**Hot Springs**

1. About the only part of Hot Springs National Park that looks like a national park is the sign outside the park office. There are no entrance fees or gates here for that matter. And this really isn’t an entrance sign per say, it’s actually just to inform visitors that they have arrived, because without it, I’m sure many would just drive right by.
2. Overlooking the curious concrete and metal plates in the grass (more on those later), one’s first impression is that this national park looks like a pretty average city park in an Anytown, USA.
3. Indeed, it’s located along Central Ave, a mere half mile from the main business district in Hot Springs, Arkansas. Don’t expect anything even remotely resembling a wilderness experience here.
4. As one blogger described it: “this is probably the least worthwhile National Park I've ever seen and could ever imagine”. I’m not sure I’d go that far, but when one of the park’s main attractions is a flaccidly spurting, warm water fountain covered with slimy mineral deposits, you’ve got to wonder if maybe someone in the Department of the Interior had their brains soft boiled after an overextended soak in one of the old bathhouses here.
5. At the time the hot springs where given federal protection back in the 1830’s, however, the existence of the enormously grander Yellowstone geothermal area had not been confirmed, so Hot Springs, Arkansas, albeit small, *was* a natural wonder. Steam billowed from dozens of hot springs, which brought water saturated in calcium carbonate to the surface where it precipitated to form thick deposits of gleaming white tufa. You can see the tufa here along Hot Spring Creek in this sketch from the 1840’s.
6. The tufa deposits are still visible, such as in this ancient hot spring mound, …
7. … but most of the hot water was diverted years ago to supply the bathhouses along nearby “Bath House Row”.
8. Most of the former hot springs have been capped …
9. … and locked to prevent contamination of the bath house water supply.
10. The few uncapped hot springs that remain have drastically reduced flow compared to the pre-bath house days. As a result, very little new tufa is deposited …
11. …and soil has begun to develop on the once lustrous tufa deposits.
12. This is one of the few remaining natural hot springs. You can see the fresh tufa deposited here.
13. The small amount of water that issues from the currently active springs is diverted into the decidedly unnatural looking “display springs”…
14. … which are lined with cemented stones made of the tufa deposited before the bath house water diversions effectively made them extinct.
15. Ironically, the bath houses are the biggest attraction at Hot Springs National Park for many visitors. This is the Fordyce Bathhouse …
16. … which has been completely restored to it’s 1920’s condition. Those where the bath house glory days, when the rich and famous flocked here ….
17. … to partake in extended, spa-centered vacations touted to renew health and vigor. Admittedly, this is probably the last image you would have imagined seeing when you signed up for a Geology of National Parks class! It looks like a sanitarium to me, which is oddly fitting, because I think it was absolutely crazy (if not criminal) to all but destroy a natural wonder so that a few rich people could have a comfy soak and indulge the fashionable quackery of the era. Let’s get out of here!
18. Ah, that’s better. This is the view from “Flatside Pinnacle” in the Flatside Wilderness about 25 miles north of Hot Springs, Ar. The bright white rock resembles the Arkansas Novaculite (more on that later) and the mountains are the Ouachitas. The formation of each, as we will see, plays a key role in the origin of the hot springs.
19. To explain the origin of the hot springs, first let’s have a look at the regional situation. Hot Springs National Park lies near the center of the Ouachita Mountains, which like the Marathon Mountains in Texas, once formed a continuous mountain range with the Appalachians.
20. Today, however, that connection is abruptly terminated by the Mississippi Embayment. One of the great geological mysteries of our nation centers around the creation of this embayment. How did the Mississippi cut clear through an Appalachian-sized mountain range?
21. On this geologic map you can see the largely Paleozoic rocks of the Appalachians and Ouachitas in purples and blues. The much younger sediments of the Mississippi Embayment are in yellow. Obviously, the mountains are older than the river, so how did the river cut from one side of the mountains to the other? One explanation is that the entire area was peneplaned after the formation of the mountains and that the river flowed over the eroded stumps of the old mountains. Then, uplift caused the river to cut down through the old mountains similar to the way water gaps formed in the Appalachians upon rejuvenation.
22. Indeed, ridges of equal elevation are common in the Ouachitas - just like in peneplaned and rejuvenated portions of the Appalachians.
23. But the gap that separates the Ouachitas from the Appalachians across the Mississippi Embayment is orders of magnitude wider than the Appalachian water gaps, so something much grander must have happened here.
24. One relatively new idea, albeit debated, is that the North American continent moved across a stationary hotspot in the mantle. The alleged hotspot currently lies just east of Bermuda, …
25. … and so is known as the Bermuda Hot Spot
26. Although the hot spot has not moved, the content has. Thus, 70 million years ago the area currently belonging to the Mississippi Embayment was sitting right on top of the hot spot. According to the hypothesis, during this time the hot spot warmed, expanded and domed the continent above it.
27. But as the continent moved west, the dome eroded while a new part of the continent was placed above the stationary hot spot.
28. With the dome completely eroded, cooling and contraction lowered the Mississippi Embayment area relative to the adjacent areas, …
29. … and the Mississippi River flowed across the low spot.
30. There are other explanations for the embayment that rely on reactivating Late Proterozoic rifts in the area,
31. … but no matter how you explain the termination of the Ouachita Mountains, their structure is undeniably similar to that of the Appalachian Valley and Ridge Province.
32. On the state-wide scale you can see that the general structure of the Ouachitas is a broad anticline that has uplifted mostly Mississippian and Devonian-aged rocks in its core. Note the Cretaceous igneous rocks in red, possibly related to the passage of the Bermuda Hotspot.
33. If we zoom in from the state wide scale ….
34. … down to the scale of the Ouachitas, we can see that there are numerous smaller folds in the aptly named “Zigzag” range superimposed on the main anticline. From their elongated “V” or “U” shapes you should recognize them as plunging folds – just like the type seen in the Appalachians. The direction of plunge is to the southwest.
35. Following the general trend of the folds in the Zigzag Range are dozens of thrust faults (the red lines here) which complete the association typical of fold and thrust belts like the Valley and Ridge Province. It is the unique combination of this structure and the peculiar rock types found here that have created a system in which groundwater can circulate to great depths, become heated, and then return to the surface.
36. Key among the rock types that promote the circulation of groundwater here is the Arkansas Novaculite - shown in the striped pattern.
37. It is by far the most resistant rock in the region and forms most of the ridges throughout the Ouachitas including those around the Hot Springs area. The Devonian to Mississippian-age formation consists of nearly pure silica …
38. … and represents a deep-sea deposit of siliceous ooze. The ooze hardened into chert, …
39. …and then during the Late Paleozoic Ouachita orogeny as South America collided with North America, mild metamorphism …
40. … slightly recrystallized the chert into Novaculite. This rock is hard, brittle, and extremely resistant to chemical weathering.
41. Fracture this stuff and you can’t ask for a better medium to transmit groundwater.
42. Stratigraphically underlying the Devonian/Mississippian Arkansas Novaculite …
43. .. is the Ordovician Big Fork Chert. In fold and thrust belts the term “stratigraphically” is handy to describe pre-deformation *sedimentary* relationships, because overturned folds and thrust faults place older units *structurally* above younger ones. This road cut illustrates the strong deformation and irregular folding characteristic of the Ouachita Orogeny.
44. Like the Arkansas Novaculite, these sediments deposited in the deep water basin that separated North America from South America…
45. … and the folding resulted from the Ouachita Orogeny. Like the Arkansas Novaculite, the chert here is brittle and thus fractured during folding. The interbedded shale here deformed plastically. Groundwater will be able to flow through the fractured chert and Novaculite, but shale will confine the flow of groundwater.
46. Stratigraphically above the Arkansas Novaculite is the Stanley shale - exposed beautifully here where the gunnite (sprayed-on concrete) has broken off a slope cut into the overturned anticline next to Hot Springs National Park. If this strata is overturned, where would the older Novaculite be? To the left or right of the photo?
47. Although to the right is the answer I was looking for, to the left is also correct, because the Arkansas Novaculite (in green here) is folded with all the other units such that the same unit may be repeated many times at the surface of a cross section like this. I know visualizing all this in three dimensions is challenging, but the important thing to keep in mind here is that the two brittle units (Arkansas Novaculite and Bigfork Chert) are sandwiched between the Stanley Shale and Womble Shale, …
48. … and that when bent, groundwater permeable fractures develop in the brittle chert …
49. … and Novaculite, …
50. … but the shale units will deform plastically without developing fractures.
51. Thus, permeable fractured units …
52. … are sandwiched between impermeable shale units.
53. This arrangement confines the flow of groundwater from the surface like a hose.
54. Faults penetrate the layers, creating a permeable routes for groundwater to flow through the otherwise impermeable Stanley Shale.
55. Because the Bigfork Chert and Arkansas Novaculite are exposed at a higher elevation than where the thrust faults intersect the surface,
56. … the weight of the groundwater at higher elevations exerts pressure on the groundwater at lower elevations such that water is forced out of the ground where the faults intersect the surface. Such springs are considered artesian.
57. The water travels slowly downward to a great depth where it is heated. Acting like a nozzle on a hose, the more narrow (but highly permeable) conduits along the faults, carry the hot water quickly to the surface, before much heat can conduct away from it.
58. The water comes out of the springs at a scalding 140-150 degrees Fahrenheit …
59. … because the rate of *convective* heat flow …
60. ... is great compared to the rate of *conductive* heat flow. This principle is acts to some degree in all hot spring systems. Or in everyday life: “Hurry up and bring me my coffee before it cools off!”
61. Most models seem to favor the Bigfork Chert as the unit through which new water is added to the aquifer – a process called recharge.
62. Others focus on the Arkansas Novaculite as the recharge unit, but all models rely on thrust faults to get the hot water to the surface quickly.