



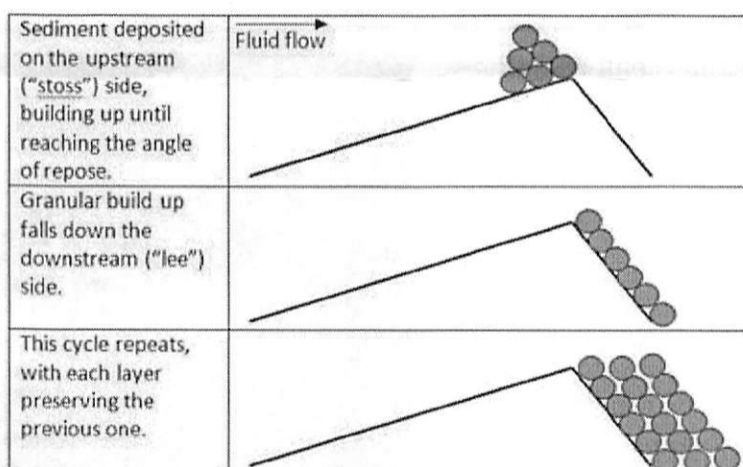
Geology

Sometime during the Pleistocene Epoch (1.3 million to 10,000 years ago), the Niobrara River began carving a broad valley through what is now eastern Wyoming and northern Nebraska. As the river cut down through the plain, it exposed layers of gray sandstone, shaping them into cliffs and buttes. These rock layers are much older than the Niobrara and reveal how the environment both sustained the animals that roamed the area 19 million years ago and then preserved their fossil remains.

Airborne Ash and Sand

Geologists classify rocks into three types: *igneous* rocks, formed by the cooling of molten material; *sedimentary* rocks, consisting of particles deposited by wind or water or through chemical precipitation; and *metamorphic* rocks, formed from pre-existing rocks altered by heat and/or pressure. The rocks at Agate Fossil Beds are a cross between igneous and sedimentary deposits, in that much of the sediment

began as ash blown out of volcanoes in southern Utah and Nevada. These repeated eruptions resembled that of Mt. St. Helens in 1980 and spread ash over a wide geographical area. Seasonal streams brought sand and silt from the uplifting Rocky Mountains to the west and with the wind, reworked the ash deposits. The resulting sediments suggest a semi-arid climate.



The dune deposits found on the Daemonelix Trail formed as ash, sand, and grit drifted with the wind. The sloping lines in the rock face are the "slip-face" surfaces of the dune, where grains blown up the stoss side of the dune cascaded down the front face. This tells us the prevailing wind direction was from the northwest at the time the dunes formed.

Ancient Habitats

Geologists divide the rock strata at Agate Fossil Beds into two formations: the older Harrison and the younger Anderson Ranch. A formation is a layer of rock that can be distinguished from other layers by characteristics such as composition, grain size, fossil content, and color. While the Harrison Formation comprises wind-blown ash and sand, the Anderson Ranch Formation is marked by the presence of ancient soils, limestone lake deposits, stream channel deposits, and the remnants of waterholes. The two formations are also separated by an "unconformity" – an ancient erosional surface that indicates a break between periods of deposition. The sediments and the fossil remains together suggest that as the sands of the Harrison and Anderson Ranch Forma-

tions were deposited east of the mountains, the climate became drier and a savannah of mixed trees, shrubs, and grass gave way to grassland, causing both plants and animals to adapt or face extinction.

The streams of the Anderson Ranch Formation cut and then abandoned channels that became water holes. These waterholes attracted animals, many of which died there during periods of drought. The rapid deposition of ash and sand provided a perfect environment for fossil preservation. They both covered the remains of ancient mammals quickly and produced an alkaline chemical environment which stabilized the bones.

From Dust in the Wind to Solid Rock

Ground water moving through the sediments carried dissolved calcium carbonate. As the water evaporated, the calcium carbonate bound the grains of sand, silt and ash together into a limestone-cemented rock. Most of the rock in the Harrison and Anderson Ranch Formations is not well-cemented and erodes easily. However, in

some places, groundwater flow has concentrated the cement, creating hard concretions that jut out of hillsides. The hard caprock topping many buttes and cliffs along the Niobrara is a thin, white limestone formed in shallow, scattered freshwater lakes.

Geologic Clocks

The volcanic ash provides a way to date the rocks at Agate Fossil Beds. Dating Zircon crystals within the ash, geologists determined that the sandstones below the bonebed on Carnegie Hill were approximately 22.9 million years old. Zircon crystals contain $^{238}\text{Uranium}$. Because $^{238}\text{Uranium}$ decays to Lead at a constant rate, geologists can compare the ratio of the two elements and determine an age for the ash. The bonebed itself is estimated to be 19.2 million years old.



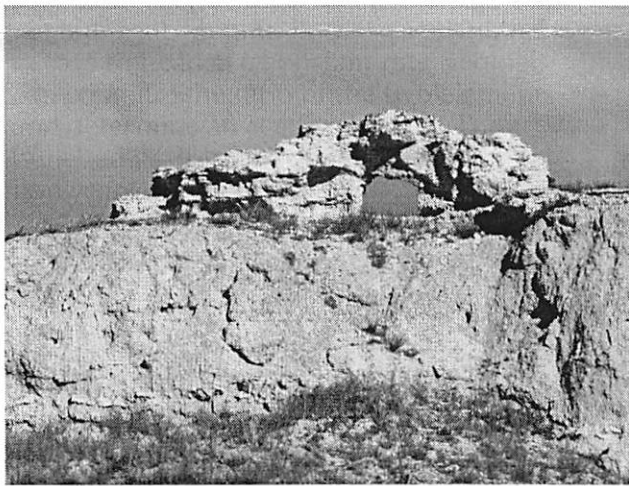
An ash deposit exposed in a white cliff north of the road, 1 mile west of the Visitor Center.

Agate

When he purchased the 04 Ranch in 1887, James Cook renamed it Agate Springs Ranch for the agate found in the area. Agate is a microcrystalline form of silica precipitated from solution in groundwater. Iron and manganese inclusions make the local stone a “moss” agate, which lacks the characteristic banding of “true” agate. While most agate occurs in volcanic

rocks, the agate found along the Niobrara formed in sedimentary rocks from silica derived from volcanic glass within the ash deposits. Native peoples rarely used Agate Springs Agate for tools, preferring to travel to chert quarries at the Hartville Uplift 30 miles to the west for more adaptable, longer-lasting materials.

Erosional Features – the Work of Wind and Water



When the ancient Niobrara began cutting down through the Harrison Formation thousands of years ago, it was a much larger stream, fed by a wetter climate. At Agate Fossil Beds, an east-west fault created a zone of weakness in the rock that the river followed. As the valley eroded, the river carved out buttes such as Carnegie and University Hills; in such places as Turtle Rock, it left only remnant spires, or “hoodoos”.

At the east boundary of the park, a circular window appears in the north cliffs. Such windows form when ground water weakens the ce-

ment binding grains within a thin “fin” of rock. Windblown sediments erode the face of the fin, eventually boring a hole, or “window” through the rock.

Erosion also exposed the long-buried fossil remains of mammals that once roamed a broad, flat plain traversed by ephemeral streams. Now, standing in a land of buttes and valleys, this lost world is both strange and familiar. Mammals still populate the landscape, but their forms have changed dramatically. The land remains arid, but now sees wide swings in temperature between summer and winter seasons. Wind and water continue to prevail as the forces that shape both life and matter in this corner of the high plains.

Regional Geology: The Bigger Picture

The sedimentary layers at Agate Fossil Beds also form the upper walls of Scotts Bluff. To the north of Agate, the White River carved the Pine Ridge Escarpment at Fort Robinson and Crawford from the Monroe Creek Formation, a late Oligocene-age windblown ash deposit which is beneath, and thus older than the Harrison Formation. Windblown ash and stream channels formed the White River deposits at Toadstool

Geological Park 38-29 million years ago, during the Eocene and Oligocene epochs. The harder sand and gravel layers of the stream deposits form the capstones of the “mushrooms” which rest on weaker ash-deposit “stems”. The White River Formation is the same rock from which the cliffs and spires of Badlands National Park in South Dakota were eroded.