GEOLOGY OF THE VORE BUFFALO JUMP

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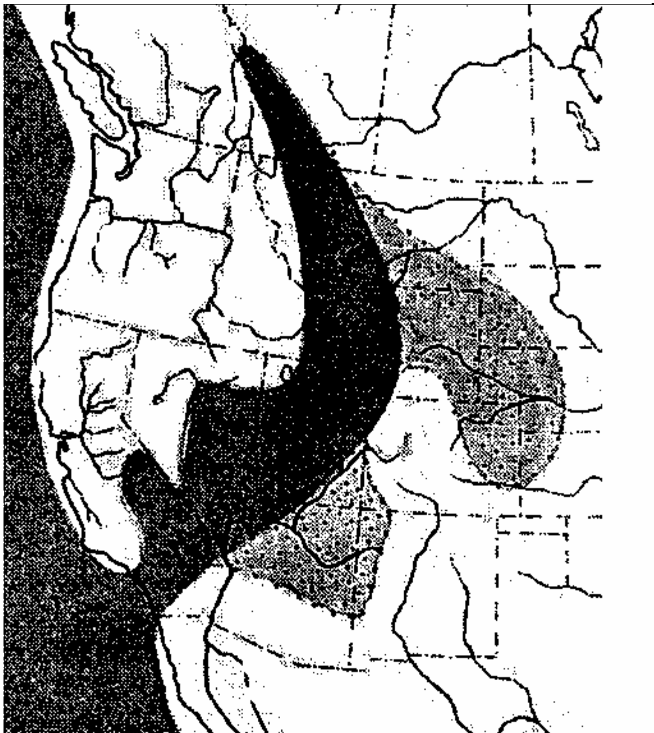
Geology of the Region

Located at the edge of the Northern Black Hills, the Vore Buffalo Jump is situated upon a layer cake of geological formations. At the surface are the prominent “red beds” of the Spearfish Formation. The red beds are a complex mixture of red shale, siltstone, and fine sandstone. They were deposited in warm, shallow water during the Triassic period (248 to 206 million years ago).



The map is of the early Triassic period in western North America (with modern drainages and state boundaries superimposed). The Rocky Mountain uplift was still almost 200 million years in the future. The Black Hills region was under shallow water at least part of the time. The Spearfish Formation red beds and deposits of gypsum formed in this context.

Immediately below the Spearfish Formation is a four-foot layer of gypsum, a soft mineral used to make sheetrock, plaster of Paris, and blackboard chalk. The soft Spearfish Formation “red beds” erode (or dissolve) more quickly than the harder strata that are found both above and below them, so they form a valley called “the red valley” or “the race track” that encircles the core of the Black Hills uplift. Often there are “hog back” ridges of Dakota sandstone outside of the race track.   This red valley is also a natural transportation route used by buffalo, Indians and cowboys, or currently, Harley’s, RV’s and 18-wheelers.

Underneath the Spearfish Formation are four strata that spread beyond South Dakota and Wyoming and date back to the Permian (226 to 227 million years ago) and the Mississippian periods (about 350 million years ago).

The first of the three Permian layers, the Minnekahta Formation, is mainly limestone. The middle layer is the Opeche (named for the Native American title for Battle Creek in South Dakota), which is made up of red shale and sandstone. The final layer is the Minnelusa Formation, which consists of interblended limestones, sandstones and shales.

The Mississippian layer is the Pahasapa (or Madison) Limestone which is very significant because it is the most important aquifer (source of ground water) in this semi-arid region. It’s also noteworthy because a number of large and famous Black Hills caves (including Wind and Jewel Caves of the National Park system) are in the Pahasapa/Madison Formation.

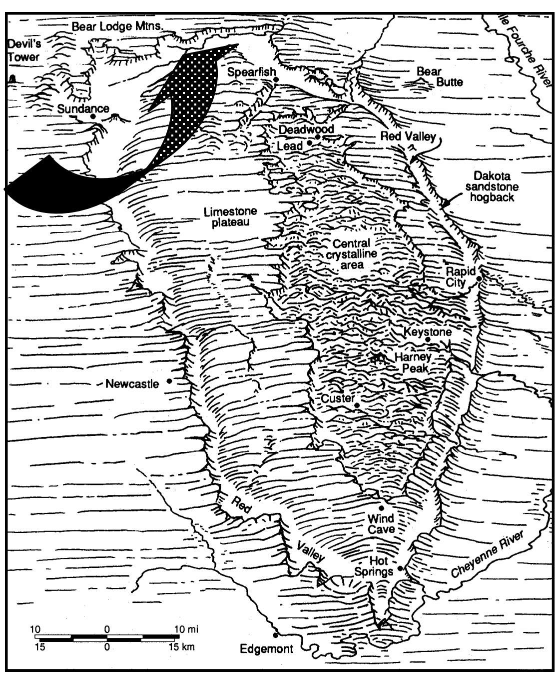
Gypsum and Limestone

To understand Black Hills geology generally and the Vore site sinkhole specifically, one needs to understand some properties of gypsum and limestone. Gypsum and limestone have in common the fact that both contain positively charged calcium ions. They differ in that the predominate negative ion in gypsum is sulfate (SO_4) while the negative ion in limestone is carbonate (CO_3). Both gypsum and limestone are somewhat soluble in water, but water can only hold a certain amount of either of them in solution. Gypsum is more soluble than limestone so it gypsum usually dissolves first when they are in water together. The opposite is true when they settle out of the water solution or “precipitate” back into a solid – i.e. lime will precipitate before gypsum. Both are less soluble than some other compounds that are commonly dissolved in water, such as table salt (sodium chloride or NaCl).   When a body of water that contains all three compounds starts to evaporate (as in a shallow sea, desert lake or swamp), lime will precipitate into a solid first, then gypsum and, finally, salt. If water returns the system later, they'll generally dissolve in the opposite order...salt first, then gypsum, then limestone.

In the Black Hills, the Madison Formation formed from shells and dissolved calcium carbonate that precipitated out of an ancient shallow sea, forming limestone. However, within the limestone, there were lenses of gypsum. Over time, cracks formed in the limestone/gypsum layer. Groundwater filled the cracks. The gypsum dissolved away leaving cavities in the limestone. Additional water, combined with organic acids the water picked up as it soaked into the ground and percolated into fissures in the rock, dissolved some of the limestone. The result is some of the largest caves in the world. One hundred and thirty-two miles of Jewel Cave have been surveyed, making it the world's third longest. Wind Cave is over 50 miles long. (Mammoth Cave in Kentucky is the record holder at 360 miles mapped and explored!)

About 60 million years ago, igneous (molten) rock pushed up and formed the bulge that ultimately became the Black Hills. During this uplift, the overlying sedimentary rocks (limestones, sandstones, shales, etc.) were tilted up. Eventually most of these overlying sedimentary rocks eroded away from the highest points in the Hills, leaving the granite core exposed in places like Terry and Harney Peaks. Erosion exposed the no-longer horizontal sedimentary layers around its flanks. These exposed sedimentary rocks on the so-called "limestone plateau" are now the primary "recharge areas" where water enters formations like the Pahasapa/Madison and Minnelusa Limestone formations.

Vore Site and Red Valley



Black Hills Geology and Landform

Once in the rocks, the water flows downhill through fissures creating considerable gravitational pressure on this groundwater at lower elevations around the base of the Black Hills. Due to pressure, water from underground aquifers will flow upward into overlying strata if it can. If the water reaches the surface, the water will form a spring or artesian well, thus relieving the pressure. Major springs such as those that create Sand Creek (a perennial stream 3 miles east of the VBJ) are an example.

However, if, on its path to the surface, the pressurized groundwater passes through rock that is particularly soluble, a cave may form. That is exactly what the current theory suggests in the Vore Buffalo Jump sinkhole. U.S. Geological Survey geologist, Dr. Jack B. Epstein, who has been studying the Spearfish Formation sinkholes believes that the VBJ sinkhole did not result from a collapse directly into a large cave in the underlying limestone. Rather, says Epstein, pressurized water in the tilted limestones rose through fissures until it reached the soluble gypsum at the base of the Spearfish formation. The gypsum dissolved creating a solution cavern near the surface . The overlying "red bed" sediments then collapsed at points into the void where the gypsum used to be creating the Vore site sinkhole and others (such as the one just north and west of the VBJ). If the bottom of the new sinkhole is above the "potentiometric surface," (the level to which water in an aquifer would rise due to the natural pressure in the rocks), then the sinkhole is dry, if not, the sinkhole will contain a spring.

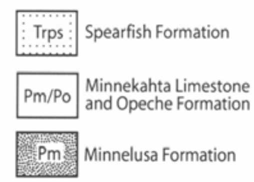
The VBJ Sinkhole

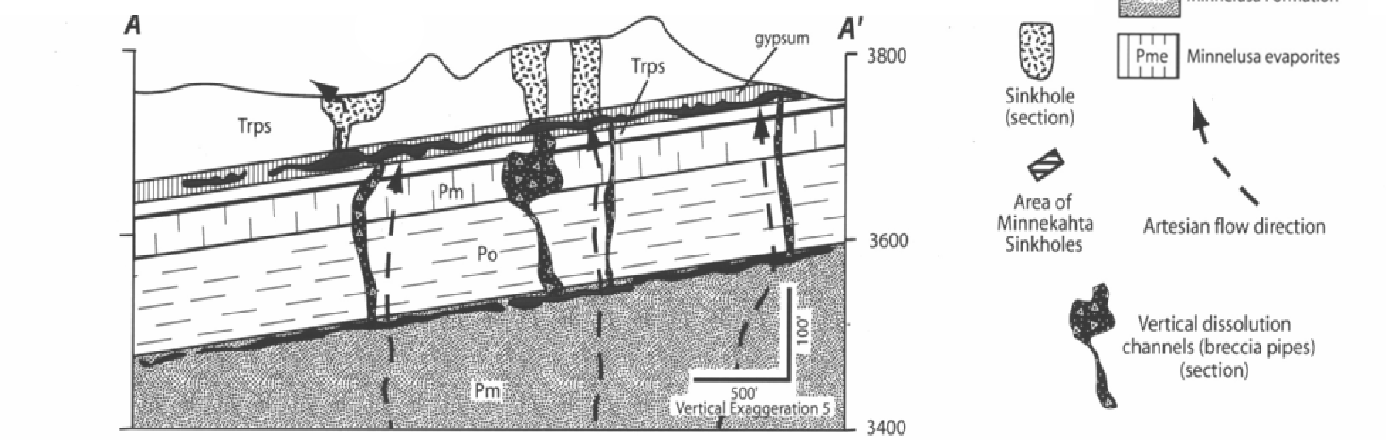
The area surrounding the buffalo jump is what is known as a Karst terrain. Due to the combination of water and soluble rock, most Karst terrains are known for their fissures, underground streams, caverns, and of course sinkholes.

The sinkhole which is the focus of the Vore Buffalo Jump is about 50 feet deep, more that 200 feet across, and is surrounded by several gypsum beds, each 8-10 feet thick. Although no gypsum is present in the current bottom of the sinkhole, gypsum veinlets can be seen in the walls of the sinkhole, and are probably a result of the expansion of the gypsum and fracturing of the surrounding rock. The layers of bone which are found to extend 20 feet below what is now the natural bottom of the sinkhole indicate that sediment was rapidly deposited over the 300-year use of the sinkhole.

Although the dissolving of limestone within the Minnelusa Formation is a feasible hypothesis for the creation of the sinkhole found at the Vore Buffalo Jump (this is how the Mammoth Site sinkhole, which is also located within the Spearfish Formation, originated), other evidence seems to suggest that dissolution in the Minnelusa may not be the direct cause which led to the formation of the Vore site sinkhole. Instead, evidence suggests that the sinkholes of this region are formed by a collapse into open passageways near the bottom of the Spearfish Foundation and the top of the Minnekahta limestone. This hypothesis is backed up by evidence found in a neighboring larger sinkhole, found just across the frontage road from the Vore Buffalo Jump. In 1985, the north end of the sinkhole collapsed to form a smaller 60-foot deep sinkhole. At the time of its formation, local ranchers heard water running beneath in a cavern that extended horizontally beyond the limits of their flashlights. Because the stream and cavern the ranchers discovered were relatively close to the surface, this incident supports the idea that both this sinkhole and the Vore site sinkhole were formed in the higher up Spearfish and Minnekahta Formations and the layer of gypsum which is sandwiched between them, rather than in the much deeper Minnelusa Formation. The presence of a cavern underneath the larger sinkhole also suggests that the Vore-site sinkhole and its neighbor may in fact be linked together by means of a subterranean cavern system which formed within the gypsum layer.

This cross-section of the geological layers underlying the sinkholes of the Beulah area, and shows the possible caverns within the gypsum layer which could extend to connect several sinkholes in the area, as well as the breccia pipes and direction of the artesian flow.





This geologic cross-section of the area around the Vore Buffalo Jump was drawn by Dr. Jack Epstein of the U.S. Geological Survey. Dr. Epstein led a tour of geologists to the area in September 2005, and the VBJ was a major stop on the tour.

"The ground on which we stand is sacred ground. It is the dust and blood of our ancestors… A few more passing suns will see us here no more, and our dust and bones will mingle with the same prairies. I see as in a vision the dying spark of our council fires, the ashes cold and white. I see no longer the curling smoke rising from our lodge poles. I hear no longer the songs of the women as they prepare the meal. The antelope have gone; the buffalo wallows are empty. Only the wail of the coyote is heard… We are like birds with a broken wing. My heart is cold within me. My eyes are growing dim - I am old. When the buffalo went away the hearts of my people fell to the ground, and they could not lift them up again...After this nothing happened. There was little singing anywhere. "

Chief Plenty Coups - Crow