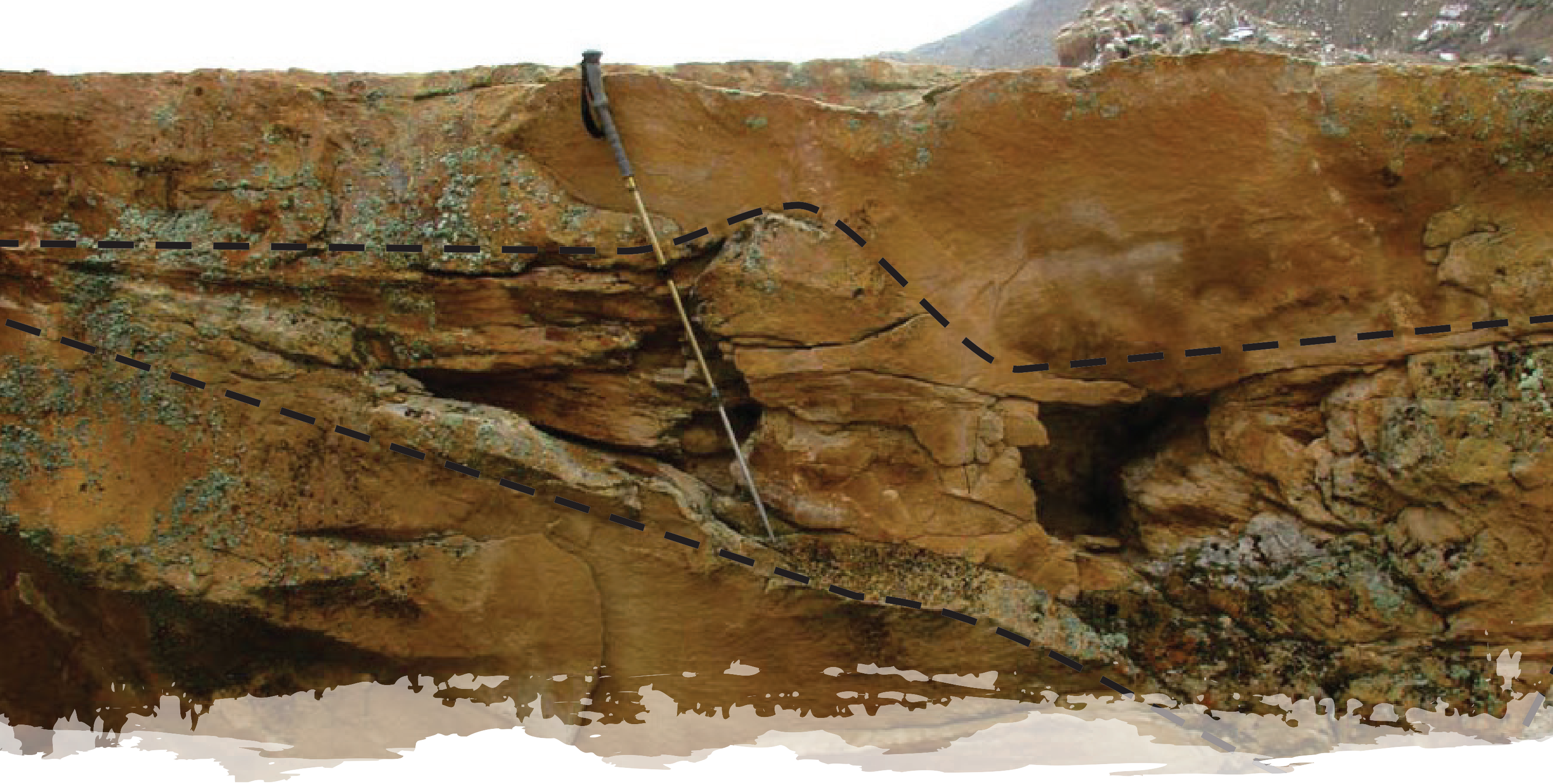

What You Can Discover on an Ancient Cretaceous Beach, a Geosite in Emery County, Utah

Paul B. Anderson
Consulting Geologist, P.O. Box 101, Emery, Utah 84522
paul@pbageo.com

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Cover Image: *Unidentified plant fossil found in the Kf-6 beach sand. Top to the right and bottom on the left. Trekking pole for scale. Dashed line approximates its outline.*

INTRODUCTION

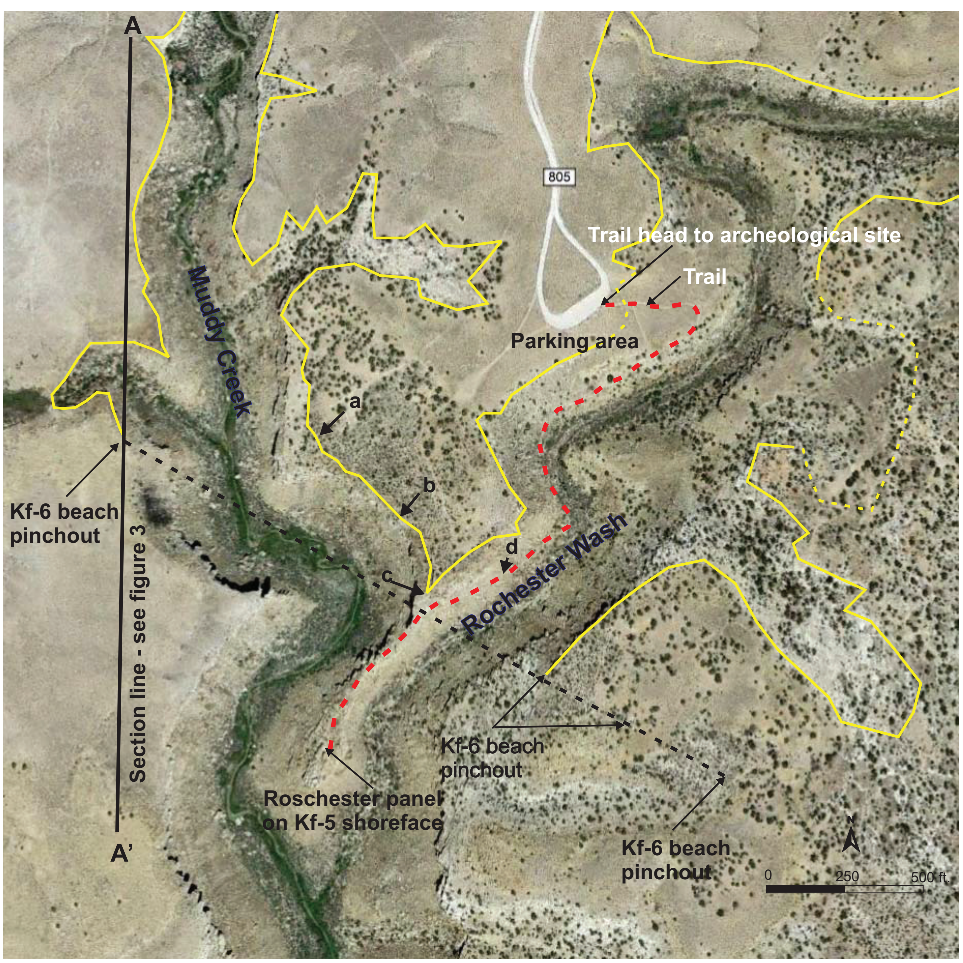
Utah was prime beach country in its central to eastern portion during the Middle to Late Cretaceous (70 to 92 million years ago). At this time, a long shallow sea extended from the Artic to the Gulf of Mexico and from central Utah east to beyond Kansas. Scores of ancient beach deposits that represent the shoreline along this seaway are exposed in the eastern half of Utah. This paper will guide you to one of these white sandy beaches that dominated central Utah during this time period. The site is located near a developed archeological site (Rochester panel, Smithsonian site number 42EM392). The Rochester panel is dissimilar to other Fremont culture images and likely dates between A.D. 500 to A.D. 700 (Loendorf, 1985). If you visit the panel please do not touch (oil from you skin damages the surface), deface, or climb on this precious resource.

DRIVING DIRECTIONS

This geosite is conveniently located near an established and often visited archeological site named the Rochester rock art panel. The panel has a developed parking area which will be your driving destination for this geosite. To arrive at the parking area from the Wasatch Front, travel south on Interstate 15 to the junction of US Highway 6, travel southeast to the town of Price, then exit Highway 6 onto State Road 10 southbound toward the town of Ferron. Continue about 9 miles (14.5 km) past the town of Ferron to the second marked left turn-off for the town of Moore (County road 801). After immediately crossing a cattle guard, proceed east 0.5 miles (0.8 km) to a right turn onto a graveled road marked with a sign, "Rochester Panel" (County road 805). Proceed south on this improved gravel road, past gravel quarries on the left (east) and at 1.8 miles (2.9 km) from the pavement, proceed past a radio tower on the left. Continue south another 2.1 miles (3.4 km), following the graveled road to a dead end in a small loop with a parking area and BLM sign (figure 1). The sign provides information about the archeological site. Park your vehicle here. However, from this point (with the GPS coordinates below) a well-marked footpath (about 1/2 miles, (0.8 km) one way) will take you to one of the state's best Fremont Indian petroglyph panels. The hike is an easy walk with about 100 vertical feet (30 m) decent from the parking area to the panel. Let me set the geologic picture of the surroundings before guiding you to several interesting geologic viewpoints. GPS coordinates for the parking area are 38°54'25"N, 111°11'43"W; (UTM 483083mE, 4306444mN).

STRATIGRAPHY

Using the parking area as our point of reference, you are parked at the approximate top of the Ferron Sandstone Member of the Mancos Shale (figure 2). Stratigraphically above this point is the Blue Gate Shale Member of the Mancos Shale, a gray-blue mudstone/shale that is visible to the northwest and continues up to the base of the tan cliff-forming unit on the Wasatch Plateau, in the distance. This first cliff-forming sandstone in the cliff face is the Star Point Sandstone (Hintze and Kowalis, 2009, section 82). Back to the parking and below the Ferron Sandstone is the Tununk Shale Member of the Mancos Shale. Look to the southeast at the tree-covered rise which follows the top of the Ferron Sandstone to a spectacular vertical cliff called the Coal Cliffs. Below the cliffs are excellent exposures of the Tununk Shale Member of the Mancos Shale (not visible from here).



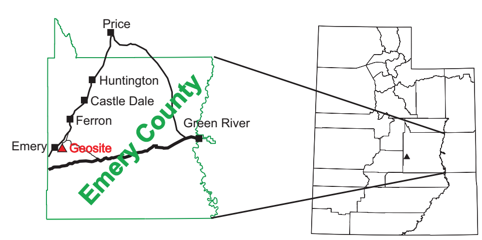


Figure 1. Index map and study area image. Yellow solid line is the top of the beach sand. Yellow dashed line is the approximate landward edge of the beach. a= access point to cliff base; b=viewing point for fossil plant; c=dinosaur tracks; d=point of departure from main trail.

The Ferron Sandstone, below your feet at the parking area, is about 500 feet (152 m) thick (Thompson, 1986) and consists of sandstone, siltstone to mudstone, and coal and almost coal (dark to black carbonaceous shale). Figure 2 is a stratigraphic column of the Ferron Sandstone found in this locale based on nomenclature from Anderson and Ryer (2004). Only the top portion of the Ferron Sandstone stratigraphy shown in figure 2 is exposed at this geosite. The sand we will focus on is labeled on figure 2 as Kf-6 and outlined in red. This further subdivision of the Ferron shown in figure 2 enables clear communication when discussing the details of the stratigraphy.

Since a large portion of the world's population is located along the seashore, rising or falling sea level is closely monitored today. The Ferron Sandstone provides us a partial record of the many changes in sea level during the Late Cretaceous. "The sea went in and the sea went out," has been used to describe the geologic history of the Cretaceous in Utah. The stratigraphic column at this site (figure 2) records five of these major shoreline fluctuations, representing about 2 million years of earth's history. Minor shoreline shifts are represented by the various sub-units (parasequences) of the Kf-2 parasequence set. The stratal package names are shown to the right of the rock column in figure 2. The naming scheme is Kf for Cretaceous (K is commonly used to denote Cretaceous because another period already claims the letter "C"), then a dash, and then a number or name. The numbered units begin at the bottom of the Ferron and are sequentially numbered in ascending order. Ryer (1981) originally described and numbered these units as "delta-front units" which formed as sediment deposited at the shoreline by rivers flowing generally from southwest to northeast. The unit we will focus on is Kf-6, or one of the shorelines that lies near the top of the strata stack.

STRUCTURE

This geosite lies on the west flank of a large elongated dome called the San Rafael Swell. Looking to the southeast from the parking lot, you will notice the tree-covered slope rising at about five degrees. The Ferron Sandstone has been tilted in this direction by the rise of this large geologic structure which began to move slightly, soon after deposition of the Ferron. The more rapid rise of the structure began about 65 million years ago (Hintze, 2005), so the rocks on the San Rafael Swell have been eroding to look like our present landscape for millions of years. This present tilt or dip of the beds of the Ferron Sandstone plays an important part our story of the present landward disappearance of the Kf-6 beach sand. You will note at the parking lot that the landscape in the opposite direction of the southeast ridge is very different. Not only is there lack of trees (pinyon and juniper trees need sandy soils), but this sharp vegetative boundary marks the top of the Ferron Sandstone Member and the base of the Blue Gate Shale Member. The softer shales of the Blue Gate erode into a wide low land or "valley," hence the name Castle Valley for this portion of Utah.

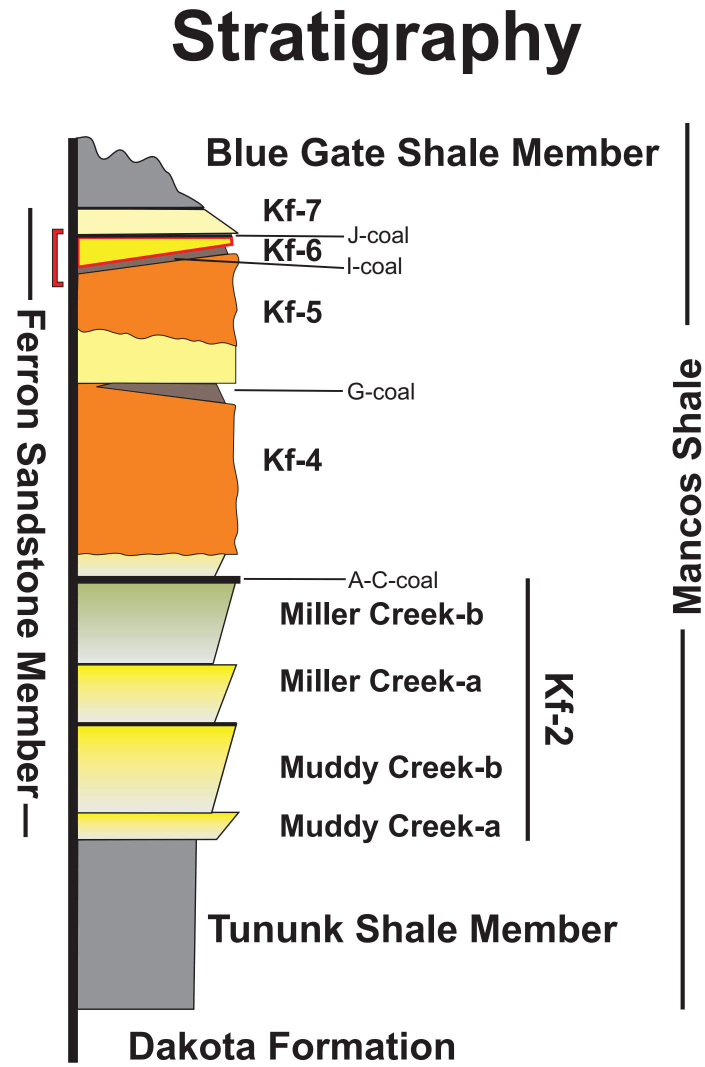


Figure 2. *Stratigraphy of the Rochester geosite. Yellow hues are shoreline or beach-related sand bodies. Orange are river-deposited, and brown and black are deposited in swamps. Gray is offshore marine shale. Red bracket – the focus of this geosite (see figure 6 for a depositional history of this interval).*

GEOLOGIC HISTORY

Setting the Scene

An important part of the story of the Ferron Sandstone "wedge" is the more regional history of the large continental plates of crustal material that "float" on the top of the earth and have dramatic movements when viewed on the scale of millions of years. Along the western edge of the North American Plate, the adjacent Pacific crustal plate was growing from a spreading center in the mid-Pacific but because of its growth along the spreading ridge the expanding plate was forced to dive or subduct along the bordering North American Plate. We call this collision zone a subduction zone. The force of the collision caused large sheets of the North American continental crust to be pushed or thrusted over one another, like a pile of playing cards being pushed together. The result was a "pile" of over-thrusted crustal pieces in western Utah and eastern Nevada. The great weight of this pile of crustal sheets (called the Sevier Orogenic Belt), loaded the North American Plate and caused it to sink, sag, or subside. Since the crust is semi-rigid, this sinking deformed the crust out in front of all this loading, causing a low or downwarp to form. Geologists call this downwarp a foreland basin because it lies in front of or before the area of crustal loading. The subsiding foreland basin eventually dropped below sea level through a good portion of the Late Cretaceous Age, forming the Western Interior Seaway (figure 3) where sediments from the eroding upland area to the west began to accumulate.

Figure 3. Paleogeographic map of North America (modified from Blakey, 2006). Red dot is our geosite.

Now we have a mechanism to explain why the Ferron Sandstone consists of a vertical stack of sandstone and other rocks. As each shoreline or delta-front fills in the shallow sea now occupying the foreland basin, the combination of loading from the deposited sediments and more thrusting and loading to west, causes the foreland basin to continue to subside, setting the stage for a shoreline to move back over the prior deposited sediments and add additional sandy shorelines and lower coastal-plain sediments into this continuously subsiding basin. These crustal fluctuations are considered "local tectonics" or plate motion, but world-wide sea level changes were also taking place. These sea level changes must be added to the possible causes of shoreline fluctuations (rise and fall). As a means of tracking these shoreline movements we often refer to movements of the shoreline towards the seaway or the basin as "seaward" and those in the opposite direction as "landward" since the shoreline is moving towards the land.

The Kf-6 beach (shoreline) edge or pinchout

Proceed west to the edge of Muddy Canyon to a point labeled "a" in figure 1 (UTM NAD83 482823mE, 4306322mN). From here you will have a commanding view of the west side of the canyon where the Kf-6 beach pinchout is superbly exposed. Figure 4 is a diagrammatic cross section drawn on a line just west of the exposed outcrop and shown on figure 1. The view of the west side of Muddy Canyon from your vantage point should be similar to the cross section, figure 4. Note the vertical exaggeration in the cross section distorts the true scale relationship, which you see in the canyon wall. The base of the cross section (figure 4) and the drainage bottom in the view to the west before you are approximately equal. The prominent gully cutting the cross section lies almost directly across the canyon. The cliff-forming sandstone, lying on the north side of the gully depicted in the cross section is the Kf-6 beach or shoreline sandstone. Please refer to figure 5a and b, which is a series of photographs taken from the east side of Muddy Canyon, and relate well to the cross section in figure 4.

In figure 5a, the prominence on the north side of the small gully across Muddy Canyon, is located at the end of the label "I coal zone." This is our "subject sandstone." Follow this sandstone to the left in the photo and on the outcrop, across (south) the small gully, to another prominence where it is now noticeably thinner than at our beginning point. Continue to trace the cliff-forming sand to the

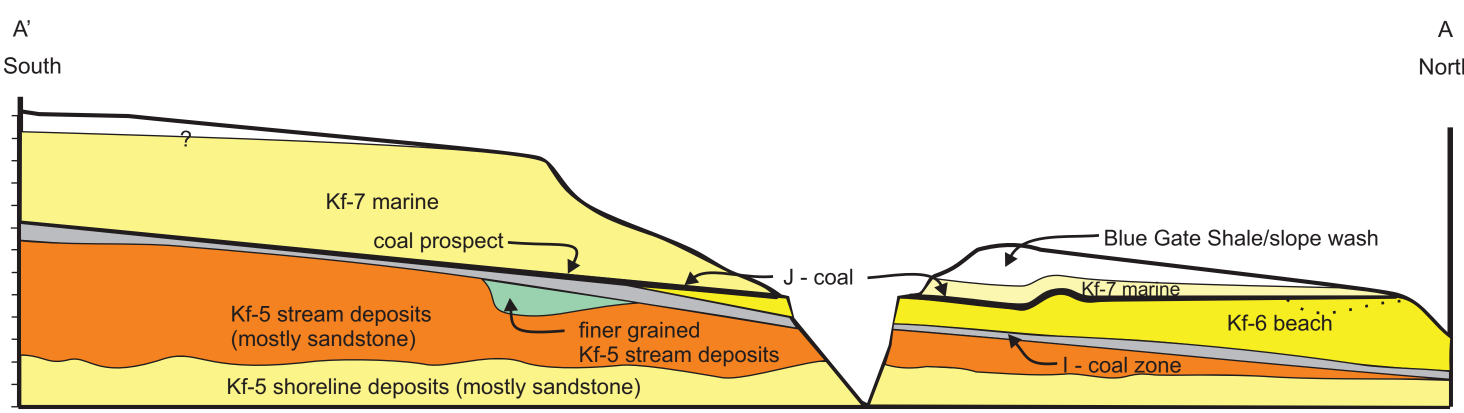


Figure 4. Diagrammatic cross section of the east side of Muddy Canyon, showing the pinchout of the beach sandstone of Kf-6 subunit (darker yellow) of the Ferron Sandstone. Line of cross section shown on figure 1.

Figure 5. Three photographs of the edge or landward pinchout of the beach sand of the Kf-6 beach. ***a)*** *View west across Muddy canyon. Partial view of the cross section in figure 3.* ***b)*** *Close up view of part of the field of view in (a). Note non-parallel bedding of the stream-laid upper portion of unit Kf-5 (orange dots) and the I coal zone (blue dots).* ***c)*** *View southeast from (a) showing the southwest (landward) thinning of the Kf-6 beach in multiple exposures along the dipping top of the Ferron Sandstone. The uppermost thinning does culminate at the pinchout.*

south (left) to a point where the sandstone thins and becomes obscured by overlying Kf-7 sandstone boulders, which have separated from the outcrop. Figure 5b is a close up of the final wedge-shaped landward edge or landward pinchout of this beach (sandstone).

Figure 5c is taken from across the canyon from your present position with the camera pointed to the southeast. You can turn from your present position on the outcrop and see a similar view. The photograph (figure 5c) is taken parallel to the shore of this approximately 89 million year old beach. Several distinctly thinning exposures of the Kf-6 sandstone cliff are visible, with the most distant (the top wedge in the photograph) also recording the un-eroded most landward position of the beach. At first glance this may seem spectacularly unimpressive, but let's connect this to a more complete picture of what this landward pinchout and several others of the same sandstone body tell us about the paleogeography and shorelines of the Ferron.

Paleogeography

Paleogeographic maps are means to express an opinion of what the landscape looked like during a specific time in the past. Figure 6 is a series of paleogeographic maps that represent the time just before, during, and after the deposition of the Kf-6 beach sand. Figure 6a depicts the time just before the Kf-6 time. The maps are drawn based on the type of rock found below the Kf-6 beach sandstone, which consists of both rocks deposited by a river system, which flowed from southwest to northeast, and a partly contemporaneous/later "I" swamp. Figure 5a shows these rocks and their relationship to those above and below. The swamp that formed the "I" coal zone was relatively close to sea. This swamp was the site of new sea level rise, likely due to new downwarping in this part of the foreland basin, which caused the shoreline of the Western Cretaceous Seaway (figure 3) to move towards the land as shown in figure 6b. At the point in time when the sea level rise stopped and the crashing waves of the sea began to establish a new shoreline, a new beach was established. With a relatively stable sea level and the continuous addition of new sand at the shoreline, the new space created by a rising sea began the slow process of filling, leaving behind the sand of the Kf-6 beach at this location (figure 6c). With each small (hundreds to thousands of years) increment of time (shown on figure 6c as Time 1-3) more sediment was added, and, with no rise in sea level, the shoreline was forced to move seaward or toward the northeast.

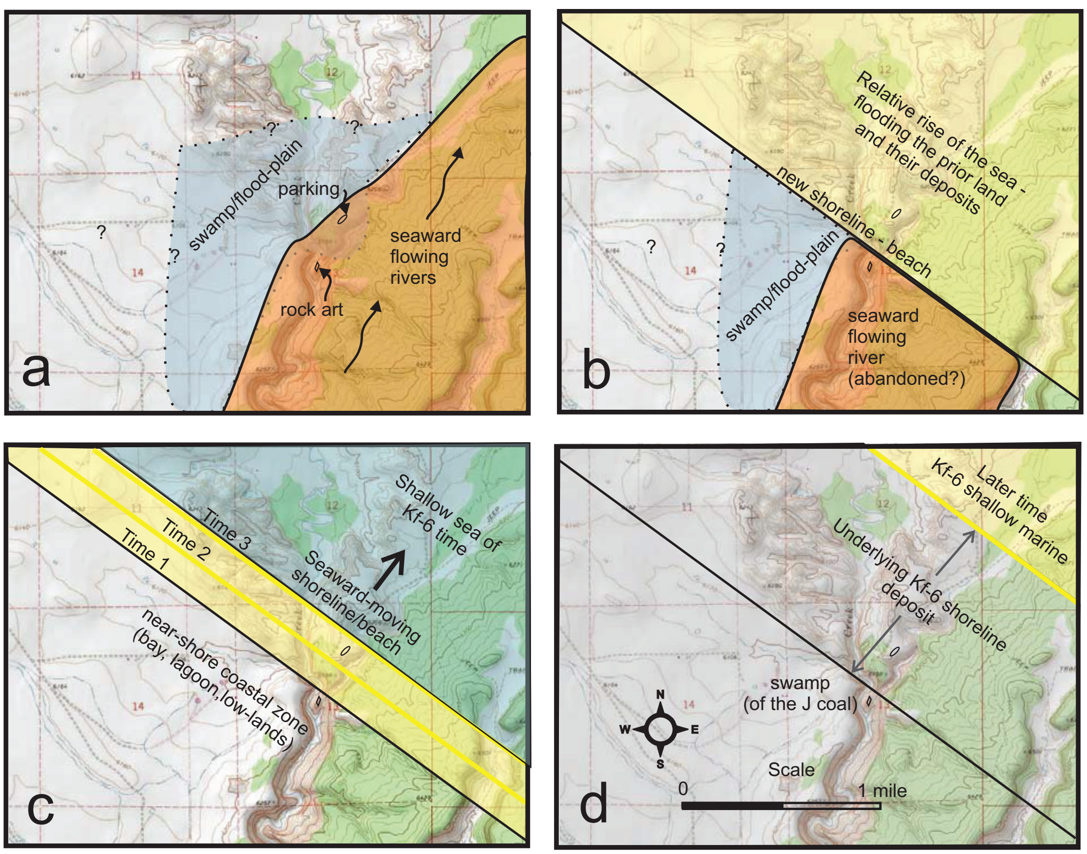


Figure 6. Maps depicting the geologic history or paleogeography (old geography) of the geosite. The stratigraphic interval depicted is shown by a red bracket in figure 2. The parking area and rock art site are labeled on (a) and shown as points of reference on all maps. a) Paleogeography of the upper portion of unit Kf-5. b) Relative sea level rises and floods over Kf-5. The first sand grains of the beach of Kf-6 are deposited at the "new shoreline - beach" (see figures 1 and 4). c) As sand is deposited along the shoreline through time (1-3) the shoreline slowly moves seaward (progrades). Landward of the shoreline are time-equivalent deposits of near-shore bays, lagoons, and low-lands. d) As the shoreline moves seaward through time, a swamp (future coal) develops at the shoreline and follows the retreating shoreline seaward. Evidence for this history is the J coal lying atop Kf-6.

The climate was subtropical during Ferron-time and the carbon dioxide levels were estimated to be about 2000 ppm (2000 mg/kg), compared to our present 400 ppm (400 mg/kg), a good time to be a plant. Not surprising, low coastal areas were the site of marshy peat swamps and that is precisely what grew on the newly created land at the seashore as the shoreline or beach retreated to the northeast. Figure 6d depicts this paleogeography with the black diagonal line representing the edge or first deposits of the Kf-6 shoreline and its movement seaward to the bold yellow line. In figure 5a a few black spots on the outcrop represent small exposures of the J coal, deposited in this swamp. Figure 7 provides additional evidence of the swamp showing rooting of the J peat into the top of the Kf-6 beach sandstone. If the top of the Kf-6 sandstone is followed on outcrop to the north about one-half mile (0.8 km), the abandoned Williams Mine will be encountered. In the late 19th century a small amount of coal was mined here from the J coal; suppling a limited local market.

Dinosaur Tracks and plant fossils

The I coal swamp, which underlies the Kf-6 beach sand, was home to dinosaurs. We know this because we find their footprints in the bottom of the Kf-6 beach sand in this location. Figure 8 depicts a couple of these better-preserved tracks. See figure 1 for the location of the photograph in figure 8. Lumpy bottom beds of the Kf-6 sandstone are common on fallen rocks in the area. Many of these "lumps" are likely created by roaming dinosaurs at the end of the I peat swamp time. The three toed prints are likely produced by an ornithopod dinosaur (Michael R. King, personal communication 2018). Ornithopods are plant-eaters. These tracks can be accessed by departing the trail to the rock art at point "d" in figure 1, by making a scramble up a steep slope and following the base of the cliff of the Kf-6 beach sandstone south to point "c" between Muddy and Rochester drainages.

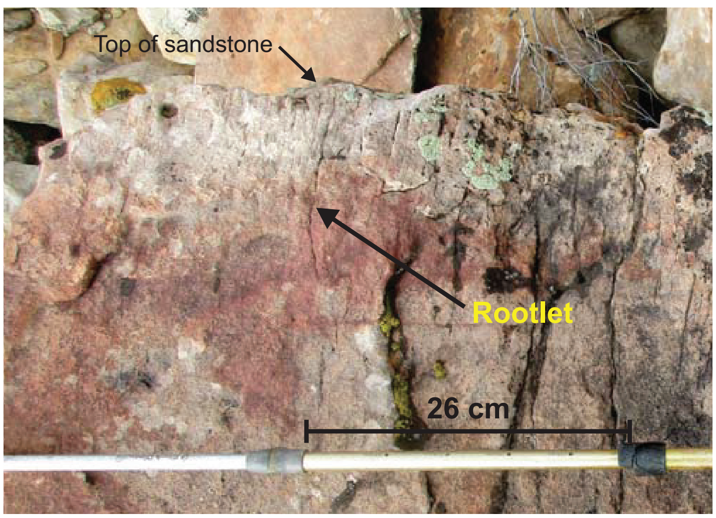


Figure 7. Rooting (black carbonaceous vertical "stringers") in the top of the Kf-6 beach sandstone supporting the development of vegetation of the J peat swamp which was established on the top of the sand.

Figure 8. Dinosaur foot prints on the bottom of a fallen block of the Kf-6 sandstone just west of the prominence separating the Muddy and Rochester drainages. Trekking pole for scale.

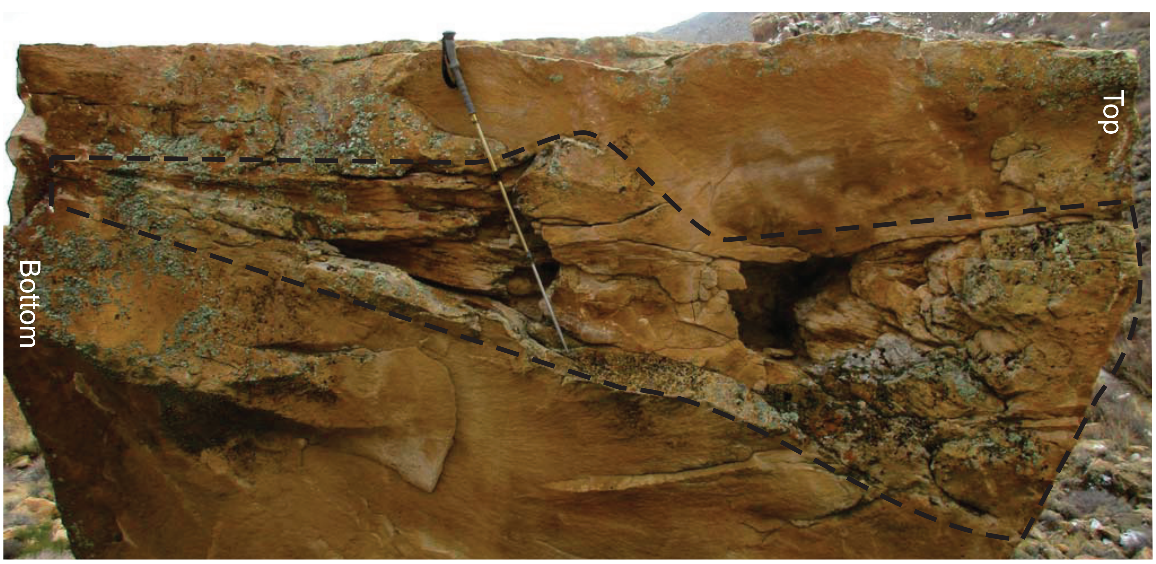


Figure 9. Unidentified plant fossil found in a boulder of the Kf-6 beach sand. Top to the right and bottom on the left. Trekking pole for scale (3.9 feet (1.2 m)). Dashed line approximates its outline. The overall length is about 12 feet (3.7 m) with the width at the upper crown at about 3.5 feet (1.1 m). Location shown in figure 1.

Plant fossils, in growth position, are common in the vertical cliffs and in fallen blocks of the Kf-6 beach sand in the area. Figure 9 is an excellent example of one of these fossils. It lies on the face of a fallen block and can be observed in detail if one is willing to clamber along the outcrop west from the dinosaur tracks. The location of the block in figure 9 is shown on figure 1, location "b." The fossil is viewable from the top of the cliff edge for those unwilling to scramble. Many other specimens of the same plant can be found in the vertical cliff face, but seem to be limited to within about 1/3 mile (0.5 km) of the landward pinchout of Kf-6. Since discovering this community of fossils, this same fossil has been identified in a similar environment of deposition in the younger Kf-4 at a different locality.

Attempts to identify the plant fossil are ongoing. Some believe it is a tree with a tap root, but good modern examples that come close but are not a perfect match. The flaring "head" of the fossil complicates the match with a tree. The fossil occurs in the sandstone at various stratigraphic positions, but rarely in the bottom 1/3 of the sandstone.

Archeological Note

Figure 1 shows the location of the Rochester Rock Art panel. Following the well maintained trial from the parking will lead you to the rock art. This spectacular panel is chipped or carved on the flat face of marine shoreface rocks from the Kf-5 stratigraphic unit. If one looks around the canyons from the panel, this same stratigraphic unit can be followed on both sides of Muddy Canyon. It is distinguished by flat vertical faces and typically a dark "desert varnish" veneer in the lower portion of a vertical cliff-face.

ACKNOWLEDGMENTS

Thomas A. Ryer first introduced me and many other geologists to this locality. Tom passed away in 2014 and this paper is a dedication to his vision and story-telling talents. Thanks to Michael (Ryan) King for his interest and help with the trace and plant fossils, and Julie Howard for her help with archeology. The reviews of Mary Ann Wright, Kathy Anderson, Ryan King, and Mark Milligan were greatly appreciated. Thanks to the editors of this volume for their dedication to education of the public about the marvels of Utah's geology.

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