

A Survey of Fossils and Geology of Red Rock Canyon Open Space, Colorado Springs, Colorado¹

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ABSTRACT

Red Rock Canyon Open Space (RRCOS) is a 785-acre open space in the western foothills of Colorado Springs, Colorado. The City of Colorado Springs opened RRCOS to the public in October 2003. Because this acreage has been in private ownership since the late 1800s, there has been little documentation of fossils or geology within this property.

Although continuous with the stratigraphy of nearby Garden of the Gods Park, the geology of RRCOS shows remarkable differences. Of primary significance are the relatively uninterrupted, upturned exposures of a sequence of strata comprised of the Fountain Formation, Lyons Sandstone, Morrison and Ralston Creek formations, Purgatoire Formation, Dakota Sandstone, the Benton Shale, Niobrara Formation and Pierre Shale. The majority of formations can be seen within a 1.5 kilometer (km) west to east transect. Lying horizontally over these vertical beds are the Mesa Gravels (equivalent to Verdos Alluvium). Within these formations several sites of geologic interest to the Colorado Springs community were recorded, in particular, the spectacular eolian crossbeds within the Lyons Sandstone.

Fossils documented through this study include apparent roots within the Fountain Formation, and numerous tree imprints, leaves, and Ankylosaurid and Iguanodontid tracks in the Dakota Sandstone. The Codell Sandstone and Niobrara Formation display shark and fish teeth, ammonites, inoceramids, a possible Mosasaur palatine tooth, and tail or fin rays of an *Ichthyodectes sp.* fish.

INTRODUCTION	2	Lower Cretaceous Dakota Sandstone	8
GENERAL GEOLOGY	2	Upper Cretaceous Benton Shale	9
Pennsylvanian Fountain Formation	2	Upper Cretaceous Niobrara Formation	11
Pennsylvanian/Permian Lyons Sandstone	4	Quaternary Mesa Gravels	12
Permian/Triassic Lykins Formation	7	ACKNOWLEDGMENTS	13
Jurassic Morrison Formation	7	REFERENCES	13
Lower Cretaceous Purgatoire Formation	8		

INTRODUCTION

Paleotrails Project: Red Rock Canyon has been a cooperative project between volunteers Sharon Milito and Michael Poltenovage, geologist Ken Weissenburger, and the Parks, Recreation and Cultural Services Division of the City of Colorado Springs, with support from the Denver Museum of Nature & Science (DMNS). The purpose of this study was to detail the fossils and geology, to provide information for the interpretation of Red Rock Canyon Open Space (RRCOS), and to supply exemplary fossil specimens for public display by the Colorado Springs Pioneers Museum and other city sites.

RRCOS is located at South Ridge Road and U.S. Highway 24 (Hwy 24), on the western edge of the city of Colorado Springs, Colorado. Although located near two major Front Range faults, the Rampart Range Fault and the Ute Pass Fault, RRCOS is relatively unfaulted and provides uninterrupted exposures of a sequence of strata dating from about 300 to 70 million years ago (Ma). The same strata in the nearby and better known Garden of the Gods Park straddle the Rampart Range Fault zone and are characterized by faulted and fractured outcrops.

In contrast to the Garden of the Gods Park, RRCOS has a long history of quarrying for sandstone blocks, gravel, gypsum, clay and limestone. Quarrying in the Codell/Fort Hays and Dakota hogbacks, in particular, has exposed otherwise concealed fossils which have been documented for the first time during this survey. Matt Mayberry, the Cultural Services Director for the City of Colorado Springs, has stated that the City has a responsibility to present and protect resources. In support of this philosophy, the Parks, Recreation and Cultural Services Department of Colorado Springs recently completed the Interpretive Master Plan for RRCOS. The City of Colorado Springs has begun to place interpretive signage at trailheads to include geology and paleontology, from information provided in part by this project. A generalized trail map for RRCOS is shown in Figure 1.

This paper is a summary of the technical report, "*Fossils and Geologic Points of Interest in Red Rock Canyon Open Space, Colorado Springs, Colorado*" (Milito, 2008), submitted to the Colorado Springs Parks, Recreation and Cultural Services and to DMNS at the conclusion of the survey. A detailed fossil inventory and stratigraphic record of fossil locations is included in that report.

GENERAL GEOLOGY

Strata in RRCOS are typical of the formations uplifted during the Laramide Orogeny along the Front Range of Colorado (Fig. 2). Paleozoic and Mesozoic strata, roughly 1500 meters (m) thick, strike approximately north and dip 70 to 90 degrees east (Fig. 3). These older sedimentary

rocks are covered intermittently by a veneer of sub-horizontal Quaternary Mesa Gravels up to 10 m thick.

A period of uplift beginning about 17 Ma (Noblett, 1994) allowed the necessary conditions for differential erosion to ultimately produce the prominent hogbacks and valleys of the area (Fig. 2). Through the recent Ice Age multiple cycles of pediment gravel deposition and subsequent dissection continued the creation of the current landscape (Chronic and Williams, 2002). Viewing RRCOS from the north, the sculpting of the landscape is evident. Crests of the outcrops are level with the neighborhood on the mesa overlooking the open space, while strike valleys and canyons 40 m below are etched between the more resistant layers. Precambrian basement rocks of the Pikes Peak region do not crop out within the boundaries of RRCOS.

The stratigraphic column (Fig. 4) presents formation thicknesses near the central portion of RRCOS along the cross-section line A-A', shown in Figure 3. Thicknesses are based on measurements from aerial photos supplemented by field checks. Qualitatively, formations thin northward in RRCOS to a minimum at the park's northern boundary.

Formation names utilized in this article are those commonly used to describe the stratigraphy of south central and southeastern Colorado, and may differ in part from terminology used elsewhere. Formation names are based on those first described by Finlay (1916), later by Grose (1960) and Noblett (1994), and more recently on geologic maps published by the Colorado Geological Survey (Keller et al., 2005; Carroll and Crawford, 2000; Morgan et al., 2003). Descriptions that follow emphasize the author's observations at RRCOS. More detailed stratigraphic information can be gained through the above publications.

The majority of fossils documented during this survey are still within their respective outcrops in RRCOS. Specimens that were collected have been accessioned into the collections of the Colorado Springs Pioneers Museum.

Pennsylvanian Fountain Formation

The Fountain Formation is generally nonfossiliferous and consists of mixed lithologies of alternating layers of arkosic conglomerate, sandstone, and mudstone. Similar to exposures in the Garden of the Gods Park, the Fountain Formation covers the western half of RRCOS, and approximately 700 m of the upper Fountain Formation is exposed. The Fountain Formation crops out as discontinuous fins; the largest, most massive fins are in the southwest portion of RRCOS, rising 40 m or more from the valley floor (Fig. 2). Visitors to RRCOS can see a low-angle, eastward-dipping fault in the Fountain Formation located in the southwest corner of the main parking lot, just west of the Hwy 24 road cut.

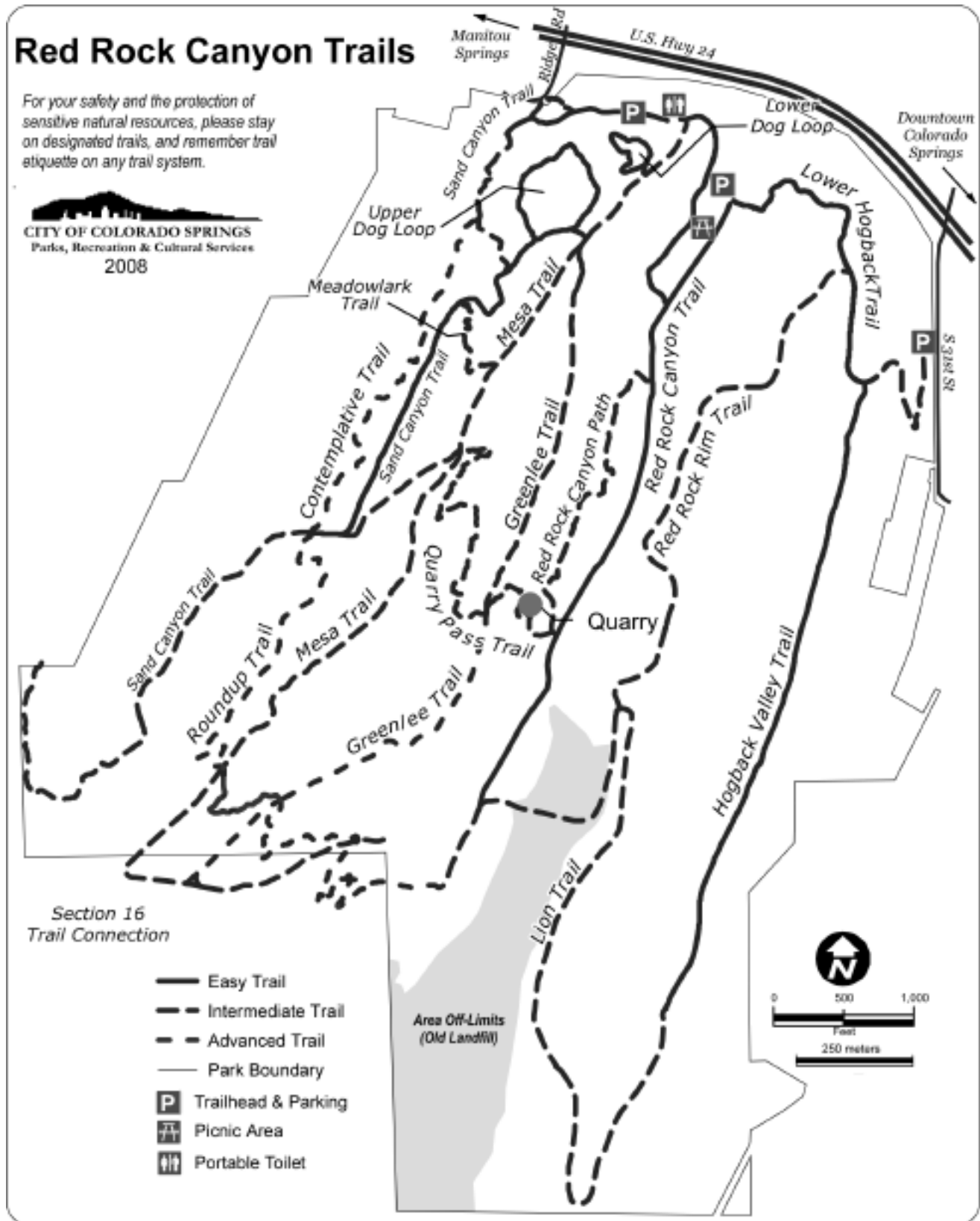


Figure 1. City of Colorado Springs Parks, Recreation and Cultural Services 2008 trail map of Red Rock Canyon Open Space shown in relation to Hwy 24.

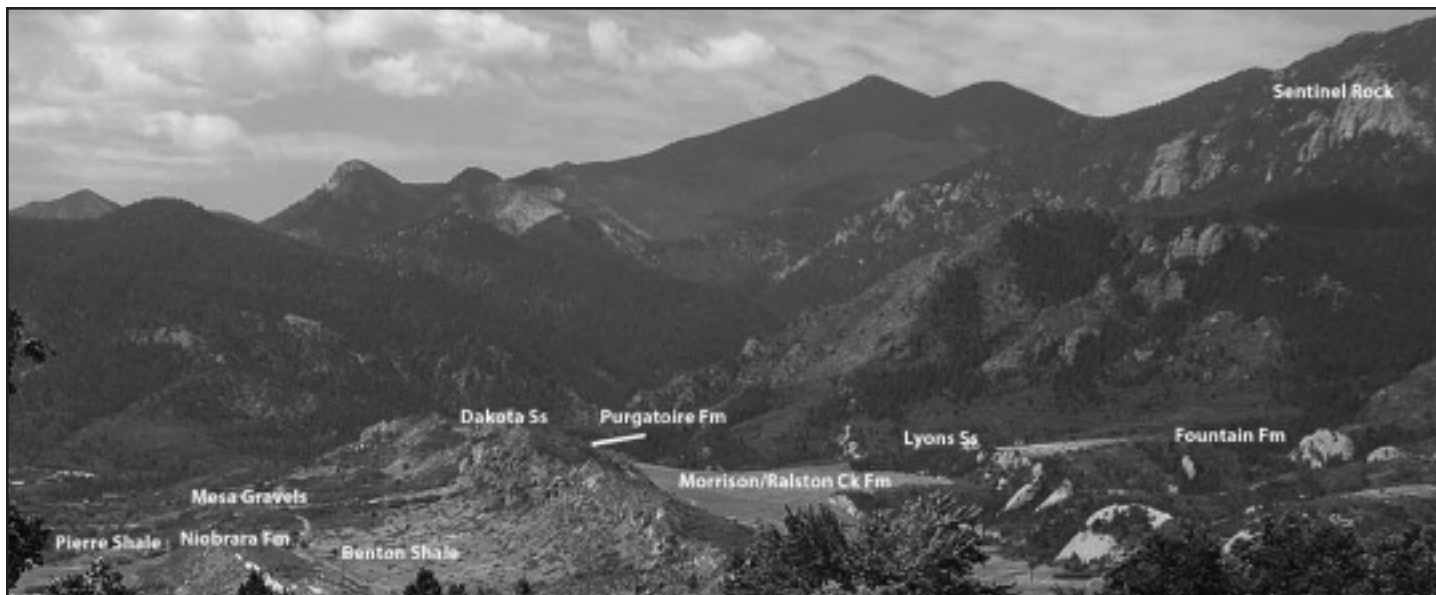


Figure 2. Red Rock Canyon Open Space, Colorado Springs, CO. Photo taken looking southwest from parking lot of Colorado Springs Shrine Club Hall, 6 South 33 Street, Colorado Springs, CO.

Conglomeratic layers displaying trough crossbedding contain clasts up to 15 centimeters (cm) in diameter of angular- to subrounded-constituents of Proterozoic Pikes Peak Granite and Idaho Springs formations (Grose, 1960), as well as chert fragments. The Idaho Springs Formation source rock is described as magmatic gneiss by Keller et al. (2005). Exposures of micaceous red and white mudstone layers are also present in several outcrops.

Near the Hwy 24 road cut at the north end of RRCOS, Cross (1894) described the Fountain Formation. There is no type locality. The Fountain Formation was named for the distinctive structures shown near Fountain Creek below Manitou Springs, Colorado consistent with the location of RRCOS (Geolex, 2008). The Fountain Formation records the uplift and erosion of the Ancestral Rocky Mountains, which rose to an elevation of 3,000 m above sea level (DeVoto, 1980). Finlay (1916, p. 6) stated, “The section of the formation between Manitou and Colorado City illustrates particularly well the several characteristic facies.” Later study by Grose (1960, p. 190) described “angular cobbles of Precambrian rocks, poor sorting, torrential crossbedding, and other features indicate short distance of transport.” The presence of mica in the mudstone layers in RRCOS also indicates deposition near the source.

Due to the high-energy streams at the time of deposition, fossils are rare in the upper 700 m of the Fountain Formation in RRCOS. The marine environment of the lower Fountain Formation (Maples and Suttner, 1990) does not appear in RRCOS. Nevertheless, near the main parking lot at the north end of RRCOS, doctoral student Dustin Sweet of the University of Oklahoma found what may be

fossil roots 2 cm in diameter and up to 30 cm in length, situated parallel to the bedding plane (Weissenburger, 2007, pers. comm.).

Pennsylvanian/Permian Lyons Sandstone

In contrast to the towering outcrops of Lyons Sandstone in Garden of the Gods Park, the red sandstone forms long, unbroken, rounded hogbacks in RRCOS. The Lyons Sandstone forms the most prominent hogback in RRCOS, and consists of mixed lithologies. It has a gradational contact with the Fountain Formation. The base and top of the Lyons Sandstone primarily consist of well sorted, pink to red, fine- to medium-grained, calcite cemented quartz sandstone. The middle of the formation is composed of arkosic conglomerate, sandstone and mudstone similar to the Fountain Formation. The basal sandstone is massive with a higher calcite content than the upper Lyons Sandstone. The upper Lyons Sandstone is strongly crossbedded and splits easily between the beds. Historically, the Hwy 24 road cut at the north end of RRCOS has been of great interest, with Lyons Sandstone visible there.

The middle Lyons Sandstone is easily eroded and forms a valley between the resistant lower and upper units. Remnants of the middle layers are exposed on the Red Rock Canyon Trail (Fig. 1) at several locations. All exposures of the middle Lyons Sandstone contain quartz and chert pebbles, and sandstone rip-up clasts up to 10 cm within a sandy, conglomeratic matrix. One location displays isolated (linguoid) current ripples. At the top of the formation, the

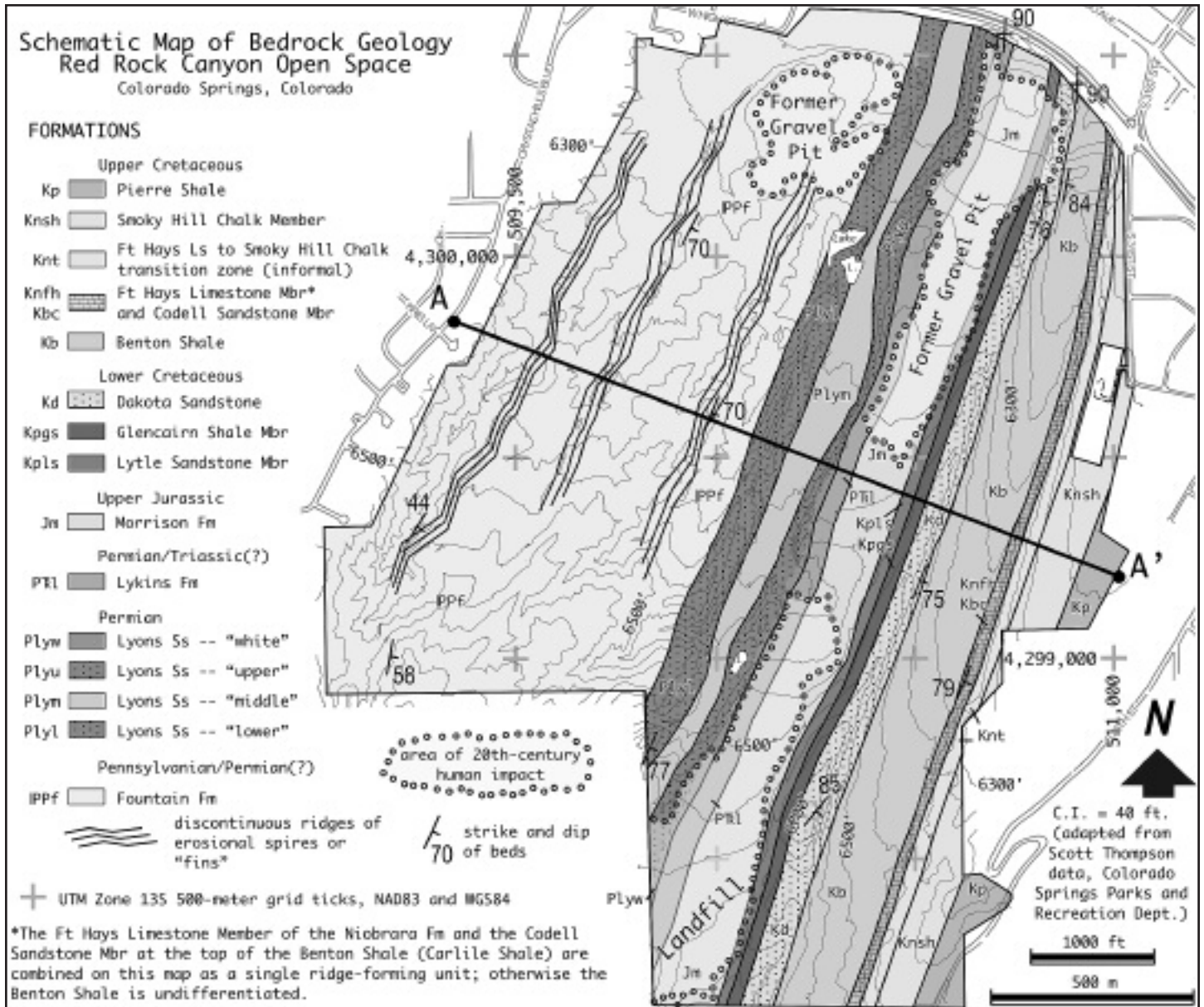


Figure 3. Geologic map of Red Rock Canyon Open Space, Colorado Springs, CO (Weissenburger et al., in press). Please note that Hwy 24 is at the top of the map.

white Lyons Sandstone crops out in limited exposures. No fossils were noted in the Lyons Sandstone outcrops in RRCOS.

Prominent features of the Lyons Sandstone are well preserved, eolian crossbeds (Fig. 5). Undisturbed by faulting and fracturing, the crossbeds in RRCOS present examples of windborne sands more typical of those on the Colorado Plateau than along the Front Range. Multiple layers of truncated dunes spanning 70 m of section can be seen in several locations preserving at least 14 cycles of sand sheet deposition along coastal Colorado (Weissenburger et al., in

press). Weissenburger's analysis of foreset crossbedding in the upper Lyons Sandstone shows a consistent prevailing wind direction from the northeast.

The red coloration of the Lyons Sandstone created by the hematite content of the rock suggests "intense oxidation because of longer exposure to subaerial weathering" (Weimer and Erickson, 1976, p. 124). From this and other evidence, Weimer and Erickson (1976, p. 127) concluded the Lyons Sandstone in the Denver/Golden area was deposited in a desert environment "between the Front Range Highland to the west and an evaporate basin to the

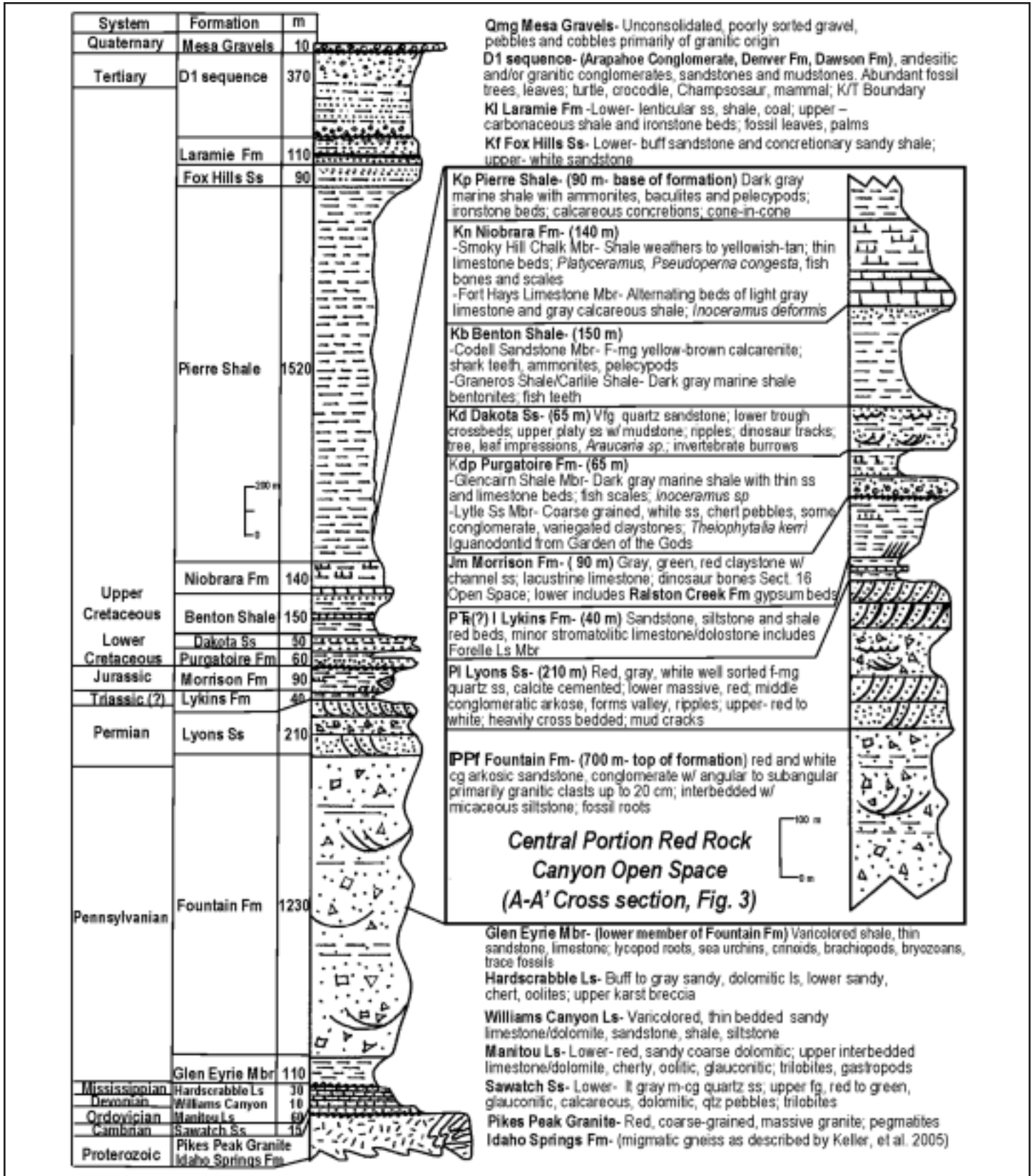


Figure 4. Stratigraphic section of Colorado Springs and Red Rock Canyon Open Space, Colorado. Colorado Springs stratigraphic column after Grose (1960).



Figure 5. Crossbeds in upper Lyons Sandstone.

east.” An outcrop in adjoining White Acres Open Space displays paleo mudcracks as viewed from the underside, and presents further evidence of an arid environment.

The lower Lyons Sandstone in RRCOS has been quarried for use in construction in the Colorado Springs and Denver regions. Redstone Castle in Manitou Springs, Colorado, as well as several Denver buildings listed on the National Register of Historic Places, such as the Molly Brown House, Central Presbyterian Church, and the Masonic Temple (Murphy, 1995) are constructed of blocks quarried at the Kenmuir Quarries and other smaller quarries in RRCOS. The bulk of stone from Red Rock Canyon Quarry was used in Denver homes and buildings during the 1880s and 1890s. Financial hard times and the development of cost effective alternatives, such as steel reinforced concrete, resulted in a short life for the Red Rock quarries. Quarries are visible in several locations in RRCOS, and stair steps chiseled into the outcrops by quarry workers are a part of the Quarry Pass Trail (Fig. 1). Within the quarries, the internal structure of the Lyons Sandstone can be examined.

Permian/Triassic Lykins Formation

The Lykins Formation consists of fine-grained sandstone, siltstone, mudstone, shale and dolomitic limestone. Broin (1957) conducted extensive studies of the Lykins Formation. One of his study sites was the Hwy 24 road cut, which was his Measured Section 28. At this location, Broin documented the following members of the Lykins Formation: the Glendo Shale Member, Falcon Tongue of the Minnekahta Limestone Member, the Harriman Shale Member, the Forelle Limestone Member, and the Strain Shale Member. The complete section at Hwy 24 was also measured and examined during this survey.

Other than the road cut, only a few sporadic outcrops of the Lykins Formation are visible within RRCOS. Two obscure outcrops display the red beds and the white dolomitic limestone containing the wavy pattern of stromatolites, indicating the fossilized remains of cyanobacteria. The Permian/Triassic boundary may occur in the upper portion of the formation (Maughan, 1980); this boundary is crossed by visitors hiking the Red Rock Rim Trail (Fig. 1).

The depositional environment of the Lykins Formation was probably an intertidal zone in an epicontinental lagoon. Stromatolites indicate a very shallow sea level while the regional geography was generally flat (Maughan, 1980). At an obscure exposure below the Red Rock Rim Trail (Fig. 1), intraformational recementing of “rind” encased limey rip-up clasts, 5-6 cm in diameter, were noted, possibly indicating a high-energy event such as a tropical storm.

Jurassic Morrison Formation

The Morrison Formation and the gypsum beds of the underlying Ralston Creek Formation are about 90 m thick at cross-section line A-A' (Fig. 3) in central RRCOS. These formations were deposited on an erosional surface (Berman et al., 1980). Both formations have largely been covered by landfill. The gypsum was mined for plaster, but was eventually covered when Gypsum Canyon was opened as a landfill in the southern end of RRCOS. The canyon was buried to a depth of about 50 m (Ellis, 2009, pers. comm.). An example of the gypsum beds is exposed in the neighborhood 600 m north of RRCOS in an outcrop at 32nd and Kiowa streets.

Measurements taken at the Hwy 24 road cut during this survey show 45 m of exposed Morrison Formation section. The lower unit is a tan to buff, pebbly sandstone and mudstone overlain by a buff sandstone with mudstone lenses. This is overlain by a limestone package containing stromatolitic limestone, and a 1 m thick cherty, globular limestone. The shale layer that overlies this limestone contains small carbonaceous particles and is topped by 10 m of cal-

cite cemented sandstone displaying trough crossbeds and ripples. The top of the exposed section consists of 17 m of gray and purple mudstone; the remainder of the formation is covered. Other than this road cut, only the maroon, green and tan mudstones of the Morrison Formation (with occasional sandstone lenses) crop out in small patches in RRCOS.

The Morrison Formation has been interpreted as flood-plain, lake and river deposits (Houck, 2001). River deposits of the Morrison Formation do not crop out within RRCOS. However, 1200 m to the south in adjacent Section 16 Open Space, several poorly preserved dinosaur bones are cemented in a channel sandstone deposit. The Morrison Formation is well known for its dinosaur remains; due to lack of exposure in RRCOS, no fossils have been located.

Lower Cretaceous Purgatoire Formation

In the Colorado Springs area, the Purgatoire Formation is mapped as a separate formation from the Dakota Sandstone (Finlay, 1916; Keller et al., 2005; Carroll and Crawford, 2000; Morgan et al., 2003). Members of the Purgatoire Formation are the Lytle Sandstone, which lies disconformably above the Morrison Formation, and the overlying Glencairn Shale. A road cut on the Lion Trail (Fig. 1) near the south boundary of RRCOS provides an excellent view of both members. As is typical in other localities (Berman et al., 1980), the contact between the Morrison Formation and Purgatoire Formation is elusive, since the distinctive maroon and tan colors of the Morrison Formation also occur in the lower muddy layers of the overlying Lytle Sandstone.

The lower Lytle Sandstone is a maroon, tan and gray siltstone topped by a medium- to coarse-grained, poorly cemented, white sandstone. This sandstone contains layers of conglomerates with multicolored, subrounded- to rounded-chert pebbles measuring 0.5 to 2 cm in diameter. At the road cut, the base of the Lytle Sandstone displays load casts. The Lytle Sandstone forms a rounded outcrop that can be followed southwest from the road cut, through the adjacent Section 16 Open Space, to a fault at 26th Street.

The Lytle Sandstone is a river-channel sandstone enclosed by siltstone and claystone flood deposits (Weimer and Land, 1972). The chert pebbles are considered to have been transported by rivers from an uplifted area in Utah (Taylor, 1999). No fossils occur in the Lytle Sandstone within RRCOS. However, recent research by Brill and Carpenter (2007) has identified a new species of iguanodontid, *Theiophytalia kerri*, from the Lytle Sandstone in the Garden of the Gods Park. The original skull, accessioned by the Yale Peabody Museum, had previously been recorded as collected from the Morrison Formation.

The Glencairn Shale is a dark gray, fissile marine shale interbedded with thin limestones and sandstones. It was deposited during a short period of time when the Arctic Sea temporarily connected with the Gulf of Mexico (Haun and Weimer, 1960). In RRCOS, the Lytle Sandstone and the Glencairn Shale are separated by 15 cm of rust-colored sandstone and conglomerate containing clasts up to 5 cm in diameter. This layer forms part of a lag deposit indicating erosion on an unconformity surface. Small invertebrate burrows penetrate the base of the sandstone. The sandstone also displays large ripple marks with a wavelength of 15 cm and an amplitude of 2.5 cm. Small fish scales can be observed in the shale. Prismatic shell material of *Inoceramus sp.* (Molenaar, et al., 2002) is preserved in the limestone. The Glencairn Shale is covered by vegetation elsewhere in RRCOS.

Lower Cretaceous Dakota Sandstone

In RRCOS, the Dakota Sandstone consists of very-fine- to fine-grained quartz sandstone, siltstone, mudstone and shale. It is characterized by great fossil diversity that includes tree, leaf and cone impressions, as well as invertebrate and dinosaur trace fossils. The Dakota Sandstone forms the highest hogback in RRCOS and extends approximately 2.1 km along strike, relatively unbroken. South of the adjacent Section 16 Open Space, Precambrian Pikes Peak Granite in the hanging wall block of the Ute Pass fault has been thrust upward truncating the Dakota hogback.

The Bott and Langmeyer quarries mined sandstone from the east face of the Dakota hogback beginning in the 1860s. The stone was cleaved from the outcrop with a pry bar, cut into blocks and loaded onto wagons that traveled on roads still detectable today. Significant local buildings constructed of Dakota Sandstone are the Glen Eyrie Castle and the old Midland Railroad roundhouse located on Hwy 24 (Ellis, 2008).

In Colorado Springs, the lower section of the Dakota Sandstone consists of two massive sandstone units (Grose, 1960). In RRCOS, this lower interval contains very-fine- to fine-grained quartz sand bodies that are lens shaped in cross section and display erosional bases. Weathering and oxidation of these channel sands, which could be fluvial or tidal, obscures most sedimentary structures other than some two-dimensional crossbedding. Weimer and Land (1972) describe similar characteristics in their study of the "J" interval of the Dakota Formation in the Golden/Morrison area. There they describe estuary/tidal channels with brackish water and/or tidal currents. Similar observations in RRCOS include trough sets up to 1 m thick, clay clasts, burrowing, oscillating ripple marks and wood imprints with *Teredo* borings at the base of some units.

Concretions of pyrite or limonite 3 cm in diameter are also common in the lower sandstone, and occasionally are as large as 15 cm. These concretions are an identifying feature in building stone (Ellis, 2008).

The upper interval of the Dakota Sandstone in RRCOS is very fine-grained and platy, and is interbedded with layers of siltstone and claystone, as well as sparse lignite layers. It contains directional and oscillatory ripples and is highly bioturbated. Similar to those documented on the Dakota Hogback west of Denver, trace fossils in RRCOS include *Opbiomorpha*, *Planolites* and *Rhyzocoralium* (Chamberlain, 1976).

The most common fossils contained in the Dakota Sandstone in RRCOS are tree and leaf imprints. In one locality, fossil trees 2 to 3 m in length are stained by iron oxide. Structures of the trees have been preserved as lines both horizontal and perpendicular to the length; some have a corded texture and many contain *Teredo* borings.

Orange, lavender and yellow mineral staining also occurs on poorly preserved fossil leaves. Two main leaf morphotypes were documented, but none were preserved with sufficient detail for identification. The most common leaf type is symmetrical, with a midvein length of 6 to 12 cm, a straight apex and base shape, an acute apex and base angle, unlobed, and with smooth margins. The second leaf type documented was much broader, with a midvein length of 7 to 8 cm, symmetrical, a concave-shaped base with an obtuse base angle, unlobed, and appearing to have a smooth margin. A fine-grained sandstone layer in an old quarry on the Dakota hogback within RRCOS displays a bedding surface encrusted with orange and lavender tree, bark and leaf imprints. Most pieces of talus below the outcrop contain fossil leaves and wood, as do two large boulders. Near this outcrop a specimen of an *Anemia* sp. fern was collected.

In two localities, several male pollen cones in the genus *Araucaria* (Figs. 6, 7) were identified by Ian Miller of DMNS (2007, pers. comm). Abundant stained leaf impressions were noted in the same proximity as the cones at both locations. The impression of the needle-like leaves of *Araucaria* sp. was also collected within the talus at the leaf locality previously mentioned.

During this survey five single dinosaur tracks were recorded, all in the lower strata of the Dakota Sandstone. Two tracks are hadrosaur or *Iguanodon* tracks (Fig. 8), as identified by Kenneth Carpenter of DMNS (2006, pers. comm.), and two are similar to tracks seen on Skyline Drive in Canon City, Colorado and are likely *Ankylosaurus* (Carpenter, 2007, pers. comm.; Kurtz, et al., 2001) (Fig. 9). According to Joanna Wright of the University of Colorado at Denver (2007, pers. comm.), markings adjacent to the *Ankylosaurus* track (Fig. 10) are similar to those reported from the Golden site west of Denver, and may be slide marks scratched by scales on the animal's foot. One cast of



Figure 6. *Araucaria* sp. cone; scale shown in cm.

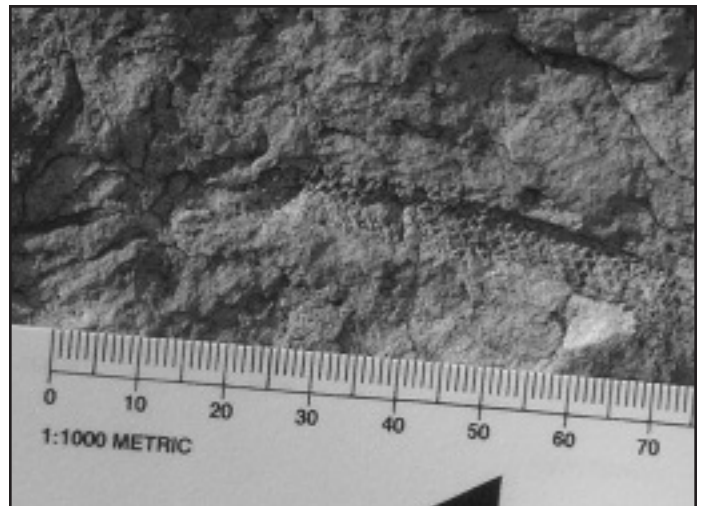


Figure 7. *Araucaria* sp. cone; scale shown in cm.

the *Ankylosaurus* track that had fallen from the outcrop was collected. In the same vicinity a poorly preserved tri-dactyl track can be viewed on the underside of a rock. Nearby, a series of undetermined trace fossils was observed, with nine oval-shaped imprints of 9 to 10 cm in length at a distance of 30 cm apart.

Upper Cretaceous Benton Shale

The Benton Shale was deposited as the land was inundated by the Western Interior Seaway. Of the four members of the Benton Shale, the Graneros Shale and the Carlile Shale members are undifferentiated in RRCOS. The Greenhorn Limestone is also indiscernible. Because of this,



Figure 8. Hadrosaur or *Iguanodon* track.



Figure 10. Slide marks near Ankylosaur track.

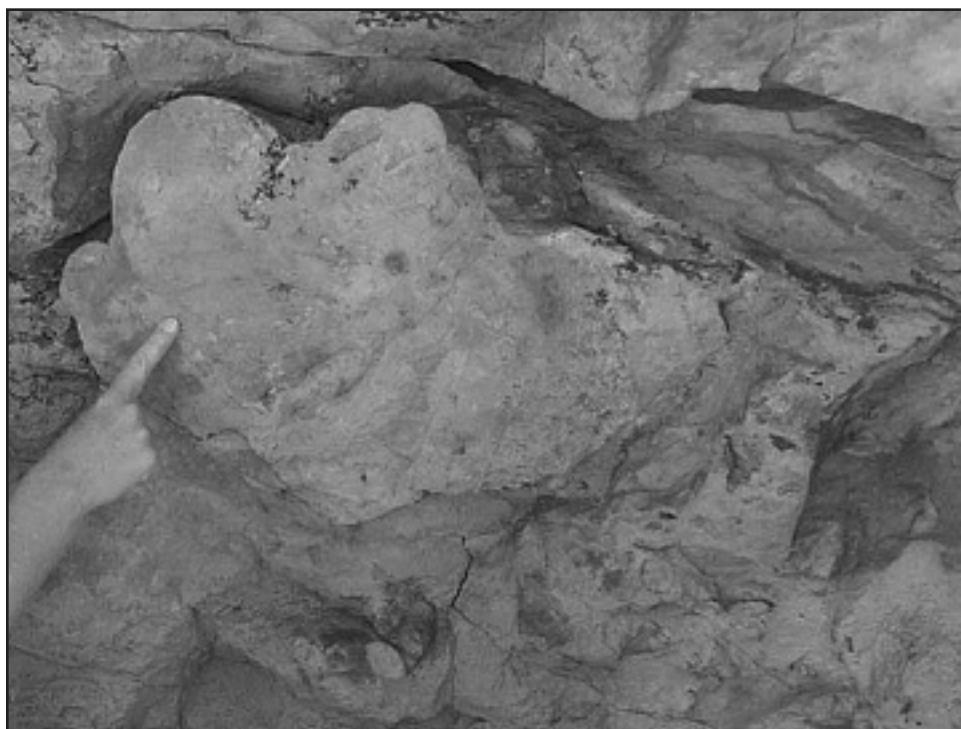


Figure 9. Ankylosaur track.

the author refers to this formation as the Benton Shale rather than the Benton Group. The fourth member, the Codell Sandstone Member, forms the easternmost hogback in RRCOS with the overlying Fort Hays Limestone.

The Benton Shale predominantly appears as dark gray, crumbly, marine shale on eroded slopes in the northern end of the RRCOS. Interbedded in the shale are thin buff- to rust-colored layers of volcanic ash. The shale forms a

large strike valley between the Dakota Sandstone and the uppermost member of the Benton Shale, the Codell Sandstone Member.

The Carlile Shale Member has a gradational contact with the Codell Sandstone Member. The Codell Sandstone is a medium- to coarse-grained, calcareous sandstone. The 2 to 4 m thick Codell Sandstone is exposed on both its lower and upper contacts due to weathering of the underlying

Upper Cretaceous Niobrara Formation

The Niobrara Formation overlies the Codell Sandstone. The Niobrara Formation consists of two gradational members (Grose, 1960): the Fort Hays Limestone, a micritic limestone interbedded with minor dark gray, calcareous marine shale layers; and the Smoky Hill Chalk. Both members are highly fossiliferous, with the primary fossil being *Inoceramus sp.* The dip of the Niobrara Formation is near 90 degrees at the 31st Street parking lot. At this locality, 78 alternating layers of limestone and thin beds of shale were measured in the Fort Hays Limestone. Down-slope creep

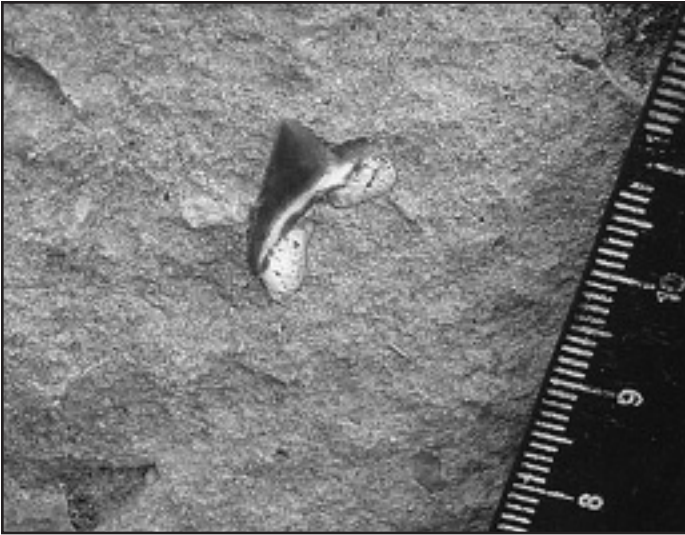


Figure 11. *Squalicorax falcatus* tooth; scale shown in cm.

Benton Shale and quarrying of the overlying Fort Hays Limestone. The largest exposure of the Codell Sandstone spans approximately 75 m in length and is viewed at the old Standard Mill Quarry near the 31st Street parking lot.

The Codell Sandstone is highly fossiliferous and bioturbated, and in RRCOS, contains shell fragments, fish bones and abundant shark teeth, including *Squalicorax falcatus* (Fig. 11) and *Ptychodus whipplei* (Edwards, 1976). Ammonite imprints (Figs. 12, 13), ranging in size from 8 to 50 cm in diameter, are common in the Codell Sandstone. The most frequently observed in RRCOS was *Prionocyclus sp.* (Fig. 12). Poltenovage collected a tooth that he has tentatively identified as a *Mosasaur sp.* palatine tooth (2008, pers. comm.). Also common throughout the Codell Sandstone are invertebrate feeding and burrowing trace fossils.



Figure 12. Freshly exposed *Prionocyclus sp.* ammonite; hand lens at bottom of photo used for scale.

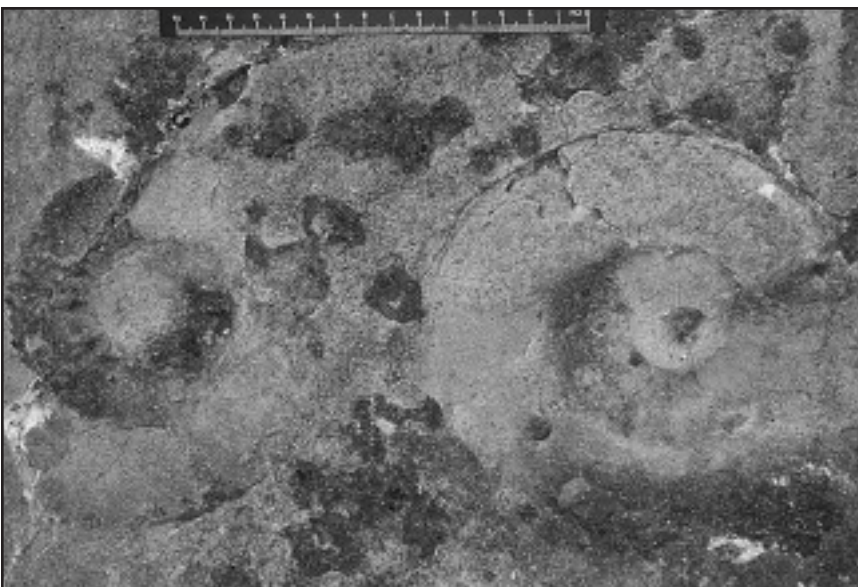


Figure 13. Weathered ammonites; scale shown in cm.

has overturned the Fort Hays Limestone at several localities. Scott and Cobban (1964) describe eight lithologic units in the Niobrara Formation in Pueblo, Colorado. Because the Niobrara Formation in the Colorado Springs area is about half the thickness of outcrops in Pueblo, and because of deformation of the strata due to the 70 to 90 degree dip of the beds, determination of the lithologic units within RRCOS is difficult.

The Fort Hays Limestone contains several well preserved specimens of *Inoceramus deformis*. Trace fossils include possible crustacean tracks, as well as feeding burrows. Within the Smoky Hill Chalk, many samples of *Platyceramus platinus* and *Volviceramus grandis*, both encrusted with *Pseudoperina congesta* (Kauffman, 1977), were documented or collected. One broken specimen of *Cladoceramus undulatopticatus* was found, which may identify one biostratigraphic zone of the Smoky Hill Chalk in the RRCOS strata (Carpenter, 2003). Tail rays from an *Ichthyodectes sp.* fish were also collected from the chalk.

The Smoky Hill Chalk has a transitional contact with the Pierre Shale on the easternmost border of RRCOS.

Quaternary Mesa Gravels

Mesa Gravels is the local name for the youngest deposit in RRCOS (Finlay, 1916), and is, in part, the equivalent of the Verdos Alluvium (Thorson et al., 2001). The Mesa Gravels is an alluvial deposit of poorly-cemented or unconsolidated red sand, rounded gravel and cobbles, and occasional boulders. The source rock of most of these clasts is the Precambrian Pikes Peak Granite.

Vertical Fountain Formation, Lyons Sandstone, Dakota Sandstone, and Codell Sandstone/Fort Hays Limestone hogbacks are overlain unconformably and horizontally by the Mesa Gravels. The Mesa Gravels form a pediment surface which originally would have been continuous with "The Mesa," the large mesa east of Garden of the Gods Park. These gravels were deposited during periods of climatic change (i.e., glacial melt) and regional uplift (Grose, 1960). This formation is of Pleistocene age, with some comparable layers in the Denver area dated at about 640,000 years (Thorson et al., 2001). Within the boundaries of RRCOS, the Mesa Gravels deposit previously supplied several gravel pits which are now largely covered by grass.

In a road cut on the Lower Hogback Trail (Fig. 1), clasts are cemented in a black, inorganic sludge, which is possibly manganese oxides (Weissenburger et al., in press). A likely source of an amazonite pebble found among the Mesa Gravels is a pegmatite north of Sentinel Rock, high above Bear Creek, west of Colorado Springs. This could indicate the origin of some of the Mesa Gravels in RRCOS.

The uplift, erosion, and deposition cycles earlier portrayed by the Fountain Formation, are duplicated within the more recent Mesa Gravels. A road cut leading east from the central RRCOS parking lot displays the streambed of a paleo Fountain Creek scouring through the vertically bedded Lyons Sandstone (Fig. 14). Within the eroded channel base lies a horizontal deposit of subrounded- to rounded-clasts, fining upward from small boulders to cobbles to gravel and sand. This "stranded" deposit lies approximately 17 m above the current Fountain Creek.



Figure 14. Mesa Gravels in paleo Fountain Creek scouring through the vertically-bedded Lyons Sandstone.

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