the dark-gray and greenish shale is cleaved at an angle to bedding it yields a ribboned surface. In many places siltstone and/or very fine-grained sandstone is present. Dense, blue-gray, thin-bedded limestones can occur throughout the interval. The occurrence of chert is usually in the upper part of the formation. Milky quartz veins are common in some areas. Graptolite fossils are sparse. Thickness ranges from 1000 to over 2500 feet (305-762 m), and the unit is conformable with the underlying formation. (McFarland, 2004).

Symbols

- Contact
- Thrust Fault
- Overturned Thrust Fault
- Sole Thrust Fault
- Tear Fault
- Fold Axis Showing Plunge
- Anticline
- Syncline
- Overturned Anticline
- Overturned Syncline
- Lamprophyric Dike
- Alkalic Dike
- Undifferentiated Dike
- Strike and Dip
- Overturned Strike and Dip
- Vertical
- Horizontal
- Pit
- Quarry
- Mine
- Shaft

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Disclaimer: This map was prepared in a digital format using ArcGIS ArcView 9.10 software on computers at the AGS. The AGS does not guarantee the accuracy of this map especially when used on any other system or with any other software. As mapping continues and is refined, the data presented on this map may be updated.

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Map and cross section digitized by Ty C. Johnson

The topographic base is a Digital Raster Graphic (DRG). The DRG is a scanned image of a U.S. Geological Survey standard series topographic map. Some of the colors of the DRG have been modified and it is displayed at 25% transparency.

Unpublished 1:100,000 COGEO mapping project (Stone and Haley, 1994) data digitized by the AGS were later modified and updated by Ty C. Johnson.

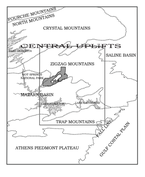
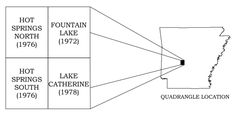
National Park Service Boundary - CADAS ARTD data.

70 - 270 bypass - ARTD data.

Quadrangle Boundaries - CAST data.

10,000 - foot grid based on Arkansas coordinate system, north zone.

100-meter Universal Transverse Mercator grid ticks, zone 15 shown in blue. 1927 North American Datum.

SCALE 1:24000

CONTOUR INTERVAL 20 FEET
NATIONAL GEOLOGIC VERTICAL DATUM 1929