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Field Trip No. 24

Geology of the Gold Belt Back Country Byway, South–Central Colorado

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INTRODUCTION

This guidebook was compiled for a Geological Society of America field trip, held on 1-2 November 1996, after the annual meeting of the Society. The field trip (fig. 1) traverses major portions of one of Colorado's most geologically interesting and scenic routes. The field trip is in south-central Colorado and extends along the western portion of the Gold Belt Tour Scenic Byway, managed through a cooperative effort between the Bureau of Land Management (BLM), the National Park Service (NPS), Teller and Fremont Counties, many of the communities in the area, and the Colorado Department of Transportation. Rocks traversed extend in age from the Early Proterozoic (Precambrian) through the Late Proterozoic, into the Paleozoic, through parts of the Mesozoic, and into the Eocene, Oligocene, and Quaternary. The field trip route and stops were selected to demonstrate, in the limited time available, important aspects of the geologic history of the area, including features associated with the Ancestral Rockies, the Laramide Orogeny, and the subsequent Cenozoic history of the Southern Rocky Mountains, including significant volcanic features and mineralization. Where possible and appropriate, human history and cultural aspects of the area are included.

Route

This field trip begins at the community of Divide and terminates in the vicinity of Cañon City (fig. 1). The first four stops of the first day are in the Florissant area (Stops 1-4), where we will examine the well-known plant-and insect-bearing lacustrine beds, including Clare's

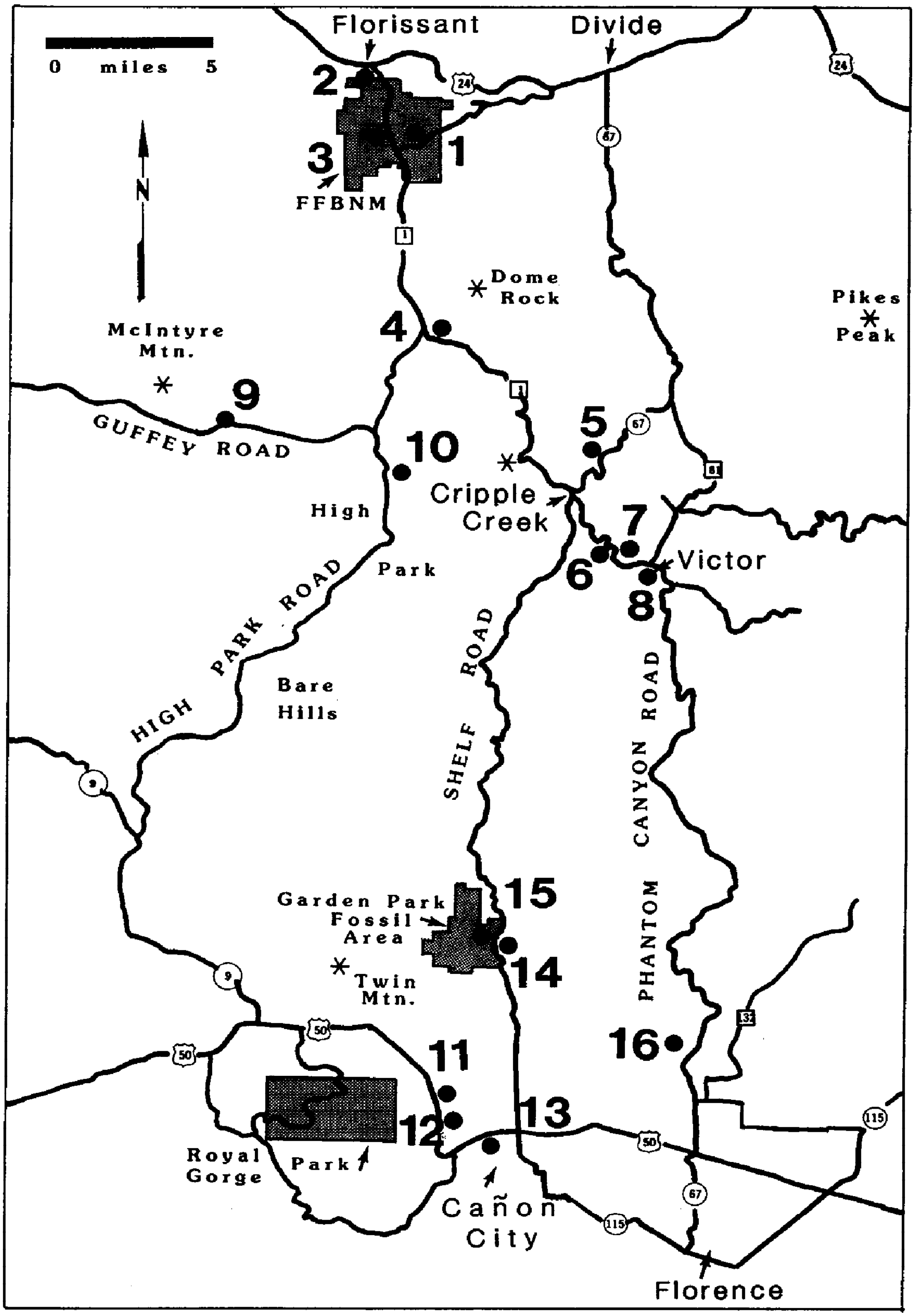


Figure 1. Field trip route. Stops shown by black dots and large numbers; U.S. Highways depicted by numbers in shield; State Routes in circles; County Roads in squares. Bar scale, upper left, 5 miles (8.1 km). FFBNM is Florissant Fossil Beds National Monument.

Quarry and the Visitor Center at Florissant Fossil Beds National Monument, and the volcanic debris flow (lahar) that blocked the valley and thus impounded the paleodrainage to create Lake Florissant. Lunch will be at Stop 3. We will view a panorama of the gold-mining area of Cripple Creek (Stop 5), once the scene of "America's greatest gold rush", and an active, large-scale, leach-pit recovery site (Stop 7) . Stops 6 and 8 of the first day are optional stops that will be made time permitting. The first night will be in Cripple Creek. Limited-stakes gambling, recently legalized in selected Colorado mountains towns, has changed significantly the complexion of these communities.

On the second day, we drive from Cripple Creek to the Cañon City area. The first stop (Stop 9) is at an overview of the Guffey volcanic center and the Thirtynine Mile volcanic field, where several coalescing stratovolcanoes were emplaced on a prominent late Eocene erosion surface. Stop 10, a view of the late Eocene erosional surface in High Park, is optional. From High Park, we will continue southward to Skyline Drive. Stop 11 (optional) is an overview of the area just west of Cañon City from Skyline Drive looking toward the Royal Gorge, and the next stop (Stop 12) also on Skyline Drive is an eastward view across the upper end of the Cañon City Embayment. Lunch will be at the new interpretative center (Dinosaur Depot) in Cañon City (Stop 13), where an orientation session will be given prior to our visiting the two closely spaced dinosaur quarries at Garden Park (Stops 14 and 15), located on BLM property and made famous by Professors Cope and Marsh. The last stop of the field trip (Stop 16) will be at the Ordovician trace-fossil locality at Indian Springs, located on a privately owned ranch and federally protected under the National Natural Landmarks Program.

The route of the field trip road log is mainly along blacktop and improved gravel county roads and state highways, with a minor stretches along U.S. Highways near Victor and Cañon City. The route along High Park Road can be traversed easily with passenger vehicles. However, the portions of the Gold Belt Back Country Byways (fig. 1) not included on the field trip (e.g., the Shelf and Phantom Canyon Roads) are mainly along narrow gravel and dirt roads with stretches accommodating only one-way traffic and have steep grades, occasional low clearances, and sharp curves. High-clearance vehicles are recommended for these routes. Access with motor homes or by vehicles pulling long campers on these routes is not feasible.

Guidebook Designations

Figures in bold to the left of each guidebook description are cumulative distances (in miles) from a given point at the start of each day or from the beginning of a new segment. The figures in bold in brackets [ ] at the end of each cumulative distance are distances (in miles) to the next point of interest. Mileage posts are sparse along the Gold Belt Back Country Byway but are noted where present. Metric equivalents in this guidebook are given in parentheses after the English measurement. Directions (north, south, etc.) with references to left and right are given in the descriptions of some feature; "clock directions" or bearings (11:00, etc.) are interspersed sparsely in the roadlog descriptions, referencing 12:00 as the direction of traverse "straight ahead".

Acknowledgements

The editors and compilers of this field trip guidebook would like to extend their appreciation to the following people who generously gave of their time and efforts: Charlie Fair (BLM) and Donald Kupfer (Garden Park Paleontology Society) of Cañon City, Superintendent Jean Rodek and Maggie Johnston (NPS) of Florissant, Robert Cushman (Loma Linda College, Calif.), and the Pikes Peak Mining Co. Most of the photographs used in this guidebook are originals, but we acknowledge that several were provided by Lee Snapp (NASA, Houston, Tex.), and the Garden Park Paleontology Society, and that the scanning-electron microscope photographs were contributed by Neal R. O'Brien (State University of New York, Potsdam). The compilers also acknowledge the geologists who have worked extensively in the area and whose knowledge upon which we have relied extensively for this guidebook. Many of these people have devoted their careers to the understanding of the geologic history of the Southern Rocky Mountains, and their names and many of their contributions are listed in the *References Cited* section of this guidebook.

DAY 1: DIVIDE TO FLORISSANT TO CRIPPLE CREEK-VICTOR

The route for the first day of this field trip is divided into three segments: Segment A (Divide to Florissant Fossil Beds National Monument), Segment B (Florissant Fossil Beds National Monument to Cripple Creek), and Segment C (Cripple Creek to Victor). Refer to figure 1 for route and to figure 2 for a stratigraphic column for the Florissant area.

Geology of the Florissant Area

The oldest rocks exposed in the immediate area around the Florissant Fossil Beds National Monument are those of the Pikes Peak Granite, dated at about 1.080 billion years (Ga) (Wobus, 1994), which comprises some

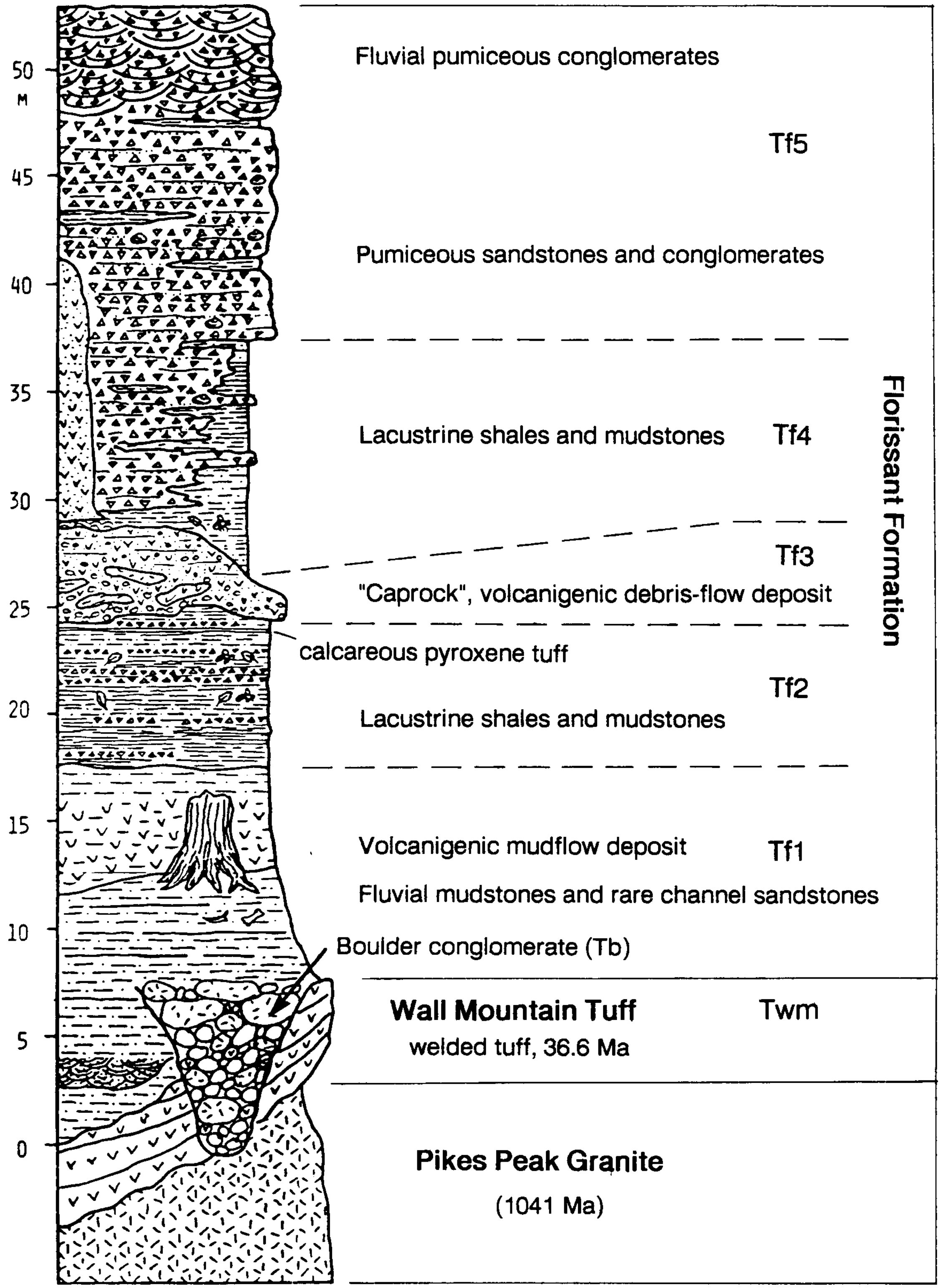


Figure 2. Stratigraphic section for Florissant area. Modified from Evanoff and Murphey (1994). Scale in meters.

of the youngest Precambrian (Proterozoic) rocks in Colorado. The Pikes Peak Granite is generally a pink to reddish-tan, medium- to coarsely crystalline, biotite and hornblende-biotite granite that surrounds the Florissant paleovalley. The Pikes Peak Granite disintegrates readily to a coarse-grained, orangish-red gruss visible along many roads in the area and forms the rounded rocky hills within the Monument, or it forms conspicuous barren exfoliation features (tors and inselbergs). It also makes up 14,110-ft (4,302-m) Pikes Peak located 15 miles (24.1 km) east of Florissant. It was formed as a large intrusive batholith that covers more than 1,150 mi^2 (3,000 km^2) and includes major intrusive centers and four smaller plutons, including the Lake George stock to the northeast of Lake George (Tweto, 1987). The granite was uplifted during the Laramide orogeny, which occurred from the Late Cretaceous (65 to 70 million years ago, Ma) into the Eocene. This period of uplift eroded away Paleozoic and Mesozoic sedimentary rocks, which were redeposited as sediments in the surrounding Denver and South Park basins. By the late Eocene (37 Ma), the Pikes Peak Granite was exposed at the surface in the vicinity of Florissant.

Most of the late Eocene rocks in this vicinity were derived from episodes of regional volcanism. The Wall Mountain Tuff, dated by $^{40}Ar/^{39}Ar$ at 36.7 Ma (McIntosh and Chapin, 1994), is a welded rhyolitic tuff (ignimbrite) formed as a pyroclastic ash-flow of crystals, ash, volcanic glass, and rock fragments suspended in gases superheated to more than 700°C. Hot ash flows accompanied by incandescent gas clouds (nueé ardantes) result from instantaneous and catastrophic eruptions from a caldera that, in this case, was located in the Sawatch Range on the west side of the Arkansas River Valley, more than 50 miles (80.5 km) west of the Monument. Debris from this eruption probably traveled at velocities between 100 and 200 miles/hour (161 to 322 km/hr), and the super-heated particles within the ash flow were fused together quickly upon settling. The Wall Mountain Tuff is the most extensive ignimbrite in central Colorado and extends as far east as the Castle Rock area (between Colorado Springs and Denver). Some of the paleodrainages developed in the late Eocene on the surface of the Pikes Peak Granite (fig. 3) and other substates are preserved by having been filled with this material. The Wall Mountain Tuff unconformably overlies the Pikes Peak Granite in the vicinity of Florissant and is exposed as isolated outcrops. It was eroded prior to the deposition of overlying Tertiary rocks. For the most part, this pre-Florissant Formation drainage system was a dendritic drainage system, with regional flow to the south.

Volcanic eruptions from the Guffey volcanic center (part of the Thirtynine Mile volcanic field), located about 18 miles (29.0 km) to the southwest, influenced the landforms and deposition in the Florissant area over a long span of time. Several large composite volcanoes developed within this volcanic center, and one of the early eruptions produced debris flows that followed the drainage of the Florissant paleovalley, inundating low-lying forests of large redwoods and other trees to a depth of about 15 feet (4.6 m) in mud and sand. The bases of these trees became petrified as silica-saturated water penetrated the wood and preserved it by permineralization. These petrified redwood stumps, some measuring over 38 feet (11.6 m) in circumference at breast height, can be observed along interpretive trails originating at the visitor center. The stumps were trees growing on tuffaceous mudstones and sandstones deposited by streams in the paleovalley. These tuffaceous sandstones and mudstones up to 33 ft (10 m) thick comprise the lowest mapped unit of the Florissant Formation within the National Monument, although a probable older lacustrine shale sequence is exposed at Clare's Quarry and at the old Colorado Midland Railroad cut (now U.S. Highway 24) a short distance east of the town of Florissant.

Several coarse-grained debris flows blocked the drainage of the Florissant paleovalley, impounding water and flooding the main drainage as well as the lower portions of tributary drainages to form ancient Lake Florissant. The shape of this lake resembled the pattern seen in modern man-made reservoirs, and is remarkably well-preserved by the modern outcrop area of the Florissant Formation. Sedimentation in this lake basin varied from slowly deposited layers less than a millimeter thick of fine, organic-rich muds (shales) commonly enriched in diatoms to rapidly deposited thick layers of coarse ash and pumice that were derived from continuing episodic eruptions in the Guffey volcanic center.

Stratigraphic nomenclature for the Florissant Formation (fig. 2) is after Evanoff and Murphey (1994), who divided this formation in the Monument into five informal map units comprised mainly of shales and interbedded volcaniclastic deposits designated as Tf1 through Tf5, from oldest to youngest. Units Tf2 and Tf4, two of the principal fossiliferous lacustrine shale units, are separated by a conglomerate, referred to as the "caprock" (Tf3), that formed as a subaqueous debris flow. Water-escape structures (i.e.,vertical conduits through which water in the saturated debris flow was "squeezed" out into the water at the bottom of the lake) are common in Tf3. This conglomerate is predominantly pebble-size with a sandy matrix and is composed of granite granules and pebbles of intermediate volcanics, but includes some cobbles and boulders. This unit is radiometrically dated at 34.2 Ma (W.C. McIntosh, per. comm., 1994).

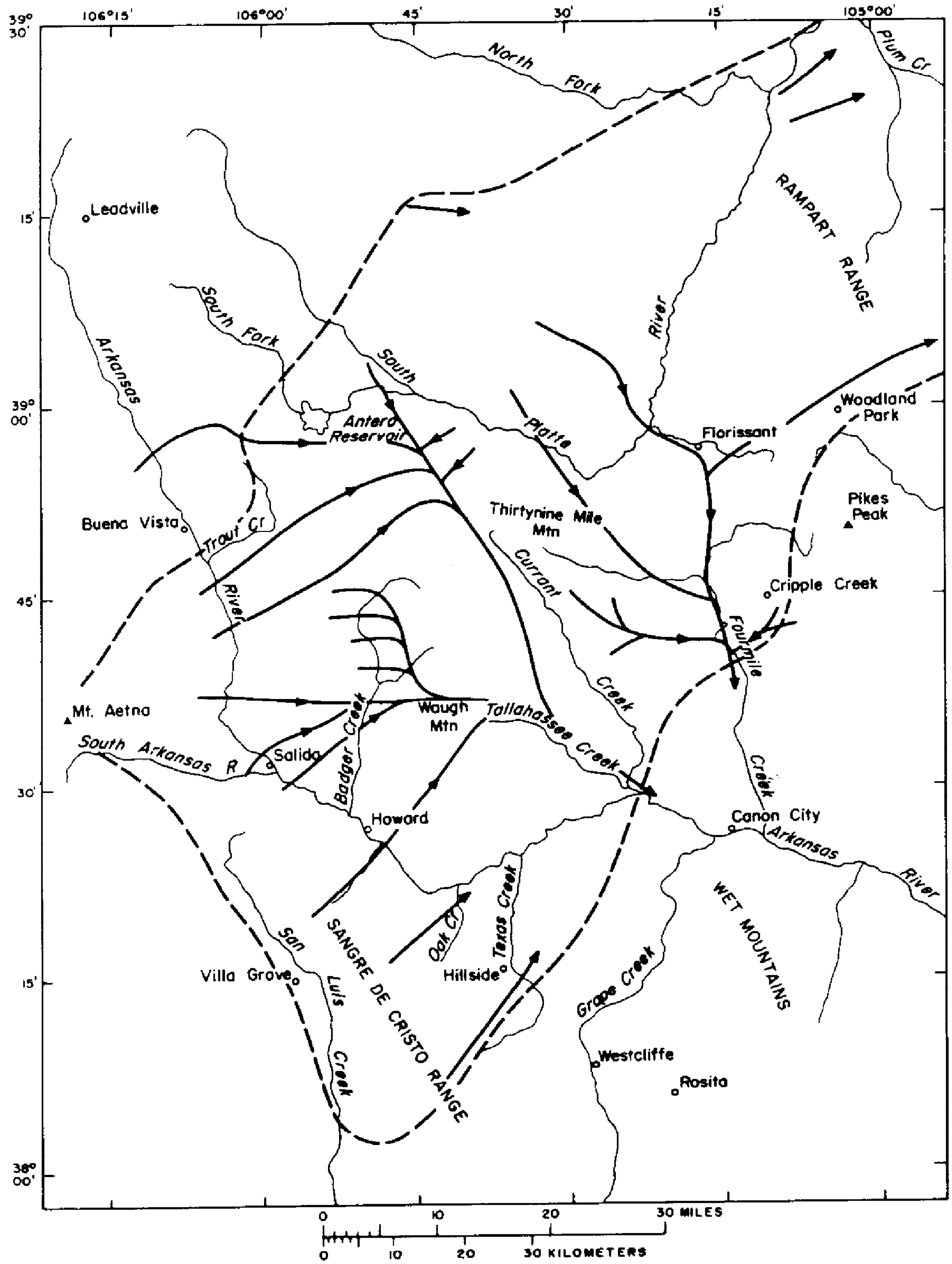


Figure 3. Paleovalleys existing at time of emplacement of Wall Mountain Tuff (from Epis and others, 1980, fig. 10). The ash flows filled the valleys, overrode many of the interfluves, and crossed the ancestral Rampart Range; the dashed line shows the inferred minimum extent of the Wall Mountain Tuff; extent west of the interred source of Mt. Aetna and east of this figure near Castle Rock is not shown.

The uppermost unit in the Florissant Formation, Tf5, is a sandstone and conglomerate and breccia composed predominately of pumice and ash. This volcaniclastic deposit evidently represents the final filling of ancient Lake Florissant. The lower part of Tf5 was deposited in the lake, and contains numerous small pelecypods, whereas the upper part, described by Evanoff and Murphey (1994) as a pumiceous conglomerate, was stream-deposited, as indicated by the presence of trough cross-bedding. Tf4 and Tf5 are not exposed in the immediate vicinity of the Visitor Center. Presumably, younger Tertiary volcaniclastics and gravels mantled the Florissant valley and have been removed by erosion. Tf5 is the youngest Tertiary bed in the Monument, and it and older Florissant beds here locally are overlain mainly by Quaternary (Pleistocene) terrace gravels and sands derived from erosion and redeposition of material from the Pikes Peak Granite.

Many of the lacustrine shale units in the Florissant Formation are finely laminated and contain alternating layers of organic-rich material and fine laminae of pumice. The abundant fossil impressions and compressions of plants and insects for which Florissant is world renowned are preserved within the fine-grained shale layers of Tf2 and Tf4 . As the shales weather, they can be separated into paper-thin sheets, the "pages" of which reveal evidence of the life and climate of the Southern Rocky Mountains during the latest Eocene. About 150 species of fossil plants provide evidence for a warm temperate forest that contrasts sharply with the modern vegetation in this area. Fossil plants include redwood, white cedar, pines, laurels, oaks, hickory, willows, several genera in the rose family, several legumes, soapberries, sumacs, palm, and many others, including some that live today only in such distant geographical areas as Mexico and eastern Asia. There are several genera of fossil plants that are extinct. The diversity of fossil insects is tremendous, with about 1,200 described species, including mayflies, dragonflies, cockroaches, bristletails, grasshoppers, earwigs, aphids, flies, mosquitoes, bugs, beetles, wasps, ants, and butterflies. Florissant is significant in having more species (12) of fossil butterflies than any other site, and the only fossil record of tsetse flies. Vertebrate fossils are uncommon, but include fish (e.g., bowfins, catfishes, suckers, and pirate perches), birds (e.g., cuckoos and rollers), and rare mammals.

Segment A: Divide to Florissant Fossil Beds National Monument

0.0 [0.1] Begin mileage at stop light in Divide, at intersection of U.S. Highway 24 and Colorado State Highway 67. Proceed west on Highway 24.

At Divide and westward for about 1.5 miles (2.4 km), the highway is situated on a prominent erosional surface mantled with gravels of probable Miocene age. This unit is a boulder gravel with sand, silt, and clay and, at Divide, includes clasts derived from the Cripple Creek volcanic center, indicating an age younger than 28 Ma. According to Evanoff (1994), the presence of these volcanic clasts and the truncation of the Wall Mountain outcrops between here and Florissant suggested that this surface is not a simple exhumed late Eocene surface as thought by some previous workers (e.g., Scott, 1975), but rather a surface that probably basically acquired its present low- to moderate-level form in the Miocene. This extensive surface rises to the south and southeast of Divide (e.g., the north flank of Pikes Peak) and continues to the north and east onto the Rampart Range. Like many alluvial surfaces (the "parks") in this area, it is generally not wooded and supports grassy vegetation.

0.1 [0.5] To right (north), cut in apex of the divide for the Colorado Midland Railroad. To the west of this point, the old railroad grade can be seen on the north (right) side of the highway. Gold- and silver-mining booms in Leadville and Aspen brought the tracks from Colorado Springs to Divide, Florissant, and points west by 1886. Cripple Creek and Victor were connected southward to the Arkansas Valley by the narrow-gauge Florence and Cripple Creek Railroad by 1892, and ore then also was processed in mills at Florence. Transportation from Cripple Creek and Victor to the Colorado Midland Railroad here and at Florissant was by stage and wagon roads until about the end of 1894, when two spurs called the Midland Terminal Railroad were completed. With these spurs, much of the ore from the Cripple Creek District was shipped by rail for processing to the Golden Cycle Mill, located between Manitou Springs and Colorado Springs. In early 1901, another narrow-gauge line (Colorado Springs and Cripple Creek District Railroad), advertised as the "shortest line to the Colorado gold fields" (hence its name The Short Line), was completed up the Cheyenne wagon road (Gold Camp Road) from Colorado Springs.

1.6 [0.3] Junction U.S. Highway 67 and Teller County Road 42 (Twin Rocks Road); turn left onto Twin Rocks Road. Pikes Peak is to the east at 9:00.

1.9 [1.3] Aquaduct venting station on left. Twin Rock road generally follows the Homestake Pipeline. [1.3] Constructed in the mid to late 1960's, a 42-inch (107-cm) steel pipe about 10 feet (3.0 m) below the surface transports water from near Vail, about 80 miles (129 km) northwest of here, across the continental divide to the northwest of here, and then to Colorado Springs. The Pikes Peak region is relatively dry, and about 80% of Colorado Springs' water comes from sources west of continental divide, where precipitation is much greater. The candycane-shaped pipe in the venting station is an air valve that allows equalization of pressure within the buried water pipe, preventing a vacuum from being created within the pipe. Several of these can be seen in the next several miles (km).

3.2 [1.1] Roadcuts through weathered Pikes Peak Granite.

4.3 [1.4] Road begins downhill grade through roadcuts of Pikes Peak Granite.

5.7 [0.3] Enter Florissant Fossil Beds National Monument.

6.0 [0.1] Turn right (north) into Barksdale picnic area.

6.2 [0.7] STOP 1. **BARKSDALE PICNIC AREA**. WALL MOUNTAIN TUFF. Park vehicles in lot.

Refer to figure 2 for the stratigraphic column for the Florissant area. The resistant exposures around this parking area (fig. 4) are formed by the Wall Mountain Tuff, the most widespread of the early Tertiary ash-flow deposits in southern and central Colorado. This formation extends for 87 miles (140 km) from the Mosquito Range to near Castle Rock on the Great Plains, and from the Wet Mountain Valley northward to the northern end of South Park, thus covering an area of *ca.* 4,000 mi^2 (10,400 km^2) (see fig. 3). The Wall Mountain Tuff was dated radiometrically ($^{40}Ar/^{39}Ar$) at 36.68 ± 0.07 Ma (McIntosh and Chapin, 1994) and is the oldest Tertiary rock unit within the Monument. Here, it rests unconformably on the irregular dendritic erosional surface cut onto the Pikes Peak Granite and, in turn, is disconformably overlain by younger Tertiary units.

The Wall Mountain Tuff generally forms reddish-brown to light-brown cliff-like outcrops in the Monument; a prominent black vitrophyre zone rarely occurs near its base in this area but is well-developed westward toward its inferred source in the Sawatch Range. Close examination of the tuff shows that it is composed of discernable crystals (phenocrysts) of glassy appearing sanidine and fresh to argillized andesine, lesser amounts of biotite and opaque oxides, and traces of pyroxene set in a finer groundmass. The tuff is chemically a potassic calc-alkalic rhyolite and mineralogically a trachyte (Epis and Chapin, 1968, 1974, 1975; Chapin and Lowell, 1979).

The volcanic event that produced the Wall Mountain Tuff was without doubt a tremendous eruption. The Wall Mountain Tuff is a moderately to densely welded ignimbrite that formed from a superheated (>700° C) cloud of volcanic glass, rock fragments, crystals, and gases. These materials were emplaced quickly and retained enough heat to become welded throughout its present geographic extent. It was emplaced as a thick pyroclastic unit that draped over local topography and mantled the sides of paleovalleys. The source of the vent that produced this ignimbrite is not certain, but thickness and petrographic trends indicate a source to the west and geochemical data suggest a source in the Sawatch Range south of the Mount Princeton batholith. Epis and Chapin (1974) and Shannon and others (1987a, b) suggested that the Mount Aetna cauldron (fig. 3) was the source of the Wall Mountain Tuff; however, Toulmin and Hammer-strom (1990) and Campbell (1994) contended that this interpretation was not supportable geochemically. Both primary and secondary flow structures and eutaxitic foliation features are conspicuous in the Monument (Chapin and Lowell, 1979). The tuff is primarily preserved in paleovalley fills throughout its extent (Epis and others, 1976, 1980; Chapin and Lowell, 1979; Morse, 1985). It is less than 50 ft (15.2 m) thick here in the Monument.

Retrace route to Lower Twin Rocks Road; turn right (west) on Lower Twin Rocks Road.

6.8 [0.5] Lower Twin Rock Road follows a side tributary off of the main axis of the dendritic paleodrainage. Similar to side tributaries of modern reservoirs, this was an arm of the ancient lake that extended for about two miles (3.2 km) to the northeast from here.

7.3 [0.1] Roadcut on right (north) exposes grus, an accumulation of fragments of decomposing granite derived locally from Pikes Peak Granite and deposited in the valleys by streams. Notice that the grus is cross-bedded and was deposited here above lake shales of Florissant Formation. It is probably Pleistocene in age.

7.4 [0.1] Bedded fossiliferous shales of the Florissant Formation (Tf_2) are exposed in the roadcut on the right (north) . Fossil collecting is not allowed within Florissant Fossil Beds National Monument.

7.5 [0.3] Continue straight (west) on Lower Twin Rock Road. At the small pullout on the south (left) side of the road, note the hill about 200 feet (61 m) behind to the east. There, an exposed section of the Florissant Formation can be seen, including Tf_1 (at base of the hill), Tf_2, and Tf_3 (the so-called "caprock", at the top of the hill). The upper portion of a fossil stump is preserved growing on fluvial crossbedded sandstones of Tf_1 about 100 feet (30.5 m) north of the road. Most petrified stumps at Florissant are redwood (*Sequoia*); this stump is one of the few angiosperm stumps recorded. The road at this point enters the main axis of the late Eocene paleodrainage in which Lake Florissant formed. Several historic fossil-plant and -insect quarries and pits in the Florissant Formation occur in this vicinity and northward toward the town of Florissant. The Tarryall Mountains to the north (bearing 3:00) are composed of Precambrian metamorphic and igneous rocks, including part of the Pikes Peak Granite batholith.

7.8 [0.3] Intersection with County Road 1; turn right (north).

8.1 [0.5] The wooden rails on both sides of the road and in the clearcut path through the forest about 0.5 mile (0.8 km) to the west (left) mark the crossing of the Homestake Aquaduct.

The County Road to the north from here follows the main, southward-flowing late Eocene paleodrainage to the town of Florissant, at which point the paleodrainage came in from the west. The upper end of the ancient lake was near present-day Lake George. The Tarryall Mountains ahead at 11:30 are composed of Precambrian metamorphic and igneous rocks, and are included in part of the Pikes Peak batholith (Tweto, 1987). The conical Crystal Peak to the north at 1:00 was formed as part of the Lake George pluton, also part of Pikes Peak batholith.

8.6 [0.3] Red barn on the right (east); intersection with road to Visitor Center for Florissant Fossil Beds National Monument; continue straight (north) on County Road 1. (Equals mileage point 13.0.)

8.9 [0.6] Big stump, a petrified redwood 38 feet (11.6 m) in circumference at breast height, is to the west, bearing 9:30, about 0.25 mile (0.4 km) across the grassy field.

9.5 [0.2] Historic Hornbek Homestead (fig. 5), a restoration of the ranch built here *ca.* 1877, on the left (west). Continue north on County Road.

In 1878, when Adeline Hornbek filed her homestead papers, she already had been widowed once and was abandoned by her second husband. At age 44, she was the sole supporter of her family of four children. Nonetheless, she was a successful business woman and rancher and was the first person to file on land that would become part of the National Monument. The main house is the only original structure remaining from the original homestead; the remainder of the outbuildings were moved in from other historic buildings located elsewhere on the Monument.

Note that the root cellar is built into the hillside just below the contact of the dark-colored shales of the Florissant Formation with the overlying Pleistocene arkosic gravels. This contact can be seen to the left (west) in the roadcut just ahead. Grape Creek now cuts through the narrow canyon in the Pikes Peak Granite to the west behind the homestead. Grape Creek once flowed on volcanic rocks that covered the granite, and it has cut through the granite as the stream incised (Evanoff, 1994). Currently, Grape Creek flows northwestward, opposite the general direction of the south-flowing drainage in the Florissant paleovalley, suggesting that area was tilted to the northwest prior to stream incisement. The County Road follows the main Florissant paleovalley northward from here.

9.7 [0.5] Roadcut exposures of Pleistocene gravels composed of grus derived from the Pikes Peak Granite. Locally, these deposits have produced mammoth fossils. Most of the low mounds in this valley are formed by these deposits.

10.2 [0.2] Junction with Upper Twin Rock road to the right; continue straight ahead (north) on County Road 1. Crystal Peak can be seen clearly at bearing 1:00.

10.4 [0.2] Northern boundary of Florissant Fossil Beds National Monument.

Fossil mammal bones and teeth occur rarely within lower fluvial unit (Tf_1) of the Florissant Formation in this area. These include *Mesohippus*, a large brontothere, and small artiodactyls, providing important evidence for a Chadronian land-mammal age for these beds.

10.6 [0.2] Large quarry in grus of Pikes Peak Granite is seen ahead just north of the town of Florissant.

10.8 [2.2] STOP 2. CLARE'S QUARRY. FLORISSANT FORMATION. Outskirts of town of Florissant; junction with County Road 1 and dirt road leading a short distance into the privately owned quarry. This junction is 0.2 mile (0.3 km) south of the intersection of County Road 1 and U.S. Highway 24 at Florissant. Turn left (west) and park just ahead.

Collecting is allowed in Clare's Quarry for a nominal hourly fee. The owners of this quarry keep a sharp watch for significant fossil finds here; part of the arrangement that the quarry owners make with collectors here is that the Clares retain the rights to scientifically significant fossils, which are commonly donated to the National

Figure 4. Barksdale Picnic Area (Stop 1); Walls Mountain Tuff in center of picture behind parking area. View looking northeastward.

Figure 5. Hornbek Homestead and Grape Creek watergap, looking westward. See text for discussion.

Monument, the Denver Museum of Natural History, and other public institutions. More common, less scientifically significant finds, including many excellent leaf imprints and fossil insects, may be kept by the finders. The operation of this private quarry takes much pressure off of the National Monument, where public collecting is not permitted.

Clare's Quarry (fig. 6) exposes fossiliferous laminated lake shales and interbedded volcaniclastics of the Florissant Formation. These lower shales are believed to lie stratigraphically below the mudflows of Tf_1, and represent the early formation of a paleolake that infilled before the mudflows, volcaniclastics, and lacustrine shales of Tf_1 through Tf_5 (fig. 2) were deposited. Topographically, the shales in this quarry lie *ca.* 180 feet (55 m) below the level of the base of Tf_2. Mapping in the area by Wobus and Epis (1978) and Evanoff and others (1994) have shown that this elevation difference is not due to faulting or folding of the Florissant Formation.

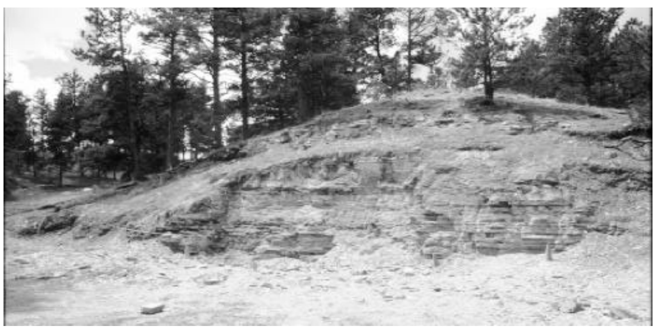
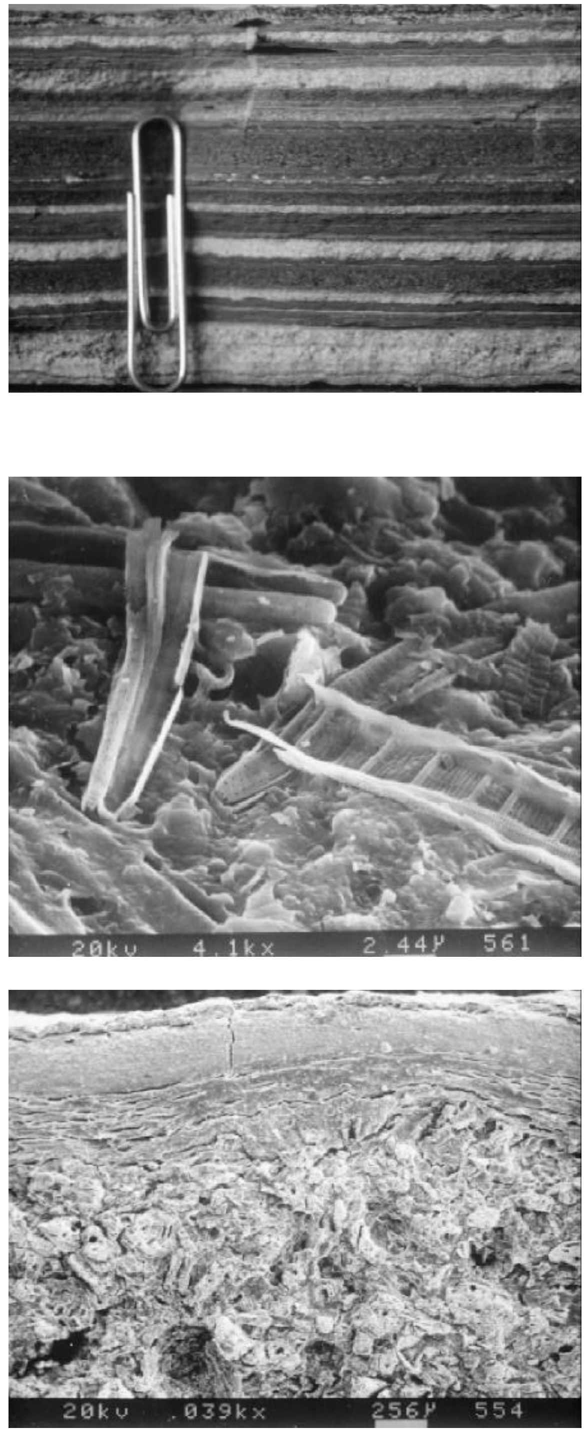


Figure 6. Clare's Quarry. Figure courtesy of Lee Snapp.

One of the characteristic features of the shales of the Florissant Formation is well developed here in Clare's Quarry. These shales are very finely laminated (on the scale of millimeters and less). These fine laminae contain alternating layers of volcanic debris (pumice and ash), diatoms, algae, sparse ostracodes, and dark organic-rich material called sapropel (figs. 7-9), indicating perhaps that the lake water was stratified. Excluding the volcanic materials, these regular laminae are thought to have recorded episodic seasonal deposition (O'Brien and Meyer, 1996). Upon minimal exposure, these shales can be split easily to expose fossil impressions and compres- sions for which the Florissant Formation is famous. These are mostly leaves, fruits, and insects (figs.10-14) although fossil fish and birds also have been found at this site.

Return to vehicles and retrace route southward back to entrance to Visitor Center.



Figures 7-9. Photomicrograph of laminae and SEM pictures of diatom-rich and pumice-rich laminae, respectively. Courtesy of Lee Snapp and N.R. O'Brien.

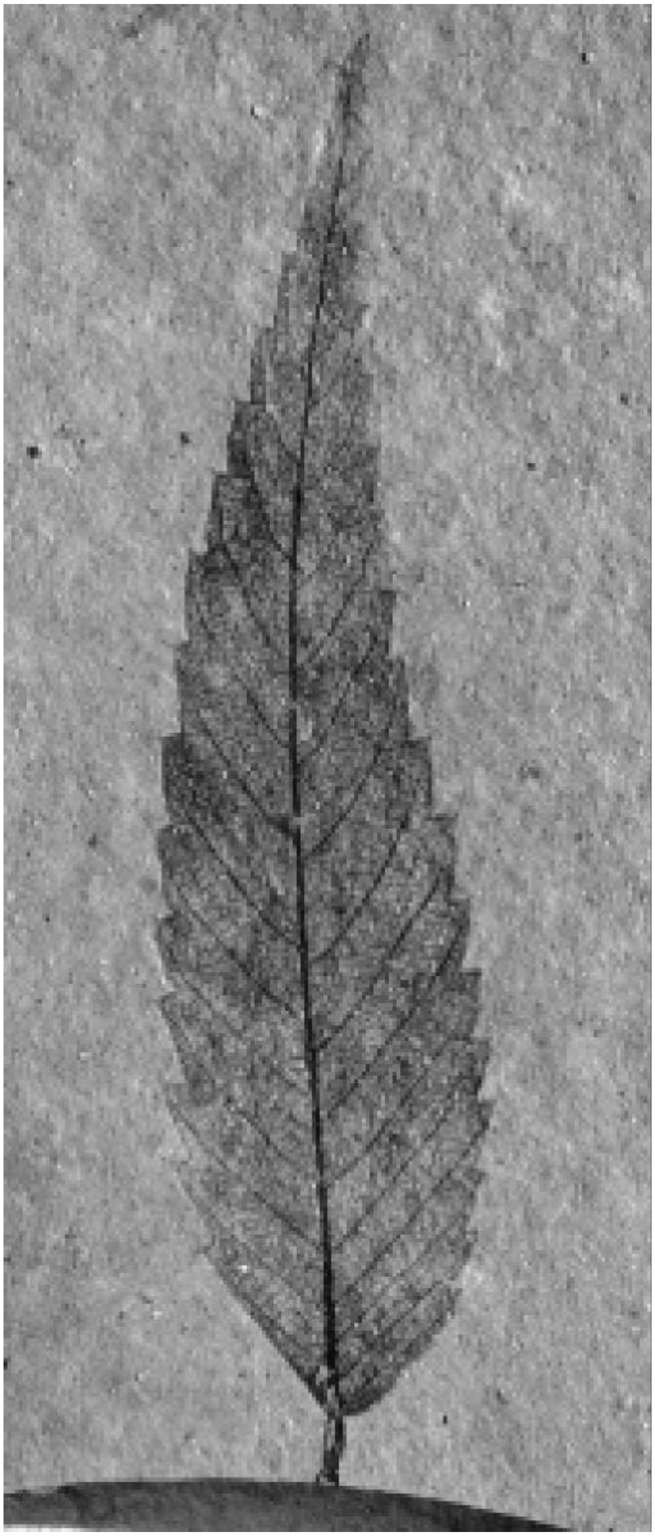


Figure 10. Photograph of leaf of *Cedrelospermum* (an extinct relative of the elm); leaf is about 3 cm long.

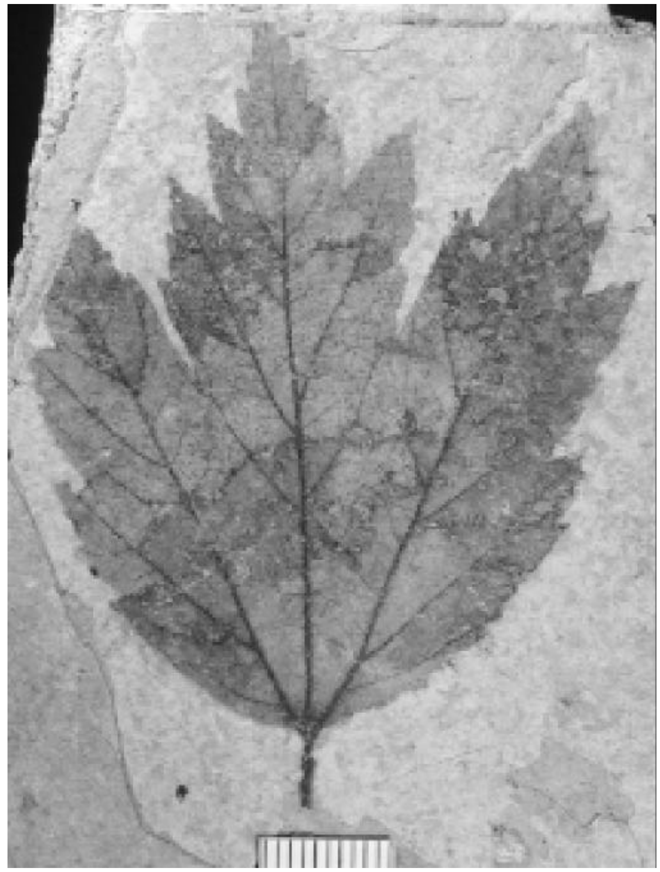


Figure 11. Photograph of *Acer florissanti* (fossil maple) leaf; scale at bottom is 1 cm.

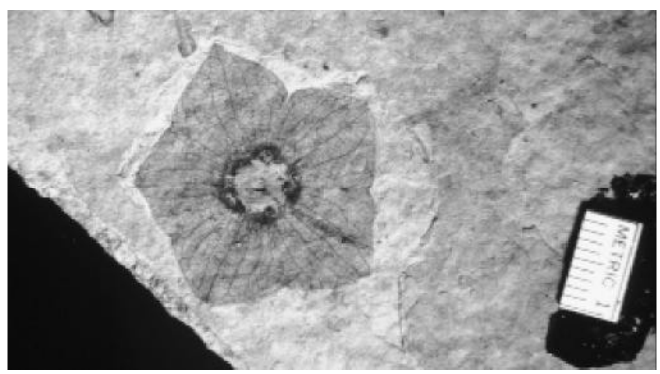


Figure 12. Photograph of *Florissantia speiri* (fossil flower); scale is 1 cm.

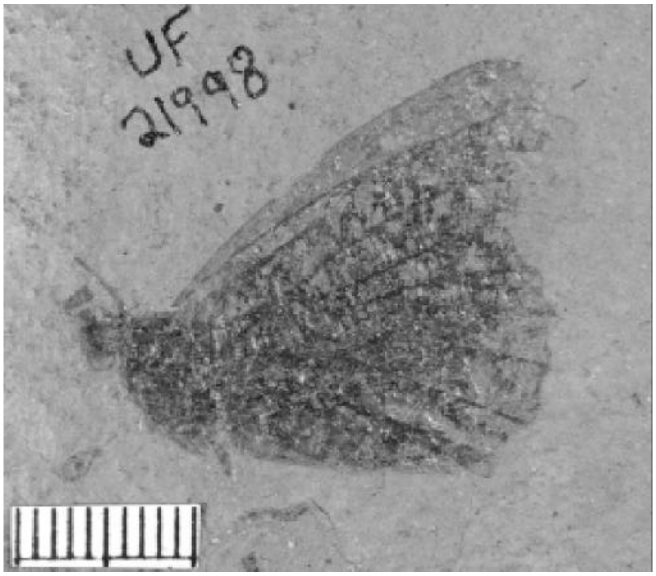


Figure 13. Photograph of fossil butterfly *Oligodonta florissantensis*; scale is 1 cm.

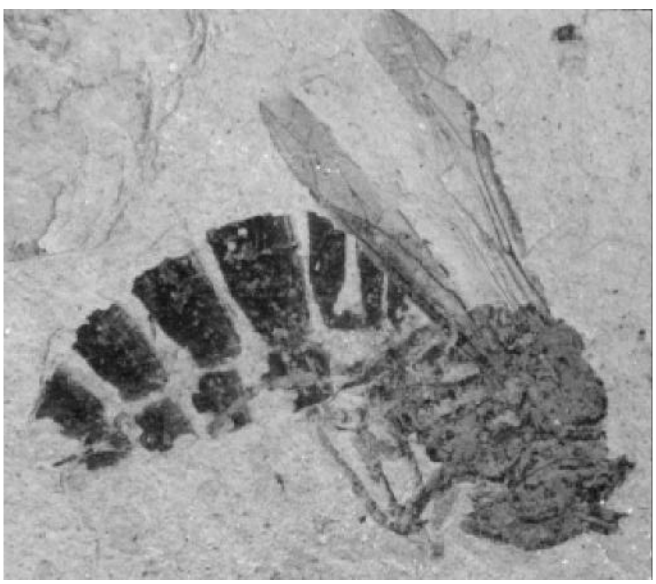


Figure 14. Photograph of fossil wasp from Florissant. Specimen is *ca.* 2 cm long.

13.0 [0.1] Entrance to Visitor Center (equals mileage 8.6); turn right (west) toward Visitor Center.

13.1 [0.2] Roadcut through Pleistocene gravel deposits. Parts of a fossil mammoth have been recovered from this outcrop. It recently has been radiocarbon dated at 49,830 ± 3,290 years, which is at the extreme limit for radiocarbon dating. It is considered as greater than 43,250 years, significant at 2 standard deviations (Thomas Stafford, written comm., 1996).

13.3 [0.3] STOP 3. FLORISSANT FOSSIL BEDS NATIONAL MONUMENT. Pull into parking area and leave vehicles.

The National Monument was established from private lands in 1969, as a means for protecting this world-famous fossil area from real-estate development. The Visitor Center of the National Monument is open every day (except Christmas and New Years Day) from 8:00 a.m. until 4:30 p.m., with extended hours until 7:00 p.m. from June through Labor Day. Interpretive programs are offered during the summer season. An admission fee is charged. The Visitor Center includes a display of fossil plant and insect impressions from shales of the Florissant Formation.

Interpretive trails originate at the Visitor Center and lead through petrified forests where the stumps of giant redwood trees can be seen. Two trails lead visitors through the petrified forest. Interpretive trail pamphlets are available at the trailhead or in the Visitor Center. These petrified stumps are the bases of once-towering redwood trees that were growing in the fluvial muds and sparse channel sands of unit Tf_1 of the Florissant Formation and that were inundated by the volcanigenic mudflow deposit that forms the top of this unit. Immediately behind the Visitor Center, several large petrified stumps can be seen from the point where the interpretive trails begin. Among these are the three interconnected stumps of the redwood trio, a "family circle" of genetically identical trees that developed by sprouting around an original parent tree (fig.15). The fossil redwoods at Florissant are most closely related to the modern coast redwood of California and Oregon, but the fossils represent an extinct species. From the petrified trio, proceed by trail another 70 yards (76 m), turn left onto the Walk Through Time trail and proceed another 15-30 yards (16-32 m) to the outcrop above the wooden rail near the junction of the Petrified Forest and Walk Through Time trails. This outcrop is formed by Tf_1 (the unit in which the petrified stumps occur), and the outcrop behind the rail exposes shales and interlaminated volcaniclastics of Tf_2, overlain by the hard, resistant "caprock" of Tf_3. Notice the vertically oriented water-escape structures visible in Tf_3. Additional fossil trees can be seen by following either the Petrified Forest trail or the Walk Through Time trail.

Retrace route to intersection of road to Visitor Center with County Road 1.

Figure 15. Photograph of stumps of "The Three Sisters", genetically identical *Sequoia* stumps at Stop 3, behind Visitor Center, Florissant Fossil Beds National Monument.

Segment B: Florissant Fossil Beds to Cripple Creek

0.0 [0.8] Intersection of County Road 1 and road to Florissant Fossil Beds Visitor Center; turn right (south) on County Road. (Equals mileage points 8.6 and 13.0 of Segment A.) *Reset odometers.*

0.8 [0.2] Junction of County Road 1 and Lower Twin Rock Road; continue straight (south) on County Road 1. (Equals mileage point 7.8 of Roadlog A.)

1.0 [0.7] The resistant rock layer low in roadcut to west (right) is a pebble conglomerate of Florissant Formation unit Tf_3 ("caprock"), which formed as debris flow into the ancient lake.

1.7 [0.4] South boundary of Florissant Fossil Beds National Monument. The granite knobs on the east (left) are formed by the Pikes Peak Granite; the butte on the west (right) is capped by the upper member of the Thirtynine Mile Andesite, composed of lava flows and breccias derived from Guffey volcanic center in the Thirtynine Mile volcanic field, about 12 miles (19.3 km) southwest of here. The Florissant paleovalley was buried beneath this volcanic debris (Steven, 1975; Evanoff and others, 1994).

2.1 [1.8] Divide between the Platte River and the Arkansas River drainages. Grape Creek flows north into the Platte, and Fourmile Creek flows south into the Arkansas. Both drainages are east of the continental divide but flow into the Mississippi River by way of very different routes. The Florissant Formation has been exposed in excavations for houses in this vicinity.

3.9 [0.8] Prominent roadcut through a knob of deeply weathered Pikes Peak Granite.

4.7 [0.5] Junction with road to the east (left) leading to a housing area; continue straight ahead (south) on County Road. This point is near the southern extent of the Florissant Formation (Wobus and Epis, 1978); laharic breccias of the lower Thirtynine Mile Andesite blocked the paleovalley just north of Balanced Rock, forming a natural dam behind which ancient Lake Florissant formed during the latest Eocene, about 34-35 Ma. A full view of Pikes Peak is seen to the east (left), with a large exfoliation dome to the south (right), and Balanced Rock to the south (right) of that; all of these features are composed of Pikes Peak Granite. The exfoliation dome formed as concentric sheets of granite were peeled away by processes of chemical and physical weathering to expose the bare rock surfaces.

5.2 [1.2] Junction with Antelope Park Road to the west (right); continue straight ahead (south) on County Road 1. The high rugged ridge to the southwest (right) is in the Proterozoic Cripple Creek Quartz Monzonite, dated at 1.4 Ga. The Pikes Peak Granite is exposed along the east (left) side of the road.

6.4 [0.3] The dark-colored andesitic rocks of the lower Thirtynine Mile volcanics are exposed in the low roadcut along the west (left) side of the road and to the east (right) side of the valley as a low wooded ridge beyond the pasture and barns.

6.7 [0.1] Evergreen Junction; intersection of County Road 1 and Guffey-High Park Road (County Road 11) to the right; continue straight ahead (south) on County Road 1. The large barn to the northeast of this junction was a rest stop for ore wagons and six-horse Concord stages from Cripple Creek enroute to the railroad which was completed to Florissant by 1886. Nine years later, spur lines connected the Mining District to Florissant and Divide, eliminating hauling ore by wagon on this route. It is estimated that the completion of these spurs and the railroad from Cripple Creek to Florence reduced the cost of transporting and processing the ores by about half (Levine, 1994).

6.8 [0.2] STOP 4. EVERGREEN JUNCTION. LOWER THIRTYNINE MILE VOLCANICS. Pull off and park at Evergreen General Store. Walk south approximately 100 yards (91 m) to the roadcut at the low divide to examine the outcrops. *Note: the roadway is narrow, and the view of oncoming drivers generally is obstructed here; thus, exercise extreme caution when crossing the road.*

The roadcut (figs. 16 and 17) exposes the laharic breccia of the lower Thirtynine Mile Andesite, dated with $^{40}Ar/^{39}Ar$ at 34.1 ± 1.1 Ma (Wobus and Hutchinson, 1988); these roadcuts are part of an extensive flow that dammed the south-flowing paleodrainage of the ancient Florissant valley and formed the lake during the late Eocene in which the Florissant Formation was deposited. The source of the lahar was the Thirtynine Mile volcanic center, located about 10 miles (16.1 km) west-southwest of here. The mudflow deposit contains sand- to boulder-size clasts of andesitic composition intermixed with older rocks such as Cripple Creek Quartz Monzonite. This area is near the contact between Pikes Peak batholith to the east and the Cripple Creek batholith to the west.

Proceed southward on County Road 1 toward Cripple Creek.

Figure 16. Roadcut exposures through lower Thirtynine Mile Andesite at Evergreen Station (Stop 4), looking at exposures on east side of Route 1.

7.0 [1.1] Low roadcut in Thirtynine Mile volcanics (Stop 4).

8.1 [0.9] Good view to the east-northeast (left) through the trees of several exfoliation domes developed by weathering of the Pikes Peak Granite (fig. 18). The largest and easternmost of these exfoliation domes is called appropriately Dome Rock. The rocks on the southwest (right) side of the road are the Cripple Creek Quartz Monzonite. The granitic rocks of Cripple Creek Quartz Monzonite are dated between 1.40 and 1.43 Ga (Rb/Sr mineral-isochron age by Hutchinson and Hedge, 1967; and Rb/Sr age by Hawley and Wobus, 1977), and, hence are older than the Pikes Peak Granite (*ca.* 1.02 Ga; Tweto, 1987).

Figure 17. Same roadcut as figure 16; closer view of laharic breccia exposed on east side of road.

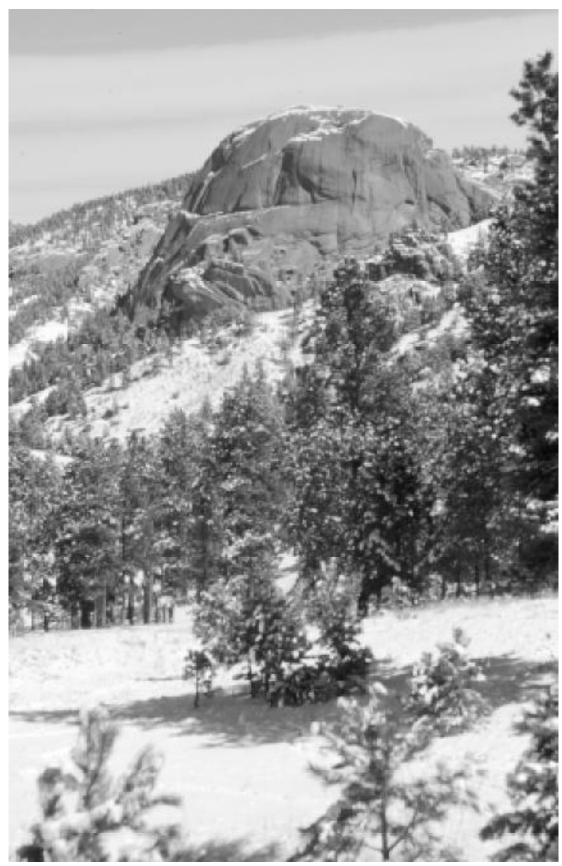


Figure 18. Dome Rock; exfoliation dome; snow on ground.

9.0 [1.3] Bridge over small creek. According to the geologic map (Wobus, Epis, and Scott, 1976), for the next several miles southward, the County Road and stream parallel the contact between the Pikes Peak Granite to the east (left) and the Cripple Creek Quartz Monzonite to the west (right).

10.3 [0.8] At small summit, roadcut on right (west) in Pikes Creek Granite; exposures of same near road from here for some distance southward.

11.1 [0.7] Entrance to Cripple Creek Mountain Estates and Country Club to the west (right); continue southbound toward Cripple Creek. Before the turn, note the prominent reddish-brown cliffs to the west (right) on the north side of Barnard Creek that are formed by the Cripple Creek Quartz Monzonite (fig. 19). The porphyritic quartz monzonite contains phenocrysts of microcline up to 1 cm long and is part of the Cripple Creek batholith. Rhyolite and Copper Mountains are the big wooded conical peaks visible to the east (left), the lower slopes of which are outcrops of the Pikes Peak Granite with phonolite and breccias near their tops. The top of conical Mt. Pisgah (another phonolite plug) is visible to the southwest at about 2:00. After the turn, the road is on the Pikes Peak Granite.

Figure 19. View looking westward from County Road 1 at cliffs of Cripple Creek Quartz Monzonite on north side of Barnard Creek.

11.8 [0.3] Pikes Peak Granite is exposed in the roadcuts and makes the cliffs to the east (left) and ahead; a syenite intrusive occurs to the west (right).

12.1 [0.9] Bridge. Just ahead on the west (right), the road cuts through the Pikes Peak Granite. A short distance beyond that, the road crosses the contact between the Pikes Peak Granite and older syenites of the Spring Creek pluton, seen as deeply weathered, orange exposures in the roadcuts. This small pluton is located on the western margin of the Pikes Peak batholith and is reported to cut the Pikes Peak Granite along its east side, but it has yielded a Rb/Sr age about the same as that of the granite and other rocks of the batholith (Barker, Hedge, and others, 1976). The main body of the stock consists of olivine syenite that locally grades to a clinopyroxene syenite, and the body is rimmed by a dark, fine-grained olivine-clinopyroxene gabbro, reported both to grade into the syenite (Barker, Hedge, and others, 1976) and to cut the syenite (Wobus and others, 1967).

13.0 [0.5] Good view of Mt. Pisgah to the southwest (at 1:00) with antennae on top. The phonolite plug that forms Mt. Pisgah is the same age and composition as those of the Cripple Creek stock. Although Mt. Pisgah bears the scars of prospect pits, it was not brecciated and hence not mineralized. The Cripple Creek volcanic center is a diatreme intrusive emplaced at the junction of four major Proterozoic rock units (Tweto, 1987; Kelley, 1994, 1996 *in press*). According to Kelley, the complex was emplaced after Lake Florissant was filled and contemporaneously with the last activity in the Thirtynine Mile volcanic field. She suggested a sequence of events in the complex as diatreme emplacement with explosive volcanism; followed by subsidence and deposition of sedimentary rocks periodically interrupted by intrusion and brecciation; followed by emplacement of surrounding phonolite plugs associated with hydrothermal mineralization; and, finally, emplacement of mafic phonolite intrusives; followed by a second episode of hydrothermal mineralization. She suggested that the magmatic activity and mineralization of the gold-silver-telluride deposits took place over a *ca.* 4.5 million year period, beginning at 32.5 Ma and ending about 28.2 Ma (based on $^{40}Ar/^{39}Ar$ dates), and noted that the phonolites, which make up the bulk of the igneous rocks within in the complex, were emplaced between 32.5 and 31.2 Ma.

13.5 [1.2] Broad curve. Just ahead, roadway is built on the Cripple Creek Quartz Monzonite.

14.7 [0.1] Road crosses a small divide; entrance to Mt. Pisgah Cemetery, located about 0.25 mi (0.4 km) to the west (right) of the County Road. The earliest marked graves in this cemetery date from 1890, the earliest days of gold mining in the Cripple Creek area (Levine, 1994).

14.8 [0.4] Northern city limits of Cripple Creek. Carr Street (County Road 1) at the city-limits marker is built on a phonolite; however, the main part of Cripple Creek is built on Early Proterozoic (1.7 Ga) biotite gneisses (predominantly biotite-quartz-plagioclase gneisses and biotite schists). Note the extensive open-pit mining to the southeast and east (left and ahead) in the distance. Referred to as “America’s greatest gold camp”, the population of the Cripple Creek area grew from a handful of people in 1890 when gold was “first discovered” to a population of 32,000 by 1900. This area was declared a gold mining district in 1891 and included the roughly 24 mi^2 (62.2 km^2) mineralized volcanic caldera. By 1900, the District had over 500 active mines within its geologic boundaries and produced 23 million ounces of gold to 1990 (Levine, 1994).

15.2 [0.4] Stop sign; turn south (right) on B Street. Follow signs for the Gold Belt Tour; in one block, turn east (left) on Bennett Street and descend into Cripple Creek. After turn onto Bennett Street, note the extensive mining on the Cripple Creek Stock on the skyline to the east (ahead). The ore is structurally controlled and occurs as disseminated, microcrystalline native gold and deposits with narrow high-grade gold-silver telluride veins. Most of the gold mineralization at Cripple Creek is believed to have been deposited after the termination of the main phase of igneous and diatremal activity (Kelley, 1996 *in press*; Pontius, 1996).

15.6 [0.9] Historic downtown Cripple Creek, the seat of Teller County. Stop sign at Bennett and Second Streets; State Highway 67 from Victor intersects County Road 1 here from south (right). Continue east (straight) on the State Highway through the business district, following the Gold Belt Tour signs. Located at the site of the Broken Box Ranch, which was established in 1884, the City of Cripple Creek began as two towns (Fremont, and Hayden Placer, platted in November 1891 and February 1892, respectively) and several other smaller towns that grew up quickly after the gold rush began in 1890. The City of Cripple Creek attained a peak population of 13,000 people in 1902 when it was the fourth largest metropolitan area in Colorado. It has been estimated that 32,000 people resided in the Cripple Creek Mining District then. By 1902, Cripple Creek had become a financial center with 52 stock brokers, 3 banks, 3 stock exchanges, 10 insurance representatives, 5 newspapers, a public library, several schools, 5 railroads, 9 jewelers, 49 grocers, several churches, 68 saloons, and numerous gambling halls and “sporting parlors” (Levine, 1994). Then, with the decline in gold prices and economic downturn, the city began a long period of decline that continued until the early part of the current decade when gold-mining was renewed and limited-stakes gambling was legalized.

16.5 [0.2] Eastern City Limits of Cripple Creek. The road here is on biotite gneisses.

16.7 [0.2] Bridge and broad curve. Prospects above the road are in light-yellowish-brown phonolite breccias of the Cripple Creek Stock.

16.9 [1.3] STOP 5. CRIPPLE CREEK OVERLOOK. Pull off State Highway 67 into the parking lot of the BLM overlook on the west (left) side of State Highway 67.

From the overlook looking due south (refer to fig. 20), on the skyline, we can see the north end of the flat-topped Wet Mountains, composed of Precambrian igneous and metamorphic rocks. The City of Cripple Creek is to the southwest. From the overlook, the hill to the northwest less than 0.5 mile (0.8 km) with reddish rocks exposed by mining is Carbonate Hill, formed by mineralized Pikes Peak Granite. Mineralized breccias of the Cripple Creek Stock are exposed uphill to the north and east with numerous prospect pits and abandoned mines. Looking due west about 3 miles (4.8 km), conical Mt. Pisgah (with communications antennae) can be seen. It is formed from the same phonolites as those of the Cripple Creek Stock; however, those of Mt. Pisgah are outside of the Cripple Creek caldera and are not brecciated and mineralized. To the right (north) of Mt. Pisgah, the dark, broad, wooded mountain is Thirtynine Mile Mountain, source of the Thirtynine Mile volcanics. The snow-covered mountains on the skyline to the west-northwest are in Sawatch Range across the Arkansas River valley; visible from the overlook are (from north to south) Mt.Harvard, Mt. Princeton, Mt. Antero, and Mt. Shavano. The source of the Wall Mountain Tuff was just south of the Mt. Princeton area. In the distance to the southwest, the broad wooded mountain is Waugh Mountain, composed of andesitic and basaltic rocks. On the skyline to the southwest are the snow-capped Sangre de Cristo Mountains.

Recent detailed geologic mapping of the Mining District (Pontius and others, 1997, *in press*) demonstrated a complex sequence of intrusive, extrusive, and diatremal eruption events. In general, the volcanic complex of the Cripple Creek District can be divided into three geologic terraines (Pontius, 1996): (1) the eastern side, characterized by a repetetitive flat-lying sequence of volcaniclastic sediments and phonolite flows; (2) the central area, dominated by complex flow-dome features that exhibit cross-cutting intrusives of varying compositions; and (3) the western side (the area in which we are presently standing), characterized by extensive areas with diatremal and volcaniclastic breccias with scattered intrusive and flow-dome features. Pontius

Figure 20. View looking southwestward from BLM overlook (Stop 5). See text for explanation.

(1996) thought that diatremal breccias underlie much of the deeper parts of the district.

Retrace route into Cripple Creek.

18.2 [0.9] Cripple Creek Town Limits. Continue into town, following Gold Belt Tour signs.

19.1 Stop sign; Bennett and Second Streets (equals mileage 15.6 of Segment B); turn left (south), continue on State Highway 67 toward Victor. *Reset odometer to 0.0.*

Segment C:
Cripple Creek to Victor

0.0 [0.2] Intersection of Bennett and Second Street (U.S. Highway 67) at the Palace Hotel. Turn southward toward Victor on State Highway 67. Geologically, Cripple Creek is underlain by Early Precambrian (1.70 Ga) biotite gneisses, thought to be metamorphosed volcanigenic rock here (Tweto, 1987).

0.2 [0.4] To the east (left) up the hill from the City of Cripple Creek lies Poverty Gulch. Although H.T. Wood of the Hayden Survey (1872-73) first recognized gold in the area near Victor (Beacon Hill), the cowboy prospector Bob Womack is credited with discovering gold here in a small placer deposit in Poverty Gulch in 1890. Shortly thereafter, high-grade gold veins were located and followed underground, thus initiating “America’s Greatest Goldrush”. At the top of Poverty Gulch, the headframe for the Hoosier Mine can be seen. The edge of the Cripple Creek Mining District is southwest of here. The roadlog will follow the western and southern boundary of this District toward Victor. The District was mined for gold and associated silver almost continuously since Womack’s discovery. Up the nearby hill stands the headframe of the Anchoria Leland Mine. All of the headframes and associated structures that can be seen are not operating at this time. The active mining, taking place at the largest scale yet seen in the District, is open-pit surface mining. These activities will be seen closer on the route to Victor.

0.6 [0.1] A silver-colored steel headframe representing the Volcano Mine can be seen. This headframe was constructed in the 1970's. Unfortunately, its construction was based on an unfulfilled promise of a rich deposit of silver; the Volcano Mine never produced any ore. Such speculative promises were prevalent in most all mining districts.

0.7 [1.0] Broad curve south of Cripple Creek. Here, the highway crosses into the Cripple Creek Quartz Monzonite, dated at 1.4 Ga, which intrudes both the biotite schist and a Precambrian granodiorite unit. The mines at the top of the hill are part of the Midget and Moon Anchor groups, which produced primarily during the 1930's and yielded *ca.* 200,000 ounces of gold. The dumps from these mines were reprocessed by means of heap-leach method in the early 1990's.

1.7 [0.3] Road rounds ridge and proceeds into Squaw Gulch. The large cribbed wall associated with the Mary McKinney Mine can be seen on the east side of the valley. The cribbing was stabilized to prolong its life by the Cripple Creek & Victor Mining Company (CC&V), whose operations will be viewed a few miles down the road. The cribbing is monitored by CC&V to assist in conservation efforts. The Mary McKinney Mine produced more than 600,000 ounces of gold from 1893 to 1935.

2.0 [0.6] STOP 6 (OPTIONAL). MINING AREA. Here is a good turnout for stopping and viewing.

Much of this route from Cripple Creek parallels the Cripple Creek & Victor Narrow Gauge Railroad on the north (left). A trip on this railroad leads to the old blacksmith shop off to the left. Not far up the highway on the left, a barred mine adit can be seen. This work, performed to protect the public, is conducted under the sponsorship of the Colorado Department of Natural Resources and their Abandoned Mined Land Program. An intensive effort to protect the public in the Cripple Creek area has been undertaken by that group.

The town of Anaconda was located in this valley. Little remains because the rigors of weather and lack of maintenance have taken their toll here and throughout the District. However, trips to the Cripple Creek Museum, the Lowell Thomas Museum in Victor, and the Western Museum of Mining and Industry north of Colorado Springs will help bring back the memory.

Above the Mary McKinney on the horizon are the Wedge and the Julia E headframes of the Ophir Gold Mines Company. Farther to the southeast is the ore house of the Chicken Hawk Mine. Just ahead in the roadcuts to the left, as the turn in the valley is approached, the contact between the Precambrian rocks and the Tertiary volcanic complex occurs. The road leading down the valley to the right is the upper part of the Shelf Road, a toll road for wagon and stage traffic connecting the Cañon City and Florence area with Cripple Creek and Victor. The toll keepers charged the drivers according to the number of horses drawing the vehicle. The Shelf Road leads through some fascinating geology and topography to the Cañon City area. It is not paved and is very narrow and winding. Off to the left at the head of the valley, just out of view from here, are the Ironclad and Globe Hill Mines of CC&V, which operated most recently from 1991 until 1994 and produced 170,000 ounces of gold. The two surface mines from this prior operation are being backfilled by CC&V with overburden from the current Cresson operation. These backfilled mines will be graded and revegetated toward the end of operations to restore the area to wildlife habitat.

Continue northward toward Victor.

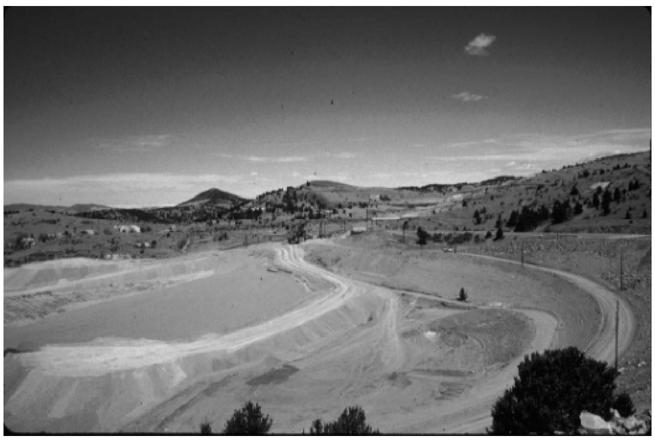
2.6 [0.3] Highway rounds ridge. Looking south as the ridge is rounded, the metal headframe from the El Paso Mine can be seen off to the right on the west side of Beacon Hill. This mine produced about 800,000 ounces of gold during the early 1900's. The mine is located along the contact of a Tertiary phonolite plug and the Precambrian granodiorite, which runs along the ridge on the west side of the valley. The granodiorite unit has been dated at 1.70 Ga and abuts the southern and eastern boundary of the volcanic complex.

2.9 [0.2] The well-preserved brick hoist building that served the Nickel shaft can be seen. A careful looks shows the collapsed shaft and underscores why it is better to view this historic area from public roads.

3.1 [0.3] STOP 7. CRESSON LEACHATE OPERATION. Rounding the ridge that extends southward forming Beacon Hill, the valley leach facility operated by CC&V for its Cresson operation can be seen. Park on the side of the highway.

The Cresson gold deposit is located in the south-central portion of the Cripple Creek Mining District, which is the third largest producing district in the United States. CC&V currently controls approximately 85% of the land area and more than 4,800 patented mining claims within the Cripple Creek Mining District (Pontius, 1996). Within these claims are current proven and probable reserves are 90 million tons, with an average grade of 0.025 opt. Au (2,259,000 ounces). This Cresson reserve is contained within a District-wide geologic resource estimated at more than 4,000,000 ounces of gold. At current prices of roughly $400 per troy ounce, this reserve is worth approximately $1.6 billion!

The valley leach facility (fig. 21 A and B) at this site holds gold ore and allows the removal of the gold from the ore using a dilute sodium cyanide solution. The gold-bearing solution is then passed through a carbon adsorption, desorption, and metal recovery (ADR) plant to produce a gold doré (a mixture of gold with a little silver). This ADR plant is the building on the far edge of the valley leach. The ore is from the volcanic complex located northeast of these leach facilities. The valley leach facility is a zero- discharge facility, constructed with a triple-liner system to prevent any solution from entering the environment. This leach facility is one of the most technologically advanced in the world.



Figures 21 A and B. Valley leach area, Cresson operation from Stop 7. A (top) - View looking to northeast. B (bottom) - Looking north, Carlton Mill is large building in midground.

The large silver-roof building to the east, by which the field trip route passes, is the Carlton Mill (fig. 21 B), commissioned in 1951 and operated until 1962, when it was the largest custom gold mill in North America. Much of the milling equipment was brought from the Golden Cycle Mill which processed much of the ore historically mined from the District. That mill was located between Manitou Springs and Colorado Springs. About 1.5 million tons of ores were milled here. The mill was designed to accept ores from numerous mines in the District, to combine these ores for milling, and then to deposit the spent ores (“tailings”) in the drainage where, now, the Cresson valley leach facility is located. The Carlton Mill tailings have been relocated by CC&V as part of the Cresson Project and covered by overburden to eliminate a periodic dust problem. This also removed the material from the active stream channel of Arequa Gulch (the name of the drainage) and placed the material where it will be encapsulated by overburden as the Cresson Project advances.

On the far side of the hill past the Carlton Mill is a conveyor belt system connecting the Cresson crushing facility with the valley leach facility. The Cresson Mine is located northeast of the mill and the eastern edges may be seen on the route toward Victor. The crusher and conveyor system transfer as much as 2,000 tons per hour of gravel-sized ore to 85-ton off-road trucks, which place the ore on the leach facility. The mining operations move 60,000 tons or more per day of ore plus overburden.

Continue toward Victor.

3.4 [0.2] Approaching the display of historic underground-mining equipment on the right, the road crosses back into the Cripple Creek volcanic complex.

The activities on the south side of the road are almost entirely in the granodiorite. The diversion ditch system passes under the highway at this point. This runoff diversion system picks up storm-water runoff from areas outside the operations. It extends north around the mine complex and diverts the water before it reaches the active mining area, thus preventing erosion. Further, in this manner, water inflow to the project operations, such as the Valley Leach Facility, is eliminated, and water flows in Arequa Gulch, the natural drainage, are maintained. In the spring and summer, flowers are abundant in the areas replanted by the CC&V.

3.6 [0.3] The Carlton Mill is on the right (fig. 21B). Note the many numbered ore “bays” that were assigned to the individual mines. The old Elkton Mine was located uphill to the left near the current Cresson crusher site. The Elkton Mine produced 800,000 ounces of gold during its lifetime. This area was another town site, and the few deteriorating structures that remained received intensive study and documentation so that their history would be preserved for future generations.

3.9 [0.4] As road turns away from the mill area, the highway crosses under the third leg of the conveyor line, and back into the granodiorite.

Looking to the south, the Valley Leach Facility with the ADR plant in the background can be seen. Ahead to the north, some of the current Cresson mining operation can be seen. Near the center of the current operation is the location of the historic Cresson Mine, developed in 1906 on a lamprophyre breccia pipe, from which was produced about 2.5 million ounces of gold. This historic underground mine was famous for the vugs that it encountered, one of which was reported to have produced 60,000 ounces of gold! The gold from this vug simply was shoveled into bags and hauled by wagon and railroad to the smelter — under shotgun guard, of course! At this point, a turnout will be developed by CC&V to explain the Cresson Project in some detail. Ahead is a new section of U.S. Highway 67 constructed by CC&V to accommodate overburden. The relocation also removed a hairpin curve and thus shortened the trip from Cripple Creek to Victor.

4.3 [0.8] Rounding the next curve, the Sangre de Cristo Range can been seen to the south. This range extends from near Salida southward into central New Mexico and is one of the youngest in the Southern Rocky Mountains. Fresh fault scarps along the Sangre de Cristo front indicates that tectonic activity is continuing today.

5.1 [0.2] STOP 8 (OPTIONAL). VICTOR CITY HALL. Pull off highway on side opposite City Hall and park. The exterior of the City Hall retains much of its original 1900 flavor, and the building is in the process of being refurbished. Note the description of the City of Victor just down the highway from the City Hall. Looking up, Battle Mountain, located to the north of the City, produced nearly 10 million ounces of gold from 1891 until 1940. The principal mines in this area were the Portland (I and II), Independence, Strong, and the Ajax. The Independence headframe, as well as the Independence Mill located immediately south of the headframe, have been placed on the National Register of Historic Places, through the sponsorship of the CC&V, the property owner.

Continue northward on U.S. Highway 67.

5.3 Turn around and return to Cripple Creek, where we will spend the night. The road ahead becomes gravel for a distance and has just passed the completely refurbished Victor Hotel and the Lowell Thomas Museum. The baseball field, known as the Gold Bowl, has a good view of the large headframe from the Cresson Mine. CC&V refurbished and moved this headframe and donated it to the City of Victor in 1994. Retrace route to Cripple Creek.

Optional. Other CC&V-relocated mining displays are located in Victor at the old Gold Coin shaft and outside the Lowell Thomas Museum. Mining took place beneath Victor, but it was generally not permitted on the surface within the town. Stories abound about those times. For example, the Gold Coin Mine was reported to have been discovered by folks excavating to build a foundation for a hotel. Word was that they changed professions immediately!

For those interested in the spectacular view of the Sangre de Cristo Range from the American Eagles lookout, Rangeview Road, which leads to that lookout, is the gravel road leading north up the side of Battle Mountain above the Gold Bowl (the baseball field).

DAY 2: EVERGREEN JUNCTION TO CAÑON CITY, GARDEN PARK, AND INDIAN SPRINGS

The second day of this field trip (fig. 1) is divided into three parts for convenience: Segment D (Evergreen Station to State Highway 9), Segment E (State Highway 9 to Cañon City), Segment F (Cañon City to Garden Park), and Segment G (Cañon City to Indian Springs. After the last stop, we will return to Denver via Penrose and Colorado Springs. Eight stops are scheduled for this second day, three of which are optional.

Geology along High Park Road, Evergreen Station to State Highway 9

Among the Precambrian rocks exposed along the route from Evergreen Junction to State Highway 9, the oldest is a Precambrian (Early Proterozoic) biotite-quartz-plagioclase gneiss, dated at 1.7-1.8 Ga (Tweto, 1987). This gneiss was formed by the metamorphism of sedimentary rocks composed of sandstones, mudrocks, and minor carbonates. The Cripple Creek Quartz Monzonite formed as part of the Cripple Creek batholith was intruded into this basement complex about 1.4 Ga, and the Pikes Peak Granite is the youngest of the Precambrian rocks along this route. The Pikes Peak Granite, dated at about 1.08 Ga (Tweto, 1987; Wobus, 1994), occurs only at the beginning of the route, near Evergreen Junction, where Segment D begins.

No Paleozoic rocks and only limited exposures of Mesozoic rocks occur along the High Park Road (fig. 22), which was part of the Front Range Highlands, an area uplifted during the block faulting and formation of the Ancestral Rockies during the late Paleozoic (fig. 23). The oldest sedimentary rock in High Park is the Jurassic Morrison Formation, which consists of multicolored gray, maroon, and green siltstones and claystones with minor sandstones, conglomerates, and lacustrine and pedogenic limestones. This formation was deposited in fluvial and floodplain environments and is widespread through the Rocky Mountains and Colorado Plateau, from Utah to Colorado, northern New Mexico, the Oklahoma panhandle, western Kansas, Wyoming, and into northern Montana. The Morrison Formation contains some of the classic North American dinosaur sites (see discussion in Segment F). The Cretaceous Dakota Group consists of crossbedded sandstones and mudrocks deposited in sequence of transgressive and regressive marginal-marine and fluvial environments on the edge of the Western Interior Seaway.

Rocks of Tertiary age (fig. 22) along the High Park Road include (by decreasing age) the Wall Mountain Tuff (36.7 Ma), Tallahassee Creek Conglomerate, lower Thirtynine Mile Andesite (34.1 Ma), and the Cripple Creek phonolites (32.5 to 31.2 Ma) (Tweto, 1987; Wobus and Hutchinson, 1988; Wobus and others, 1990; Luedke, 1991; Kelley, 1994; McIntosh and Chapin, 1994). The Tallahassee Creek Conglomerate is a poorly sorted conglomerate composed of pebbles to huge boulders of volcanic clasts eroded from the Wall Mountain Tuff and from andesites produced by early eruptions in the Thirtynine Mile volcanic field. The conglomerate was deposited by streams in paleovalleys that were channeled into the surface of the Wall Mountain Tuff (Epis and Chapin, 1975). The Tallahassee Creek Conglomerate is overlain by the Thirtynine Mile Andesite, which is divided into lower and upper members consisting of laharic mudflows, lava flows, and breccia derived from volcanism in the Thirtynine Mile volcanic field. This volcanic field consisted of several coalescing composite volcanoes that developed on the Eocene erosion surface. The Cripple Creek phonolite consists of flows and domes that were produced by the Cripple Creek volcanic center with dates clustering closely between 32.5 to 31.2 Ma (Kelley, 1994).

Quarternary deposits are mainly confined to the stream valleys in this area.

Segment D: Evergreen Station through High Park to Cañon City

0.0 [1.8] Junction at Evergreen Station of Teller County Road 1 and High Park-Guffey Road (County Road 11). Proceed southward on High Park-Guffey Road.

The road junction is situated near contact between the Pikes Peak batholith to the east and the Cripple Creek batholith to the west. The Cripple Creek Quartz Monzonite is exposed in knob to the west (right) after the turn. For the next mile (1.6 km), rocks of lower Thirtynine Mile Andesite are visible in the roadcuts and in the low hills in fields beside the road. Two exfoliation domes formed from the Pikes Peak Granite can be seen to the east (left) of the road.

1.8 [2.3] Wright's Reservoir on east (left). Road is on lower Thirtynine Mile Andesite. The Cripple Creek Quartz Monzonite makes up the ridges about a mile (1.6 km) away from either side of the road.

4.1 [1.3] Junction of High Park Road (Teller County Road 11) and Guffey Road (County Road 112); turn west (right) toward Guffey.

The road here is on the Tallahassee Creek Conglomerate (fig. 22), which stratigraphically underlies the lower Thirtynine Mile Andesite. The andesites originated in the Thirtynine Mile volcanic center, a group of large coalescing composite volcanoes west of this point, and flowed eastward down the paleovalley occupied by West Fourmile Creek, out of the valley, and filled northward up the paleovalley toward Florissant.

5.4 [0.9] Continue westward on Guffey Road.

Granitic rocks form the ridges here on either side of the valley of West Fourmile Creek; Tertiary sedimentary deposits occur in the valley. The topography is an exhumed late Eocene surface, and West Fourmile Creek generally follows the paleovalley here.

6.3 [0.2] Ahead to the northwest (at 2:00), West Fourmile Creek makes a notch canyon through the Cripple Creek Quartz Monzonite.

After the late Eocene paleovalley was filled with sediments and volcaniclastics, West Twomile Creek was diverted northward from its late Eocene course, was superimposed onto the underlying quartz monzonite, and cut its way through it, joining the paleovalley here (fig. 24).

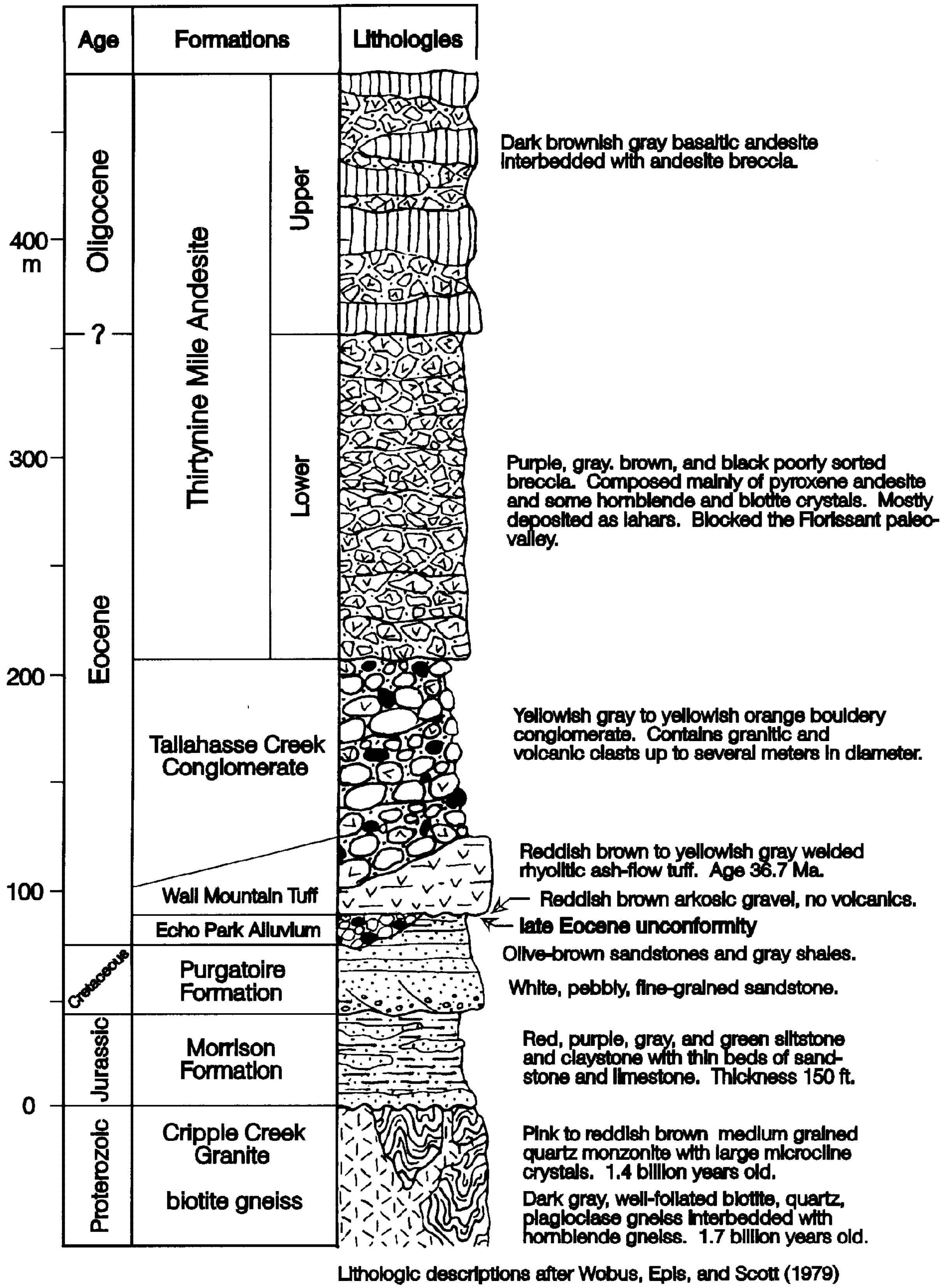


Figure 22. Stratigraphic section for High Park area. Scale to left is in meters.

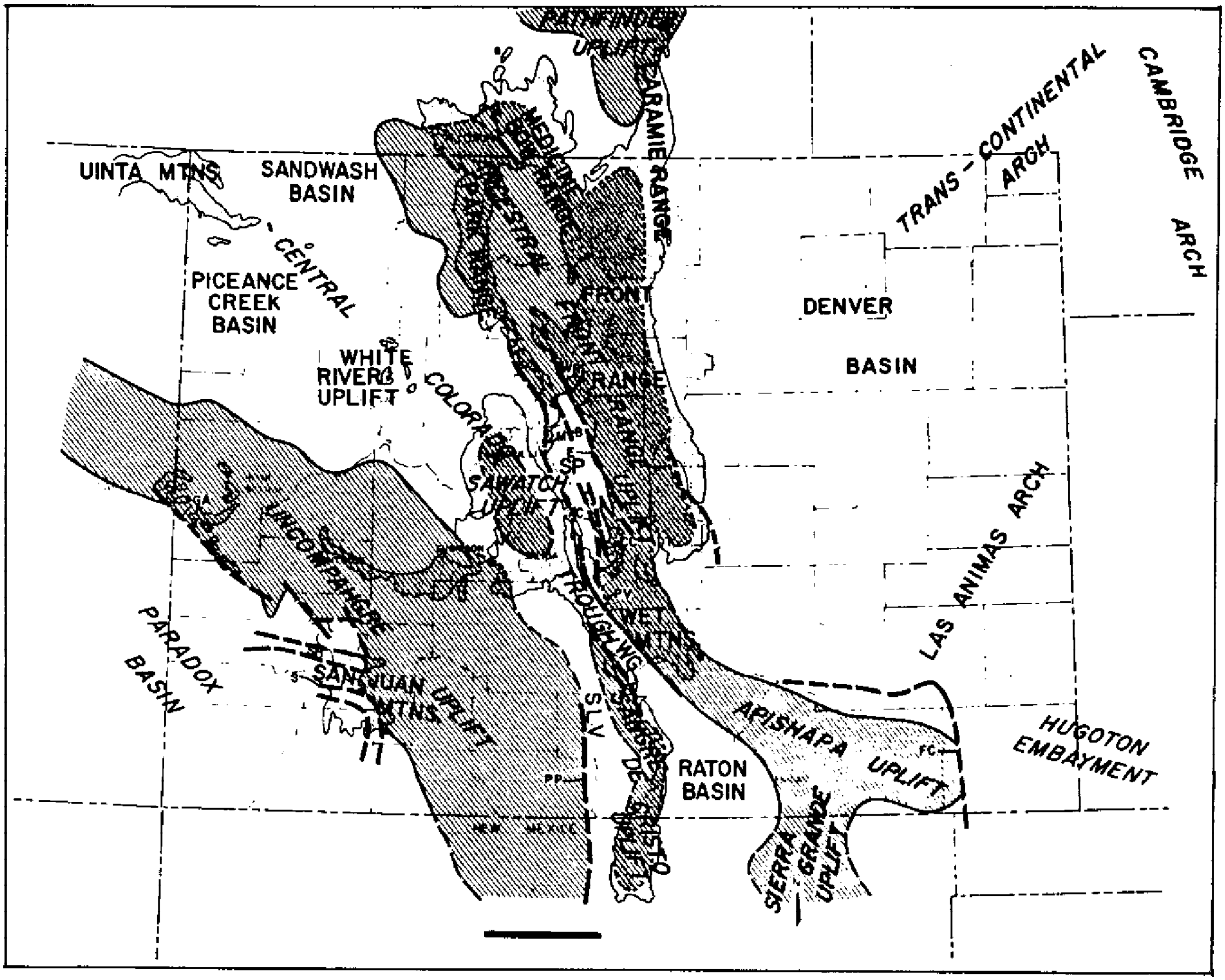


Figure 23. Paleotctonic features of Southern Rocky Mountains in Colorado (from De Voto, 1980b, fig. 3, with permission). Outcrop areas of Precambrian rocks shown in stippled pattern; Pennsylvanian uplift (Ancestral Rockies) and erosional areas shown in darker stipple. Pennsylvanian faults shown with heavy dashed lines.

Figure 24. Notch valley cut by West Fourmile Creek through Cripple Creek Granodiorite. View to northwest from Teller County Road 112 (Guffey Road).

6.5 [0.5] Enter Park County; Teller County Road 112 becomes Park County Road 102.

7.0 [2.7] STOP 9. OVERVIEW OF THIRTYNINE MILE VOLCANIC FIELD. At the small divide, park the vehicles on the south (left) side of the road.

The most striking features from this divide are the conical to flat-topped mountains on the skyline to the west. From south to north, they include Witcher, McIntyre, Castle, Saddle, and Thirtynine Mile Mountains (fig. 25). These mountains are the eroded remnants of a complex of stratovolcanoes that were built around the Guffey volcanic center. The mountains are composed of interbedded intermediate volcanic flows and laharic breccias that dip away from the volcanic center. Thus, the volcanic rocks of Witcher Mountain dip to the south (left); the rocks in McIntyre Mountain dip to the east toward us; and the rocks of Thirtynine Mile Mountain dip to the north (right). No circular faults have been found in the interior of this ring of mountains (Epis, Wobus, and Scott, 1979; Wobus, Epis, and Scott, 1979a, b), and, thus, the mountains represent erosional remnants of the stratovolcano complex, not the rim of a caldera. Laharic breccias flowed out of these volcanoes, filling paleovalleys such as the dark, vegetated ridge in the foreground and south (left) of Park County Road 102.

We are standing on a north-south trending outcrop of the Cripple Creek Quartz Monzonite that butted up against this paleovalley. The rolling surface to the north (right) is cut across the Proterozoic quartz monzonites. On top of this surface are scattered outcrops of the Wall Mountain Tuff, even on interfluves, indicating that it represents an exhumed late Eocene surface. The Thirtynine Mile breccias filled the paleovalleys and covered this surface. Streams flowed on these volcanics independent of underlying structures and lithologies, and, as they later cut dow through the volcanics, they did not follow the paleovalleys. A good example is where West

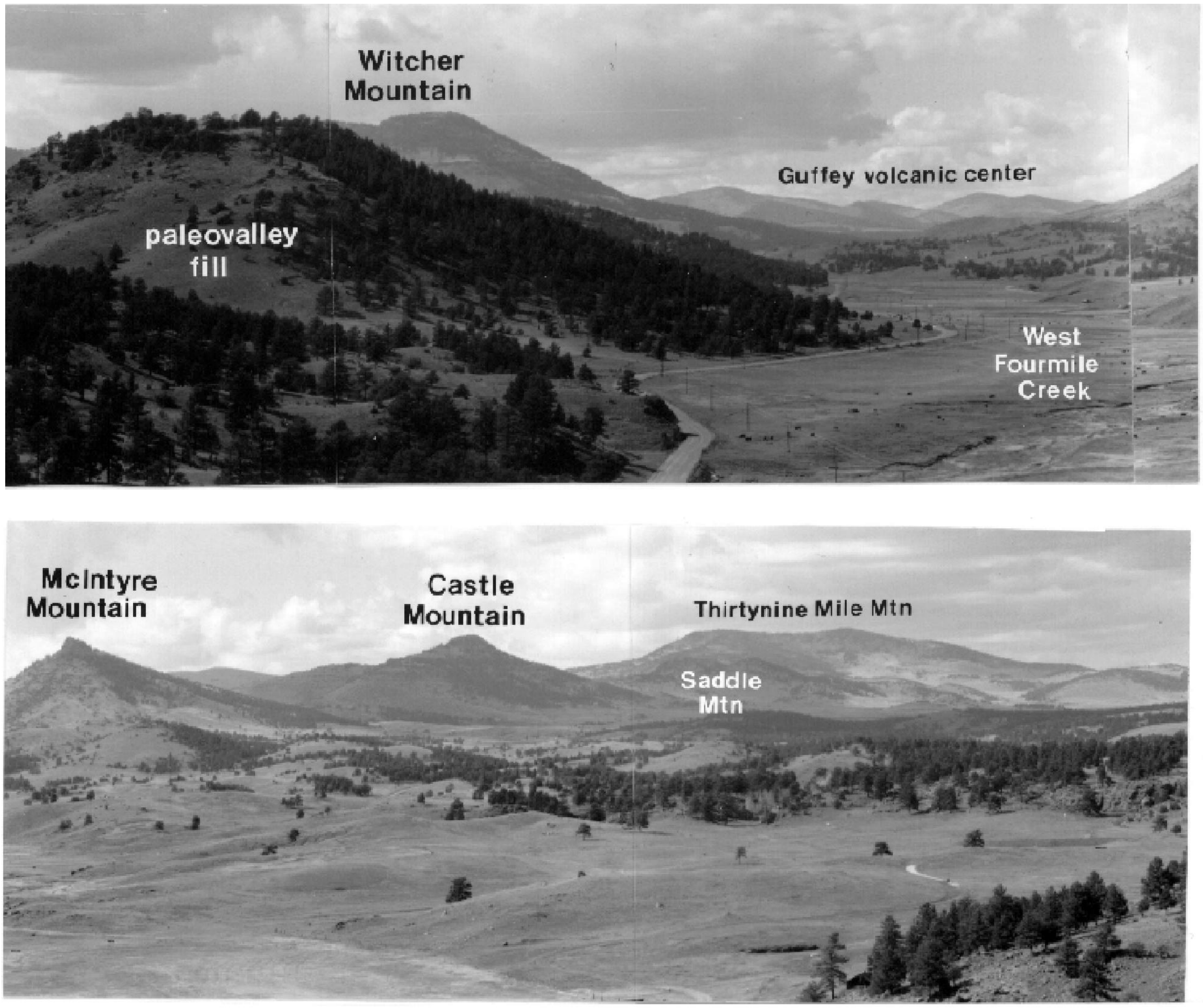


Figure 25. Composite photographs looking westward up valley of West Fourmile Creek from knob at Stop 9 (From Evanoff, 1994, with permission). Right side of upper composite figure fits left side of lower one.

Fourmile Creek parallels the paleovalley in a wide valley to the west and has cut a narrow notch through the grano-diorite ridge just north of there.

From the top of the ridge to the east (behind) us is an excellent view not only to the west, but also the east down the broad lower valley of West Fourmile Creek toward Pikes Peak and Mt. Pisgah. Access to the ridge top is much easier from the east side.

Return to vehicles and retrace route to intersection of Teller County Road 1 and Guffey Road.

9.7 [1.4] Junction of Guffey Road and High Park Road (Teller County Road 11). (Equals mileage 4.1 of Segment D.) Bear southeast (right) toward Cañon City. The large conical mountain ahead to the east is Mt. Pisgah. The road travels southward along the contact between the Cripple Creek Quartz Monzonite on the right side (west) and the Tallahassee Creek Conglomerate on the left (east).

11.1 [0.3] The road rises out of the valley and onto the Cripple Creek Quartz Monzonite.

11.4 [1.5] STOP 10 (OPTIONAL). VIEW OF LATE EOCENE GEOMORPHIC SURFACE. Near the summit of the low divide, an unimproved road leads southeast (left) beyond a steel gate to an open hilltop with panoramic views especially to the south and west. High-clearance vehicles can drive 0.5 mile (0.8 km) to the grassy hilltop; others should park here near the highway and walk.

From the grassy hilltop is an outstanding panoramic view of the northern end of High Park and the surrounding area (fig. 26). Pikes Peak is visible at N 65 degrees E, and the conical mountain at N 83 degrees E in the midground is Mt. Pisgah, located just northwest of the City of Cripple Creek. The relatively flat-topped dark mountains at S5 degrees E are the Wet Mountains, and, on the horizon at S 25 to 40 degrees W, are the Sangre de

Figure 26. View looking south-southwestward from Stop 10 into High Park. See text for explanation.

Cristo Mountains, comprised predominantly of middle and late Paleozoic sedimentary rocks and Precambrian gneiss and granite (fig. 26). The high, relatively flat surface with low hills on the horizon between S45 degrees W and due west is part of the Thirtynine Mile volcanic field. The hilltop and surrounding vicinity predominantly covered by grassy vegetation (fig. 26) is on the beveled (stripped) late Erosion surface developed here on the Cripple Creek Quartz Monzonite. A small pit dug near the apex of the grassy hill here reveals the thin alluvial veneer and dark-colored paleosol containing pebbles and cobbles of igneous material and white "bull" (vein) quartz overlying the weathered Precambrian rocks. This pre-volcanic, late Eocene geomorphic surface is characterized by low to moderate relief and included shallow, broad, generally dendritic streams and valleys, such as the valley in which the lake beds of the Florissant Formation were deposited later to the north of here. The widespread nature and importance of this erosional surface as a datum for Cenozoic structural and geomorphic reconstruction was recognized by the end of the last century (Cross, 1894). This geomorphic surface is reported to have extended throughout south-central Colorado (Chapin and Epis, 1964; Epis and Chapin, 1968, 1974, 1975; Scott, 1975; Scott and Taylor, 1986). It is probable that parts of this late Eocene surface toward the east have been modified by subsequent erosion events (see discussion at mileage 0.0 of Segment A of this roadlog). It is predominantly the surface upon which the oldest and most widespread of the Tertiary volcanics in this area, the Wall Mountain Tuff, was deposited.

Return to the vehicles and proceed southward toward Cañon City.

12.9 [0.4] Bridge over Little High Creek.

High Park is formed by the late Eocene stripped erosional surface underlain here by the Cripple Creek Quartz Monzonite. Note the grassy vegetation that commonly develops on erosional and alluviated surfaces such as this.

13.3 [1.1] High Park Road turns left and in 0.2 mile turns right, passing around a low hill with lower Thirtynine Mile Andesite above and the extremely coarse-grained Tallahassee Creek Conglomerate below.

Straight ahead (to the southeast), Booger Red Hill is composed of phonolite at its summit with the Tallahassee Creek Conglomerate, Wall Mountain Tuff, and Cripple Creek Quartz Monzonite below. Giant boulders ("corestones") exposed in the grassy areas on both sides of road are typical of the Tallahassee Creek Conglom-erate, which contains clasts of the Wall Mountain Tuff and other andesites derived from the west. Some of the boulders in this formation are blocks as large as 30 feet (9 m) in diameter (Epis and Chapin, 1974). The conglomerate was deposited in paleovalleys that drained the Sawatch-Mosquito highlands to the west and crossed the Tallahassee Creek and High Park areas to the southeast before the major development of the Thirtynine Mile volcanic field (Evanoff, 1994). The Talahassee Creek Conglomerate near its base also contains petrified stumps and thin limestone interbeds that contain a freshwater (lacustrine) fauna (De Voto, 1971).

14.4 [0.9] Cattleguard with nearby pullout. Continue toward Cañon City.

High Park Road here is on the Tallahassee Creek Conglomerate. The Bare Hills, a topographic feature, make up the flat to the south-southwest (left and ahead) on the skyline. The lower slopes of the Bare Hills are formed by the Tallahassee Creek Conglomerate capped by the lower Thirtynine Mile Andesite. The conical buttes are phonolite intrusions. To the northwest (right) side of the road, the low hills on the side of the open valley are on the opposite side of the High Park Fault Zone, exposed at the base of the low hills. The High Park Fault Zone is an early Cenozoic structural feature with the far side upthrown. The small patches of reddish soil on this side of the fault are formed by the weathering of Jurassic Morrison Formation, which here rests on Precambrian rocks.

15.3 [0.1] Road crosses small drainage.

The road goes onto the Early Proterozoic (1.7 Ga) biotite gneiss, which it follows for next 4 miles (6.4 km). The large boulders on the ridge to northwest (right) are in the Tallahassee Creek Conglomerate. The road climbs onto the stripped early Tertiary surface and into piñon woodlands.

15.4 [0.1] Milepost 1.

15.5 [1.0] Cross small drain; biotite gneiss on both sides of the road.

16.5 [1.3] Teller-Fremont County Line at High Creek.

17.8 [0.4] High road cut.

The exposures on the northwest (right) side of the road reveal the jointing and deep spheroidal weathering of the biotite gneiss, which develops concentric shell-like layering (“onionskins”) around a spherical core. These features form as feldspar and micas are weathered to clay and expand with the addition of water, weakening the outer rock crust and causing it to separate from the less-weathered core.

18.2 [0.3] High Park Road intersects Bare Hills Fault.

18.5 [0.0] Leaving BLM land; the entrance to High Park Ranch is on the left (south). The sharp conical butte to the southeast (left) is a phonolite plug. For the next 2 to 3 miles (3.2 to 4.8 km), the road follows the Bare Hills Fault, which is displaced down to the southeast.

19.4 [0.2] Cattleguard.

19.6 [0.2] Milepost 9; gneiss is exposed on the north (right) side of the road; a short distance ahead, the road crosses the contact from the biotite gneiss back onto the Cripple Creek Quartz Monzonite (Taylor and others, 1975; Wobus and Epis, 1978).

19.8 [0.4] Small outcrop of Morrison Formation on south-southeast (left) side of road.

20.2 [1.90 Divide (elev. 8,363 ft) on Cripple Creek Quartz Monzonite.

As the road drops into the drainage of City Creek just to the southwest of this divide, it again follows the biotite gneiss for about 1.5 miles (2.4 km), still paralleling the fault zone. The Sangre de Cristo Mountains can be seen ahead.

22.1 [0.5] Cattleguard; valley opens up.

This area was uplifted primarily by block faulting during the late Paleozoic with the formation of the highlands of the Ancestral Rockies and the complementary intermontane basins, and the older Paleozoic rocks were removed by erosion (see fig. 23). The sediments derived therefrom were deposited in the down-faulted intermontane basins. According to De Voto (1972, 1980b), this aggressive block-faulting tectonism that occurred throughout the Pennsylvanian was similar in style to that of the Late Cretaceous and early Cenozoic Laramide Orogeny. This Pennsylvanian tectonism resulted in the development of ranges with as much as 10,000 feet (3,000 m) of relief that were roughly coincident with many of the present-day uplifted blocks (e.g., the Front Range, Wet Mountains, northern Sangre de Cristos). The oldest sedimentary rocks in the High Park area are those of the Jurassic Morrison Formation, which rests directly on the Precambrian rocks here.

This valley and the lower slopes of the surrounding hills are in the Morrison, which can be seen as small red outcrops peeking through the grassy vegetation. Sandstones of the Dakota Group cap the near ridge at 10:00 ahead. The Dakota Group as mapped in this area includes a basal white sandstone (Lytle Sandstone Member of Purgatoire Formation) (see fig. 22). A fault can be seen in the grassy saddle to the north (left).

22.6 [0.8] Lake on southeast (left) side of road. The road climbs onto the Cripple Creek Quartz Monzonite.

The high buttes to the northwest (right) on the skyline are called Cap Rock Ridge (elev. 9,826 ft). The upper beds formed by the resistant upper Thirtynine Mile Andesites reveal prominent columnar jointing. These are underlain by less resistant, slope-forming lower Thirtynine Mile Andesites, seen yesterday at Stop 4 and earlier today at Stop 9. The main body of the Thirtynine Mile volcanic field (including the Guffey volcanic center) was developed extensively north of this ridge, out of view from this point.

23.4 [1.2] Cattleguard.

24.6 [0.5] Road junction to Giddings Ranch to the northwest (right); turn south (left) following High Park Road.

The road is on the Tallahessee Creek Conglomerate for the next 0.6 mile (0.9 km). The view to the north (right) is of Cap Rock Ridge, to the southwest ahead along the road is of the Sangre de Cristos, and to the northeast (behind) is of Pikes Peak.

25.1 [0.1] Small summit; good exposures of the Tallahassee Creek Conglomerates are seen in the roadcuts.

25.2 [3.1] Road drops into a faulted shear zone in the Cripple Creek Quartz Monzonite, which it follows along Miner Gulch for the next 3 miles (4.8 km).

28.3 [0.3] A distinct brown lamprophyre dike can be seen to the south (ahead) about 0.25 mile (0.4 km) to the right of the junction of High Park Road and State Highway 9.

This lamprophyre cuts a light salmon-pink pegmatite within the Upper Proterozoic gneiss complex. This pegmatite is located in a shear zone within the Currant Creek Fault Zone.

28.6 [2.6] Intersection of Fremont County Road 11 with State Highway 9. Bear left on State Highway 9. The highway follows the Currant Creek Fault Zone for about 2.5 miles (4.0 km) (Taylor and others, 1975); Gribble Mountain is straight ahead.

31.2 [0.3] Enter Twelvemile Park. The valley opens up here.

Enter Twelvemile Graben, an internally complex and cross-faulted structural block.that trends northwest-southeast. In this small graben, which is about 7 miles (11.3 km) long and 2.5 miles (4.0 km) wide, rocks range from the Morrison Formation through the Pierre Shale (Scott and others, 1978) (see fig. 27). The Morrison here rests on 1.78 Ga granodiorite. The Morrison is mainly composed of finer-grained terrigenous clastics, commonly mudstones, which, when exposed to weathering and erosion at the surface, offer little support for overlying massive sandstones and thus form a medium in which large-scale slumping commonly develops, such as the large Quaternary landslide units containing blocks of broken Dakota sandstones on the west (right) side of the highway as we enter the graben.

31.5 [0.3] Continue southward on State Highway 9.

Steeply dipping, overturned light-colored beds of the Cretaceous Greenhorn Limestone are seen on the right (west) side of the highway at the small pulloff. The view from the road is of the bottoms of the overturned beds, and the traces of feeding burrows of invertebrate fossils (pelecypods, arthropods, etc.) can be seen on the intensively bioturbated beds. *Inoceramus* (large bowl-shaped pelecypods) and other invertebrate fossils are found within the beds and on the upper bedding surfaces.

31.8 [0.5] The Fort Hayes Limestone Member of the Niobrara Formation outcrops on the northeast (left) side of the road.

32.3 [0.6] Mileage Post 5; curve to the east with well-cemented Quaternary gravels in northeast (left) cuts.

33.9 [0.4] Roadcuts through Quaternary gravels; the broad valley ahead is formed by the Pierre Shale, which is about 3,900 ft (*ca.* 1,190 m) in the Cañon City area.

34.3 [0.2] Bridge over Currant Creek.

This stream flows through a deep canyon superimposed into the Precambrian metamorphic rocks north of this point, crosses Twelvemile Park, then flows back into the Precambrian to the southwest, west of Cactus Mountain (at 2:00). The road is on the Cretaceous Niobrara Formation here. The ridge to the northeast (left) exposes a stratigraphic section from the Dakota Group into the Niobrara (fig. 27).

34.5 [1.1] Outcrops of Niobrara Formation on the northeast (left) side of the road in a small cut.

Shortly ahead, the Fort Hayes Limestone Member of the Niobrara is exposed in the roadcut and forms a low ridge to the northeast (left) side of the highway.

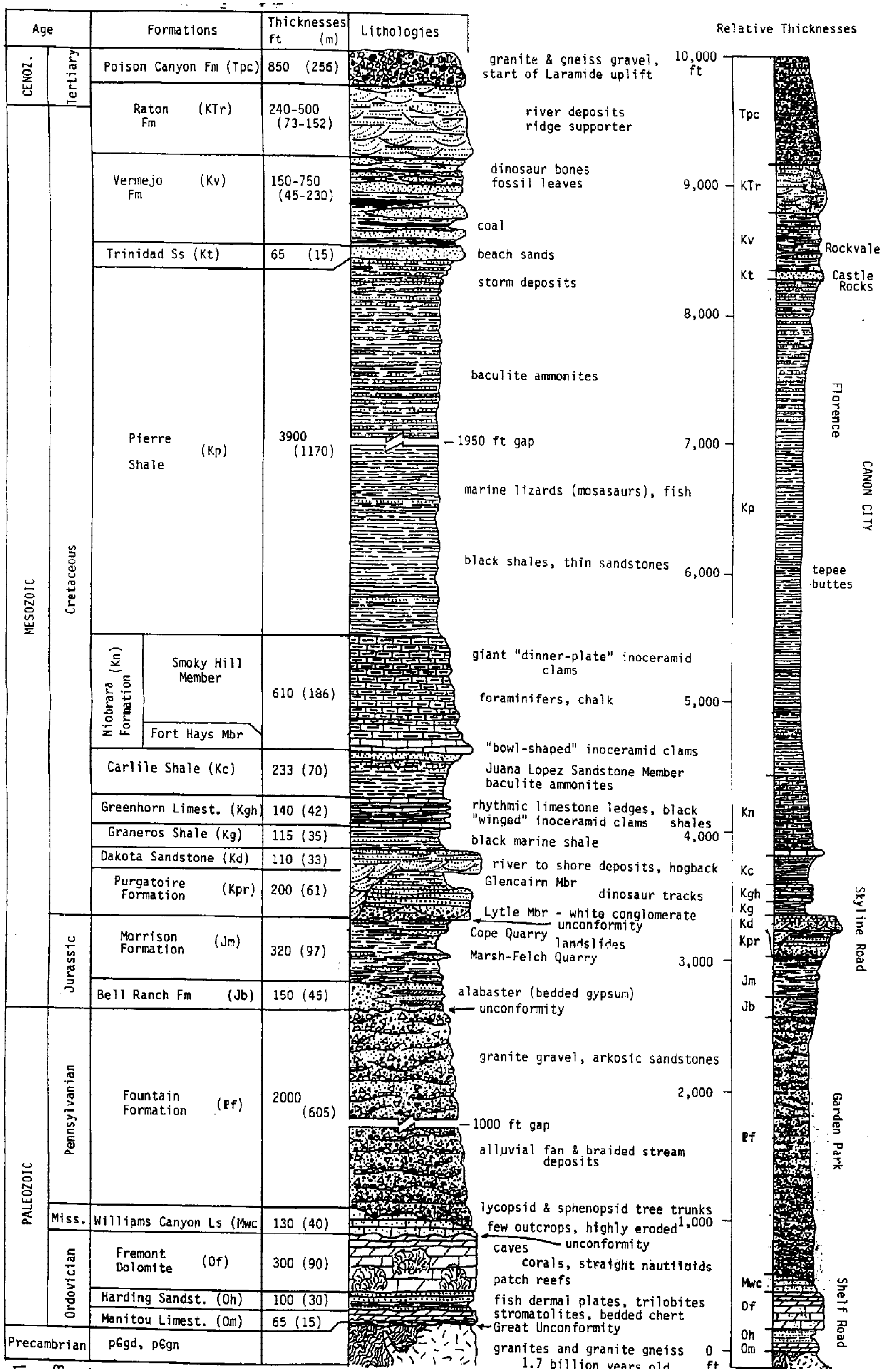


Figure 27. Stratigraphic section for Cañon City area.

35.6 [1.8] Top of divide.

Coarse-grained Pliocene(?) conglomerates with strongly developed, light-colored carbonate cement formed as part of a paleosol profile, are exposed in roadcuts. The Royal Gorge is just ahead with a view of the Wet Mountains, at the skyline. The Wet Mountains are part of the Ancestral Rockies that were uplifted again during the Laramide and again after the late Eocene (fig. 23). Ahead, the highway drops down into the Greenhorn Limestone and the sandstones of the upper part of the Dakota Group.

37.4 [0.7] Junction of State Highway 9 and U.S. Highway 50; turn east (left) toward Cañon City.

Before the turn, the highway crosses the nose of a faulted, northwest-plunging syncline; the sandstone ridge formed by the Dakota Group is exposed along the highway on both sides of the intersection, and is especially visible to the right (west). These Dakota sandstones are faulted against the Precambrian granodiorites by the Mikesell Gulch Fault at the intersection.

38.1 [1.0] The highway traverses the Morrison Formation for the next 0.5 mile (0.8 km).

39.1 [1.6] Intersection of U.S. Highway 50 with the turnoff to the Royal Gorge (County Road 3A) to the right (south); continue eastward on U.S. Highway 50. Royal Gorge is located approximately 3 miles (4.8 km) due south of this intersection.

In 1906, 5,000 acres (*ca.* 20.7 km^2) of land was ceded to the City of Cañon City by the Federal government for a public park (fig. 1) featuring the Royal Gorge (Kessler, 1941). A century earlier, during an expedition through the southern part of the Louisiana Purchase, U.S. Army Lt. Zebulon Pike wrote in his diary that the 7 mile (11.3 km) long, sheer-walled chasm that is locally 1,200 feet (366 m) deep, was "insurmountable". He wrote that "the Grand Cañon of the Arkansas river" was too wide at the rim to span, its walls were too steep to descend, and its bottom was too narrow and rough to traverse. However, spurred by the silver strikes in the Central Rocky Mountains in the late 1870's, the Denver and Rio Grande Railroad completed tracks up the Arkansas River after a protracted period of violence known as the "Royal Gorge War" with the competing Santa Fe Railroad. The Royal Gorge Suspension Bridge, the "World's Highest Bridge", was completed in 1929; a cable-operated inclined railway down the gorge was completed in 1930; and, finally, an aerial tramway spanning the gorge was added in 1969.

The granitic surface through which the Arkansas River flows here basically developed its low relief and geomorphic character as a result of Mesozoic erosion (Scott and Taylor, 1986), undoubtedly with subsequent early Cenozoic modification, but the Royal Gorge itself is a relatively young topographic feature. According to Raabe (1984) the Gorge was cut primarily during the Pleistocene by stream capture by the lower Arkansas River of the upper Arkansas drainage, which formerly flowed southward into the Rio Grande. Thus rejuvenated, the Arkansas River quickly cut deeply into the Precambrian migmatitic gneisses.

The migmatites into which the Arkansas River has cut are interpreted from petrographic evidence (Taylor and others, 1975) to have formed from high-grade metamorphism of a sedimentary and volcanic sequence that contained rhyodacitic to intermediate flows and tuffs with sedimentary interlayers composed of volcanic detritus and other clastic materials. Minor stratabound zinc, copper, lead, silver, and gold deposits are present in the migmatites (Raymond and Sheridan, 1980), but they are not economically significant. However, pegmatites are common in the Precambrian metamorphic complex, and a number of these have been mined in the vicinity of the Royal Gorge. These include pegmatites rich in beryl, microcline feldspar, tourmaline, rose and milky quartz, garnet, columbite, and muscovite (Voynick, 1991; Hodgson, 1993). The biggest producers in the Royal Gorge area were the Mica Load and the Meyers Quarries, both of which worked a pegmatite dike approximately 2,000 ft (610 m) long and up to 400 feet (122 m) wide. By 1950, these two mines alone yielded 170,000 tons of microcline feldspar, 35,000 tons of mica, and 57 tons of a greenish beryl. The latter occurred commonly as well-defined, hexagonal crystals, some of which were over six feet (1.8 m) long and 3 feet (0.9 m) wide (Voynick, 1991). Currently, the only operations in these pegmatites are for landscaping stone and for sales of specimens to rock and mineral shops.

40.7 [0.3] Nonconformity with Lower Ordovician Manitou Limestone resting directly on the Precambrian granodiorites on the north (left) side of highway (fig. 28). The Harding Sandstone is exposed in the next roadcut 0.1 mile (0.2 km) ahead to the east (0.01 km). The yellow bed at the top of the exposures on the slopes to the northeast of here is recognizable over a wide area in the Cañon City embayment.

Refer to figure 27 for a stratigraphic section of the Cañon City area. This area was block-faulted downward during the formation of the Ancestral Rocky Mountains during the Pennsylvanian (De Voto, 1980b; see fig. 23)), and a suite of pre-Fountain Formation Paleozoic rocks generally is preserved beneath the Mesozoic sedimentary section. This situation is in contrast to the High Park area, which was part of the Front Range Highlands (Tweto, 1975, 1980a,c), that formed in the Pennsylvanian and from which were stripped the thin cover of pre-Pennsylvanian rocks. There, the oldest sedimentary rocks are the Jurassic Morrison Formation. The stratigraphic relationships of the Paleozoic section are complicated in the area just west of Cañon City because of periodic subaerial exposure and extensive development of karst features in the Devils Gap syncline area just ahead.

Figure 28. Nonconformity (at hand and foot of geologist) with Manitou Limestone resting on Lower Proterozoic granitic gneisses on north side of U.S. Highway 50.

41.0 [1.6] Enter the upper end of Devil's Gap Syncline. The vehicles will slow here.

Begin a 0.4 mile (0.6 km) long roadcut exposing complex karst features, including breccia-filled sinkholes and breccia pipes, developed in the Paleozoic section, extending from the Lower Ordovician Manitou Limestone through the Lower Mississippian Williams Canyon Limestone. Most apparent in these roadcuts is the *terra rosa* regolith characterized by the intensive brownish-red color of these pre-Fountain units. According to De Voto (1980a), much of southern and southwestern Colorado underwent extensive "humid-climate solution erosion" and karsting during the Meramecian and Chesterian (Late Mississippian). Carbonate-breccia-filled sinkholes, karst towers, and related features are present at many localities in south-central and southwestern Colorado.

As the valley opens up ahead, the highway follows the Pennsylvanian Fountain Formation, an arkosic redbed sequence of alluvial braided-stream and fan deposits derived from the weathering and erosion of the Ancestral Rockies.

42.6 [0.7] Junction of U.S. Highway 50 and County Road 69 (Shaw's Park Road) from the north (right); continue straight ahead on U.S. 50.

The highway at the junction is on the red-colored arkosic conglomerates, sandstones, and mudrocks of the Pennsylvanian Fountain Formation, from which have been recovered lycopsid and sphenopsid tree trunks and other plant fossils. The reddish sandstone just above the highway level is at the base of the Jurassic Bell Ranch Formation along the highway here. The local community is planning to build a unique interactive facility to be called the Dinosaur Discovery Center about 5 miles (8.1 km) north of this intersection.

43.3 [0.1] Junction with Skyline Drive Road; bear left on Skyline Drive and drive beneath the stone arch at the Trading Post. *Exercise extreme caution because the one-way road is narrow and winding and has few guardrails.* The roadway at the junction is on the upper part of the Fountain Formation. A large quarry in the Ordovician Harding Sandstone can be seen to the right (southwest) across the valley as the road begins its ascent.

43.4 [0.2] Contact between the Fountain Formation (Upper Pennsylvanian) the Bell Ranch Formation (Jurassic).

The Bell Ranch Formation in this area, consisting of a thick sequence of brown sandstones, previously was referred to the Ralston Creek Formation because of its gypsiferous nature.

43.6 [0.5] Morrison Formation exposed on left.

44.1 [0.1] Contact between the Morrison and Purgatoire Formations.

44.2 [0.7] STOP 11 (OPTIONAL). WEST SIDE OF SKYLINE DRIVE. Pull off onto small turnoff on west (right) side of Skyline Drive and park. *Be cautious because the road is narrow.*

Figure 29 is a view from this location. Looking down to the west from here, U.S. Highway 50 is on the Fountain Formation with the Williams Canyon Formation near the base of the flatirons across the valley. The flatirons are formed primarily by the Ordovician Fremont Dolomite overlying the Middle Ordovician Harding Sandstone. The underlying Manitou Limestone does not occur in this vicinity. Fremont Peak in Precambrian rocks of the Gorge Hills is on the skyline to the west-southwest of the pullout. Several old quarries, including that of the type locality of the Harding Sandstone, exploited primarily for building stone, and several more recent quarries are located on the northwest side of the valley, including a limestone quarry operated by the CF&I steel mill in Pueblo.

Figure 29. View looking west toward Royal Gorge Hills from Stop 11. See text for explanation.

The type locality for the Harding Sandstone is in the abandoned quarry mentioned at mileage 43.3 and above. Timothy W. Stanton collected a fossil fish plate from the Harding Sandstone in 1888 and made large collections of vertebrate fossils from this quarry in the summer of 1890 (Yochelson,1983). From these collections, Charles D. Walcott (1892) described the vertebrate fauna of the Harding. These fossils were for many years the oldest vertebrates known and occur in immense numbers generally as bone beds more than 2 feet (0.6 m) thick. They are especially common in the middle part of the Harding Sandstone, which is approximately 100 feet (30 m) thick in this area. An extensive literature exists for the Harding, its invertebrates, and its primitive vertebrate fauna, including conodonts (among others, Sweet, 1945, 1961; Ørvig, 1958; Gerhard, 1967; Spjeldnaes, 1967, 1979; Fischer, 1978a, b; and Thyer, 1991).

The turnoff is just above the contact between the Morrison Formation and the overlying Purgatoire Formation, which is mapped as the basal unit of the Dakota Group. The Lytle Sandstone Member of the Purgatoire Formation, at the base, is the conspicuous light-colored sandstone. The overlying dark-gray shales and thin-bedded sandstones of the Glencairn Shale Member of the Purgatoire contain abundant trace fossils and sparse molds of invertebrate fossils and was deposited in marginal-marine and estuarine environments here.

To the north on the skyline in the distance are North and South Twin Mountains. Looking westward from these peaks and following the distinctive, east-dipping Dakota hogback, a monocline can be seen that is developed in the Fountain Formation; this monocline abruptly develops into a sharp anticline, which, in turn, splits into two parallel anticlines in Ordovician and Mississippian carbonate rocks are exposed. Both of these anticlines become normally downfaulted farther to the west on their southern flanks. Still farther westward, these two faults become thrust faults on which Precambrian metamorphic rocks on the north are thrust over the Ordovician section to the south (Taylor and others, 1975).

Proceed south up Skyline Drive.

44.9 [0.1] Steeply dipping beds of Dakota sandstones occur on the right (west) side of the road; note the abundant marine invertebrate trace fossils.

45.0 [0.3] STOP 12. CAÑON CITY BASIN OVERLOOK. Pull in parking lot and overlook.

To the east plainly visible from this stop is the Cañon City Embayment (fig. 30), also commonly called the Cañon City-Florence Basin or, simply, the Cañon City Basin. This structural feature is a relatively small topographic and structurally low area located at the junction of the Wet Mountains to the south and southwest and the Front Range to the north and northwest. The basin is clearly outlined on the surface on three sides here (west, north, and northeast) by the resistant sandstones of the upper part of the Dakota Group, on which we are standing (Scott, 1977; Scott and other, 1978). About 4,000 feet (1,220 m) of structural relief is mapped in the basin, which is a relatively broad, flat-floored feature with a strongly dipping west flank butting against the Wet Mountains in fault contact and a more gently dipping east flank. Looking to the northeast from this overlook, the axis of the basin trends *ca.* S 30 degrees E and extends for a distance of approximately 25 miles (40.3 km) from south of the Garden Park area a few miles (km) north-northwest of Cañon City, through Florence, and to the south-southeast (Scott and others, 1978).

For orientation, the Garden Park Area (Stops 14 and 15) is just beyond the head of the embayment through the watergap formed by Fourmile Creek (fig. 30) cutting the Dakota ridge to the north-northeast of here and due north of Cañon City. The final stop (Stop 16) at Indian Springs is on the northeast flank of the embayment, just out of view from here.

The basin is underlain by the same Lower Proterozoic metamorphic rocks that we have been viewing from High Park southward (Tweto, 1980b, 1987). The Cañon City Basin is filled with sedimentary rocks ranging in age from Lower Ordovician (Manitou Limestone) into the Paleocene (fig. 27). There are no Cambrian sedimentary rocks in southeastern Colorado. The Paleozoic, Mesozoic, and lower Cenozoic rocks in the

Figure 30. View to northeast from overlook on Skyline Drive (Stop 12) of northern end of Cañon City Basin. Cripple Creek Mining District is on skyline just off right margin of photograph.

basin were deposited in a series of marine and terrestrial environments that record the depositional history of the area and the intermittent tectonic history during the Pennsylvanian (Ancestral Rockies) and the latest Cretaceous-early Paleocene tectonic events (Laramide Orogeny) responsible for the formation of the Southern Rocky Mountains (Gerhard, 1967). During these episodes of mountain-building, older sedimentary rocks on the edge of the basin were tilted toward the basin center as younger sediments were deposited toward its center. Most of this repeated orogenic activity occurred along major faults and shear zones that formed in the basement complex during the Late Precambrian (Tweto, 1975, 1980a, c).

According to Gerhard (1967), the embayment attained substantially its present form by the time of formation of the Ancestral Rocky Mountains, with the periodic block uplift of the Ancestral Front Range to the north and northwest and the Apishapa Uplift, of which the present-day Wet Mountains are a part, to the west and southwest. By the end of the Paleozoic, the adjacent highlands had been reduced by erosion and were covered by a thin veneer of mostly terrestrial sediments (mainly Morrison Formation) during the early Mesozoic. In Tweto's (1980c, p. 129) words: "By the beginning of Cretaceous sedimentation, a nearly planar surface existed that was underlain partly by huge bodies of Precambrian rocks beneath a thin cover of sedimentary rocks, and partly by basins filled with thousands of feet of sedimentary rocks. Cretaceous sedimentation then produced a [thick] cover of intertonguing marine and continental rocks ... over the entire State." The area here was located near the western margin of the vast Western Interior Seaway, and source areas of clastic material was from highlands far to the west. The Cretaceous section alone in the Cañon City area is roughly 6,300 feet (1,920 m) thick (fig. 28).

The Laramide was not synchronous throughout Colorado, starting at somewhat different times in different places. In Colorado, it started in the southwestern part of the state in the Uncompahgre-San Louis area, where it predates 70 Ma. In the Cañon City area, the Laramide Orogeny developed in the latest Cretaceous-earliest Paleocene (*ca.* 62 Ma) and continued into the early Cenozoic (Tweto, 1975, 1980a, c).

The buttes seen in the midground to the southeast of this point (Stop 12) are formed by the Upper Cretaceous Trinidad Sandstone, overlain by the Vermejo Formation which contains coal beds, fossil plants, and dinosaur fossils, and the Raton Formation, which spans the Cretaceous-Tertiary boundary. Capping these buttes locally is the Paleocene Poison Canyon Formation, consisting of granitic and gneissic gravels (Scott and others, 1978) derived from highlands to the west developed during reactivated block faulting during the Laramide (Tweto, 1975, 1980a, c).

Continue on Skyline Drive toward Cañon City.

45.3 [0.3] Switchback; road begins descent down east side of Skyline Drive.

45.6 [0.3] Second switchback, in outcrops of Grenaros Formation.

45.8 [0.1] Fossiliferous Greenhorn Limestone forms the first low ridge; the second (higher) ridge to the east is formed by the Juana Lopez Sandstone Member of the Carlile Shale and the overlying Fort Hayes Limestone Member of the Niobrara Formation. Proceed east through the small water gap.

45.9 [0.8] Turn left (south) on Fifth Avenue; edge of Cañon City.

The first American known to visit the area of present-day Cañon City was Lt. Zebulon Pike, who established a temporary camp near here in 1806, during his survey of the southern part of the Louisiana Purchase. The site was settled about 1860 by the Rudd family. Cañon City, like Florence, Colorado Springs, and other communities in the area profited from the gold mining in the Cripple Creek District. Although it never became a gold-refining or milling center like Florence or Colorado Springs, many of its merchants nonetheless became wealthy by supplying materials to the Mining District. The Colorado Territorial Prison ("Old Max") was built here in 1868, and Cañon City has become known widely for the large number of other penal institutions more recently located in the area.

46.7 [0.2] Junction of Fifth Avenue and Royal Gorge Boulevard (U.S. Highway 50) in Cañon City. Turn right (west) at this corner, proceed one block to the next intersection, and turn left (south) at the Dinosaur Depot.

46.9 [3.2] STOP 13. DINOSAUR DEPOT. Pull into parking lot close to the railroad tracks behind the Dinosaur Depot. We will eat lunch here and have an orientation session prior to the visit to the Garden Park Fossil Area.

Dinosaur Depot (fig. 31) is a small museum located in a historic fire station in downtown Cañon City. It is one component of an urban revitalization project, known as the River Station Project. This project will include significant historic-preservation projects, retail development, and recreational projects and will connect historic downtown Cañon city with the Arkansas River. The Dinosaur Depot was opened in July of 1995, and is managed by the Garden Park Paleontology Society (GPPS), a non-profit organization with a focus on education, environmental care, and encouragement of scientific research. It is staffed mainly by volunteers and has a primary focus of interpreting for visitors the geology, paleontology, and history of the world-famous Garden Park Fossil Area. The Dinosaur Depot is funded by means of a small admission charge, product sales, and donations.

Figure 31. Dinosaur Depot (Stop 13), downtown Cañon City. (Photograph courtesy of GPPS.)

A modern vertebrate preparation laboratory is included in the Dinosaur Depot, where a *Stegosaurus* skeleton is being prepared by Donna Engard, under the guidance of Ken Carpenter from the Denver Musuem of Natural History. This skeleton was excavated in 1992 from the Garden Park Fossil Area and is on loan from the Denver Museum. A miniature video camera hooked up to one of the preparation microscopes gives visitors a "close up" view of the care and detail that goes into the skilled preparation of a fossil dinosaur. In addition to the *Stegosaurus*, a number of other vertebrate fossils are being prepared. Also featured is an exhibit area with interpretive panels and exhibits that describe the Garden Park Fossil Area. Included is a fulll-sized *Allosaurus* model and a reconstruction of a dinosaur trackway, based on the famous Morrison dinosaur trackway at Picket Wire Canyonland, south of La Junta, Colo.

The GPPS can be contacted at the Dinosaur Depot, and tours of the Garden Park Fossil Area and special programs about dinosaurs and the paleontology of the Cañon City area can be arranged.

From Dinosaur Depot proceed northeast on U.S. Highway 50 (Royal Gorge Boulevard) through the heart of Cañon City for 2.0 miles (3.2 km) to Raynolds Avenue.

Segment E:
Cañon City to Garden Park

0.0 [0.7] Intersection of U.S. Highway 50 and Raynolds Avenue (Fremont County Road 9). *Reset odometer.* Turn left (north) on Raynolds and proceed through East Cañon City.

The low-relief surface over which we are driving is formed by a pediment developed on the Pierre Shale. The thin gravel veneer capping this pediment was mapped by Scott (1977) as "Piney Creek Alluvium", which here is about 20 ft (6.1 m) above the level of the Arkansas River.

0.7 [0.1] Turn left (west) and proceed through residential area on main road.

0.8 [0.3] Turn right (north) on Field Avenue (County Road 9) and follow Scenic Byway signs.

1.1 [1.6] Drop off of Pleistocene gravel-capped pediment just before the bridge over Fruitland Ditch; road drops down onto the Upper Cretaceous Pierre Shale.

Just ahead to the left (west) of the road is a small conical hill held up by a bioherm in the Pierre Shale dominated by *Baculites scotti*. The Pierre is a dark, organic-rich shale that is both the source and reservoir rock for the Florence Oil Field, located *ca.* 5 miles (8.1 km) southeast of here, and which, in 1876, was the first field developed in the state. The Pierre Shale and many of the other Cretaceous marine deposits are highly fossiliferous, and a detailed ammonite zonation has been established and mapped throughout much of this area (Scott and Cobban, 1975). Because of the lithic nature of the Pierre Shale, it is easily eroded and generally forms very broad, low relief valleys, generally covered by a veneer of sands and gravels, such as the so-called Piney Creek Alluvium. Some of the terraces seen to the northeast of here a little less than a mile (1.6 km) are formed by the older Pleistocene deposits.

2.7 [0.4] Approximate axis of Cañon City Basin.

3.1 [0.1] Black shale outcrops of the Sharon Springs Member of the Pierre Shale are seen on the scarp to the left (northwest) of the road. This distinctive member commonly contains marine vertebrate fossils, including large mosasaurs.

3.2 [0.6] Road junction; continue northward on road, which climbs back onto alluvium-veneered pediment just ahead.

3.8 [0.3] Bedded outcrops in roadcut on the left (west) are in the Greenhorn Limestone, which contains common *Inoceramus* and other mollusks here.

4.1 [0.1] Bridge over Wilson Creek, which joins Fourmile Creek just to the east (right) of here. Continue north.

The valley of Wilson Creek to the left (west), cut in the Graneros Shale, follows the Chandler Syncline, one of the branches of the northwestern end of the Cañon City Basin (Scott and others, 1978). A view of East Twin Mountain can be seen on the horizon up the valley to the west (left).

4.2 [0.2] Enter water gap of Fourmile Creek through the hogback formed by massive sandstones of the Dakota Group here.

The upper sandstones of the Dakota in this area contain dinosaur tracks. Just ahead, we enter Fourmile (or Oil Creek) Graben.

4.4 [0.4] Red mudrocks in upper part of Morrison Formation overlain by colluvium exposed on left (west) side of road. These beds are at about the same level as the dinosaur-bearing beds at the Cope Quarries.

4.8 [0.3] Stone monument on left. Massive Dakota sandstones form the cliffs above. Four Mile Creek, also called Oil Creek in this area, is on east (right).

Before the arrival of the white man, Indians knew about the oil seeps in the area and used the mineral springs and hot springs located in this area for medicinal purposes. On the opposite side of Fourmile (Oil) Creek here, Gabriel Bowen and Matthew Pratt dug four pits at the oil seeps in the 1860's, and oil was found in two of these. Casings are still present from drilling activity in the 1920's. The stone monument reads: "*Monument to first oil well west of the Mississippi River. The well was at an oil seep in the creek bottom. The well was dug to a depth of 50 feet in 1862 and wooden casing was used. When Hayden first visited the area he found the well producing with oil residues left in barrels along the side of the well. This residue was used for axle grease and was available free of charge to anyone making the trip to the area.*" This was especially convenient, because the continuation of this road northward to the Cripple Creek District (the Shelf Road) was completed in 1892 as a toll road for ore and supply wagons and stage coaches traveling between Cañon City and the mining district.

5.1 [0.3] Mileage Post 2. Sandstone ledge on right (east) side of valley is in the middle part of the Morrison Formation and can be mapped for a considerable distance.

5.4 [0.2] Artesian well in small stone house to right (east) of road. Enter public lands (BLM).

This well is about 3,000 ft (915 m) deep and originally was drilled in search of oil. However, instead of oil, the hole hit artesian water and still supplies water to the northern part of Cañon City.

5.6 [0.4] Petroglyphs are visible on the large Dakota sandstone boulders in the landslide deposits on both sides of the road.

6.0 [0.4] Road to the Cope Quarries intersects Fourmile Creek Road sharply from the left (southwest). Continue straight ahead.

The Garden Park Fossil Area is one of the most important Late Jurassic vertebrate localities in North America. This was the scene of the "Great Dinosaur Race", a vigorous "scientific" competition that occurred between 1877 and about 1890 between the two principal opponents Professors E.D.Cope (The Academy of Sciences of Philadelphia) and O.C. Marsh (Yale Peabody Museum of Natural History) in order to get "the first, the biggest, the best, and the most" dinosaur skeletons into their respective museums. This race was scientifically productive and a most colorful part of our paleontologic heritage. In the early 1970's, the Garden Park Fossil Area was designated a National Natural Landmark, and, in 1990, it was designated a Research Natural Area by both the BLM and the State of Colorado. The Cope Quarries were the were the first dinosaur sites exploited (1877 to 1880), resulting in several significant early discoveries of dinosaurs. Excavations in the Morrison Formation in the area by numerous universities and institutions has produced 20 genera and 19 described species of fossil fishes, turtles, rhynchocephalians, crocodiles, dinosaurs, and small mammals. Eight species of vertebrates were described originally from here, including the dinosaur genera *Allosaurus*, *Camarasaurus*, *Ceratosaurus*, and *Diplodocus* (Kuntz, Armstrong, and Athearn, 1989). In addition to the high diversity of the vertebrate fauna, many specimens have been recovered. Most major natural history museums in the United States and others in Canada and in Europe display material from here. Unlike the other well-known Morrison dinosaur sites in the United States (e.g., Como Bluff in Wyoming and Dinosaur Quarry in Utah), dinosaurs have been recovered from stratigraphically throughout the Morrison Formation in Garden Park. In addition to the vertebrate faunas, the Morrison Formation here has yielded abundant freshwater mollusks and arthropods and contains the type localities for 13 species of freshwater clams and snails and for three species of freshwater ostracodes (Kuntz, Armstrong, and Athearn, 1989). The Bell Ranch Formation in the area has produced a species of *Todiltia*, one of the oldest genera of teleost fish.

6.4 [0.2] STOP 14. CLEVELAND QUARRY. Pull vehicles into turnout on right (east) side of road and park for a brief rest stop. Restroom facilities are available.

The Cleveland Quarry (fig. 32) is just above water level on the opposite side of Fourmile Creek. The Cleveland Museum of Natural History (CMNH) sponsored an excavation at this site between 1954 and 1957. Dr. Edwin Delfs headed the expeditions that worked this site, from which a new species of large sauropod, *Haplocanthosaurus delftsi*, was excavated. This specimen was prepared by the CMNH with assistance from the American Museum of Natural History and has since become a major attraction at the CMNH. It is the only mounted *Haplocanthosaurus* skeleton in the world.

Continue north on Fourmile Creek Road.

6.6 [0.2] STOP 15. MARSH QUARRY. Drive into pullout on left (west) side of road at "Type locality of dinosaurs" monument.

The plaque on the monument reads: "*The first remains of several species of dinosaurs were found within a two mile radius of the point in 1877 by Prof. O.P. Marsh of Yale University and Prof. E.D. Cope of the Academy of Sciences of Philadelphia. This discovery of extinct reptiles in the western hemisphere received world wide acclaim.*" Some of the other information is incorrect. An *Allosaurus* instead of a *Tyrannosaurus* was excavated here, and the actual museum locations of the specimens described are as follows:

- *Stegosaurus* — U.S. National Museum (USNM) (Smithsonian), Denver Museum of Natural History (DMNH), and Dinosaur Depot.
- *Brontosaurus* (*Apatosaurus*) — None from Garden Park on display at any museum.
- *Allosaurus* — an *Antrodemus* (*Allosaurus*) is on display at the USNM.
- *Ceratosaurus* — USNM.
- *Diplodocus* — Partial skeleton at the DMNH.

The Marsh Quarry site (fig. 33) is about 0.2 mile (0.3 km) up the road on the north side of the gully on the left (to the northwest). Looking up at the quarry, we can see a good example of a sandstone deposited in an ancient river channel that ran through a valley approximately 150 million years ago. The landscape during that time was a typical river floodplain with shallow lakes and ponds surrounded by a low-relief area similar to that of the present-day African savanna. The climate was subtropical with alternating wet and dry seasons, and there was an abundant supply of water. The dinosaurs lived along the

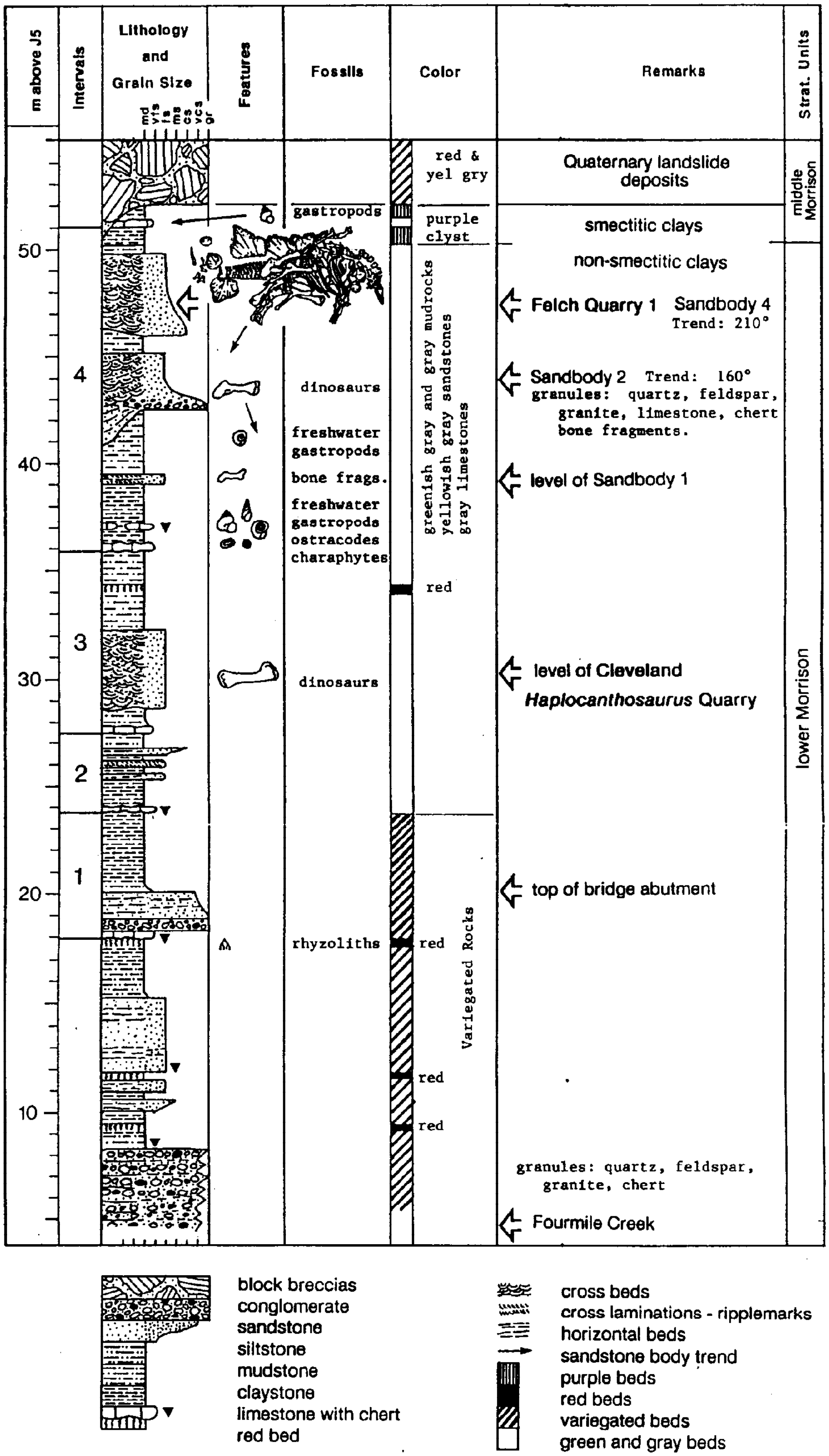


Figure 32. Measured stratigraphic section (by Emmett Evanoff) for Garden Park area, showing stratigraphic positions of local vertebrate quarries and other fossiliferous horizons. Scale in meters.

stream, and, following their deaths, their corpses collected along sand bars in the river. Flooding buried the skeletons quickly, thus contributing to their excellent preservation.

Dinosaur bones were first noticed here a by local rancher, M.P. Felch, who found the site in 1876 and notified Prof. Marsh at the Peabody Museum. It is interesting to note that Marsh did not respond to Felch's letter until after he learned that his rival Prof. Cope was planning on digging in this area . This quarry was worked from 1877 to 1888 mainly by Felch under the sponsorship of Prof. Marsh but mainly under the direction of Prof.Benjamin F. Mudge, the first State Geologist of Kansas and a noted vertebrate paleontologist, until his death. Mr. Felch completed the excavations in 1888. The quarry (fig. 33) was also worked by the Carnegie Museum of Natural History from 1900 to 1901. The quarry was under private ownership until 1995, when it was purchased through Land and Water Conservation Funding and placed into the public domain as part of the Garden Park Fossil Area.

Figure 33. View of the Felch (Marsh) Quarry looking northwest and taken from an a *ca.* 1888 photograph (courtesy of GPPS).

The wagon road leading up to the Marsh Quarry is barely visible across the gulley. Several hundred boxes of bones were carried to the train station in Cañon City in 1887 and 1888 and shipped to the Yale Peabody Museum, but the Smithsonian later took possession of them. About 65 different specimens of dinosaurs were excavated from the Marsh Quarry, including three complete articulated skeletons, an *Allosaurus*, a *Stegosaurus*, and a *Ceratosaurus*, all of which are on display in the USNM in Washington, D.C. The first Jurassic mammals discovered in North America came from this quarry as well.

Before we leave this stop, it should be noted that several other significant dinosaur sites occur in the Garden Park Fossil Area. A partial skeleton of *Diplodocus longus* reposited at the DMNH was collected from a quarry site located in 1915 by Dall DeWeese about 2 miles (3.2 km) east of here. From a quarry located about a mile (1.6 km) east of here, a complete, well-preserved specimens of *Stegosaurus stenops* was recovered in 1937 and is on display at the DMNH. Based on this specimen, *Stegosaurus* became the Colorado state fossil in 1982. In 1992, another excellent *Stegosaurus* skeleton was discovered by the DMNH about 1.5 miles (2.4 km) east of here. This fully articulated skeleton, complete with the articulated tail with attached spikes, is the one being prepared by both the DMNH and the volunteers at Dinosaur Depot. Finally, crushed dinosaur eggs were discovered in mudrocks of the Morrison Formation in 1993 in the Garden Park Fossil Area. These are the oldest dinosaur eggs thus far found in North America.

Continue north on Fourmile Creek Road.

6.8 [0.4] Bridge over Fourmile Creek. The stratigraphic section shown as figure 32 was measured on the west side of the creek here, beginning at creek level.

7.2 [0.4] Entrance to Dilley Ranch to left (west).

We have entered Garden Park here and are traversing the Pennsylvanian Fountain Formation. Garden Park received its name from the vegetable farms that thrived in this relatively protected, well-watered valley around the turn of the century. The fresh produce was shipped by wagon to the Cripple Creek Mining District for market. To the left (west) across the valley can be seen a section exposing the upper part of the Fountain Formation (at the base), overlain by the Morrison, Purgatoire Formation (including the light-colored Lytle Sandstone Member and the overlying shaley Glencairn Member), and the massive sandstones of the upper part of the Dakota Group.

7.6 [1.5] To the west at 9:00 is the Nipple at the Cope Quarries. Continue northward on County Road 9 (Shelf Road).

The Nipple (fig. 34) is the small conical butte located near the skyline in the distance between the higher, flat-topped buttes held up by the Lytle Sandstone Member of the Purgatoire Formation. The Cope Quarries are located at the base of the Nipple. These quarries were worked by the local school teacher Othoniel Lucas, who is credited with first discovering massive bones of dinosaurs in the Morrison Formation in this general area in 1876 and who subsequently continued excavations under the guidance of Professor E.D. Cope. Several significant discoveries were made here including the discovery of a *Camarasaurus* in 1877. A full-sized drawing of this dinosaur was constructed and went on display at Philadelphia's Fairmont Park in December of 1877. This event attracted worldwide attention to the western Jurassic dinosaur sites including the Garden Park Fossil Area.

Figure 34. View to west from Shelf Road of Nipple at Cope's quarry (on skyline in left of photograph). Section extends from upper part of Fountain Formation through part of the Dakota Group on skyline in right of photograph.

8.9 [8.9] Sharp right turn in Shelf Road to due north; old stone building of Garden Park School is on the right just before the turn. This was where Othoniel Lucas taught.

The Shelf Road continues northward to Cripple Creek, from here a distance of about 17 miles (27.4 km). Red Canyon Park, managed by Cañon City and so-named because of the brilliant colors of its outcrops, is a short distance ahead in the upper end of Garden Park. Spectacular sandstone monoliths are common there. A few miles (km) north of the park, the roadway enters the narrow canyon of Fourmile Creek. The Shelf Road becomes very narrow and winding once it enters the gorge and is aptly named because of its precarious perch on the edge of the canyon, commonly 800 or 900 feet (244 to 274 m) above the creek. Cañyon City completed the Shelf Road as a toll road in 1892, and it became the first stage and wagon route connecting the Mining District with the Arkansas River Valley.

Turn around and retrace route to Cañon City.

17.8 1.5 Intersection of U.S. Highway 50 and Raynolds Avenue (mileage 0.0 of Segments E and F). Turn left on U.S. 50 and proceed through East Cañon City.

Roadlog Segment F: Cañon City to Indian Springs

0.0 [1.7] East side of Cañon City; intersection of U.S. Highway 50 and County Road 123 (Fourmile Lane) from north. Turn northward on Fourmile Lane and the proceed eastward, paralleling U.S. 50 for a short distance. *Reset odometers.*

For next 1.5 mile (2.4 km), we will be driving to the east-northeast along a thin veneer of what was mapped as the Quaternary Piney Creek Alluvium, which mantles the pediment cut on the Pierre Shale; outcrops of the grayish-black shales of the Sharon Springs Shale Member of the Pierre with marine vertebrates are ahead on right (southeast) side of road.

1.7 [0.5] County Road 123 bends due east at curve.

We are crossing the approximate axis of the Oil Creek Anticline, a weak southwest-trending structure developed on the northeastern side of the Cañon City Basin. Outcrops of Smoky Hill Shale Member of the Niobrara Formation occur on the right (northwest) before the turn. The Smoky Hill contains seven sparsely fossiliferous units, including thin limestone interbeds, and totals about 570 feet (174 m) thick in this vicinity (Scott, 1977).

2.2 [0.4] Road crosses abandoned Cañon City spur line of Florence and Cripple Creek Railroad.

2.6 [0.2] Note dipslope of cuesta to left (north) of road.

This cuesta is formed by Ft. Hayes Limestone Member of Niobrara Formation, dipping about 10^{m} SE here. The Ft. Hayes is about 40 feet (12 m) thick, is composed of light-gray fossiliferous limestone layers and thin interbeds of dark-gray shale, and makes persistent ledges or cuestas that can be mapped easily around the northern and northwestern end of the Cañon City Basin.

2.8 [0.4] Just beyond the small rise, outcrops of grayish-black shale of the Sharon Springs Shale Member of the Pierre Shale occur to the right (south) of the road.

3.2 [0.4] Bridge over Sixmile Creek.

Dark-gray shale outcrops in the Pierre Shale are exposed to on the south (right) side of the road in arroyo with outcrops of the Ft. Hayes Limestone Member of the Niobrara Formation seen to the north (left).

3.6 [0.2] A low conical hill (locally called a “tepee butte” and which may be submarine spring deposits) in the Pierre Shale is seen a short distance to the south (right) side of the road.

3.8 [0.8] Junction of County Road 123 (Fourmile Lane) and County Road 67 (Phantom Canyon Road); turn left (north) on Road 67.

After the turn, ahead in the distance is the Dakota hogback, which clearly delineates this part of the Cañon City Basin.

4.6 [0.1] Low wooded cuestas formed by the Ft. Hayes Limestone Member of the Niobrara Formation are seen a short distance away on both sides of the road.

4.7 [0.1] Small, low outcrop of the Greenhorn Limestone occurs on right (southwest) side of the road just beyond the ditch.

4.8 [0.1] Oro Junta (“Gold Junction”); historical sign at pulloff on left of road. Continue northward on Phantom Canyon Road.

In the early 1890’s, the City of Florence financed the construction of a stage and wagon road up Eightmile Creek through Phantom Canyon, which was completed in 1893 as a free road. The Phantom Canyon Road from Florence and the Shelf Road from rival Cañon City became the two routes linking the Arkansas River Valley with the Mining District. In 1894, the narrow-gauge tracks of the Florence and Cripple Creek (F&CC) Railroad were laid up Phantom Canyon from Florence and quickly became the major transportation link with the gold camps from the Arkansas valley. With the completion of the railroad, the cost was reduced significantly to transport raw ore to the mills at Florence, where both plentiful supplies of water and coal from mines in the Vermejo Formation were available. Both Florence and Cañon City competed to be the terminus and base of operations for the F&CC, a contest which Cañon City eventually won. In 1899, the shops and railyards were moved to Cañon City, although Florence continued to process gold ore in reduction mills until about 1912, when the railroad was abandoned. Here, at Oro Junta (in English, was the site of a spur of the F&CC Railroad to Cañon City, the abandoned line that we crossed at mileage 2.2 of this fieldtrip segment.

4.9 [0.1] Road passes into the water gap formed by Eightmile Creek cutting through massive sandstone beds of Dakota Group.

5.0 [0.2] On the northeast side of the road is a well-cemented Pleistocene(?) boulder conglomerate resting unconformably on steeply dipping sandstone beds in the upper part of the Purgatoire Formation.

This exposure is just below the contact between the thinly bedded Purgatoire Formation and the overlying massive sandstones of the Dakota Group that form the major hogback. Boulders, cobbles, and pebbles in the Pleistocene conglomerate consist of granitic gneiss from the Precambrian section and grayish-red sandstone from the Fountain Formation, dolomite from the Fremont Dolomite and Manitou Limestone, chert from the Manitou Limestone, and other rock types from these and formations that were exposed upstream.

5.2 [0.2] Mile Post 3; enter Sixmile Park; grayish-red mudstones and fine-grained sandstones of the Morrison Formation are exposed on the east (right) side of the road.

5.4 [0.3] Quaternary cobble-boulder conglomerate rest here with an angular unconformity on the grayish-red mudstones of Morrison Formation .

5.7 [0.7] Junction of Phantom Canyon Road (County Road 67), which is trending northeast here, and the turnoff to Indian Springs Ranch to the north (left). Turn left and proceed toward the ranch and campground.

Sixmile Park is a narrow, approximately 6 mile (9.7 km) long, northwest-southeast trending feature, drained in its lower reaches by Sixmile Creek, which has its confluence with Eightmile Creek just to the southeast of here. The park is floored in its upper (northwest) two-thirds by Precambrian metaquartzites and migmatitic gneisses that were originally quartz-rich sandstones, mudstones, and volcaniclastic rocks and that are flanked on the northeast and southwest by Precambrian granodiorites (Scott and others, 1978). Looking to the southwest from here toward the lower (southeastern) part of Sixmile Park, a structurally slightly complex sequence can be seen of lower Paleozoic sedimentary rocks, mainly the Ordovician rocks of the Fremont Dolomite, Harding Sandstone, and Manitou Limestone, which rests nonconformably on the Precambrian granodiorites. The road junction here at mileage 5.7 is in the Fountain Formation.

6.4 [1.2] Campground (privately owned) and office of Indian Springs Ranch. Pull into parking area. The Indian Springs trace-fossil site is on the Indian Springs Ranch, owned by the Thorson Family. It is protected federally as a National Natural Landmark, and tours may be arranged to the trace-fossil locality for a modest fee at the Indian Springs Ranch office. We will be shuttled via four-wheel drive vehicles up a rough trail from here northwest to the site.

The published faunal record of the Harding Sandstone is meager and has focused mainly on the vertebrate faunas (including conodonts). The invertebrate fauna is more poorly known because invertebrate body fossils are generally sparse and poorly preserved. They are limited to a few molluscan genera (mainly pelecypods and gastropods and sparse nautiloid cephalopods), the phosphatic inarcticulate brachiopod *Lingula*, two genera of trilobites, poorly preserved leperditid ostracodes, a few bryozoans (growing on the nautiloid shells), and the enigmatic phosphatic organism *Dichtyorhabdus*, which may or may not be an invertebrate. Calcareous body fossils are restricted to certain horizons and are more common in the middle part of the Harding. Phosphatic fossils, including the vertebrates and conodonts, are stratigraphically more widely distributed.

7.6 STOP 16. INDIAN SPRINGS TRACE-FOSSIL SITE. The trace fossil site is located up a small south-flowing side tributary of Sixmile Creek accessible by a rough four-wheel drive trail.

The Indian Springs trace-fossil site (fig. 35) is a relatively small, bedding-plane exposure in a small quarry in the lower part of the Harding Sandstone. Here, the beds strike E-W and dip 10° S into the Cañon City Basin. The site was discovered by Bennie Thorson, who contacted W.A. Fischer, a professor at Colorado College in Colorado Springs. Fisher worked extensively on these outcrops and a roughly 10-acre (4.1-hectare) exposure in this vicinity with Mr. Thorson for five field seasons prior to the publication of his conclusions (Fischer, 1978a, b).

Figure 35. Indian Springs trace fossil site (Stop 16); Carlee Thorson is in picture. See figure 36 for section.

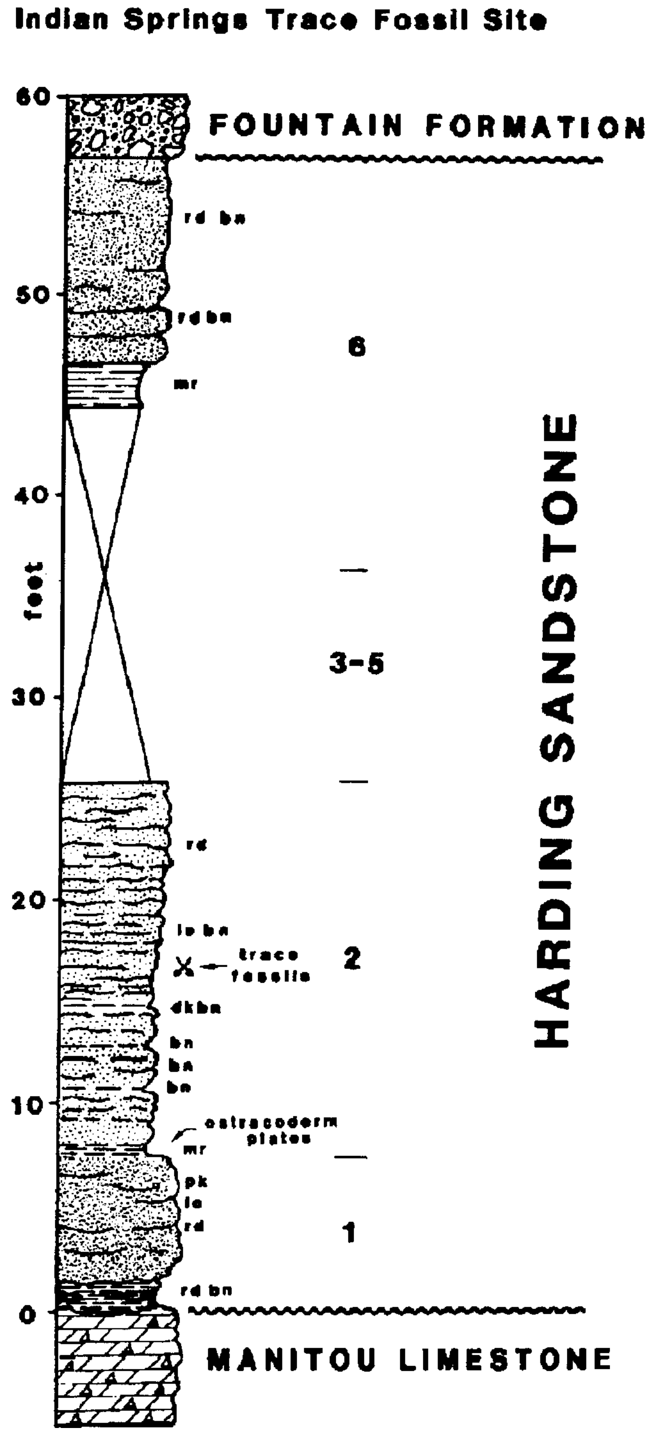


Figure 36. Measured stratigraphic section at Indian Springs trace fossil site (modified from Thyer, 1991, pl. 4). See text for discussion.

Figure 36 is a detailed stratigraphic section measured at the Indian Springs trace-fossil site (Thyer, 1991, pl. 4). This section was measured from the upper part of the Lower Ordovician Manitou Limestone, on which the Middle Ordovician Harding Sandstone unconformably rests here (regionally, a low angular unconformity), through the Harding Sandstone, and into the overlying Fountain Formation. At Indian Springs, three informal Harding subdivisions (lower sandstone, middle shale, and upper sandstone sequences) can be recognized, although they are markedly thin relative to thicknesses measured in sections nearby (Fischer, 1978a; Thyer, 1991). The Harding Sandstone is only approximately 57 feet (17.4 m) thick here (fig. 36), and is overlain unconformably by the (Pennsylvanian) Fountain Formation. Here, the thick Upper Ordovician Fremont Dolomite and the upper part of the upper Harding sand sequence have been cut out by erosion prior to deposition of the Fountain Formation. About 1.1 miles (1.8 km) east-southeast of the small quarry, the unconformity at the base of the Fountain has truncated all the middle shale sequence, and only 20 feet (6.1 m) of the Harding remain. These and other field relationships suggest that the area was repeatedly structurally active in the early Paleozoic and in the late Paleozoic during the formation of the Ancestral Rockies (Gerhard, 1967, 1974; Fischer, 1978a, b).

Fischer (1978a, b) described a remarkable array of invertebrate and vertebrate trace fossils from the Indian Springs locality. This quarry is the type locality for eight trace-fossil (ichnofossil) genera, the types of which are reposited at the University of Colorado Museum. Several of these specimens are reillustrated here as figures 37-40 to emphasize the diversity of types.

The quarry is in unit 3 of Fischer's (1978a, b) and unit 2 of Thyer's (1991) measured sections here (fig. 36), approximately 16 to 18 feet (4.9 to 5.4 m) above the base of the Harding Sandstone in a sequence of light-colored, thin-bedded, very fine grained, quartzose sandstones with thin interbedded shales. Sedimentary structures in these beds include current ripple marks, cross-laminae, and mud cracks. Trace fossils occur both on the upper and lower bedding-plane surfaces of the beds of Thyer's unit 2, and the beds themselves are strongly burrowed and otherwise bioturbated, indicating both epifaunal and infaunal habits of the organisms. They are dominated by a diverse ichnofauna of medium- to large-sized arthropods including trilobites, eurypterids, merostomes, and limulids (horseshoe crabs). Also present are trace fossils of nemotodes, several types of vertebrates (including ostracoderms), and other animals. Body fossils are sparse in these beds, but ostracoderm plates, an articulated partial specimen of the ostracoderm *Astraspis desiderata* (a bony fish), merostome fragments, and conodonts are

Figure 37. *Homopedichnus polydactylus* (arthropod trackway on left, UC 29130) and other trace fossils, possibly limuloids, on right. Scale is 1 cm.

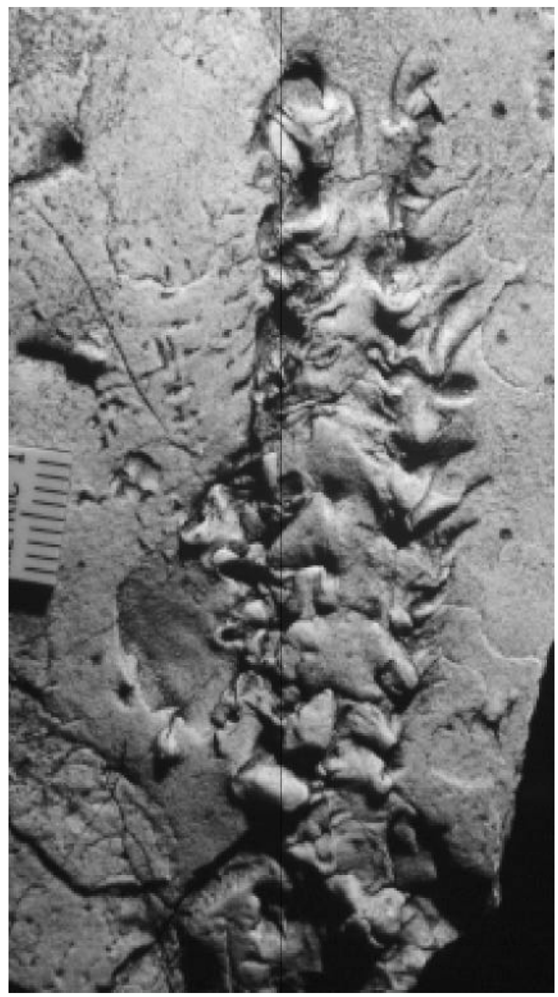


Figure 38. *Kouphichnium* sp. (walking trace of limuloid; UC 29142).

Figure 39. ***Zoophycus* sp. (UC 29166). Scale is 1 cm**.

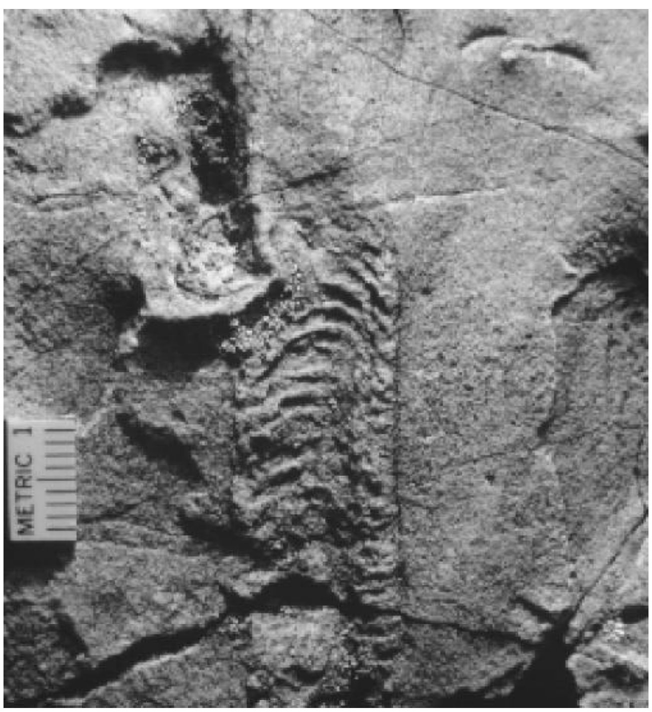


Figure 40. ***Rhizocorallium* sp. (UC 29173). Scale is 1 cm.**

present. Based on the type of trace fossils, body fossils, and the sedimentary structures, Fischer (1978a, b) concluded that this unit was deposited in an estuarine (lagoonal) environment, an interpretation verified by Spejaldnes (1967, 1979). This interpretation is important because it demonstrates that the primitive vertebrates were part of the estuarine ecosystem. Furthermore, to quote Fischer (1978a), "*The Thorson Trace Fossil Site is a classic example of the bias of the fossil record and provides a unique 'window' for the observation of Ordovician life.*" Both the invertebrate and vertebrate faunas of the marginal marine environments of the Harding Sandstone were far more diverse than the study of the body fossils alone would indicate.

Important discoveries from this locality follow (Kuntz, Armstrong, and Athearn, 1989):

- Mold of part of an ostracoderm showing the anatomy and configuration of the respiratory pouches.
- Earliest fossil record and occurrence of the walking, foraging, and burrowing activity of the horseshoe crab.
- Earliest record of scorpionid locomotion and some indication of scorpionid morphology.
- Earliest record of eurypterids in the western United States.
- Earliest body- and trace-fossil evidence of the extinct arthropod *Aglaspis* (similar to a horseshoe crab), which was known previously from only one locality in Minnesota.
- Detailed walking and swimming tracks of a giant isotelid trilobite, revealing important data on the nature, structure, and function of both the epipodite and pre-epipodite.
- Body-fossil evidence of an extinct merostome revealing the ventral side of the animal.

The vehicles will shuttle us back to the office of the Indian Springs Ranch and our vehicles. Return to U.S. Highway 50 and return to Denver. We hope you have enjoyed this field trip.

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