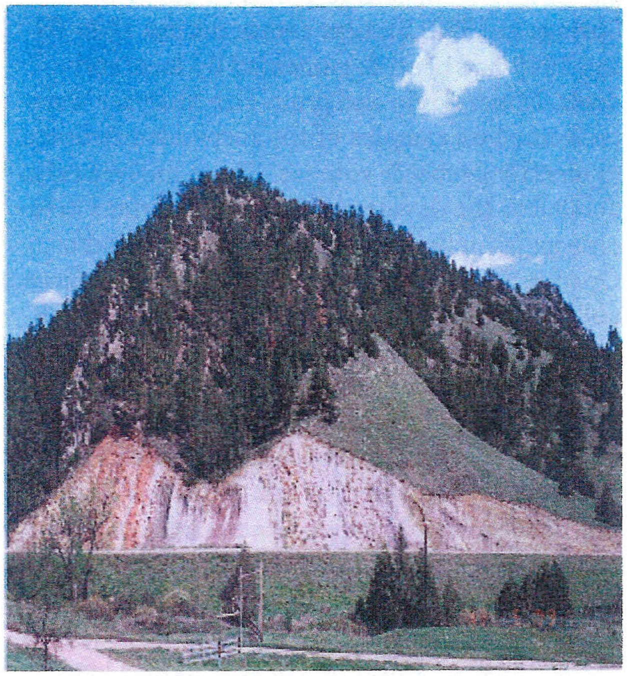
The Nature Conservancy

SAVING THE LAST GREAT PLACES ON EARTH

HYDROGEOLOGY OF CASCADE SPRINGS
NATHANIEL AND MARY WHITNEY PRESERVE at CASCADE CREEK
by Rick Clawges

The Cheyenne River Canyons Project area of The Nature Conservancy lies southwest of Hot Springs and is comprised of over 40,000 acres. The area lies within the southern Black Hills and is part of a hydrogeologic setting characterized by streamflow losses that occur as streams cross outcrops of the Madison (or Pahasapa) Limestone (Mississippian age) and Minnelusa Formation (Pennsylvanian to Permian age) (Driscoll and others, 2002). Within this setting, large artesian springs, originating primarily from the Madison and Minnelusa aquifers, occur in many locations downgradient from the loss zone, most commonly within or near the outcrop of the Spearfish Formation (late Permian to Triassic age). These springs provide an important source of base flow in many streams beyond the periphery of the Black Hills (Rahn and Gries, 1973; Miller and Driscoll, 1998). Cascade Springs is a group of artesian springs within the Cheyenne River Canyons Project area on the Nathaniel and Mary Whitney Preserve. Year-round discharge from Cascade Springs contributes the majority of flow to Cascade Creek, a tributary to the Cheyenne River.

Cascade Springs consists of six known discrete discharge points. The three most upstream discharge points are within a flat-bottomed upper spring basin. Two discharge points farther downstream and near the gazebo, are located within an area of hummocky relief where depressions may indicate other abandoned discharge points. The most downstream discharge point occurs just upstream of where Cascade Creek flows underneath South Dakota Highway 71 (Hayes, 1999). The six discharge points occur within Quaternary-age alluvial deposits in a narrow valley along the contact between the Spearfish Formation and the underlying Minnekahta Limestone (Permian age), near the crest of the Cascade Anticline (Hayes, 1999).



ROCK EXPOSURE ON WEST FLANK OF THE CASCADE ANTICLINE

[An anticline is an archlike upfold in which rock strata dip away from the foldcrest. The Cascade Anticline plunges to the south and is most steeply tilted on its west side]. The contact between the Spearfish Formation and Minnekahta Limestone has been documented as a typical location for large springs that discharge from aquifers in the Madison Limestone and Minnelusa Formation.

Scientists have determined that source water from Cascade Springs is likely a combination of water from the Madison and Minnelusa aquifers. This determination was based on an analysis of sulfur isotopes (Back and others, 1983), and geochemical computer modeling of water along a hydrologic flowpath using chemical and isotopic data (Whalen, 1994; Hayes, 1999). Geochemical modeling indicated that upward leakage from the Madison aquifer causes dissolution of anhydrite and dolomite within the upper Minnelusa Formation, leading to formation of solution collapse breccia pipes (Hayes, 1999). Breccia pipes are chimney-like features filled with angular clasts in a fine-grained matrix. The discharge points at Cascade Springs are likely developing subsurface breccia pipes.

Hayes (1999) investigated the discharge of red suspended sediment that occurred from two of the six known discharge points at Cascade Springs in 1992. Similar events during 1906-07 and 1969 had been documented by local residents. Mineralogic and grain-size analyses were performed on samples of the suspended sediment to identify probable sources. These analyses also pointed to the development of a subsurface breccia pipe(s) in the Minnelusa Formation and/or Opeche Shale (Permian age). Suspended sediment collected from the 1992 discharge event, which was about 90 percent silt and 10 percent clay, matched mineralogies for the upper Minnelusa Formation and Opeche Shale. The hypothesized origin of water from the Madison and Minnelusa aquifers, accompanied by anhydrite dissolution and dedolomitization (replacement of dolomite by calcite) in the upper Minnelusa Formation, would account for the net removal of minerals that would lead to breccia pipe formation by gravitational collapse. Episodic collapse events lead to the discharge of sediments from Cascade Springs. Water from Cascade Springs is normally clear.

Breccia pipes in the Minnelusa Formation were recognized as early as 1905 (Darton) as being distinctive features throughout the southern Black Hills. Bowles and Braddock (1963) examined the occurrence and formation of breccia pipes and compiled a map showing locations of breccia pipes and collapse features in the southern Black Hills. These features occur in clusters from Hot Springs in Fall River County northwest into Custer County, with some occurring in Wyoming just east of Newcastle. Solution in the Minnelusa Formation began in early Tertiary time (60 to 65 million years ago) when the Black Hills uplift was initiated during the Laramide orogeny (mountain building episode). Hayes concluded that the locations of artesian spring-discharge points probably have been shifting outwards from the center of the Black Hills uplift, essentially keeping pace with regional erosion and geologic time. Cascade Springs represents a current discharge location.

In response to regional erosion, hydraulic heads in the Madison and Minnelusa aquifers have declined over geologic time, as indicated by exposed breccia pipes located upgradient from Cascade Springs (Hayes, 1999). Further supporting evidence is provided by Ford and others (1993), who concluded that water level declines of more than 300 feet have occurred in the Madison aquifer during the last 350,000 years, based on geochemical data for Wind Cave. Artesian springs are essentially a "pressure relief" mechanism that influence the upper limit for hydraulic head. Springs such as those at Cascade, where hydraulic head is substantially above land surface, generally have relatively stable discharge. Flow from Cascade Springs averages

SOUTHERN MAIDENHAIR FERN
ALONG CASCADE CREEK

about 20 cubic feet per second (about 150 gallons per second), with little variability.

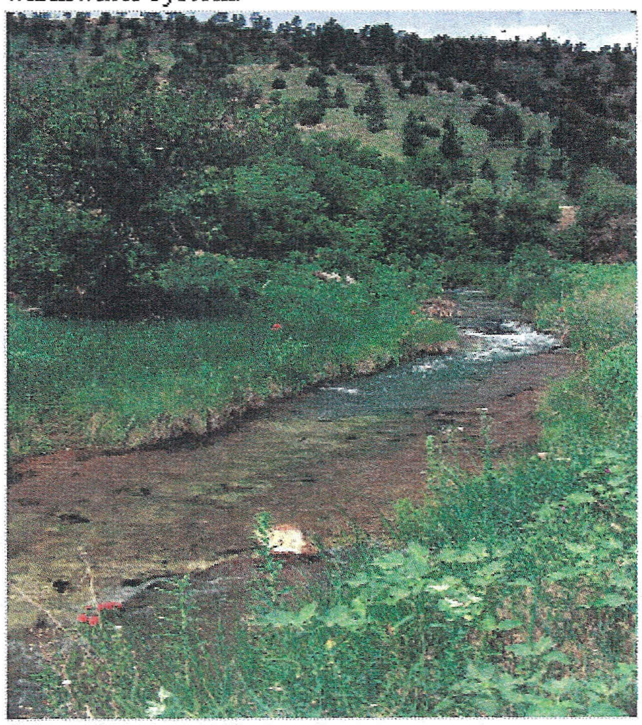
The waters of Cascade Springs are rich in calcium-containing minerals, dissolved from rocks the water comes into contact with as it moves through the ground-water flow system. Upon discharge, some of these minerals precipitate out of solution on the streambed and form deposits of calcium carbonate called travertine. These deposits are highly visible at Cascade Falls, a mile and a half below the springs, where water from Cascade Creek flows over prominent travertine terraces (Gries 1996).

CASCADE FALLS

The radioisotope tritium has been used to estimate the age of water discharging from Cascade Springs. Tritium is used by scientists for age dating of water because large temporal variations of tritium concentrations in precipitation have resulted from atmospheric testing of thermonuclear bombs during the 1950s and 1960s. Although tritium is produced naturally in small concentrations by cosmic radiation in the stratosphere, tritium concentrations in the atmosphere increased sharply in 1953, peaked in 1963, and then declined. Because precipitation contains tritium, scientists use tritium to estimate the age of water that recharges the ground-water system through precipitation. Water discharging from Cascade Springs contains some tritium, but in relatively low concentrations, indicating that most of the water was recharged prior to nuclear testing, but that a smaller proportion of "modern" or post-nuclear-testing water is also present. The major proportion of Cascade Springs water has probably been out of contact with the atmosphere for more than 40 years, indicating long travel times from precipitation recharge to discharge at the springs (Naus and others, 2001; Driscoll and others, 2002).

Cascade Springs differs from many other artesian springs occurring around the periphery of the Black Hills, however, because of the relatively high temperature (about 20° C, or 68° F) of the water discharging there. Other springs discharging around the City of Hot Springs, including those at Evans Plunge, have similar high relative temperatures. The cause of anomalously warm water in springs and wells of the southern Black Hills remains an enigma. Theories for the cause include heat generation by radioactive decay of basement rocks, a partially-cooled magma lying at shallow depth in the southern Black Hills, and areas of high geothermal gradients caused by close proximity of heat-conducting Precambrian rock (Rahn and Gries, 1973: Schoon and MacGregor; 1974; Knirsch, 1980; Whalen, 1994).

The hydrogeologic features found at Cascade Springs—deep source with relatively old recharge water, developing breccia pipe, constant flow of thermal waters, downstream travertine terraces—provide for a natural setting that supports a unique warm riverine ecosystem where plants, birds, fish, and other wildlife can find a year-round source of ice-free water. Four warmwater plants, normally found hundreds of miles away, depend on this warmwater system.



CASCADE CREEK

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