OPEN-FILE REPORT 07-7

Geologic Map of the Mount Deception Quadrangle, Teller and El Paso Counties, Colorado

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FOREWORD

The purpose of Colorado Geological Survey Open File Report 07-7, *Geologic Map of the Mount Deception Quadrangle, Teller and El Paso Counties,, Colorado* is to describe the geologic setting, mineral and water resources, and geologic hazards of this 7.5-minute quadrangle located in the Front Range, north of Woodland Park, Colorado. Consulting geologists Jay Temple and Rich Madole, staff geologist John Keller, and field assistant Dawn Martin completed the field work on this project during the summer of 2006. The sedimentary bedrock unit descriptions, structural geology, and water resource sections of this report were written by Mr. Temple. Dr. Madole completed the sections on surficial deposits and geologic hazards. Mr. Keller contributed the crystalline bedrock unit descriptions and mineral resources section. Miss Martin contributed to descriptions of the sedimentary bedrock.

This mapping project was funded jointly by the U.S. Geological Survey and the Colorado Geological Survey. U.S. Geological Survey funds were received under STATEMAP award number 06HQAG0045. STATEMAP is a component of the National Cooperative Geologic Mapping Program, which is authorized by the National Geologic Mapping Act of 1997. The Colorado Geological Survey matching funds are drawn from the Colorado Department of Natural Resources Severance Tax Operational Funds, which are obtained from the Severance Tax paid on the production of natural gas, oil, coal, and metals in Colorado.

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LOCATION AND GENERAL GEOLOGY

The Mount Deception 7.5-minute quadrangle is located in Teller and El Paso Counties, Colorado, in the southern part of the Colorado Front Range (fig. 1). The city of Colorado Springs (Census 2000 population of 360,890) is located approximately 17 miles southeast of the quadrangle. The town of Woodland Park (Census 2000 population of 6,515) is partially located in the southern part of the quadrangle and is accessible from Colorado Springs via State Highway 24. State Highway 67 transects the center of the quadrangle from north to south, connecting Woodland Park with the towns of Deckers, Buffalo Creek, and Pine Junction. Trout Creek, the major drainage throughout the west-central part of the quadrangle, flows northward to join the South Platte River near the town of Deckers. The South Platte watershed supplies a large share of water consumed by Denver and other cities to the north and east along the foothills of the Front Range. Several creeks and streams that originate in the mountains in the eastern and western parts of the quadrangle flow into Trout Creek. Fountain Creek is located just south of the quadrangle and flows southeastward through Ute Pass and into Monument Creek in Colorado Springs. The Fountain Creek watershed provides a major supply of water for the region to the south and southeast. The highest point in the quadrangle is the quadrangle's namesake, Mount Deception, located in sec. 13 of T. 11 S., R. 69 W. (elevation 9,363 feet), and the lowest point (elevation 7,600 feet) is in the Trout Creek valley bottom in the northwestern part of the quadrangle.

The quadrangle can generally be described as having a central, north-south trending valley, bordered on the east and west sides by mountainous terrain (fig 2). The eastern mountains are part of the Rampart Range, which trend north-south for over forty miles from Colorado Springs to Kassler. The West Creek Range borders the western part of the quadrangle. Most of this mountainous region is rugged, forested land administered by the U.S. Forest Service (Pikes Peak Ranger District, Pike National Forest). A significant portion of this Forest is comprised of the Manitou Experimental Forest which was established by the U.S. Forest Service in 1936 to study problems of land use and its relation to the management of natural resources in the Front Range ponderosa pine zone (Gary, 1985). The ponderosa pines are accompanied by lodgepole pine, Douglas-fir, Engelmann spruce, and aspen. Average precipitation is 16 inches near Manitou Lake, with seventy percent accounted for by rain from April through August and the remaining thirty percent from snow during the winter months.

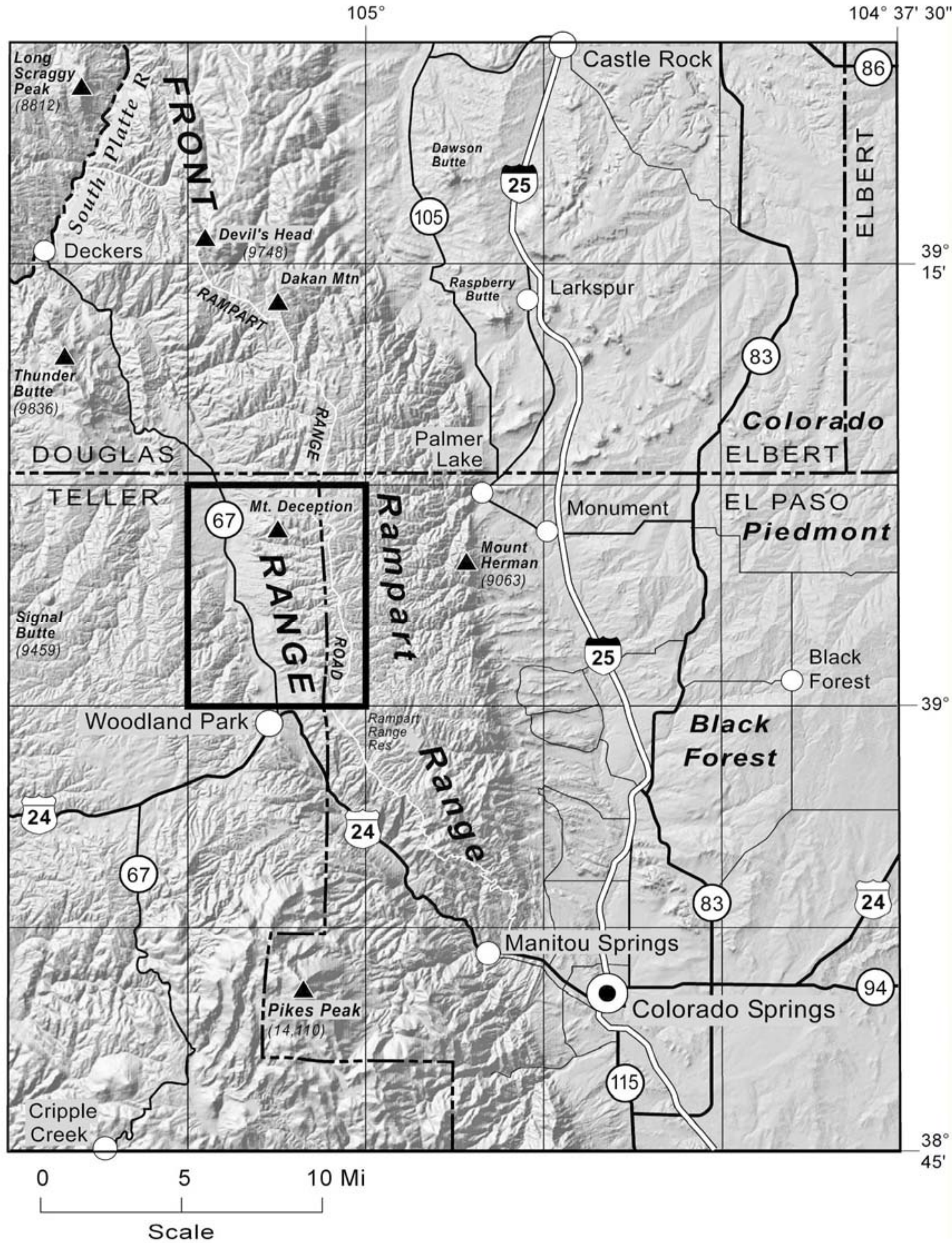


Figure 1. Shaded relief map of the region surrounding the Mount Deception quadrangle (bold black outline) shows cities and towns, major roads, and other geographic features.

The range-core rocks in the mapped area and surrounding region are typically of granitic composition and are part of the late Mesoproterozoic Pikes Peak batholith. Throughout the central part of the quadrangle, younger Paleozoic sedimentary rocks and a veneer of Quaternary surficial materials flank the eastern and western granitic cores. The "Great Unconformity", a nonconformity where the Cambrian Sawatch Sandstone lies directly upon the Precambrian granitic basement, is spectacularly exposed in the east-central parts of the quadrangle at Soldier Mountain and north of Johns Gulch and also north of White Spruce Gulch in the north-central part of the quadrangle. Faulting is generally responsible for the juxtaposition of the Paleozoic rocks adjacent to the Proterozoic rocks. The dominant fault in the east-central part of the quadrangle is referred to as the Mount Deception fault. This fault strikes north-south and is interpreted to be a low-angle, west-directed reverse fault. The dominant fault in the west-central part of the quadrangle is the regional scale Ute Pass fault. It dips west at 46 to 52 degrees, making it a low-angle, east-directed reverse fault. Subsidiary footwall faults closely parallel these two major faults, resulting in the juxtaposition of Lower and Upper Paleozoic sedimentary rocks. These sedimentary rocks lie between granitic basement carried on the Mount Deception and Ute Pass fault systems to form the downthrown block referred to as the Woodland Park or Manitou Park graben. Subsequent erosion has differentially removed the softer sedimentary rocks to create the north-south-trending topographic low that encompasses the park land.

Figure 2. Photograph looking south from Mount Deception towards Pikes Peak. View on the left shows the rugged terrain of the western flank of the Rampart Range on the eastern side of the quadrangle. View on the right side of the photograph shows the lower topography of the Woodland Park or Manitou Park graben.

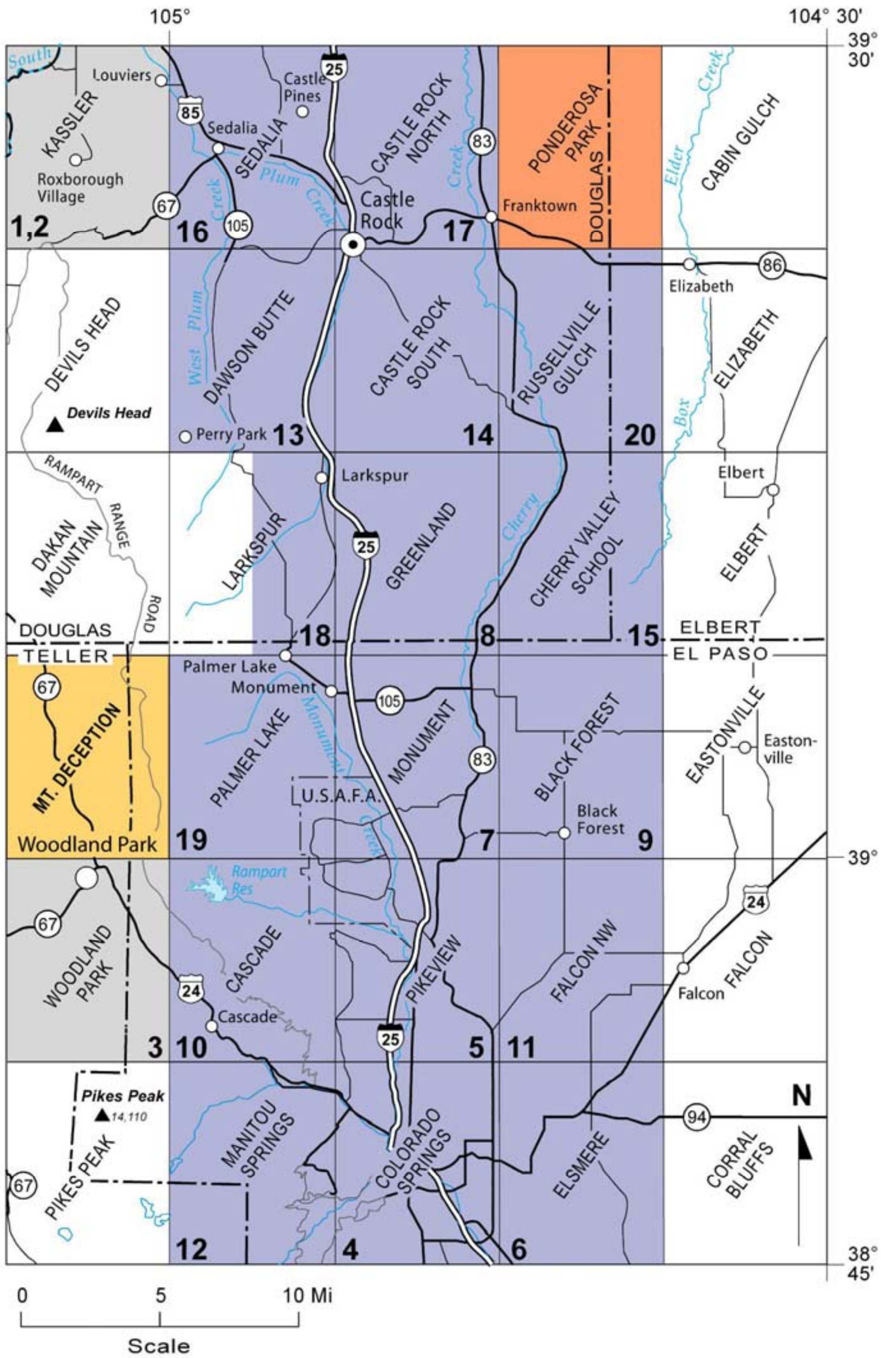
SCOPE OF WORK

Geologic mapping of the Mount Deception 7.5-minute quadrangle was undertaken by the Colorado Geological Survey (CGS) as part of the STATEMAP component of the National Cooperative Geologic Mapping Act, which is administered by the U.S. Geological Survey. Geologic maps produced by the CGS through the STATEMAP program are intended as multi-purpose maps useful for land-use planning, geotechnical engineering, geologic-hazards assessment, mineral resource development, and groundwater exploration. Figure 3 shows the status of geologic maps of 7.5-minute quadrangles in the Colorado Springs area. This is the twentieth quadrangle in this area to be mapped by the CGS.

The geologic interpretations shown on the map were based on (1) field investigations in 2006; (2) prior published and unpublished geologic maps and reports; (3) interpretation of black and white 1:24,000-scale U.S. Geological Survey aerial photography flown in 2005, a 10-meter digital elevation model (DEM), and a 1-meter resolution USGS digital orthophoto quadrangle (DOQ) derived from recent black and white photography. Bedrock geology and surficial deposits were mapped in the field on topographic maps of the quadrangle and on aerial photographs. The photos and maps were scanned, georeferenced, and imported into ERDAS Imagine OrthoBase, where they were photogrammetrically corrected and rendered in 3D. Line work was traced directly from ERDAS Imagine Stereo Analyst and exported as ESRI shapefiles into ArcGIS 9.1. Universal Transverse Mercator (UTM; North American Datum 1983, Zone 13) coordinates are provided for key geologic areas and photographs.

PREVIOUS GEOLOGIC MAPPING

Geologic mapping in the late nineteenth and early twentieth centuries targeted areas to the north, south, and east of the Mt. Deception quadrangle but did not include it as part of a compilation for the Geologic Atlas of the United States by the U.S. Geological Survey. The region northeast of the Mt. Deception quadrangle was mapped at a scale of 1:48,000 for the Castle Rock Folio by Richardson (1915); to the east for the Colorado Springs Folio by Finlay (1916); and to the south for the Pueblo Folio by Gilbert (1897). Descriptions of the rock units, chemical analyses of some of the Proterozoic igneous rocks, and structural interpretations were parts of these folios. Several graduate theses were completed in the quadrangle by students from the University of Colorado and the University of Iowa (Bennett, 1940, Fowler, 1952, and Sweet, 1952). The Front Range, including the Mount Deception area, was also mapped and described as to structure and stratigraphy in a tectonic synthesis by Boos and Boos (1957). The Denver 1:250,000 scale geologic map by Bryant and others (1981) included the area of this quadrangle. The Woodland Park quadrangle, immediately to the south of the Mt. Deception quadrangle, was mapped in reconnaissance fashion by the U.S. Geological Survey (Wobus and Scott, 1977). Recent detailed geologic mapping in the Colorado Springs area at 1:24,000 scale has been conducted by the Colorado Geological Survey (fig. 3).



Completed 1:24,000-scale geologic maps:

Index Map No.	Publication No.	Date
1	USGS PP-421-A Scott	1963
2	USGS PP-421-B Scott	1963
3	USGS MF-842 Wobus & Scott	1977
4	CGS OF 00-03 Carroll and Crawford	2000
5	CGS OF 01-03 Thorson and others	2001
6	CGS OF 02-02 Madole and Thorson	2002
7	CGS OF 02-04 Thorson and Madole	2002
8	CGS OF 03-09 Thorson	2003
9	CGS OF 03-06 Thorson	2003
10	CGS OF 03-18 Morgan and others	2003
11	CGS OF 03-08 Madole	2003
12	CGS OF 03-19 Keller and others	2005
13	CGS OF 04-07 Morgan and others	2004
14	CGS OF 04-05 Thorson	2004
15	CGS OF 04-6 Thorson	2004
16	CGS OF 05-6 Morgan and others	2005
17	CGS OF 05-2 Thorson	2005
18	CGS OF 05-7 Thorson	2005
19	CGS OF 06-6 Keller and others	2006
20	CGS OF 06-8 Thorson	2006

Explanation

- This report
- Mapped concurrently with this report
- Completed CGS geologic maps
- Completed USGS geologic maps

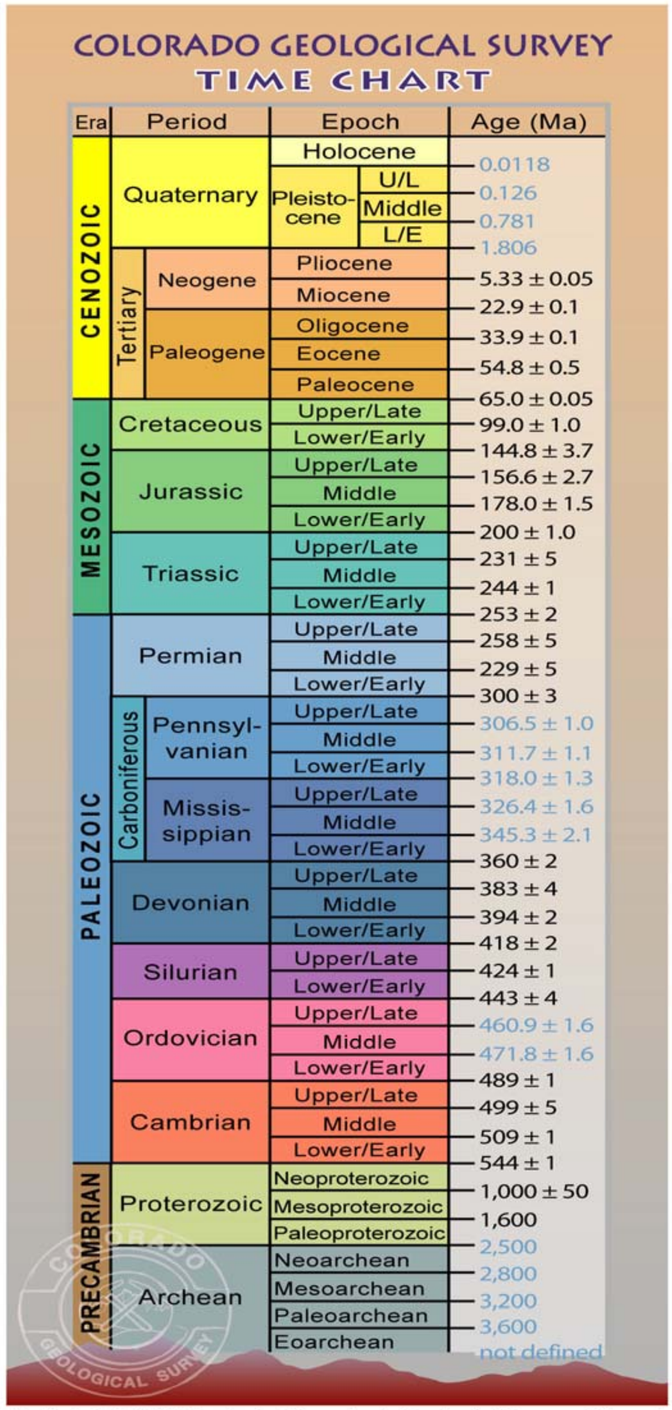
Figure 3. Location map and index of selected published 1:24,000-scale geologic maps in the vicinity of the Mount Deception quadrangle.

ACKNOWLEDGMENTS

The authors are grateful to the landowners of the Mount Deception region for their permission to access the areas necessary to complete this map. The dominant landowner in the region is the U.S. Forest Service, and the Pikes Peak Ranger District's Jeff Hovermale provided key support for access to these lands. The Manitou Park Experimental Forest staff, consisting of Steve Tapia and Richard Oakes, was also very supportive of our efforts. We would like to thank Sid and Sandy Miller, Bruce and Sandy Bausman, John McClelland, Bill and Pat O'Dell, Ken and Arlan Gerhardt, Dave and Carol Warren, Oded and Donna Light, George and Debbie Erb, Don and Dorothy Phillips, Ken and Carolyn Elliott, Denny and LaVon Blevins, the people of Quaker Ridge retreat, the people of Sky High Scout camp, the Colorado Lions Camp, and the residents of Majestic Park for their cooperation during this project. Key support during the digitizing of maps and compiling of figures was provided by Colorado Geological Survey personnel Matt Morgan, Nick Wattterson, and Larry Scott. Tom Neer of Digital Data Services was invaluable during the editing stage of the quadrangle map. Field checks and suggestions for the manuscript were provided by Vince Matthews, Matt Morgan, and Beth Widmann, also from the Colorado Geological Survey. Ms.Widmann was also instrumental in guiding the authors in the direction of key personnel and procedures in order to complete this project. Discussions with Paul Myrow and Christine Siddoway of Colorado College were extremely helpful to better understand the stratigraphy and structure of the area. A detailed critique of the manuscript was performed by Ned Sterne of Petro-Hunt LLC, and Jane Ciener of the U.S. Geological Survey for which we are very appreciative.

DESCRIPTION OF MAP UNITS

Geologic time divisions used in this report are shown in Table 1. Numerical ages were taken from the Geological Survey of Canada (Okulitch, 2002) and the International Commission on Stratigraphy (2005).



Okulitch, A.V., 2002, Geological time chart: Geological Survey of Canada, Open File 3040 (National Earth Science Series, Geological Atlas) –BLACK DATES.

International Commission on Stratigraphy, 2005, International stratigraphic chart: downloaded January 2006 from the International Commission on Stratigraphy website, www.stratigraphy.org/chus.pdf–BLUE DATES.

Table 1. Geologic time chart used by the Colorado Geological Survey.

SURFICIAL DEPOSITS

Unit Descriptions. The surficial deposits of the Mount Deception quadrangle are generally not well exposed. Consequently, the thickness of most units is estimated and descriptions of physical characteristics such as texture, stratification, and composition are based on observations at a small number of localities. Surficial deposits in the Mount Deception quadrangle are poorly sorted, most contain a broad range of particle sizes from clay to pebbles. The modified Wentworth scale (Ingram, 1989) is used to describe particle size, and Pettijohn's (1949) classification of roundness is used to describe particle shape. In the modified Wentworth scale, gravel includes pebbles, cobbles, and boulders. Also, because gravel has the connotation of rounded rock fragments (Bates and Jackson, 1995), angular rock fragments larger than 1/12 inch (2 mm) are referred to as pebble size or cobble size, as the case may be. Clast, as used here, is limited to rock fragments (rounded or angular) that are larger than 1/12 inches (2 mm) in maximum dimension, and matrix refers to fragments that are smaller than 1/12 inches (in other words, sand-, silt-, and clay-size particles). The colors of surficial map units were determined using Munsell Soil Color charts (Munsell Color, 1973) and are of dry materials only.

Age Assignments. The age limits of divisions of Pleistocene time (Table 1) are those proposed by the International Commission on Stratigraphy (2005). The 11,800-year date for the Pleistocene-Holocene boundary is the approximate calibrated equivalent of 10,000 radiocarbon years. The INQUA (International Union for Quaternary Research) Commission for the Study of the Holocene established the 10,000-radiocarbon-year date for the Pleistocene-Holocene boundary in 1969 (Farrand, 1990), a time when calibration back to 10,000 years had not yet been achieved. Generally accepted divisions of Holocene time have not been agreed upon, so, as used here, sediment referred to as upper Holocene was deposited at some time during the interval between 4,000 years ago and the present.

Numerical ages such as determined by radiocarbon, cosmogenic, or OSL (optically stimulated luminescence) dating methods have not been determined for any surficial deposits in the Mount Deception quadrangle. Thus, the unit ages listed here are estimated on the basis of relative-dating methods. These include stratigraphic relations (superposition, cross-cutting contacts, and unconformities), position in the landscape (primarily height above a datum, such as stream level), differences in degree of weathering and soil development, and inferred correlations with deposits elsewhere whose ages have been determined by numerical-dating methods.

HUMAN-MADE DEPOSITS—Earth materials emplaced by human beings.

af **Artificial fill (upper Holocene)—**Earth materials (sand, silt, clay, and rock debris) emplaced to construct buildings, parking lots, athletic fields, roads, and earthen dams. Unit is 3-30 feet thick.

ALLUVIAL DEPOSITS—Gravel, sand, silt, and clay transported and deposited by flowing water, either in channels (fluvial deposits) or as unconfined runoff (sheet flow). Alluvium of fluvial origin is the principal sediment underlying stream channels, flood plains and terraces, whereas alluvium resulting from sheet flow, referred to as sheetwash alluvium, blankets the lower parts of slopes, especially the footslopes of valley sides.

Qa1 **Channel and flood-plain alluvium (upper Holocene)—**Unit consists chiefly of pale-brown to brown, poorly sorted, angular to subrounded pebble gravel and sand underlying stream channels and flood plains. Deposits of Qa1 wide enough to show on the map are present only in the valleys of Trout Creek and Long Gulch. Flood plain is used here in the geomorphologic sense (as opposed to engineering definitions). The term refers only to flat areas adjacent to streams and that were constructed by the stream in the present climate and are flooded frequently (Dunne and Leopold, 1978). Areas flooded only once or twice per century (in other words, inundated by 100- or 50-year floods) are not included in the flood plain. Much of unit Qa1 probably was deposited during historic time. Deposits are thin and overlap unit Qa2 in many places. Estimated thickness is 2-6 ft.

Qa2 **Valley-floor alluvium (upper Holocene)—**Unit consists mostly of interbedded pale-brown to brown, poorly sorted, angular to subrounded pebble gravel, sand, and silty sand. It underlies a low terrace on the valley floor of Trout Creek that is about 5 ft higher than stream level. A weakly developed soil (A/C horizon sequence) has formed in Qa2. Infrequent large floods may inundate areas underlain by this unit. Estimated thickness is 3-10 ft.

Qa3 **Valley-floor and terrace alluvium (upper Pleistocene)—**Unit consists chiefly of pale-brown to brown, poorly sorted sand and fine pebble gravel that blankets the floors of tributaries to Trout Creek and, in a few places (mostly where the channel of Long Gulch is incised), it underlies a terrace that is as much as 10 ft higher than stream level. In the southern part of the map area, just north of the drainage divide between the South Platte and Arkansas Rivers, streams have incised through the thin (2-4 ft) layer of Qa3 into bedrock. A soil profile consisting of an A/B/C horizon sequence is developed in unit Qa3. Infrequent large floods may inundate unit Qa3 in many places. Unit thickness is estimated to be 2-10 ft.

Qau **Alluvium, undivided (Holocene and Pleistocene)—**Chiefly pale-brown to brown, poorly sorted sand and pebble gravel. Alluvium is undivided where it consists of deposits of different kinds of alluvium (sheetwash and fluvial) or different ages of fluvial deposits (Qa1, Qa2, and Qa3) that are either too small or too poorly exposed to distinguish at the scale of this map. On the floors of deep, narrow valleys cut in Proterozoic rocks in the eastern and southwestern parts of the map area, the unit consists primarily of units Qa1, Qa2, and Qa3 undivided, but includes sheetwash alluvium and colluvium locally. In areas within the Manitou graben, Qau consists chiefly of interbedded sheetwash and stream-deposited alluvium. The unit includes sediment that is correlative with that in units Qsw, Qa1 Qa2, Qa3, Qfy, and Qfo. Estimated thickness is 1-20 ft.

Qsw **Sheetwash (Holocene and Pleistocene)—**Pale-brown, brown, or reddish to reddish-brown, thinly bedded, poorly sorted sand, matrix-supported sandy pebble gravel and angular to subrounded sandy fine-pebble gravel that was deposited primarily by unconfined flow. Unit exists principally in sheets and wedges along valley sides and footslopes. In some places, it grades upslope into unit Qac, and locally Qsw includes colluvium such as debris-flow deposits. A blanket of Qsw commonly conceals bedrock along the lower parts of escarpments capped by gravel units (Qg1, Qg2, and Qg3). Some deposits of Qsw are at least partly correlative with units Qg1, Qg2, and Qg3. Estimated thickness is 1-40 ft.

Qg1 **Gravel one (upper middle Pleistocene) —** Reddish-brown, crudely stratified, thin beds of poorly sorted sand and angular to subrounded pebble gravel in a sandy matrix. Gravel is composed primarily of fragments of Pikes Peak Granite, but it also includes clasts of Paleozoic sedimentary rocks in some places. Most of the unit was eroded from older fan gravel (Qg2 and Qg3) as gullies cut headward from trunk streams that flow approximately parallel to the axis of the Manitou graben. Relict soil profiles consisting of A/E/Bt/Btk/ Ck/C horizon sequences are present in some places. Bt denotes clay accumulation and Bk denotes accumulation of secondary $CaCO_3$; atmospheric dust is a major source of both materials. The zone of clay accumulation (Bt and Btk horizons) is nearly 3 ft thick. Secondary carbonate (Btk and Ck horizons) is present primarily as coatings on grains smaller than 2 mm, but it also coats a small percentage of pebbles. Because side valleys deposited most of the unit, its height above Trout Creek increases away from the axis of the Manitou graben. Near Trout Creek, the upper surface of Qg1 is 50-60 ft higher than stream level. Unit thickness is variable, but it is probably between 30 and 50 ft in most places.

Qg2 **Gravel two (middle Pleistocene)—**Qg2 has essentially the same characteristics as unit Qg1, except that the Bt horizon developed in it appears to contain more illuvial clay and the Btk and Ck horizons probably contain more $CaCO_3$. However, it is difficult to compare the soils developed in units Qg1 and Qg2 because relict soils are not preserved everywhere and unit Qg2 is exposed only in a few places. Most of the unit appears to have aggraded in valleys that were cut into unit Qg3. Unit Qg2 filled the valleys nearly to the level of the upper surface of unit Qg3. Unit Qg2 is part of a broad alluvial slope that extends into the Manitou graben from the edge of the fault-bounded west flank of the Rampart Range. Locally, the alluvial slope superficially resembles coalescing alluvial fans, but in most places, the alluvial slope lacks the concave longitudinal profile and convex cross profile of alluvial fans. Unit Qg2 was derived chiefly from erosion of Pikes Peak Granite in drainage basins on the west flank of the Rampart Range; some also was eroded from unit Qg3 (fig. 4). Along the distal edge (farthest from point of origin) of Qg2, the contact between bedrock (Fountain Formation) and Qg2 is barely higher than the upper surface of Qg1. The base of the distal edge of Qg2 is about 120-140 ft. higher than Trout Creek. Typical thickness is estimated to be about 40 ft.

Figure 4. Photograph of unit Qg2 in a road cut in the NE ¼ of sec. 35, T. 11 S., R. 69 W. Unit consists of reddish-brown, crudely stratified, thin beds of poorly sorted sand and pebble gravel in a sandy matrix. Pebbles are composed of Pikes Peak Granite and various Paleozoic sedimentary rocks. The visible part of the knife is 7.5 inches long and the larger pebbles are 1-2 inches in maximum dimension.

Qg3 **Gravel three (lower? Pleistocene)—**Deposits of Qg3 are comparable in setting and nature to those of unit Qg2. Near the mountain front on the east side of the Manitou graben, the upper surfaces of Qg2 and Qg3 are at nearly the same level. However, the surfaces diverge slightly westward from the flank of the Rampart Range. Where the upper surfaces of units Qg2 and Qg3 are nearly at the same level, they are distinguished by differences in drainage density and depths of channel incision, which are greater in Qg3 than in Qg2. Also, deposits of Qg3 appear to be more intensely oxidized than deposits of Qg2 and possibly contain soils that are more developed than those in Qg2, but exposures in which to observe these differences are few. Unit thickness is variable, but it is probably between 30 and 50 ft in most places.

QTg4 **Gravel four (lower Pleistocene and upper Tertiary?)—**Unit Qg4 is similar in color, composition, and grain size to deposits of Qg3, but is about 80 ft higher than Qg3. Unit is recognized in only one locality, which is near the east edge of the Manitou graben in the central part of the map area. The deposit caps a bedrock knoll and is undissected, beyond the dissection that isolated the bedrock knoll and mantle of QTg4. The weathering profile developed in QTg4 is not exposed. If exposed, the profile probably would not be representative of deposit age because at least part of it has been eroded. Unit is probably between 30 and 50 ft thick.

QTg5 **Gravel five (lower Pleistocene and upper Tertiary?)—**Reddish-brown, crudely stratified, extremely poorly sorted sand and pebble gravel, mostly angular to subangular, similar to that in units Qg1, Qg2, Qg3, and QTg4. Unit QTg5 underlies the highest part of a large alluvial fan that emanates primarily from Lovell Gulch at the north edge of Woodland Park. The southern side of the fan is deceptively low in the landscape for its inferred age. However, stream incision and vertical separation of alluvial units is much less in this area than it is east of the Rampart Range or along the east flank of the Front Range farther north. The close proximity of areas flanking the east and west sides of the Rampart Range suggests that differences in rates and magnitudes of stream incision between them is not due to differences in climate or tectonism, but rather is due to differences in stream power, which in this case is influenced mainly by differences in drainage basin size. Stream power is a function of slope and discharge, and stream power is proportional to drainage basin area. Large areas provide more runoff than small areas, if all other factors are comparable. Unit QTg5 is in the uppermost part of a drainage basin that is tributary to the South Platte River, and it is practically on the divide between the South Platte and Arkansas River drainage basins. Hence, stream power is understandably less here than in the principle streams draining the east flank of the Rampart Range, and less than in the lower part of the Trout Creek drainage basin. The upper surface of Qg3 is only 80-100 ft higher than adjacent valley floors on the south but is 200-240 ft higher than a valley on the north. For this area, the north-flowing valley (tributary to Long Gulch) is unusually broad (1000-2000 ft) and deep for the head of such a small drainage basin. The valley cuts into the well-indurated rocks of the Fountain Formation. A thin remnant of alluvium on a small, isolated ridge near the southern edge of the map area is included in QTg5 for convenience, even though it may be older than the rest of the unit. QTg5 is estimated to be at least 65 ft thick.

ALLUVIAL AND COLLUVIAL DEPOSITS—These units contain material of both alluvial and colluvial origin that are mapped as a single unit because the different kinds of deposits are (1) interbedded, (2) juxtaposed but are too small to show individually, or (3) interspersed and have contacts that are not clearly defined. Following the definitions of Hilgard (1892) and Merrill (1897), colluvium is a general term for all earth materials transported by mass wasting; that is, primarily under the force of gravity and not transported by a medium, such as wind, flowing water, or glacier ice. According to Hilgard, the principal attributes of colluvium are that it (1) was derived locally and transported only short distances, (2) may contain clasts of any size, (3) has no structures indicative of sedimentation or stratification by water flowing in channels, and (4) has an areal distribution that bears no relation to channelized flow of water.

Qdf **Debris-fan deposits (Holocene and Pleistocene)**—Fan-shaped bodies of pale-brown, brown, and reddish-brown, extremely poorly sorted sand, silt, and gravel deposited primarily during intense thunderstorms, times of heavy snowmelt runoff, and by debris flows (mixtures of sediment and lesser amounts of water and air that move as a mass; fluidity varies depending on the proportions of debris and water present). Units of Qdf along the margins of Trout Creek and Long Gulch are mostly alluvial-fan deposits that formed during the Holocene, some during historic time. In contrast, deposits of Qdf in the deep, narrow valleys cut in the Proterozoic rocks in the eastern and southwestern parts of the map area contain both alluvium and debris-flow deposits and in some places also include material derived by rock fall. This unit may be flooded frequently, and in some places, it may be subject to infrequent debris flows and rock fall. Most deposits of Qdf are probably 20-40 ft thick.

Qac **Alluvium and colluvium, undivided (Holocene and Pleistocene)—**Sheet or wedge-shaped masses of pebble- to boulder-size rock fragments, sand, silt, clay that are present mostly just below slopes that range between about 15º and 35º. The material was transported and deposited primarily by rock fall and slide, debris flows, sheet flow, and thunderstorm-generated floods. Most Qac in the map area is on the high fault-bounded scarp that bounds the upland just east of Woodland Park. Unit is estimated to be 3-30 ft thick.

MASS-WASTING DEPOSITS—Earth materials that were transported downslope primarily by gravity. Mass wasting differs from other modes of material transport in that the material moves as a mass rather than as individual fragments borne along by a transporting medium such as wind or flowing water. Although water is an important constituent of most mass movements and commonly triggers movement, water is part of the moving mass rather than the transporting agent.

Qls **Landslide deposits (Pleistocene)—**Nonsorted, heterogeneous mixtures of surficial materials and fragmented rock debris in a wide range of sizes. The deposit matrix (material less than 2 mm in size) and rock types and sizes of fragments present reflect the properties of the bedrock units involved in the slide. Unit may include areas of exposed bedrock in slide paths and scarps at the heads of slides, as well as the material deposited in the lower part of the slide area or zone of accumulation. A variety of human activities can trigger failures, even in old, seemingly stable, landslide deposits. Unit thickness is estimated to range from 3 to 50 ft.

BEDROCK UNITS

Tdg **Gravel at Divide (Miocene)—** Unit is present in the southeastern part of the map area but is not exposed except in shallow excavations, primarily road cuts. According to others who have examined exposures in areas south, southeast, and west of the Mountain Deception quadrangle (Scott and Wobus, 1973; Taylor, 1975; Wobus and Scott, 1977; Scott and others, 1978), Tdg consists of bouldery gravel and crudely stratified siltstone, mudstone, and claystone. In the map area, subangular to subrounded rock fragments ranging in size from pebbles to boulders are widespread on the surface. These fragments were derived from a variety of rock types, including granitic and metasedimentary rocks. The most distinctive clasts are of Oligocene volcanic rocks from sources farther west. Wobus and Scott (1977) believed that most volcanic boulders in unit Tdg in the Woodland Park quadrangle are from the Thirtynine Mile and Cripple Creek volcanic fields. However, it should be noted that Oligocene hornblende andesite is present in a volcanic neck called Signal Butte, about 12 miles northwest of the Tdg in the Mount Deception quadrangle (Bryant and others, 1981).

PPf **Fountain Formation (Lower Permian and Pennsylvanian)** — The Fountain Formation is primarily a light-red to pink, fine- to coarse-grained, poorly sorted, arkosic sandstone and pebble conglomerate. Clasts are subangular to rounded and consist of quartz and coarse-grained intrusive rocks ranging in size from less than an inch to several inches in size. Cross bedding and graded bedding are common. Locally, the formation contains beds of dark-red to red to reddish-brown, thinly bedded shales and mudstones. The formation is generally soft and friable due to intense weathering throughout the mapped area with the exception of the areas near White Gulch and Long Gulch in the south-central part of the quadrangle and areas in the north-central part of the quadrangle north of the Manitou Experimental Forest Headquarters. At these locations the formation is well indurated, resistant, and is exposed in topographic “hoodoo” features reaching several tens of feet in elevation from ground to top (fig. 5).

Figure 5. View to the north from near Red Rocks campground in the south-central part of the quadrangle (UTM83 493801, 4321475). Rocks in the foreground are Pennsylvanian-Permian Fountain Formation arkosic conglomerates forming "hoodoo" structures. Note slight westerly dipping beds which the Fountain Formation maintains throughout the low-lying central portion of Manitou Park.

Many of these resistant features can be seen east and west of State Highway 67 in the vicinity of Manitou Park Lake and southwest of White Spruce Gulch in the northwestern part of the quadrangle. The depositional environment for the arkosic sandstones and conglomerates of the Fountain Formation was one of fluvial channels, overbank deposits, and alluvial fans. The source is material from the uplift of the Ancestral Rocky Mountains, a series of roughly north-trending, basement-involved highlands that formed in the western part of North America during the Pennsylvanian-Permian periods (Hoy and Ridgway, 2002). The formation thickness was not measured in the mapped area due to Quaternary deposits which limit the formation's exposure. However, it is over 4,000 feet thick ten miles to the southeast in the Cascade quadrangle (Morgan and others, 2003). A gravity survey performed through the quadrangle by the U.S. Geological Survey computed a maximum depth to the base of the Fountain Formation in the Manitou Park graben at 2,000 feet (Miller, 1963). The Fountain Formation unconformably overlies the Leadville Limestone.

Mlw Leadville Limestone and Williams Canyon Member of the Leadville Limestone, undivided (Mississippian)--- The Mississippian rocks mapped in the Mount Deception quadrangle include the Leadville Limestone and the Williams Canyon Member of the Leadville Limestone. The Williams Canyon Member was observed at only one location in the quadrangle (NE ¼, NE ¼, sec.11, T. 11 S., R. 69 W.; UTM83 493604, 4329393). This location is near the boundary line separating section 2 from section 11, and is about 200 feet north of Forest Service Road 347. Here, the member consists of calcitic sandstones, lime mudstones, and dolomitic mudstones that unconformably overlie the Manitou Formation. The basal part of the member is composed of a thin (< 1 foot) quartz sandstone that is medium to coarse grained, well rounded, and moderately sorted. The sandstone grades upwards into approximately 30 feet of lime mudstones and dolomitic mudstones that are a light gray to greenish gray, mottled, and locally contain vugs filled with calcite crystals. Scattered lenses of rounded and frosted quartz grains are common throughout the mudstones. The Leadville Limestone conformably overlies and may even interfinger with the Williams Canyon Member as reported several miles to the north in the Dakan Mountain quadrangle by Hill (1983). The Leadville Limestone consists of a light-gray to tan, very fine-grained limestone that is typically massive and contains pitted surfaces and vugs from dissolution. The formation was measured in White Spruce Gulch in the northern part of the quadrangle (SE ¼ sec.2, T. 11 S., R. 69 W.) to be near 50 feet in thickness, with outcrops forming cliffs up to 40 feet above the valley floor. At this location, the formation is brecciated and contains abundant fractures, frequently filled with calcite. Our classification of the Leadville Limestone and Williams Canyon Member of the Leadville Limestone as an undifferentiated mapped unit in the Mount Deception quadrangle deviates from the same rock unit mapped in the Manitou Springs quadrangle (Keller and others, 2005) and the Cascade quadrangle (Morgan and others, 2003). In these earlier mapped quadrangles, the Leadville Limestone was mapped undifferentiated as MDlh-the Hardscabble Member of the Leadville Limestone (Mississippian) and the Williams Canyon Formation (Devonian). On the basis of detailed stratigraphic correlations and conodont identification by Hill (1983) throughout south-central Colorado, we have adopted the age and classification of the Williams Canyon Member as Mississippian and as a member of the Leadville Limestone. The depositional environment of the Williams Canyon Member was most likely an intertidal-supratidal zone as suggested by thin parallel beds, a lack of fossils, and abundant rounded and frosted quartz grains originating from windblown sands. The Leadville Limestone facies would represent a nearshore marine environment as suggested by micritic carbonates, dolomite mudstones, and fossil assemblages containing brachiopods, bryozoans, ostracodes, and conodonts (Hill, 1983).

Om Manitou Formation (Lower Ordovician) ---- The Manitou Formation consists of resistant, fine-grained limestone and dolomitic limestone. The formation is easily recognized by pink to pinkish-gray carbonates that weather to a fine, reddish-colored soil. The formation in the mapped area is composed of two slightly different and informal members. These members were measured and described near the Woodland Park Filtration Plant in the center of section 7, T. 12 S., R. 68 W. The lower member rests unconformably on the Sawatch Formation, described as the Mid-Rossodus unconformity, based on extensive biostratigraphic investigations by Myrow and others (2003). The lower member is a pink to light-red to maroon, fine-grained limestone and dolomitic limestone. Beds average 4 to 6 inches in thickness with occasional 1 to 2 foot beds. The thickness of this member is about 55 feet. The upper member is composed of thicker beds (1-3 feet) of more coarsely crystalline light-pink to light-gray limestone and dolomitic limestone, with thin, resistant, gray chert layers occurring near the top. This member was measured to be 65 feet thick. The combined thickness of the two members is 120 feet. This is in close agreement with the measured thickness in Missouri Gulch, eight miles to the northwest in the Dakan Mountain quadrangle, as reported by Myrow and others (2003). The Manitou Formation is locally fossiliferous, represented primarily by Lower Ordovician conondonts. However, incomplete and poorly preserved parts of trilobites were described by Berg and Ross (1959). The trilobites of the Manitou Formation have been the focus of recent collection activities in the Rainbow Falls State Park area, three miles north of the mapped quadrangle. The collecting was coordinated by the Denver Museum of Natural Science (Jeff Hovermale, oral commun., 2006). Descriptions of wave-rippled grainstones, thin-bedded and bioturbated micrites, and fossil assemblages of trilobites and gastropods described by Myrow (1998) are indicative of a shallow marine environment of deposition for the Manitou Formation.

Cs **Sawatch Formation (Upper Cambrian)----**The Sawatch Formation is composed of a medium- to coarse-grained, quartz-rich sandstone that overlies the Mesoproterozoic crystalline basement rocks in a nonconformable contact. This dramatic contact is referred to as the "Great Unconformity", and is spectacularly exposed in the east-central parts of the quadrangle at Soldier Mountain and north of Johns Gulch, and also north of White Spruce Gulch in the north-central part of the quadrangle (fig. 6). The Sawatch Formation in the mapped area was described and measured as four informal members at a location near Missouri Gulch (SW ¼ sec. 1, T. 11 S., R. 69 W.). At and above the contact with the crystalline rocks, the basal member is a light-gray to light-yellow, coarse- to medium-grained quartz pebble conglomerate averaging about 4 feet in thickness. Clasts are composed primarily of rounded to sub-rounded quartz grains up to ¼ inch in size with local cross-bedding prevalent in the finer matrix. The basal conglomerate grades upward into a resistant, gray to tan, medium-grained, locally cross-bedded, quartz sandstone. This member was measured to be 33 feet in thickness. Characteristics of this member are massive, resistant layers, intermittent zones of glauconite, and maroon-colored, weathered surfaces, suggestive of higher iron content. Glauconite concentration varied significantly throughout the quadrangle and was observed only in outcrops on the eastern, Rampart Range side. The third informal member consists of light-brown to tan, fine- to medium-grained, quartz-rich sandstone characterized by thin beds ranging from 3 to12 inches in thickness. Grains are rounded to sub-rounded and locally cross bedded. This member is 10 feet in thickness. The uppermost member is a distinctly darker, red to maroon, medium- to coarse-grained, quartz-rich sandstone that is less resistant and highly porous. Local cross bedding is also common. This member was measured to be 9 feet thick. Combined thickness for the four informal members of the Sawatch Formation at this location is 56 feet. It should be noted that complete and near complete sections of the Sawatch Formation were only observed on the eastern, Rampart Range side of the quadrangle. The limited exposures of the Sawatch Formation observed at the base of the West Creek Range on the west side of the quadrangle consist of brown to dark-brown, fine- to medium-grained, low-porosity, quartz-rich sandstones that are intensely fractured as a result of their location in the footwall block of the Ute Pass fault. Numerous sandstone dikes are observable in the crystalline rocks of the hanging wall of the Ute Pass fault throughout the western part of the quadrangle. We interpret these sandstone dikes as sourced from the lower plate Sawatch Formation. This will be discussed in more detail in the Structural Geology section of this report. The Sawatch Formation has been interpreted in the area near Manitou Springs by Myrow (1998) to be transgressive deposits that include subaqueous, tidally influenced dune deposits suggestive of shallow marine deposition.

Figure 6. Photograph of the "Great Unconformity" in the northern part of the Mount Deception quadrangle, near Missouri Gulch (UTM83 493923, 4329664). Note the flat surface of the Proterozoic crystalline rocks (near center of rock hammer handle) upon which the basal sands and pebble conglomerate member of the Sawatch Formation is deposited.

MESOPROTEROZOIC IGNEOUS ROCKS OF THE PIKES PEAK BATHOLITH

Late Mesoproterozoic granitic rocks of the Pikes Peak batholith are the oldest rocks exposed in the Mount Deception quadrangle. The Pikes Peak batholith is exposed over an area of 1,200 square miles in the southern Front Range (Tweto, 1987). Numerous studies have been conducted on the batholith, which was emplaced 1090 to 1020 Ma (Aldrich and others, 1957; Bickford and others, 1989; Unruh and others, 1995; Smith and others, 1999a). Cross (1894) first mapped the geology of the Pikes Peak region and in 1894 applied the formal name Pikes Peak Granite (Ypp) to the most common rock type in the batholith. Hutchinson (1972, 1976) studied the granite tectonics and modes of intrusion of the batholith and showed that the batholith is composite in nature. Barker and others (1975) produced a comprehensive petrologic and geochemical description of the rocks that comprise the batholith and noted that the batholith is composed of granites that have two distinct chemical trends, or series: the dominant potassic series and a sodic series. Wobus (1976) provided petrologic and major-element chemical data for smaller plutons of both the potassic and sodic series.

Smith and others (1999b) studied the petrology and geochemistry of late-stage intrusions of the batholith and showed that both fractionation of mantle-derived magmas and melting of preexisting crustal rocks (anatexis) were involved in the petrogenesis of the batholith. The potassic series granites, including the Pikes Peak Granite, are interpreted to be derived from crustal anatexis. Smith and others (1999a) provide a review of the chemistry and genesis of the Pikes Peak batholith and note that the batholith is an example of A-type granitic magmatism. Pegmatites and veins in the Pikes Peak batholith have locally produced an abundance of specimen-quality minerals. Foord and Martin (1979) and Muntyan and Muntyan (1985), among others, describe the mineralogy of the pegmatites in the Pikes Peak batholith.

Ypeg **Pegmatite (Mesoproterozoic)** — Very coarse grained pink and white veins and masses consisting chiefly of feldspar and quartz (fig. 7). Elongated, lath-like or bladed crystals of black to weathered bronze-green biotite are present in some areas within the large pegmatites. Equant masses of black hematite (pseudomorphic after magnetite?) to 0.5-inches in diameter also occur locally. Most pegmatites in the quadrangle are small, less than 5 feet thick and 50 feet in length, and thus were not mapped separately. Two large pegmatites, both of which have been mined in the past for feldspar and/or quartz, are mapped in the northeastern corner of the quadrangle. The largest of these is along the eastern quadrangle boundary adjacent to Forest Road 324. This pegmatite, up to 100 feet wide in places, was partially mined along an open cut approximately 400 feet long (see Mineral and Energy Resources section).

Figure 7. Very coarse-grained crystals of feldspar (light pink) and quartz (white to very light gray) in a pegmatite dike exposed in a small, abandoned surface mine in the northeastern part of the Mount Deception quadrangle (UTM83 498943, 4330497).

Ypb **Porphyritic granite of the Pikes Peak batholith (Mesoproterozoic) ---** Pink, fine- to medium-grained porphyritic biotite granite with phenocrysts of spherical gray quartz, and subhedral microcline and oligoclase. This unit is prevalent in the north-central portion of the quadrangle. The contact of this unit with the Pikes Peak Granite was not observed, however, field relations suggest the transition occurs over a few tens of feet. The unit is mapped as younger than the Pikes Peak Granite.

Ypp **Pikes Peak Granite (Mesoproterozoic)** — Pikes Peak Granite is the most abundant rock type in the Mount Deception quadrangle. This hornblende-bearing biotite granite is the main constituent of the potassic series of intrusives that constitute more than 90 percent of the Pikes Peak batholith (Wobus, 1976; Smith and others, 1999b). Pikes Peak Granite is pink to light gray, coarse grained, and usually equigranular. It weathers to form rounded, bouldery outcrops. Weathering of Pikes Peak Granite usually produces deposits of grüs (loose, disaggregated mass of constituent minerals). Grüs is best developed on north-facing slopes and can accumulate to thicknesses as much as 150 feet (Blair, 1976). Grüs develops first along joints in the granite. More resistant rock between joints may remain intact as rounded “corestones” (Blair, 1976). Gross and Heinrich (1965) described the petrology of the Pikes Peak Granite in detail. The constituent minerals of Pikes Peak Granite are perthitic microcline (35-50 percent), quartz (20-35 percent), plagioclase (oligoclase; 10-20 percent), biotite (2-7 percent), and hornblende (<0.5 – 2 percent). Accessory minerals include zircon, apatite, magnetite, and fluorite, plus rare allanite and bastnaesite. Major and trace element analyses of the Pikes Peak Granite were reported by Smith and others (1999b). Fine- to medium-grained aplite dikes, typically 0.5 to 2.0 feet in width, are widely scattered in the Pikes Peak Granite but were not mapped separately. Small pegmatite dikes and quartz veins are locally common and also were not mapped separately.

STRUCTURAL GEOLOGY

The type of deformation in the Mount Deception quadrangle is dominated by the brittle behavior of rocks in the form of regional and local faulting, fault imbricates, slickensides near the fault zones, intense fracturing, and emplacement of sandstone dikes, presumably by cataclastic flow. Two regional fault systems transect the length of the quadrangle: (1) the Ute Pass fault zone which strikes north-south through the west-central part of the quadrangle and (2) what we refer to as the Mount Deception fault system, which strikes north-south through the east-central part of the quadrangle. Both fault zones have field relations showing that they are reverse faults with the hanging wall blocks composed of Proterozoic crystalline rocks and the footwall blocks composed of Lower Paleozoic sedimentary rocks. These two reverse fault systems are largely responsible for the downthrown, north-south-trending, low-relief topography in the central part of the quadrangle in what is known as the Woodland Park graben, or Manitou Park graben. Although the term “graben” in geological literature generally implies extension accomplished through normal faulting, this central area can still be referred to as a graben in the sense that it is a downthrown block and a topographic low between two parallel fault systems; the east-directed reverse faulting along the Ute Pass fault zone and the west-directed reverse faulting along the Mount Deception fault zone. However, our interpretation implies that the Woodland Park/Manitou Park graben is contractional rather than extensional. The rocks in this central region are primarily represented by outcrops of Upper Paleozoic sedimentary rocks of the Fountain Formation and Tertiary to Quaternary alluvial fans and surficial deposits.

Ute Pass Fault Zone

The Ute Pass fault zone consists of at least two north- to northwest-striking faults that transect the entire western part of the Mount Deception quadrangle. Each of these faults is easterly-directed and places either granitic basement over Lower Paleozoic sedimentary rocks or Lower Paleozoic strata over Upper Paleozoic strata. Locally, several fault imbricates are also visible within the fault zone. The fault zone generally coincides with a break in slope between the steep, rugged topography of the Proterozoic crystalline rocks of the West Creek Range in the western part of the quadrangle and the more subdued topography in the central part of the quadrangle underlain by Paleozoic strata and Quaternary deposits. The Ute Pass fault zone continues to the south and southeast of the quadrangle through Green Mountain Falls and Chipita Park as mapped by Wobus and Scott (1977) and through the Manitou Springs quadrangle mapped by Keller and others (2005). These maps and reports indicate that the Ute Pass fault is a steeply dipping to vertical reverse fault. From Manitou Springs to the south, the Ute Pass fault zone corresponds with a broad zone of north-northwest-striking, high-angle reverse faults that forms the range-bounding structure for the southern Front Range (Kupfer and others, 1968; Carroll and Crawford, 2000; Rowley and others, 2003). North of the Mount Deception quadrangle, the fault has been mapped for another 18 miles before changing strike to the west, becoming the Willow Creek fault (Scott and others, 1978, Epis and others, 1980, Dickson and others, 1986).

The Ute Pass fault zone is interpreted as a Laramide (Late Cretaceous-Tertiary) fault system that was reactivated from an Ancestral Rockies (Pennsylvanian) structure (Kluth, 1997; Hoy and Ridgeway, 2002). Evidence exists from outcrops in the Manitou Springs quadrangle to support movements of fault segments associated with the Ute Pass fault zone during Ancestral Rockies time (Kluth, 1997; Keller and others, 2005). The character of its Laramide phase is best demonstrated south of the Mount Deception quadrangle in drill cores beneath Cheyenne Mountain showing granitic basement thrust over Cretaceous Pierre Shale along a fault with 45 degree west-southwest dip (Hembre and Terbest, 1997). The fault zone has been suggested to have continued movement into the Neogene and possibly Quaternary time on the basis of offset of the Eocene erosion surface and late Tertiary sedimentary deposits (Epis and Chapin, 1975). Taylor (1975) estimated that a minimum of 1000 feet of Neogene vertical displacement occurred across the fault zone west of Woodland Park. Kirkham and Rogers (1981) described features that suggest the possibility of Quaternary movement of the fault near the eastern base of Cheyenne Mountain.

The Ute Pass fault zone in the Mount Deception quadrangle primarily consists of two parallel faults interpreted to be within a few thousand feet apart. The most exposed segment is the western segment that places granitic basement in the upthrown block against intensely deformed sandstones of the Sawatch Formation in the downthrown block. The eastern segment is entirely concealed by Quaternary deposits but must exist because of the close proximity of Fountain Formation exposures to the Sawatch sandstones and the absence of the Manitou Formation and Leadville Limestone. Although this eastern segment is concealed, the gentle west dips of the Fountain Formation maintained throughout Manitou Park between the eastern and western granitic cores require fault displacement of at least 2,000 feet, as depicted on cross-sections A-A' and B-B'.

The contact between the upthrown Proterozoic rocks and the downthrown Sawatch sandstones of the western segment of the Ute Pass fault zone can be seen directly at two locations and partially at a third location in the Mount Deception quadrangle. The first location is in the SW ¼ of the NW 1/4, sec 27, T. 11 S., R. 69 W., (UTM83 490661, 4323848). At this location, the western fault juxtaposes the Pikes Peak Granite adjacent to the Sawatch Formation with a strike orientation of 180 degrees. The Sawatch Formation is overturned, dipping to the west at 52 degrees, and strikes parallel to the dip of the fault surface (fig. 8). The upthrown granitic rocks are intensely fractured, and numerous sandstone dikes, interpreted to be sourced from the Sawatch, are emplaced within the granite near the contact. The fault zone is about 10 feet in width and has been dug out as a prospect pit mine for potential secondary mineralization. The second exposure is about 1000 feet south-southeast of the first location, in the NW ¼ of

Figure 8. Field assistant and co-author Dawn Martin stands on the Ute Pass fault contact (UTM83 490661, 4323848). The upthrown Pikes Peak Granite (behind geologist) is intensely fractured and mineralized. The downthrown Sawatch Formation (lower and right part of the photograph) is also highly fractured and bedding is overturned to the west. View is to the north.

the SW ¼ , sec 27, T. 11 S., R. 69 W. (UTM83 490803, 4323662). Here, the Cambrian Sawatch Formation is highly fractured and overturned, dipping 56 degrees to the west with a strike direction of 160 degrees. This zone is highly deformed with probable fault imbricates and sandstone dikes. The third area is on the Phillips Ranch in the NW ¼ of sec. 2, T. 12 S., R. 69 W. (UTM83 492694, 4320799), where the fault is not actually exposed but can be isolated to within 15 feet of where the upthrown Proterozoics crop out to the west and the downthrown Sawatch Formation is exposed to the east. Here, Sawatch sandstone beds strike 200 degrees and are overturned to the west, dipping 46 degrees.

The three areas mentioned above reveal the intense, brittle style of deformation associated with the upthrown crystalline rocks of the western Ute Pass fault, the extreme folding in the downthrown sedimentary rocks near the fault, and the reverse orientation of the fault (46 to 56 degrees). These exposures are not only important for the understanding of the geometry of the fault but also because they suggest that the overturned beds of the downthrown Sawatch Formation sandstones are a direct result of forces from the movement of the Proterozoic crystalline rocks. At numerous locations along the mapped Ute Pass fault zone where the fault is not exposed, outcrops of the lower plate Sawatch Formation show bed orientations that are overturned or at high angles. This would imply that the fault is in close proximity to these beds. As the distance from the fault increases, the Sawatch Formation orientations decrease significantly and dip normally to the east. For example, at the outcrops on the previously mentioned Phillips Ranch, the Sawatch Formation sandstone goes from a westerly, overturned dip of 46 degrees to an easterly dip of 34 degrees in less than 500 feet. This suggests a narrow, but intense, zone of deformation associated with the western Ute Pass fault segment.

This style of deformation where downthrown sedimentary rocks are folded near low- to medium-angle reverse faults throughout the Rocky Mountain Foreland has been referred to as “fold-thrusts” by Berg (1962), “drape folds” by Prucha and others (1965), Stearns (1971,1975), “forced folds” by Stearns (1978), Matthews and Work (1978), and recently as “fault-propagation folds” by Nesse (2006). These authors also importantly note that this structural style is characteristic of Laramide-age deformation. In this report, we will refer to this type of deformation in the sedimentary cover near crystalline basement faults as forced folding.

Fault imbrications and associated forced folding are also present along the trace of the western Ute Pass fault with the best exposures occurring in the central part of section 21 of T. 11 S., R. 69 W., south of Quinlan Gulch. Repeated sections of Sawatch Formation sandstones and Proterozoic crystalline rocks suggest the presence of at least two imbricates associated with this fault segment. Field observations in the southwestern quarter of the quadrangle also suggest this western segment bifurcates northwest of the previously mentioned Phillips Ranch (NW ¼ of sec. 2, T. 12 S., R. 69 W.). The western imbrication lies in the Trout Creek bottom as suggested by a significant increase in high-angle fractures in both the upper and lower plate granitic rocks in the immediate vicinity of the creek. The eastern imbrication is identified by following the steeply dipping and overturned beds of the Sawatch Formation near the upper plate Proterozoic rocks.

The amount of vertical uplift on the western Ute Pass fault segment is difficult to determine because erosion has removed the Paleozoic sediments from the top of the West Creek Range along the western part of the quadrangle. However, because the sediments must have been above the current highest elevation Proterozoic core of the range, a minimum estimate of vertical displacement can be made. The highest elevation of the West Creek Range in the quadrangle occurs in the NW ¼ of section 16, T. 12 S., R. 69 W. in the extreme southwest corner of the quadrangle (9084 feet at UTM83 489633, 4318157). Directly to the east near Trout Creek, the Ute Pass fault overrides the Sawatch Formation at an elevation of about 8400 feet. This would suggest a minimum amount of vertical displacement on the fault of near 700 feet. Combined, the two fault segments of the Ute Pass fault zone account for at least 2,700 feet of vertical displacement.

It is important to note that the eastern fault segment, with significant vertical displacement, appears to have no visible deformation associated with the Fountain Formation sediments in the footwall block. This is a significant change in structural style when compared with the western fault segment that shows significant deformation of the Sawatch sandstones in its footwall block. It can be argued that there is enough Quaternary sedimentation on the Mount Deception quadrangle to conceal this potentially narrow range of deformation, however, reconnaissance mapping by the authors to the northwest in the West Creek quadrangle reveals outcrops of gentle westerly dips in the Fountain Formation in the footwall block within a hundred feet of the granites in the hanging wall of the eastern Ute Pass fault segment. One explanation would be that the eastern and western segments of the Ute Pass fault zone have two distinctly different periods of movement where changes in environmental parameters such as temperature, pressure, and strain rate could allow for different deformational styles.

Westerly-Directed Faults and the Ute Pass Fault Zone

Indirect evidence of westerly-directed faults occurs in the western city limits of Woodland Park in section 14 of T. 12 S., R. 69 W. In the center of this section, a large circular knoll consisting of Proterozoic crystalline rocks at elevations exceeding 8700 feet forms a prominent topographic landmark. Immediately to the west of this knoll, near the Trout Creek bottom, the Sawatch Formation is exposed in vertically dipping beds at elevations near 8400 feet. East of this knoll of Proterozoic granites, the highly decomposed beds of the Fountain Formation are exposed at elevations near 8400 feet in the downthrown block of the eastern segment of the Ute Pass fault. Our explanation for these relationships is that the Proterozoic crystalline knoll is the upthrown block of a westerly-directed fault splaying from the eastern segment of the Ute Pass fault. Further to the north in the western ½ of section 2, T. 12 S., R. 69 W. on the Phillips Ranch, a smaller ridge of Proterozoic crystalline rocks similarly separates the Sawatch Formation to the west from the downthrown Fountain Formation to the east. We interpret this granite ridge as being the upthrown block of the same westerly-directed fault mapped to the south, although the fault is concealed by Quaternary deposits. This is best understood by viewing the cross section B-B’. This style of deformation has been interpreted as backthrusts along the eastern margins of the Colorado Front Range by numerous authors (Erslev, 1986; Grose, 1990; Erslev and Selvig, 1997; Weimer and Ray, 1997; Sterne, 2006).

Mount Deception Fault System

The Mount Deception fault system is the name we have given to the faults bounding the western flank of the Rampart Range in the east-central part of the quadrangle. The faults consist of en-echelon west-directed fault strands that transfer displacement along their trend. The more easterly strands largely juxtapose granitic basement next to Lower Paleozoic strata although, in places, the faults ramp up section to juxtapose Lower Paleozoic strata adjacent to Upper Paleozoic strata. These faults strike north to northwest throughout most of the quadrangle and appear to terminate in the extreme northern end of the quadrangle. The faults may also turn to the east or northeast into the crystalline rocks where field evidence becomes more difficult to identify their location. The Mount Deception fault system, like the Ute Pass fault zone to the west, also coincides with a break in slope between the steep, rugged mountain topography of the Proterozoic crystalline rocks of the Rampart Range and the gentler, lower relief topography of the Paleozoic sediments in the central part of the quadrangle. This fault system apparently begins near the town of Crystola in the Woodland Park quadrangle where it is mapped as a splay off the Ute Pass fault (Wobus and Scott, 1977). Their map shows a single fault continuing to the north where it joins with the Mount Deception quadrangle. These authors also map steeply dipping and overturned Lower Paleozoic strata on the downthrown side of this fault zone. At the southern limits of the Mount Deception quadrangle, the Mount Deception fault system is obscured by surficial deposits eroded from the Rampart Range. However, Fountain Formation deposits are exposed in the Forest Edge Park subdivision in the southern part of section 18, T. 12 S., R. 68 W., about 1000 feet west of exposures of Proterozoic crystalline rocks of the range core. Since Fountain Formation strata once covered the crest of Rampart Range, an estimate of minimum vertical displacement can be made. Bald Mountain (UTM83 497163, 4317212) lies in the SE ¼ of sec. 18, T. 12 S., R. 68 W. at an elevation of 9440 feet, immediately east of the Fountain Formation deposits exposed at 8700 feet in the subdivision. This gives a minimum vertical displacement of near 1100 feet on the Mount Deception fault system at this southernmost location. As the fault trace is followed to the north, steeply dipping Sawatch Formation deposits outcrop east of the Woodland Park Filtration Plant in section 7 of T. 12 S., R. 68 W. This suggests that fault displacement may be decreasing to the north and/or that additional fault segments exist where displacement is being transferred. Indeed, an additional fault segment is apparent in the SW ¼ of section 6, T. 12 S., R. 68 W. Here and to the northwest, the Fountain Formation is juxtaposed against the Leadville Limestone at elevations lower than can be explained by stratigraphic succession based on nearby dips of 20 to 30 degrees measured in both formations. This western fault segment is mapped to the north where it is partially responsible for the eastern boundary of Long Gulch and is eventually buried by Quaternary gravel deposits in the SW ¼ of section 25, T. 11 S., R. 69 W. These gravels are thought to conceal the fault system throughout the central portion of the quadrangle until it is once again apparent north of Forest Service Road 346 in the NW ¼ of section 14, T. 11 S., R. 69 W. The easternmost fault segment continues to the north on the basis of outcrops of steeply dipping beds of the Sawatch and Manitou Formations. The occurrence of Sawatch Formation float with abundant slickenline striae in close proximity to the Proterozoic crystalline rocks throughout this traverse is also suggestive of fault contact. These relationships continue northwards to the vicinity of Soldier Mountain (SW ¼ sec. 30, T. 11 S., R. 68 W.). At and immediately west of Soldier Mountain, the Sawatch Formation dips gently to the southwest at less than 25 degrees and is in nonconformable contact with the Proterozoic crystalline rocks. This is in marked contrast to the westerly dips of greater than 45 degrees observed in the downthrown block of the Mount Deception fault system to the south. We interpret these relationships to suggest that the eastern segment of the Mount Deception fault system mapped from the southern limits of the quadrangle is terminating in the area south and east of Soldier Mountain. We also interpret that the western segment or an additional splay of the Mount Deception fault system picks up this displacement in en-echelon type geometry and continues to the north. This interpretation is supported by steeply dipping beds of the Leadville Limestone southwest of Soldier Mountain and a spectacular outcrop of the same formation west of Soldier Mountain that is overturned and dipping to the east at 78 degrees. The authors realize the danger in making an interpretation based on one outcrop; however, this overturned exposure suggests the Mount Deception fault system is a set of high-angle reverse faults dipping to the east. The western fault segment and newly formed central fault segment continue to the north as suggested by steeply dipping beds of the Sawatch and Manitou Formations in the downthrown block. This structural interpretation places the nonconformable contact on and around Soldier Mountain in the upthrown block of the Mount Deception fault system.

Immediately north of John's Gulch (NW ¼ sec. 24 and SE ¼ sec. 14, T. 11 S., R. 69 W.), the Sawatch Formation is once again exposed with dips of less than 25 degrees and in nonconformable contact with the granite. These are some of the best exposures of the "Great Unconformity" in the quadrangle. The Mount Deception faults are to the south and southwest of the nonconformity on the basis of an outcrop of the central fault along Forest Service Road 345 (UTM83 493210, 4326116). At this location, the fault juxtaposes gently dipping Manitou Formation strata against steeply dipping and highly deformed beds of the Leadville Limestone, which suggests a vertical offset on the fault of around 100 feet. An alternative explanation to this fault interpretation is that the Leadville Limestone deformation could be the result of karst collapse, which is definitely observed within this formation in the quadrangle (Vince Matthews, oral commun., 2006). However, within 200 feet west of the Leadville Limestone exposures, outcrops of the Fountain Formation are dipping 70 degrees to the southwest, suggestive of folding associated with the fault. These relationships also place the "Great Unconformity" in sections 24 and 14 upthrown to the Mount Deception fault system. This interpretation, where the unconformity is exposed and gently dipping in the upthrown, hanging wall of the system, is consistent with the same interpretation near Soldier Mountain to the south.

The central fault segment continues northward as suggested by dramatic hogbacks of vertically dipping beds of the Sawatch Formation beginning in the center of section 14, T. 11 S, R. 69 W. One of the most beautiful of these hogback exposures occurs along Forest Service Road 346, less than a mile southeast of the Manitou Experimental Forest Headquarters. This Sawatch Formation hogback ridge continues with a strike direction of due north to 15 degrees east of north for more than one and one-half miles to White Spruce Gulch, where it is observed to terminate in the Proterozoic rocks on the Warren Ranch (SW ¼, SW ¼, section 1 and SE ¼, SE ¼ section 2, T. 11 S., R. 69 W.). Near this location on the Warren Ranch the dips of the Sawatch Formation near the last trace of the central fault are 85 degrees to the west. As the fault throw terminates, the dips of the Sawatch Formation decrease to 24 degrees and then 15 degrees and the sandstone is then exposed in nonconformable contact with the underlying Proterozoic basement rocks. The western fault segment again becomes apparent west of the hogbacks in section 14, T. 11 S, R. 69 W. where for one and one-half miles to the north, the fault juxtaposes the Manitou Formation to the east adjacent to the Fountain Formation to the west, and the Leadville Limestone is missing. This places a minimum amount of throw on the fault of about 50 feet. As the fault approaches White Spruce Gulch in the north-central part of the quadrangle, it veers to the northwest and terminates in the Fountain Formation where dips of less than 25 degrees are observed. These relationships strongly suggest that the steeply dipping beds of the overlying sedimentary veneer result from movements of high- to medium-angle faults originating in the basement. Also of importance near the Warren Ranch is the slight offset of the Sawatch and Manitou Formations north and south of White Spruce Gulch. This suggests the presence of a concealed fault that strikes through the gulch in a direction of N 55 W. This fault apparently terminates in the Fountain Formation to the northwest and is difficult to trace to the southeast into the granites past the hairpin turn on Forest Service Road 347. These structural relationships in the vicinity of the Warren Ranch may be suggestive of an underlying basement geometry where the corners of two blocks meet and have moved independently.

The age of the Mount Deception fault system is interpreted to be Laramide since Paleozoic rocks from the Cambrian Sawatch Formation through the Pennsylvanian-Permian Fountain Formation are deformationally involved with the fault movement. Cross section's A-A' and B-B'depict this fault as a high-angle reverse fault dipping to the east, as previously discussed.

High-Angle Faults in Proterozoic Rocks

High-angle, north-south striking faults transect the Proterozoic crystalline rocks in the northeast parts of the quadrangle as identified from the topographic map, DEM, aerial photographs, and observations of outcrops that have an increase in fracture density. These high-angle faults are represented by three closely spaced faults east of Mount Deception and one southeast of Mount Deception that closely parallels Rampart Range Road. Each of the identified faults is interpreted to be up-to-the-east and high-angle, which results in the progressive increase in surface elevations towards the east. These faults are interpreted to be Laramide in age; however, the absence of Phanerozoic sedimentary rocks makes the determination of the relative timing of fault initiation or any later rejuvenation difficult if not impossible.

The three closely spaced faults in the northern part of the quadrangle are located east of and parallel to the Mount Deception fault where it is decreasing its vertical offset and eventually terminating near White Spruce Gulch. It may be that the vertical offset associated with the Mount Deception fault is being transferred northeastwards to the interior part of the Rampart Range where the Proterozoic crystalline rocks are exposed. This interpretation would suggest that the three high-angle faults in the Proterozoic rocks would most likely be reverse rather than normal faults.

Fracture and joint data measured from the Proterozoic rocks are depicted on the map (plate 1) and cumulatively plotted on a stereonet diagram (fig. 9). Data were taken from the Proterozoic crystalline rocks on both the Rampart Range side and West Creek Range side of the quadrangle. These data do not show a preferred strike direction; however, moderate-to-steep inclinations are dominant throughout the quadrangle.

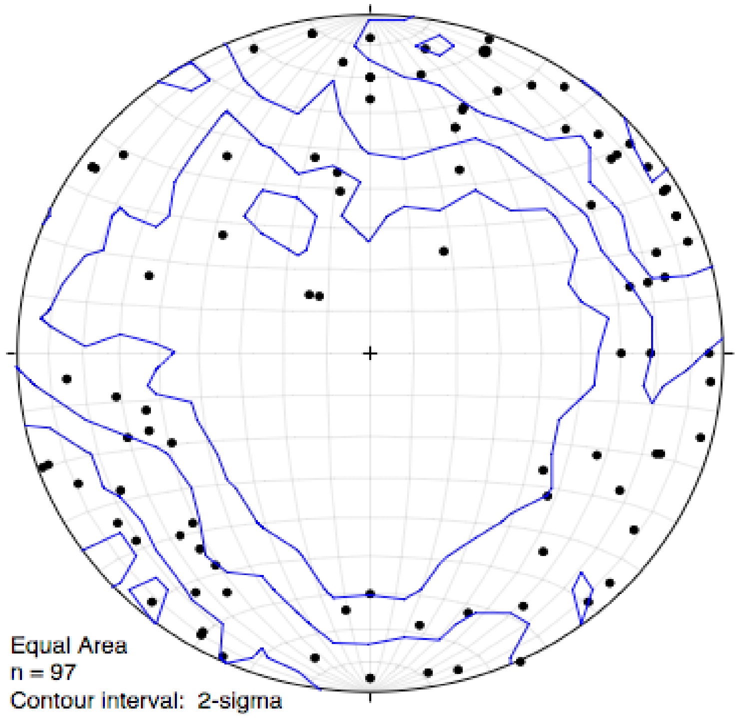


Figure 9. Stereonet diagram of poles to fracture and joint planes for 97 points in the Proterozoic crystalline rocks in the Mount Deception quadrangle. Lower hemisphere projection.

Sandstone Dikes and the Ute Pass Fault

Numerous sandstone dikes are present in the hanging wall of the western Ute Pass fault segment along its trace in the southwestern part of the Mount Deception quadrangle. The dikes range in thickness from several inches to over five feet and, in one location, could be traced for several hundred feet laterally. The dike outcrops are recognized by a deep maroon to dark-brown, fine-to medium-grained, poorly sorted, quartz-rich sandstone that sharply contrasts with the surrounding pink granites of the Pikes Peak batholith (fig. 10). Detailed descriptions and possible origins of similar sandstone dikes throughout the southern Front Range have been provided by Crosby (1895: 1897), Finlay (1916), Roy (1946), Vitanage (1954), Harms (1965), and Kost (1984).

Figure 10. Sandstone dike (about 3 feet wide) in the Majestic Park subdivision (UTM83 492581, 4317385). Note the abrupt and planar contact with the granite on both sides of the dike. Rock hammer (for scale) is below and to the left of plant in center of photo.

Four sandstone dikes were studied in the Majestic Park subdivision in the western ¼ of sections 11 and 14 of T. 12 S., R. 69 W. An additional dike was studied along the western side of Rule Creek in the center of section 34 of the same township and range. Observations of these five sandstone dikes in the hanging wall of the western Ute Pass fault are as follows: (1) the dikes are all within 2,000 feet horizontal distance from the fault contact, (2) the dikes are steeply dipping, wedge-shaped bodies, composed of sand-sized quartz grains and enclosed within the Proterozoic crystalline rock, (3) the strike of the dikes is from 345 degrees to 015 degrees, (4) the dike walls are smooth and planar, and (5) the average composition, grain size, grain shape, and color of the sandstone dikes indicate that the material is sourced from the Cambrian Sawatch Formation.

Our interpretation of the origin of these features is that extensional fractures were first opened within the Proterozoic granitic rocks of the hanging wall as a result of frictional movement between the upthrown and downthrown blocks of the western Ute Pass fault. A buildup of excess pressure in the lower plate Sawatch Formation sandstones resulted in movement of the sands by partial fluidization, cataclastic flow, or a combination of both, into the overriding fractures. A similar type of explanation for the mechanics of clastic dike intrusion has been proposed by Jolly and Lonergan (2002). Critical to our interpretation is the timing of fault movement. Laramide movement in the Late Cretaceous to Early Tertiary would have found the Sawatch Formation completely indurated as a quartzite and an unlikely candidate for fluidization. The possibility should be considered that these dikes originated by movement of the western Ute Pass fault during Pennsylvanian to Permian aged Ancestral Rockies deformation, or an earlier event that predated lithifaction of the Cambrian Sawatch Formation. The absence of these dikes in the granite knolls in the hanging wall of the eastern Ute Pass fault segment in sections 2 and 14 of T. 12 S., R. 69 W. may lend support to the previously mentioned explanation of two separate times of movement for the western and eastern segments of the system.

MINERAL AND ENERGY RESOURCES

Pegmatites

Quartz and feldspar were mined in the past from open cuts on two pegmatite bodies (unit Ypeg) near the Ice Cave Creek forest road in the northeastern part of the Mount Deception quadrangle. Both of the mined pegmatites are enclosed within Pikes Peak Granite (unit Ypp). Bladed biotite crystals up to 6 inches long are common in some parts of the pegmatite, and specular hematite is present locally. The largest of the pegmatite mines was operated by Colorado Quarries, Inc. and was permitted by the Colorado Division of Reclamation, Mining, and Safety in the late 1970s under the name Limber Pine Mine. It is located near the head of the Ice Cave Creek drainage in the northeastern corner of the map area. There has been no mining at the site since the permit was terminated in 1996. Some mining also took place prior to the 1970s as indicated by tree growth on older, smaller pits to the west of the main mine workings. Clean, white, crystalline quartz and pink microcline feldspar were mined from parts of the Limber Pine pegmatite in several small open pits. The largest of these pits is about two hundred feet long and 50 feet wide (fig. 11). The pegmatite itself is roughly crescent shaped and is up to 100 feet wide in the eastern part of its exposure and is continuous for 1300 feet along its exposed length. The pegmatite terminates in the adjacent Palmer Lake quadrangle to the east (Keller and others, 2006).

Another pegmatite was partially mined in the past (possibly during the 1970s) from a small open-cut 3200 feet west-northwest of the Limber Pine Mine. This pegmatite is similar in composition to the Limber Pine pegmatite described above. The pegmatite is approximately 250 feet long and 150 feet wide and is elongated in an east-northeast direction.

Figure 11. The largest of the open-cuts at the abandoned Limber Pine pegmatite mine, northeast part of the Mount Deception quadrangle (UTM83 499933, 4330072).

Gravel (aggregate)

The Trout Creek gravel pit is the only recently active and permitted mining operation in the quadrangle (Colorado Division of Reclamation, Mining, and Safety; mining permit database). The small operation is located west of Woodland Park in the SW¼ of sec. 14, T. 12 S., R. 69 W. Production at the site recently terminated. Gravel was produced from the grüs of the Pikes Peak Granite (Ypp). Another small gravel pit was operated in the 1980s by the City of Woodland Park near Loy Gulch in sec. 7, T. 12 S., R. 68 W.

Grüs (decomposed granite)

Grüs is formed from the weathering of coarse-grained granite into fragments consisting mainly of individual component mineral grains, principally feldspar and quartz. Grüs is common in areas of Pikes Peak Granite and is thickest on north-facing slopes (Blair, 1976). Elsewhere in the Pikes Peak region, grüs is mined for use as fill material or aggregate. It is a potential resource in the Mount Deception quadrangle but is not presently being mined.

Metals

Several small, abandoned underground and open-cut mines and prospect pits are present in the western part of the Mount Deception quadrangle. These mines are not denoted on the USGS topographic sheet for the Mount Deception quadrangle. The mines are mostly situated along the Ute Pass fault where it separates Pikes Peak Granite (unit Ypp) and deformed Sawatch Quartzite (unit €s), although a few are entirely in the hanging wall of the fault, within the granite. No production records or descriptions of these mines were found in the published literature. Local residents report that these were gold mines and were small operations run by individuals or small, private groups.

On the basis of forest overgrowth on the mines and their waste rock piles, the mines have not been significantly worked for at least 40 years. Our sampling of altered rock from waste rock piles and exposed mine faces (samples JT-06-09 and JT-06-10, table 2) indicates no economic concentrations of gold or silver. Mineralization is associated with narrow, irregular veins and veinlets containing quartz, iron-oxides, and other oxides in highly fractured and altered rocks within and near the fault contact. The age of the mineralization is not known, but it is most likely coeval with or younger than the Laramide age of the faulting.

Geochemical analyses for metals and trace elements for Proterozoic granites sampled in the Mount Deception quadrangle are listed in Table 2.

Sample ID	Au	Ag	Be	Cr	Cu	Mn	Ni	U	Zn
JT-06-01	<0.2	<0.2	0.6	3	2	148	1	<10	27
JT-06-02	<0.2	<0.2	<0.5	3	7	175	<1	<10	40
JT-06-03	<0.2	<0.2	0.8	5	2	273	1	<10	58
JT-06-04	<0.2	<0.2	<0.5	4	3	168	<1	<10	40
JT-06-05	<0.2	<0.2	0.7	6	2	1000	4	<10	20
JT-06-06	<0.2	<0.2	0.5	4	3	345	<1	<10	59
JT-06-07	<0.2	<0.2	1.7	7	1	230	1	<10	24
JT-06-08	<0.2	<0.2	0.6	3	2	19	<1	<10	6
JT-06-09	<0.2	<0.2	0.6	2	2	25	<1	<10	3
JT-06-10	<0.2	<0.2	<0.5	2	1	22	<1	<10	4

Table 2. Metals and trace element analyses of samples from Proterozoic crystalline rocks throughout the Mount Deception quadrangle. (Sample locations are shown by numbers 1 through 10 in parentheses on Plate 1. All analyses were performed by ALS-Chemex. Numbers represent parts per million.)

Several gold occurrences are reported in the U.S. Geological Survey's Mineral Resource Data System (MRDS) in the Signal Butte quadrangle to the west (Wilson, 2003). These appear to be small mines or prospects and the database refers to them as part of the West Creek district. Some are reported to be placer deposits.

Oil and Gas

No hydrocarbons have been produced in the Mount Deception quadrangle. No potential hydrocarbon source or reservoir rocks are known to exist in the quadrangle. The nearest productive oil and gas fields to the Mount Deception quadrangle are the Hoy Gulch, Wallbanger, and Caledonia fields about 36 miles to the northeast in Elbert County (Wray and others, 2002). Production from these fields is from the Lower Cretaceous Dakota Sandstone. Two new wildcat exploration wells are proposed in the adjacent Palmer Lake quadrangle to the east (Keller and others, 2006), but drilling has not begun as of this writing. Dyad Petroleum Company of Midland, Texas plans to drill these wildcat wells near Mt. Herman in the Rampart Range. One of the wells is proposed to be spudded in Pikes Peak Granite.

Soil-gas samples collected in the Rampart Range indicate that hydrocarbons, derived from Mesozoic and Paleozoic strata that are projected to underlie Pikes Peak Granite below the Rampart Range Fault, may be migrating upward through Pikes Peak Granite along fractures and faults (Jacob and Fisher, 1985). Samples collected over north-south-trending fractures and faults inferred from aerial photographs contained anomalous concentrations of methane, ethane, propane, and butane. Additionally, oil seeps were reported in the past at Saylor Park in the northeast part of the Mount Deception quadrangle and at Leo Lake just east of the quadrangle boundary, in the Palmer Lake quadrangle (Jacob and Fisher, 1985).

Coal

No known coal resources are present in the Mount Deception quadrangle, and none of the rock units present are coal bearing anywhere else in Colorado. All known coal resources in the state occur in strata that are much younger than bedrock present in the Mount Deception quadrangle. The nearest historic coal-producing region is the Colorado Springs coal field, 15 miles to the southeast in the Pikeview quadrangle. Coal from this field was produced in the early part of the twentieth century from beds in the Upper Cretaceous Laramie Formation (Carroll and Bauer, 2002).

GEOLOGIC HAZARDS

Floods

Floods are the most serious hazard in the map area because they occur more frequently than other hazards, and they affect larger areas and impact areas of higher risk. Risk as used here refers to the potential for loss of life and property should a hazardous event occur rather than to the likelihood that a hazardous event will occur. In the Mount Deception quadrangle, floods may be triggered by heavy snowmelt runoff, but, as along the east side of the Rampart Range, prolonged or intense rainstorms are likely to produce the most serious flooding. Areas underlain by map units Qa1 and Qa2 will flood frequently, and large, but infrequent (once per 50 to 100 years) floods will inundate many, if not most, areas underlain by Qa3. The network of small, chiefly ephemeral streams in narrow valleys and gullies in the high-relief terrain in the eastern and southwestern parts of the map area contain deposits of Qa that are too small to show at the scale of this map. These valleys can be expected to flood frequently, and the floods will impact roads or other structures that cross them. Given the abundance of granitic detritus in the residuum and surficial deposits in the map area, small floods may erode and deposit surprisingly large quantities of sediment, especially where construction has disturbed the ground surface or impounded or redirected runoff.

Rock Fall

Rock fall is used here as a generic term for a range of mass movement that begins when a rock falls or topples, and then continues to move downslope by bouncing and rolling. Rock fall areas in the Mount Deception quadrangle are widespread but small. Most areas are in high-relief terrain in the eastern part of the quadrangle (valleys of the Rampart Range) and in the southwestern part of the map area. Rock fall generally occurs where rock crops out along drainage divides or on the upper parts of slopes that are steeper than 24°. Talus deposits that are too small or thin to show at the scale of this map are present downslope from outcrops that are sources of rock fall. Rock-fall hazards can be identified on aerial photography and by inspection on the ground. Where rocks fall frequently, they pile up or litter the ground surface. Many boulders in deposits of Qac on steep slopes in the southern part of the map area may have originated as rock fall. However, some of these rock-fall deposits may be relicts of Pleistocene glacial and periglacial climates. During glaciations, alpine tundra may have expanded downward in this area to levels that were several hundred feet lower than the highest parts of the Rampart Range.

Debris flows

Debris flows are dense mixtures of sand, silt, clay, rock debris, and lesser amounts of water and air that move as a fluid mass. Debris flows commonly resemble wet concrete that varies in degree of fluidity depending on the proportions of debris and water present. The amount of debris (material larger than 2 mm) in debris flows may range from as little as 20 percent to as much as 80 percent (Cruden and Varnes, 1996). Flows in which less than 20 percent of the material is debris are called mudflows in some mass-movement classifications

(Selby, 1993). Debris in flow deposits in the Mount Deception quadrangle tends to be in the lower half of the 20-80 percent range. Debris flows originate in the upper reaches of many gullies and small valleys that drain into the Manitou graben from highlands on either side. Soils in the highland areas, which consist chiefly of the Legault, Pendant, and Sphinx soil series (Moore, 1992), are thin (less than 2 ft), coarse, and highly permeable. Thus, they quickly become saturated during intense thunderstorms, and then surface runoff is high and the resulting erosion of soil and surficial material is severe. Debris-flow deposits make up parts of unit Qfy and Qfo, particularly in the high-relief terrain in the southwestern part of the map area that is dissected by Trout Creek and its major tributaries and also in the small alluvial fans in the Rampart Range. Construction projects on and adjacent to units Qfy and Qfo should be cognizant of the potential for flooding and debris flows in these areas.

Landslides

Landslide classifications include most forms of mass movement. Consequently, landslide has become a generic term landslide for all but the slowest forms of movement regardless of whether it was by fall, flow, or slide. Landslide deposits large enough to show at the scale of this map are present in only a few places, and those that were identified are probably relicts of the Pleistocene. In other words, they formed under different conditions of climate and vegetation than exist today and probably are stable under present conditions. However, stable slopes, whether underlain by surficial deposits or bedrock, can be destabilized by human activities that replicate the wetter conditions that prevailed at times during the Pleistocene. The natural events that trigger landslides are well known. Worldwide, they include intense rainfall, rapid snowmelt, water-level changes, and strong ground shaking during earthquakes (Wieczorek, 1996). Unfortunately, humans also trigger landslides because simple fundamentals that have been well understood for decades (Brunsden, 1993) are neglected. Humans generally trigger landslides either by adding weight to the natural slope, which increases the shear stress in the area where the weight was added, or they remove support by excavating material, which reduces shear strength (the force that resists downslope movement of material). Excavations on slopes, particularly at or near the toe of a slope, are especially troublesome. The weight of earth material commonly is overlooked when material is being rearranged by excavation and filling during construction. A layer of earth fill one-foot thick is equivalent in weight to that of a single-story home of equal area (Erly and Kockelman, 1981). Also, activities that cause water—either ground water or surface water—to be concentrated in localities that previously had not been heavily soaked can cause slopes to fail. The added weight of the water increases shear stress and increases pore-water pressure, which reduces shear strength. Human activities known to have triggered landslides include (1) excavating, or cutting benches into hillsides for construction of roads or buildings, (2) emplacement of artificial fill, (3) diversion of surface runoff by roads, ditches, and various other land-surface modifications, (4) irrigation of crops and lawns, and (5) installation of septic tanks and leach fields. The areas most vulnerable to human-caused slope failures are in the high-relief terrain in the eastern and southwestern parts of the Mount Deception quadrangle.

Earthquakes

The Ute Pass fault zone trends north–south through the Mount Deception quadrangle. Movement may have occurred on this fault some time after the beginning of the middle Pleistocene, but before Holocene time (Widmann and others, 1998). A similar structure (Rampart Range fault) bounds the east flank of the Rampart Range north of Colorado Springs. The Colorado Geological Survey considers both the Ute Pass fault zone and the Rampart Range fault to be potentially active. The epicenter of a magnitude 4 earthquake that occurred on December 25, 1994, was determined to be on the east side of the Rampart Range about 2.5 miles north of Perry Park (MicroGeophysics Corporation, 1995). The focus of this earthquake was at a depth of 14.6 miles. Seismic risk should be included in the design of all major construction in the map area. For more details on earthquake hazards see Widmann and others (1998, 2002) and the geologic hazards section of the Colorado Geological Survey website at http://geosurvey.state.co.us.

WATER RESOURCES

Surface Water Resources

The Mount Deception quadrangle lies almost entirely within the drainage area of Trout Creek, which originates in the West Creek Range just to the southwest of the quadrangle. Numerous tributaries originate in the West Creek Range and Rampart Range and flow towards the topographically lower Manitou Park area and into Trout Creek. Trout Creek continues to the north and flows into the South Platte near the town of Deckers.

The U.S. Geological Survey Water Resources Data website (http://co.water.usgs.gov/Website/projects/viewer.htm) indicates that stream gauge data are available only for one station (10190002) on Trout Creek at a location five miles north of the quadrangle. Data collected from this location represent surface water flow conditions from an area covering 106 square miles that includes most of the Mount Deception quadrangle. Data were collected only from April through September for the years 2003 through 2006. Average discharge peaked in the month of May at 16 cubic feet per second and decreased to an average low of 3.0 cubic feet per second in the month of September.

Manitou Park Lake, located in the north-central part of the mapped quadrangle, is the only reservoir. This lake, constructed in 1937 for water storage from Trout Creek, covers 12 acres and is now used primarily for recreational purposes.

Ground Water Resources

Ground water provides a primary resource for municipal and domestic water use throughout the Mount Deception quadrangle. Ground water can be found in one, or a combination of two hydrogeologic units: (1) consolidated bedrock aquifers of Paleozoic age sedimentary deposits, and (2) fractured crystalline rock aquifers of the

Mesoproterozoic Pikes Peak batholith.

Bedrock aquifers of Paleozoic age sedimentary deposits are primarily confined to the Pennsylvanian-Permian Fountain Formation in the central graben area. The Fountain Formation has been estimated to be about 2,000 feet in thickness in the central regions of the quadrangle where it is the primary reservoir. The porosity of the sandstone and conglomerate beds ranges from 3 to 12% and averages approximately 7% (Robson and Banta, 1987). Permeability varies considerably based on cementation and fracture conduits. Water level data for the Fountain aquifer can be obtained from the Division of Water Resources (DWR) well permit files. Water levels in the Fountain aquifer vary considerably throughout the region and are based on location, elevation, porosity, and permeability.

The Proterozoic crystalline rock aquifer system underlies the eastern one-third and western one-third of the quadrangle. Since these are igneous rocks, primary porosity is effectively zero, and the water is produced from fractures and fault zones. Locally, it is possible to complete a well in highly weathered granite if the depth of weathering is substantial and the site is close to perennial surface water. Finding productive fractures and fracture zones is unpredictable and yields can be quite low. The fracture data from figure 10 document the high angles of fractures measured in the quadrangle; these fractures would enhance the infiltration of precipitation and snowmelt recharge. Information obtained from a ground-water filing for the Ridgewood Subdivision in the north-central part of the quadrangle indicates that most wells in this area are completed between 100 and 400 feet in depth and yield from 1 to 10 gallons per minute. Landowners with wells near the Ute Pass or Mount Deception fault systems report higher flow rates due to the increase in fracture density.

Water-quality data for the Fountain and Proterozoic crystalline aquifer systems within the quadrangle are non-existent. However, the water quality is adequate for domestic use except in areas of mineralization where metallic or acidic waters may be present (Topper and others, 2003). Ground water from both of these reservoirs is considered “tributary” and is thus subject to the State of Colorado surface water appropriations system.

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