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Field Trip No. 9

Geology of the Western San Juan Mountains and a Tour of the San Juan Skyway, Southwestern Colorado

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INTRODUCTION

This road log is a modified and much abridged version taken from the book **Western San Juan Mountains: their geology, ecology and human history**, Rob Blair (ed) published by the University Press of Colorado, 1996. This log follows a 235 mile paved loop (San Juan Skyway, Fig. 1) which begins and ends in Durango, Colorado. The trip can be done in a long day, but if one wishes to see and feel the mountains and their geology then two days is recommended.

DAY ONE - DURANGO TO OURAY

Stop 1. Carbon Mountain landslide. This slide forms the hummocky debris seen beneath the siltstone and shale bluffs to the west of the highway just above the local shooting range. The slide formed in the winter of 1932-1933 when water-saturated Fruitland Formation collapsed and slid upon the sloping Picture Cliffs Sandstone ledge. The maximum rate of movement was clocked at 30 ft (9 m) per day and it became such a popular tourist attraction that an enterprising young man set up a hot dog stand one weekend in early January of 1933.

Stop 2. Lions Shelter overlook. Durango (elevation: 6512 ft., population: 12,430) is built on Animas River gravels which rest upon late Cretaceous sedimentary rocks, principally the Mancos Shale (Fig. 2). Perins Peak (west) and Raider Ridge (east) are capped by the Point Lookout Sandstone. Animas City Mountain (north) is capped by the Dakota Sandstone and forms a conspicuous sloping surface dipping to the southwest about 7 degrees. All formations in the Durango area dip to the south towards the center of the San Juan basin, a structural basin with a sedimentary thickness of nearly 12,000 ft (3,700 m). Just south of town the formations steepen to 35 degrees and form prominent hogbacks that represent the Hogback monocline and mark the approximate physiographic boundary between the Southern Rocky Mountain province to the north and the Colorado Plateau province to the south. Five miles (8 km) south of town the beds then become nearly horizontal. River terraces form the flat areas upon which Durango is constructed. For example, Main Street is built upon an 18,000 to 25,000 year old Wisconsin glacial outwash terrace, and

East Second Avenue is built upon a higher 36,000 to 40,000 year old glacial outwash terrace. The steep riser between these terraces can be seen along any east-west street in downtown Durango. These terraces merge to the north with late Wisconsin glacial end moraines. The Lions Club shelter provides the best views of north Durango and the Animas Valley. The shelter is built upon approximately 300,000 year old end moraines called the Durango Moraines. The Fort Lewis College campus is built upon glacial outwash gravel of this same age. Mantling the gravel is 10 to 30 ft (3-9 m) of red loess, a wind-blown silt deposit thought to be derived from the southwest around Monument Valley. Glacial end moraines form the east-west parallel ridges along 32nd Avenue. These glacial deposits are the Animas City Moraines and formed between 18,000 and 25,000 years ago. An older suite of end moraines, called the Spring Creek Moraines, are 80,000 to 150,000 years old and can be seen capping the hills just north of Florida Road before it passes northeast out-of-town.

Stop 3. Baker's Bridge. The 1,720 million year old Baker's Bridge Granite is exposed here and to the north for several miles along the Animas River. From here south, the granite is buried under alluvium and Paleozoic rocks. The contact between the granite and overlying Upper Devonian Elbert Formation is a nonconformity and represents a missing time gap of 1,200 to 1,300 million years. The unconformity is clearly displayed just west of the west bridge. This 400+ million year old erosion surface is noted for its weathered granite hillocks lying beneath the 70 ft (21 m) thick McCracken Sandstone Member of the Elbert Formation. The overlying 40 ft (12 m) of the Elbert consists of shales containing scales and plates of primitive fish. At the bridge site, glacial and fluvial erosion have stripped off the sedimentary cover to expose the Precambrian granite. Glaciation, in particular, has produced prominent rock steps seen east from the main highway and north of the bridge. Lateral moraines found high on the west and east sides of the valley indicate the Animas glacier maintained a thickness of 2000 ft (600 m) or so in this part of the valley. North of Baker's Bridge, the Animas River is entrenched into granite to form a narrow gorge. As can be seen from the bridge, the path of this channel is largely

controlled by jointing. Previously, the river split into two channels just above Baker's Bridge; thus, it once flowed in the abandoned channel just west of the main bridge. South of the bridge where the granite disappears below the surface, the river takes on the characteristics of a gravel bedded channel and is braided for much of the next 5 mi (8 km).

Stop 4. Purgatory Ski Area. The Needle Mountains form the bold peaks seen to the east. From north to south is Pigeon Peak (13,972 ft, 4259 m), Turret Peak (13,835 ft, 4217 m) and Eolus Peak (14,084 ft, 4293 m). All are glacial horns surrounded by cirques, tarns and U-shaped valleys.

Glacial ice thickness in this area has been estimated between 2,500 and 3,000 ft (750 - 900 m) thick. These peaks and others such as Engineer Mountain rose above the San Juan ice field like rock islands surrounded by a sea of ice. The Needle Mountains are eroded from the Eolus Granite (1,460 million years old). These mountains lie within the Weminuche Wilderness Area, the oldest and largest (459,804 acres, 186,082 hectares) designated wilderness area in Colorado. South of the Needle Mountains is Mountain View Crest. The crest is covered with lower Paleozoic strata that show the regional southerly dip down off the south flank of the San Juan dome.

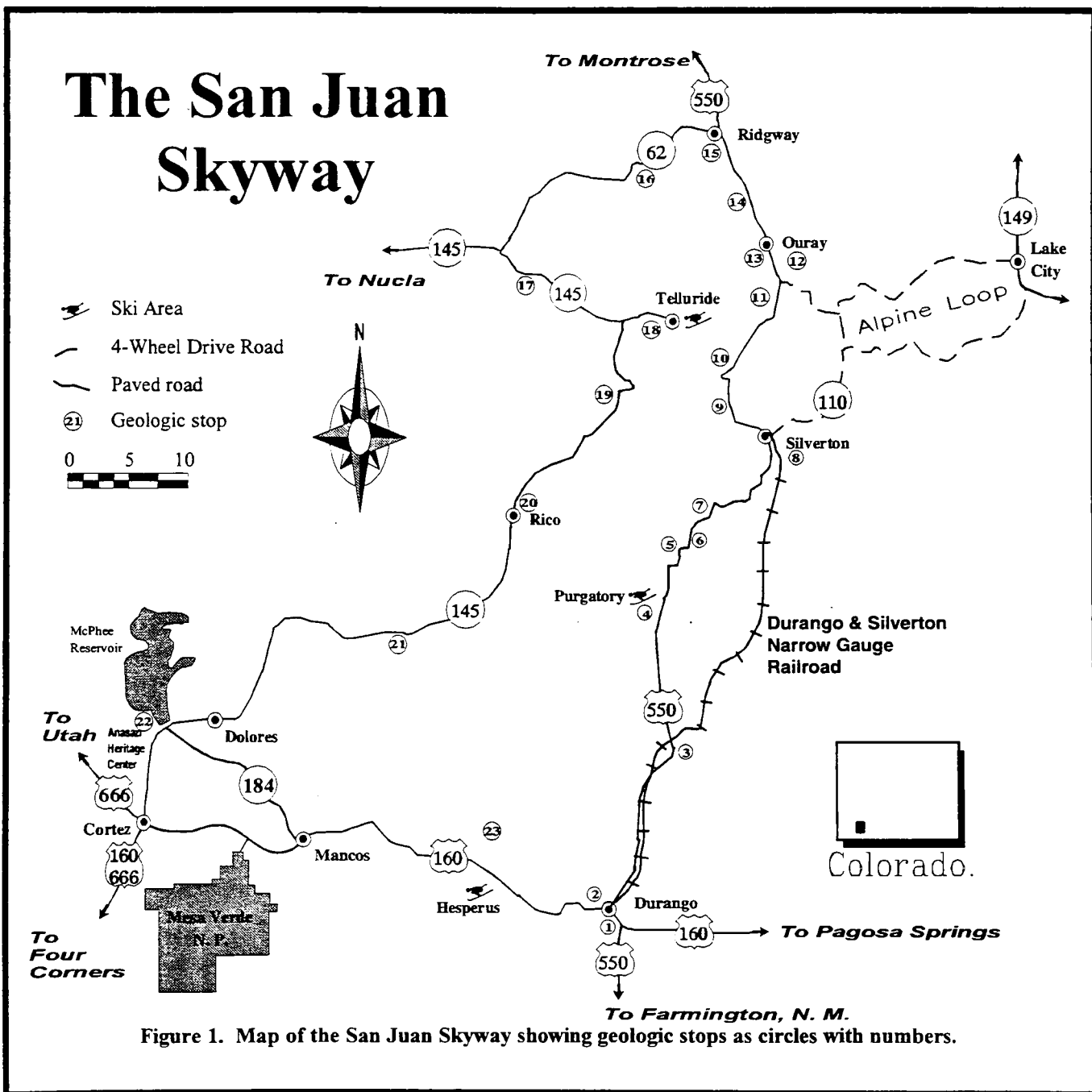


Figure 1. Map of the San Juan Skyway showing geologic stops as circles with numbers.

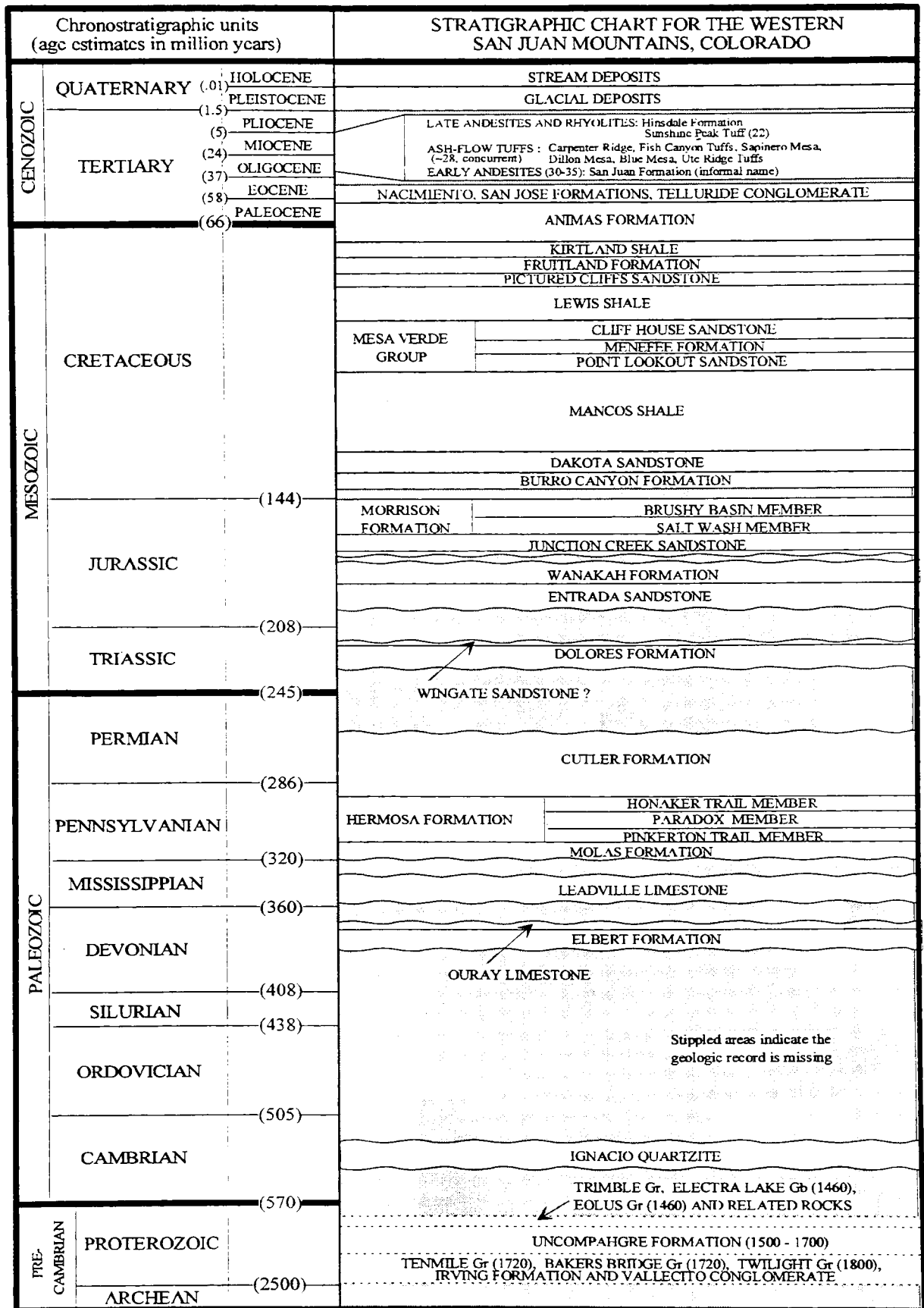


Figure 2. Stratigraphic Chart for the Western San Juan Mountains. Modified after MacLachlan, 1981.

Stop 5. Coal Bank Pass. From the parking lot at Coal Bank Pass, a short walk can traverse a variety of geology. Three hundred feet (100 m) or so south and just west of the highway a thinner than normal lower Paleozoic section is exposed. Here the Cambrian Ignacio Formation is a coarse conglomerate. It is exposed above the dark purple weathered Precambrian Twilight Gneiss and is overlain by the Upper Devonian McCracken Sandstone Member of the Elbert Formation. The upper shales of the Elbert are, in turn, overlain by thin carbonate layers of the Upper Devonian and Mississippian Ouray-Leadville Limestones, and several tens of feet of red Molas Formation. Overlying the Molas is the Pennsylvanian Honaker Trail Formation forming the cliff bands above the pass. The lower Hermosa Group is missing, which suggests that this region was a highland in early Pennsylvanian time.

The trace of the Coal Bank fault follows the prominent gully just north of the pass. The toilets are built upon the upthrown block. This fault is one of a swarm of fractures trending generally east-west which have a long history of complex movement beginning in the Precambrian. The initial episodes of movement along the fault were apparently oblique-slip with the north block dropping down and to the east. This sense of movement was determined north and below the pass where the fault separates the younger Uncompahgre Formation from the older Twilight Gneiss. The fault was reactivated during the Cambrian (?) when the north block went up, shedding coarse Uncompahgre sediment to the south and producing a basal conglomerate of the Ignacio (?) Formation. During or prior to the late Devonian Period the north side again went down according to Don Baars (1992) who cites evidence of deeper water sediments north of the fault in the late Devonian Ouray Formation. The Leadville and lower Hermosa are missing north of the fault, thus suggesting that prior to and during Pennsylvanian time the north block again went up, only to drop down again some time after the Hermosa was deposited. If you are confused about this history you are not alone. Geologists are still arguing over the details of the evidence and their interpretation.

Today, the Precambrian Twilight Gneiss is exposed at the pass on the south block of the fault. The sedimentary beds of late Pennsylvanian Honaker Trail Formation make up the north block. The Twilight Gneiss on the north side of the fault is approximately 750 ft (229 m) lower than the same Twilight Gneiss exposed at the pass.

Stop 6. Lime Creek overlook. The Twilight Peaks to the southeast are eroded from the Twilight Gneiss (1,780 million years old). The valley to the southeast is carved from vertically-oriented quartzites and phyllites of the Uncompahgre Formation (1,690 million years old). The rounded, polished and scratched bedrock surfaces are the

legacy of the erosive action of the Animas Glacier. The Lime Creek syncline is seen due east. Its axis crosses the highway just north of the parking area. This doubly plunging syncline has its low point (nadir) just to the east of Lime Creek. The south limb of the syncline was formed from drag along the Snowdon fault, while the north limb was tilted from the injection of the Lime Creek pluton, a laccolith perhaps of the same age as the intrusive cap of Engineer Mountain. The roadcut west of the parking area displays steeply inclined strata of the Honaker Trail Formation on the southern limb of the syncline. Note the channel scour in the more southerly and middle sandstone layers.

Stop 7. Molas Pass area. Eighteen thousand years ago this region was buried beneath a 500 to 1000 ft (115-330 m) ice field. The ice surface was at a level close to that of the present tree line, about 12,500 ft (3830 m). The high peaks in the area were islands of rock projecting above the ice surface. This ice field fed the Animas Glacier, one of the longest valley glaciers documented in the Rocky Mountains of Colorado. Glacial features abound. Look for cirques, horns and U-shaped glacial valleys. Many outcrops display scratches and grooves from the ice dragging stones across the bedrock. Which direction was the ice moving locally?

The sloping benches at and above road level are the Honaker Trail Formation consisting of carbonate-clastic sequences representing cyclic sedimentation. The benches are the resistant limestones or arkosic sandstones and the slopes are siltstones. The limestones are fossiliferous and contain phylloid algae, pelecypods, crinoids, fusulinids, gastropods, and brachiopods. Many of these 300 million year old fossils can be found in the local outcrops scattered about the area.

From the pass one can see structural elements of the Grenadier Horst, a Paleozoic highland. The horst is expressed as high peaks making up the Grenadier Range to the southeast. The Molas Creek valley, seen south of Molas Lake, is the topographic expression of the Molas graben. This is a local down-faulted block bounded on the north by the northeast trending Molas-Andrews Lake fault and to the south by the Snowdon fault, which passes just north of Snowdon Peak seen due south.

To the north is Grand Turk Mountain. This peak is capped by the San Juan Formation. This 30-35 million year old volcanic unit overlies a thin prominent cliff of the Telluride Conglomerate, a late Eocene pediment-fan gravel, which rests upon a late Eocene erosion surface, locally called the Telluride peneplain. This surface is an angular unconformity and indicates the uplifting and erosion of the San Juan dome during the Laramide Orogeny in late Cretaceous and early Tertiary time. Note the red Permian Cutler Formation dipping slightly southwest beneath the Telluride cliff below Grand Turk. Can you pick out any faults which offset these formations?

To the east of the highway at the north end of Molas Lake, a paleokarst tower is partially exposed in an old quarry east of the road. This quarry exposes the contact between the light gray Mississippian Leadville Limestone and the overlying dark red shales of the Pennsylvanian Molas Formation. The quarry was excavated into the west side of a buried 330 million year old karst tower and karst breccia. The Leadville Limestone is partly recrystallized and contains bryozoa, coral, brachiopods and crinoids. These fossils indicate this area was once a shallow-water carbonate platform. After the sea withdrew, the region became humid subtropical to tropical. This led to aggressive solution weathering of the exposed limestone and to the eventual development of numerous karst towers, sinkholes and caves. Around the lake at least three buried karst towers have been located, one with a height 65 ft (20 m). The Molas siltstones and shales are thought to represent a paleo-oxisol soil similar to the type of soils now forming in Java and North Vietnam.

Stop 8. Silverton (elevation: 9,318 ft (2840 m). Population: 716). Silverton lies along the southern margin of the Silverton caldera, the collapsed interior of an ancient volcano which last erupted about 27 million years ago. The caldera rim is outlined by the Mineral Creek and upper Animas River valleys. Christ of the Mines Shrine, located immediately northwest of town, is built on an old landslide. The shrine was constructed in 1959 as a monument to the local miners. The alcove is constructed from local stone and the 12 ton statue carved from Carrara marble from Italy.

Stop 9. Mineral Creek valley is a typical U-shaped glacial valley, whose walls are now marked by numerous snow avalanche tracks. Mineral Creek is carved along ring fractures which outline the southwestern rim of the Silverton caldera. In general, the rocks to the south and west of the road represent the caldera walls of the Silverton caldera. The rocks to the north and east are the 3,000 ft (900 m) thick Henson and Burns Formations. These volcanic rocks inside the caldera rest upon a collapsed, complexly fractured caldera floor at some unknown depth. The slopes of Anvil Mountain exhibit brilliant reddish and yellowish scree derived from the highly altered volcanic rocks. After the collapse of the Silverton caldera some 27 million years ago, sulfataric fluids percolated along fractures and escaped from around the caldera rim, and in the process, altered the enclosing rocks to colorful iron oxides and silicified clays.

Stop 10. Red Mountain Pass area. Red Mountain Peaks, east of the highway, consist of a complex system of flows, flow breccias, and pyroclastics of rhyolite and latite making up the Burns Formation. These units in turn have been penetrated by fingers of rhyolite and quartz

latite porphyry intrusives. Most of the rocks have been highly altered by late Tertiary hydrothermal activity and have subsequently weathered to a variety of iron oxides with shades of red, orange and yellow-brown. Fresh exposures of the altered rock are commonly white, greenish white or gray, and represent an assortment of clay minerals mixed with primary alteration minerals such as pyrite, chlorite, alunite and quartz. Throughout there are patches of silicified breccias derived from replacement of shattered parent rock. Landsliding is common on the slopes of these highly altered and fractured rocks, especially on the west slope of Red Mountain No. 2.

Stop 11. Uncompahgre Gorge. The gorge was carved out of Precambrian quartzites and slates of the Uncompahgre Formation by the erosive action of glaciers and streams. The quartzites and slates were metamorphosed between 1,720 million years ago and 1,460 million years ago and tipped up on edge so that many of the layers are now near vertical. The formation is thought to be over 8,000 feet (2,448 m) thick.

These Precambrian rocks represent part of an east-west trending, uplifted fault block known as the Sneffels Horst, which is bounded on the south by the Dunmore fault and on the north by the Ouray fault. The tectonic history of the Sneffels Horst has had a profound influence on the rock sequence in this region. For example, just north of Ironton Park, the Paleozoic section is absent and the San Juan Formation rests unconformably on the Uncompahgre Formation. However, when following this erosion surface north one encounters a wedge of Paleozoic rocks which thicken to approximately 800 ft (245 m) just north of Ouray. This Paleozoic section spans from the Devonian Elbert Formation through the Pennsylvanian Hermosa Group and these sedimentary rocks are in turn overlain by the Telluride Conglomerate and the San Juan Formation. The unconformity on top of the Precambrian rocks is tilted toward the northwest, and in certain localities marks the lower boundary of late Tertiary mineralized veins and near Ouray constitutes the upper boundary of late Cretaceous mineralization.

Stop 12. Ouray. Ouray occupies the floor of a glacial valley in a small mountain park at the juncture of five creeks. Ouray is surrounded on the west, north and east by about 4,000 ft (1200 m) of Paleozoic and Mesozoic sedimentary rocks dipping gently to the north and northwest. To the south the dominant rocks are the Precambrian quartzites and slates of the Uncompahgre Formation that lie south of the Ouray fault. The first 1,500 ft (450 m) of ledgy gray and buff strata above the valley floor to the west, and northeast are the sandstone and limestone layers of the Pennsylvanian Hermosa Group. Above these layers are the red beds of the

Permian Cutler Formation and the Triassic Dolores Formation. An angular unconformity separates these two formations and suggests that there were several episodes of uplift along the Ouray and other local faults around 245 million years ago. All of these formations are blanketed by a thick sequence of volcanic rocks, mostly the lower Tertiary San Juan Formation.

DAY TWO - OURAY TO DURANGO

Stop 13. Box Canyon. Box Canyon is a 20 ft (6 m) wide and 285 ft (87 m) deep canyon and waterfall associated with the Ouray fault. The initial escarpment was due to glacial erosion of the relatively soft sediments to the north of the fault leaving the resistant Precambrian quartzites as a cliff on the south. Water plummeting over the cliff from Canyon Creek, created plunge pools and potholes from the vigorous turbulent water charged with swirling stones. Erosion is greatest at the base of the falls; thus, a vertical channel is cut. The vertical channel is slowly migrating upstream. A view from the high trail west across Box Canyon shows a textbook angular unconformity with the vertical Uncompahgre Formation capped by the nearly horizontal Elbert Formation.

Stop 14. Uncompahgre Valley. This valley is almost a mirror image of the lower Animas Valley north of Durango. The valley from Ouray to Ridgway was buried beneath 1,000 ft (330 m) or more of glacial ice some 18,000 to 16,000 years ago. Originally the valley was probably U-shaped, but subsequently it was filled with alluvium and lake sediments to produce the flat-floored valley seen today.

Between Ouray and Ridgway the Uncompahgre Valley is bounded on both sides by cliffs composed of Paleozoic and Mesozoic strata dipping to the north and northwest. Near Ouray the Pennsylvanian Hermosa Group forms the valley walls and is overlain by 2,150 ft (655 m) of Permian red beds of the Cutler Formation. The boundary between the Hermosa and Cutler is based upon the uppermost occurrence of limestone in the Hermosa and is not based on color; thus, the boundary is difficult to detect. The northward dipping beds of the Cutler Formation are, in turn, truncated by the flatter lying Triassic Dolores Formation. The resulting angular unconformity marks a time of tectonic instability and erosion. The northern part of the valley is bounded by strata from the Jurassic Entrada Sandstone and Morrison Formation followed by the Cretaceous Dakota Sandstone and Mancos Shale.

Stop 15. Ridgway. The town of Ridgway is built upon alluvium deposited by the Uncompahgre River. The low-lying hills east, north and northwest are end moraines deposited from the last glacial advance from the Uncompahgre Glacier 18,000 to 16,000 years ago. These river and glacial deposits rest directly upon the Mancos Shale.

The Ridgway fault runs east-west, just south of Log Hill Mesa. This fault represents the southern edge of the Uncompahgre Uplift and has a displacement of about 1,500 ft (459 m) with the south block down. One of the stronger earthquakes recorded in Colorado had an epicenter about 10 mi (16 km) east of Ridgway and just north of Owl Creek Pass. It occurred on October 11 1960 with a magnitude of 5.5 on the Richter scale.

The "Ridgway Tillite" is a conglomerate of disputed origin. It is exposed beneath the San Juan Tuff and Telluride Conglomerate, but above the Mancos Shale in the east-facing slopes due west of Ridgway, near the top of Miller Mesa. Atwood (1915) described this conglomerate as a glacial moraine deposit. This would suggest glacial conditions in Eocene time some 45 to 55 million years ago. A number of geologists, however, believe that mild Mediterranean-like climates existed during this time. Closer examination of this deposit by geologists in the 1950s and 1960s, indicates that this conglomerate is an old mudflow, not a glacial till and may be more closely associated in age and origin with the Paleocene Animas Formation exposed south of Durango.

Stop 16. Dallas Divide. The east side of Dallas Divide is mostly Mancos Shale. The road on the west side of the divide cuts through the local Mesozoic and upper Paleozoic section. Mount Sneffels is the triangular shaped peak forming the centerpiece for the skyline to the south. The peak itself is eroded from an early Miocene (?) intrusive. The intrusive rock is slightly more resistant to weathering than the weaker volcanic rocks; thus, Mount Sneffels towers over the neighboring peaks. The whole mountain crest is part of an uplifted fault block called the Sneffels Horst. The summits of the other mountains consist mostly of a sequence of Oligocene ash-flow tuffs, erupted from the Silverton and Lake City calderas. These units, in turn, lie upon about 2,000 ft (615 m) of the San Juan Formation. A Tertiary sill (mp 13-14.6) is intruded into the Mancos Shale and exposed in the north roadcut.

Stop 17. San Miguel Canyon. At Placerville a look west down the canyon will reveal bedrock strath terraces cut in the Culter Formation mostly on the north side of the river. The trend of the north wall of the canyon for the next three miles west of here may be partly influenced by the Black King fault, a normal fault with the north side down by about 500 ft (152 m). Across the river, south of Placerville, are the Placerville Hot Springs. The sulfurous spring water flows out from a fault in the Cutler Formation and maintains a temperature of about 94o F (34.4o C).

The canyon cuts through a sequence of Paleozoic and Mesozoic sedimentary rocks dipping gently to the south. The oldest sedimentary layers are found near Placerville. Plant fossils were discovered in the Dolores Formation (approximately 220 million years old) just south of the river in 1952 by G. Edward Lewis and Roland W. Brown of the U.S. Geological Survey. They uncovered the palm-like

leaves of *Sanmiguelia lewisi*, the oldest flowering plants found in the Western Hemisphere. An olivine basalt dike (gray) can be seen on both sides of the highway (mp 77.1 & 77.4) and has been traced for more than three miles. The dike is expressed as either a slot when enclosed by more resistant bedrock or as a free-standing wall when surrounded by more easily erodible rock.

Stop 18. Telluride. Telluride occupies the floor of the narrow glaciated Main Fork Valley of the San Miguel River. The steep valley walls rise over 4,500 ft (1370 m) to the surrounding summits. Two miles east of Telluride the valley terminates in a glacial cirque with a headwall 2,400 ft (732 m) high. The Main Fork Valley is a U-shaped valley filled with over 500 ft (152 m) of lake sediment and alluvium.

Paleozoic and Mesozoic strata make up the north and south valley walls and dip gently towards the west. The reddish-brown Cutler Formation of Permian age forms the basal band of rocks seen at valley level, which in turn, is overlain by the brick-red Dolores Formation of Triassic age, the Jurassic Entrada Sandstone, the Wanakah Formation, and the Morrison Formation capped by the cliff-forming Cretaceous Dakota Sandstone. The Cretaceous Mancos Shale forms the dark grey slopes above the Dakota cliff above town to the west. It is upon the Mancos Shale that the airport runway is built. As many home owners can probably attest to, the Mancos Shale is associated with landsliding, mudflows and swelling soils.

Because these formations dip westerly and because there is an easterly dipping Tertiary erosion surface truncating the layers, the formations wedge out towards the east. In fact, at the head of the Main Fork Valley only the Cutler and Dolores Formations are left below the erosion surface. This surface has been called the Telluride peneplain and marks a time in late Eocene when the whole region was tectonically stable. Overlying this surface is the 250 ft (76 m) thick Telluride Conglomerate which forms a prominent cliff chock full of pebbles and cobbles consisting of many lithologies. Late Tertiary volcanic tuffs are draped over the conglomerate like a blanket. The lowest and thickest (~2,000 ft, 610 m) of these volcanic formations is the San Juan Formation, followed by several rhyolite ash flow units from the Lake City and Creede calderas.

Associated with the late Tertiary volcanic outpourings was fracturing and subsequent mineralization to form rich veins containing gold and silver. Much of the silver is tied up in minerals which also contain arsenic, antimony and sulfur, such as stephanite (Ag_5SbS_4). Most of the early mined gold occurred as visible free gold.

Stop 19. Lizard Head Pass area. During each of the last glacial epochs, ice covered this divide and filled the surrounding valleys. Glacial moraine deposits can be seen just south of Trout Lake and form the hummocky topography viewed there. From Trout Lake to the southern edge of the subalpine meadows (mp 57) the road is built upon Upper

Cretaceous Mancos Shale. South of the meadows the road is confined to the Dolores River Canyon and passes down through the Mesozoic section consisting of the Dakota Sandstone, the Morrison Formation, the Wanakah Formation and the Dolores Formation. These formations all dip generally 5 to 10 degrees to the north off the northern flank of the Rico dome.

Lizard Head (13,113 ft, 3997 m) is the conspicuous spire located north of the highway. Lizard Head was first climbed in 1920 by Albert Ellingwood and Barton Hoag. The ascent is considered to be the hardest of any 13,000 ft peak in the state of Colorado. In fact, an early climbing guide for the mountains of Colorado described the approach to the base and then recommended the climbers take a photograph and return home. When the peak was first seen by early miners, it had a bulge of rock at the top on the east side giving it the appearance of a reptile's head. This section collapsed as a rock fall in the early part of the century. The upper 500 ft (152 m) of the spire is composed of a late Tertiary ash flow tuff resting upon the San Juan Formation and the Telluride Conglomerate.

Stop 20. Rico. The town site of Rico occupies essentially the center point of the Rico dome. The east-west axis of the dome crosses at the north edge of town. From almost any commanding position, the Paleozoic sedimentary strata can be seen dipping away from the town in all directions. Exceptions to this exist when the strata are faulted or come in direct contact with igneous intrusives.

The two dominant formations comprising the valley walls and the core of the dome are the Pennsylvanian Hermosa Group (1,200 ft, 366 m), and the Permian red beds of the Cutler Formation (2,100 ft, 640 m). Both are laced with numerous Tertiary igneous dikes and sills.

The center of the dome has been shattered by numerous faults trending mostly east-west and northwest-southeast. These faults produced pathways for mineralized fluids which reacted with and replaced some of the limestones in the Hermosa Formation with pockets of silver, lead, zinc and pyritic ore. The intense fracturing also contributed to the instability of the surrounding outcrops, because within a two mile radius of the town center over 70 percent of the bedrock is covered with either landslide or talus.

Stop 21. Dolores River Canyon. Upper Paleozoic and Mesozoic strata make up the canyon walls. These sedimentary formations dip one to two degrees towards the west and southwest; thus, the oldest layers encountered along the road are to the east towards Rico and youngest to the west towards Dolores. The slopes surrounding the town of Dolores are the late Jurassic Morrison Formation, which is best exposed north and east of town. This formation is divided into an upper and lower unit, the Brushy Basin Member and the Salt Wash Member respectively. The prominent cliff capping the north canyon wall is the Dakota sandstone. This late Cretaceous formation is the upper-most

rim rock for nearly the full length of the Dolores Canyon. Stop 22. The Anasazi Heritage Center. The Anasazi moved into this region about 1,500 years ago and after about 800 years of farming the red soils they mysteriously left. In 1776 two Franciscan priests, Fathers Escalante and Dominguez and eight civilians arrived at the Dolores River and from their explorations in this area, they came upon the ancient ruins of a small Indian village. Escalante made note of them in his journal. This site is believed to be the ruins he observed, which makes it the first archeological site recorded in Colorado.

Stop 23. La Plata Mountains. These mountains encompass some 22 major peaks and numerous other minor summits to form a circular mountain range 9 mi (14 km) in diameter. The La Plata River along with glaciers have carved out a deep valley which bisects the heart of the range. From satellite images, a radial drainage pattern can be traced radiating away from the range center like the spokes of a bicycle wheel.

Spanish explorers passed by and into the La Plata Mountains in the mid and late 18th Century and possibly found ore there, but serious prospecting and discovery only began in 1878 with the opening of the Comstock Mine. Between 1878 and 1900, additional mines became operational, but their production was comparatively small. However, between 1900 and 1937 several productive deposits were discovered and nearly \$6,000,000 worth of ore had been processed, mostly from the May Day and the Idaho Mines. Gold was the principal objective, but over two million ounces of silver along with lead and copper have been recovered.

The La Plata Mountains are the erosional relics of a structural dome uplifted from the forceful injection of magma 65 to 67 million years ago into a thick sedimentary sequence of upper Paleozoic and Mesozoic rocks. The injected igneous bodies produced more than half a dozen stocks and multiple sills, dikes and pipes. Some of the stocks could be called laccoliths because of their near mushroom-like geometry.

The sedimentary strata, which ring the flanks of the La Plata range, generally dip down and away from the dome's crest, located in the vicinity of Diorite Peak. However, variations in formation dip do occur in close proximity to local intrusions and faults.

The igneous rocks can be classified into two broad groups, an older porphyritic intrusive and a younger nonporphyritic intrusive. The quartz diorite porphyry is the most abundant rock type and comprises most stocks, sills and dikes. The younger nonporphyritic intrusives form singular stocks and associated dikes with compositions of syenite, monzonite and diorite.

The district is best known for its veins and replacement deposits of gold-bearing and silver-bearing telluride ores, which account for the greatest production. An incredible variety of deposit types have been identified within the district. These include gold-bearing contact ore, disseminated platinum-bearing chalcocopyrite, veins of ruby silver and veins of mixed base-metal sulfides containing silver or native gold. Gold-bearing placers have also been mined but were generally nonproductive.

The relationship between these different deposit types has been confusing, but it seems certain that they were formed through a wide range of temperatures and to a lesser degree pressures. Some of the ore bodies are zoned. Several lines of evidence suggest that all the deposits (excluding placers) were formed during one general period of hydrothermal activity that followed closely on the heels of the last igneous event associated with the nonporphyritic rocks.

The La Plata Mountains have been glaciated, but they did not support glaciers as large or extensive as found in the San Juan Mountains to the north and east. Remnants of an end moraine can be found near the town, Mayday, which grades into a glacial outwash terrace to the south called Gold Bar.

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