OPEN-FILE REPORT 09-02

Authors' Notes

Geologic Map of the Divide Quadrangle, Teller County, Colorado

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Geologic Map of the Divide Quadrangle, Teller County, Colorado

Description of Map Units, Structural Geology, Geologic Hazards, Mineral Resources, and Ground Water Resources

by
Jay Temple and Alan Busacca

Pikes Peak from Highway 24, east of the town of Divide (UTM83 488011, 4310995)

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Geologic Mapping Program under STATEMAP Agreement No. 08HQAG0094

FOREWORD

The purpose of Colorado Geological Survey Open File Report 09-02, *Geologic Map of the Divide Quadrangle, Teller County, Colorado* is to map and describe the geologic setting, structure, geologic hazards, and mineral and ground-water resources of this 7.5-minute quadrangle located to the northwest of Colorado Springs in central Colorado. Consulting geologists Jay Temple and Alan Busacca completed the field work on this project during the summer of 2008. Jay Temple was the principal mapper and author for this report, using maps and field notes generated by both investigators. The bedrock mapping and unit descriptions, structural geology, and water resource sections of this report were written by Mr. Temple. Dr. Busacca completed the mapping and sections of the report on surficial deposits and geologic hazards.

This mapping project was funded jointly by the U.S. Geological Survey (USGS) and the Colorado Geological Survey (CGS). USGS funds were received under STATEMAP award number 08HQAG0094. STATEMAP is a component of the National Cooperative Geologic Mapping Program, which is authorized by the National Geologic Mapping Act of 1997. Matching funds were 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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ACKNOWLEDGMENTS

The authors are grateful to the landowners of the Divide region for their permission to access the necessary areas for the completion of this map. Specifically, we thank the U.S. Forest Service and the staff at Mueller State Park for their cooperation during the mapping phase of this project. We also would like to thank Dave Wiley and Karen Leute of Black Mountain Drilling, Divide, CO for their help in access to water well data throughout the quadrangle. Key support for the digitizing and display of the maps was provided by Caitlin Bernier and David Barnett of Pangaea Cartographic, Montrose, CO. Many of the figures were provided by Larry Scott of the Colorado Geological Survey. Field checks and suggestions for the author's notes were provided by Vince Matthews and Dave Noe, also from the Colorado Geological Survey. Discussions with Christine Siddoway and Eric Leonard of Colorado College were helpful in understanding the structure and stratigraphy of the area.

INTRODUCTION

Previous Work

Geologic mapping in the late nineteenth and early twentieth centuries targeted areas to the north, south, and east of the Divide 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 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. The Pueblo 1:250,000 scale geologic map by Scott and others (1978) included the area of this quadrangle. Reconnaisance mapping in the adjacent Woodland Park quadrangle was completed by Wobus and Scott (1977). Recent detailed geologic mapping in the Rampart Range area at 1:24,000 scale has been conducted by the Colorado Geological Survey (fig. 1).

Overview of Geologic Setting

The Divide 7.5-minute quadrangle is located in Teller County, Colorado, in the southern part of the Colorado Front Range (fig. 1). The mapped area is predominantly mountainous terrain that surrounds a rolling grassy hill region in the east-central part of the quadrangle where the town of Divide is located. The city of Colorado Springs (Census 2000 population of 360,890) is located approximately 28 miles southeast of the quadrangle. The town of Woodland Park (Census 2000 population of 6,515) is located 8 miles northeast of the quadrangle. U.S. Highway 24 transects the central part of the Divide quadrangle as the major east-west artery and connects the town of Divide with Woodland Park to the east and Florissant to the west. State Highway 67 connects the town of Divide with the mining town of Cripple Creek, 14 miles to the south.

The Divide quadrangle lies within the South Platte River basin, which supplies a large share of water consumed by Denver and other cities to the north and east along the foothills of the Front Range. The highest point in the mapped area is an unnamed peak located in the extreme southeast part of the quadrangle in sec. 32 of T. 13 S., R. 69 W. (elevation 10,720 feet). The lowest point (elevation 8,580 feet) is in the west-central part of the quadrangle where U.S. Highway 24 joins the Lake George quadrangle.

The mountainous region in the northern and southeastern parts of the quadrangle is rugged, forested land administered by the U.S. Forest Service (Pikes Peak Ranger District, Pike National Forest). A significant portion of the mountainous region in the south-central part of the quadrangle lies within the Mueller State Park and Wildlife Area. Average precipitation is 16 inches at the town of Divide, with seventy percent accounted for by rain from April through August and the remaining thirty percent from snow during the winter months.

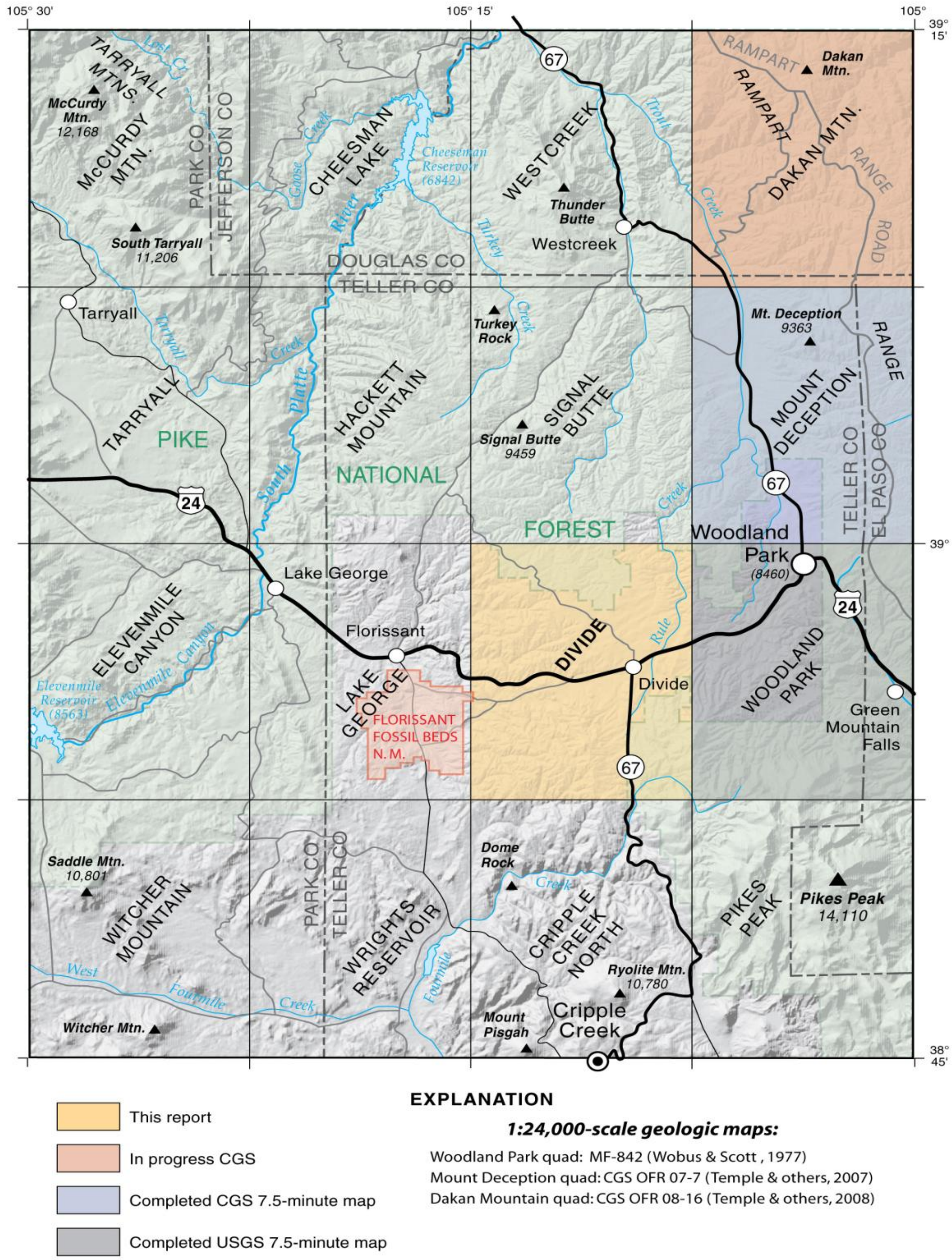


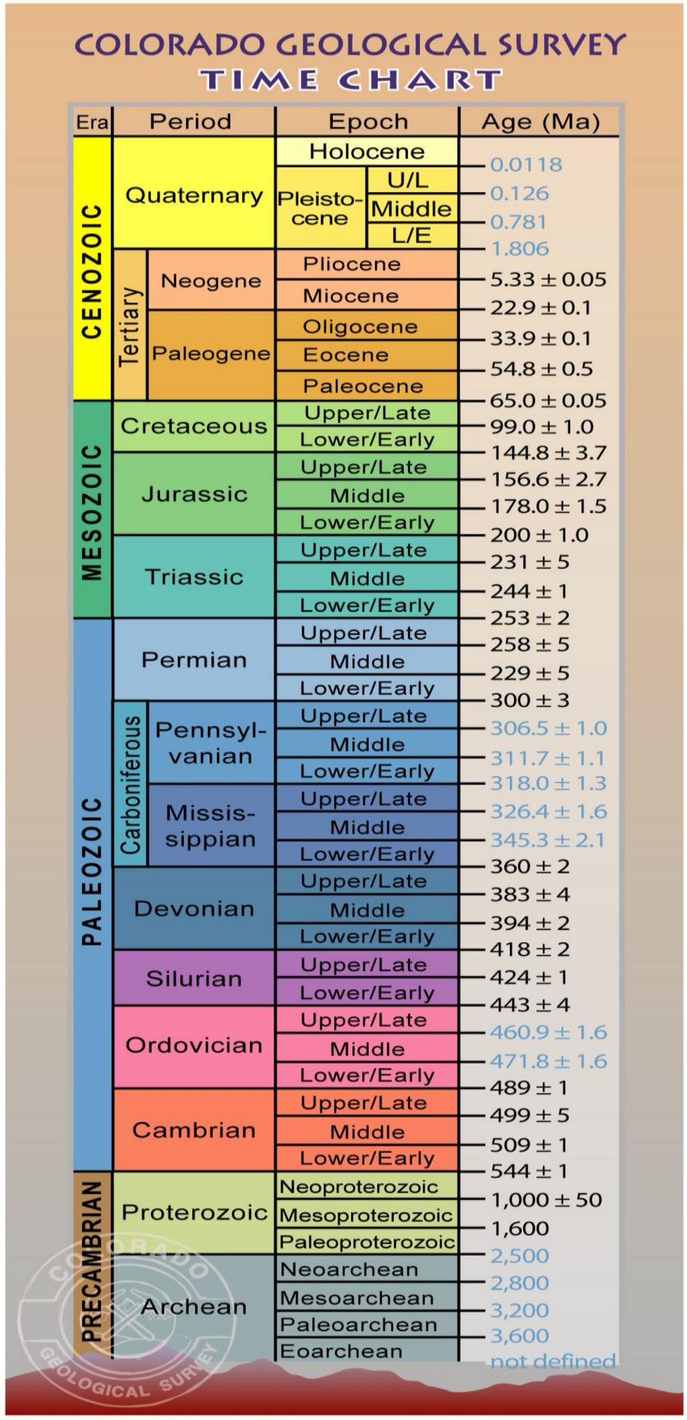
Figure 1. Shaded relief map of the region surrounding the Divide quadrangle showing towns, major roads, and other geographic features. Selected published 1:24,000-scale geologic maps in the vicinity of the Divide quadrangle also shown.

The bedrock in the map area and surrounding region is primarily of granitic composition and is part of the Neoproterozoic Pikes Peak batholith. High-angle faults that generally strike north-south are common throughout the granitic core. The east-central and central low-lying grassy part of the quadrangle consists of Tertiary gravels known informally as the Gravel at Divide. These gravels lie unconformably on the Pikes Peak granite (fig. 2).

Figure 2. Grassy area in the east-central part of the Divide quadrangle that is underlain by the Tertiary gravels (UTM83 486810, 4309255).

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 area of surficial deposits of Pleistocene and Holocene age in the Divide Quadrangle is small, probably less than ten percent of the quadrangle.

The Divide quadrangle is well named from the perspective of the modern stream drainage pattern, as the quadrangle is the locus or point of origin of no fewer than four stream systems that flow, respectively, west (Twin Creek), south (Hay Creek), north (Rule Creek), and northwest (West Creek) away from the center of the quadrangle. All of the streams in the quadrangle have very low stream power and low flow because they are at their respective headwaters in the quadrangle.

These streams are isolated far from major trunk drainages such as the South Platte River, and thus they are isolated from major changes in base level. For this reason and because they have limited flow, the streams have very limited ability to erode and deposit sediments and the deposits are simple valley fills that grade smoothly into side slopes in ephemeral and small perennial streams. Nowhere in the Divide Quadrangle did we recognize systems of stream terraces.

The thicknesses of most units are not known with any certainty because they are poorly exposed, which also means that our descriptions of the surficial deposits are based on observations at a small number of localities.

Surficial deposits in the Divide quadrangle are poorly sorted and most contain a broad range of particle sizes from clay to pebbles and cobbles. 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 Washable Soil Color Charts, 2000 Version; X-Rite Corporation; accessed at: http://www.xrite.com/product_overview.aspx?ID=872 on January 26, 2009) and are for the dry state of the materials.

Age Assignments. The age limits of divisions of Pleistocene time (Table 1) are U.S. Geological Survey Geologic Names Committee (2007). The 11,800-year age for the Pleistocene-Holocene boundary is the approximate calibrated equivalent of 10,000 radiocarbon years. No formal divisions of Holocene time have been agreed upon, so sediment referred to here as upper Holocene was deposited during the interval between 4,000 years ago and the present.

None of the surficial deposits in the Divide quadrangle have been dated directly by any radiometric method, such as radiocarbon, cosmogenic, or luminescence dating. Thus, the unit ages listed here are estimated on the basis of relative-dating methods. These include stratigraphic relationships (superposition, unconformities, etc.), geomorphic position in the landscape (mainly height above stream level), differences in degree of weathering and soil development, and best possible 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 mainly to construct roads and earthen dams. Unit is 6-50 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 deposited from confined channel flow is the principal sediment underlying streams and flood plains. Alluvium resulting from sheet flow, referred to as sheetwash alluvium, blankets the lower parts of most slopes but was mapped only where especially prominent.

Qau **Alluvium, undivided (Holocene and Pleistocene) —** Unit is mainly pale-brown and brown, poorly sorted sand and pebble gravel. Qau was mapped where it consists of deposits of different kinds of alluvium (sheetwash and fluvial) that are either too small or too poorly exposed to map separately at the scale of this map. Locally includes colluvium. Estimated thickness is 1-20 ft.

BEDROCK UNITS

Tdg **Gravel at Divide (Miocene) —** This unit is present in the central and east-central parts of the quadrangle and occupies the area beneath most of the gently rolling grassy hills around the town of Divide. The unit is rarely exposed except in shallow excavations, primarily roadcuts and where new structures are being built.

This unit is composed of gray, poorly indurated conglomerates and sandstones that are interbedded with pale brown to light brown siltstones, mudstones, and claystone beds. 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 come from Oligocene volcanic rocks from the Thirtynine Mile volcanic area to the west and the slightly younger (32-30 Ma) Cripple Creek phonolitic intrusions to the south. Therefore, the age of the Gravel at Divide is younger than the Oligocene Cripple Creek intrusions. Regional relations and the poorly consolidated nature of these conglomerates led Taylor (1975), Scott (1975), and Scott and others (1978) to consider their age to be Miocene and correlative to the Ogallala Formation of the Great Plains (Leonard and others, 2002).

Correlative gravels are mapped to the east in the Woodland Park quadrangle (Wobus and Scott, 1977) and on the Rampart Range east of Woodland Park in the Mount Deception quadrangle (Temple and others, 2007), the Cascade quadrangle (Morgan and others, 2003), and the Palmer Lake quadrangle (Keller and others, 2006). These relations suggest northerly and easterly directions of transport. Direction of transport is also indicated by evaluation of the gravels west of Woodland Park at the 2007 excavation site of the Pikes Peak Regional Hospital on U.S. Highway 24 where cross-bedding and inclination of graded beds support an easterly flow direction (fig. 3). The thickness of the unit in these previously mapped quadrangles has ranged from 15 to 50 ft. Data provided by a recently drilled water well in section 7 of T. 13 S., R. 69 W., about one-half mile south of Divide, show the well reached a total depth of 308 ft. and was still in the gravels. Therefore, a minimum thickness of 308 ft. is established for this unit in the Divide quadrangle.

Figure 3. Fresh exposure of the Gravel at Divide at the excavation site for the Pikes Peak Regional Hospital on U.S. Highway 24, about one mile west of Woodland Park. View is to the northwest. Cross bedding indicates flow from west to east. (Photo by David Adkins).

Twm Wall Mountain Tuff (upper Eocene) — The Wall Mountain Tuff is a moderately to densely welded tuff of rhyolitic composition (Izett and others, 1969; Epis and Chapin, 1974). It is generally light- to medium-brown when fresh but is occasionally medium-gray in a few of the more densely welded outcrops. On weathering, the tuff may be light brown, lavender, pink, reddish brown, or maroon. The fine-grained groundmass usually contains small phenocrysts of biotite and sanidine, and occasionally near the base may contain quartz grains and small arkose fragments ripped up from the underlying strata. The Wall Mountain Tuff was emplaced in the western part of the Divide quadrangle as an ash-flow that was hot enough that the ash compacted and welded into a viscous plastic-like consistency after emplacement. In places, the welded ash flowed and developed flow layering before cooling and solidifying.

The Wall Mountain Tuff has been dated at about 36.7 million years in age by McIntosh and others (1992) and McIntosh and Chapin (1994). The ash flow eruption which deposited the Wall Mountain Tuff has been considered in the past to be an Oligocene event (for example see Trimble and Machette, 1979). However, the age for the end of the Eocene is now recognized to be 33.7 Ma (Remane and others, 2002), so the Wall Mountain Tuff should now be considered to be late Eocene.

The Wall Mountain ash-flow was erupted from an unidentified location west of the upper Arkansas River valley between Salida and Buena Vista (Epis and Chapin, 1974). The Wall Mountain Tuff is less than 30 ft thick in the three erosional remnants in the west-central part of the quadrangle where it rests on the Pikes Peak Granite. Figure 4 shows the tuff in contact with the granite as an apparent north-south trending channel fill.

NEOPROTEROZOIC IGNEOUS ROCKS OF THE PIKES PEAK BATHOLITH

Neoproterozoic granitic rocks of the Pikes Peak batholith are the oldest rocks exposed in the Divide 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 applied the formal name Pikes Peak Granite (Ypp) to the most common rock type in the batholith. Hutchinson (1972, 1976) studied the 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.

Figure 4. Light brown to tan Wall Mountain Tuff (right side of photo) filling an apparent channel within the Pikes Peak Granite (Ypp). Rock hammer in right center of photo placed at the contact. Photo by Dave Noe. (UTM83 479543, 4307367).

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 pre-existing 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 (Neoproterozoic) —** Very coarse-grained pink and white veins and masses consisting chiefly of feldspar and quartz (fig. 4). Elongated, lath-like or bladed crystals of black to weathered bronze-green biotite up to one foot in length are present in the Black Cloud mine in the NW ¼ Sec. 10, T. 13 S., R. 70 W. Most pegmatites in the quadrangle are small, less than 5 feet thick and 50 feet in length, and thus were not mapped separately. The Black Cloud mine is the only mapped pegmatite in the quadrangle and has been mined in the past for feldspar and quartz.

Figure 5. Pegmatite (Ypeg) at the Black Cloud mine. Elongated dark areas in the photo are biotite crystals up to about one foot in length. Pink is mainly microcline; white is quartz (UTM83 481521, 4309782).

Ywp Windy Point Granite (Neoproterozoic) — Windy Point Granite is pinkish-gray to pinkish-tan, fine- to medium-grained granite and quartz monzonite. The unit weathers to reddish-tan to tan and is usually porphyritic. Microcline phenocrysts up to 0.75 inches across commonly stand out giving weathered surfaces a "knobby" appearance in contrast to the more commonly rounded weathered outcrops of the Pikes Peak Granite. Quartz phenocrysts may also be present but are not as large as the microcline phenocrysts. Lenses of the Windy Point Granite are only present in the southeastern part of the quadrangle near Raspberry Mountain. Windy Point Granite is geochemically similar to Pikes Peak Granite and is thought to be a late-stage, rapidly cooled variant of the Pikes Peak Granite (Wobus, 1976).

Thin section analyses show the principal minerals of this unit are quartz (~38%), alkali feldspar (mainly microcline; ~30%), plagioclase (albite-oligoclase; ~25%), and biotite (~6%) (Wobus, 1976). Trace minerals include zircon, apatite, fluorite, and muscovite. The microcline is partly perthitic and the quartz usually occurs as individual grains rather than as clusters of grains.

Finlay (1916) originated the name Windy Point granite for plutons exposed on Pikes Peak. The unit was referred to as “porphyritic granite” by Gross and Heinrich (1965). Wobus (1976) applied the formal name Windy Point Granite to finer-grained, locally porphyritic potassic granites that intrude the dominant coarse-grained Pikes Peak Granite in large areas of the batholith.

Ypp **Pikes Peak Granite (Neoproterozoic) —** Pikes Peak Granite is the most abundant rock type in the Divide 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 masses of constituent minerals of sand and gravel size). 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 %), quartz (20-35 %), plagioclase (oligoclase; 10-20 %), biotite (2-7 %), and hornblende (<0.5 – 2 %). 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 Divide quadrangle is dominated by the brittle behavior of rocks in the form of regional and local faulting, fault imbricates, slickensides near the fault zones, and intense fracturing. One regional fault system, the Oil Creek fault, transects the area from north to south in the east-central part of the quadrangle. Other more localized faults within the Proterozoic crystalline rocks are mapped primarily in the southern half of the quadrangle and generally strike north to northeast and are accompanied by fracture sets suggestive of high-angle faults.

Oil Creek Fault Zone

The Oil Creek fault is exposed at only one location in the quadrangle where an active gravel mining operation in the Pikes Peak Granite in the SW ¼ of sec. 30, T. 13 S., R. 69 W. reveals intense fracturing associated with the fault. At this location, the fractures within the Proterozoic crystalline rocks strike N. 10 degrees W. and dip from 84 degrees east to 72 degrees west, suggestive of a high-angle fault. From this location northward through the quadrangle the Oil Creek fault is concealed by the Tertiary gravels. No offset of the gravels was observed along the suspected locations of the concealed fault, which suggests that the fault movement preceded the presumed Miocene-age deposition of the gravels. Previous mapping by Scott and others (1978) depict the Oil Creek fault with a northerly strike south of Divide along Rule Creek to Coulson Lake and then continuing north through the center of section 6 of T. 13 S., R. 69 W. and section 31 of T. 12 S. R. 69 W. We depict this fault to continue along Rule Creek northeast of Coulson Lake, slightly east of the projected strike of the previous authors.

High-Angle Faults in Proterozoic Rocks

High-angle, generally north-south striking faults transect the Proterozoic crystalline rocks throughout the quadrangle as identified from the topographic map, DEM, aerial photographs, and observations of outcrops with significant increases in fracture occurrence. These high-angle faults are more numerous in the southern half of the quadrangle and are primarily up-to-the-east. These faults are interpreted to be Laramide in age; however, the absence of Phanerozoic sedimentary rocks makes it difficult to determine the relative timing of fault initiation or any later rejuvenation.

Fracture data measured from the Proterozoic rocks for the Divide quadrangle are depicted on the map (plate 1). These data are cumulatively plotted on a stereonet diagram (fig. 5). These data do not show a preferred strike direction; however, moderate-to-steep inclinations are dominant throughout the quadrangle. It should be noted that multiple fracture and joint sets were often taken at a single outcrop. For map display purposes the symbols for these data had to be moved slightly to allow the data to become legible. The exact UTM locations for these data can be found in a Microsoft Excel file on the CD ROM that accompanies the map.

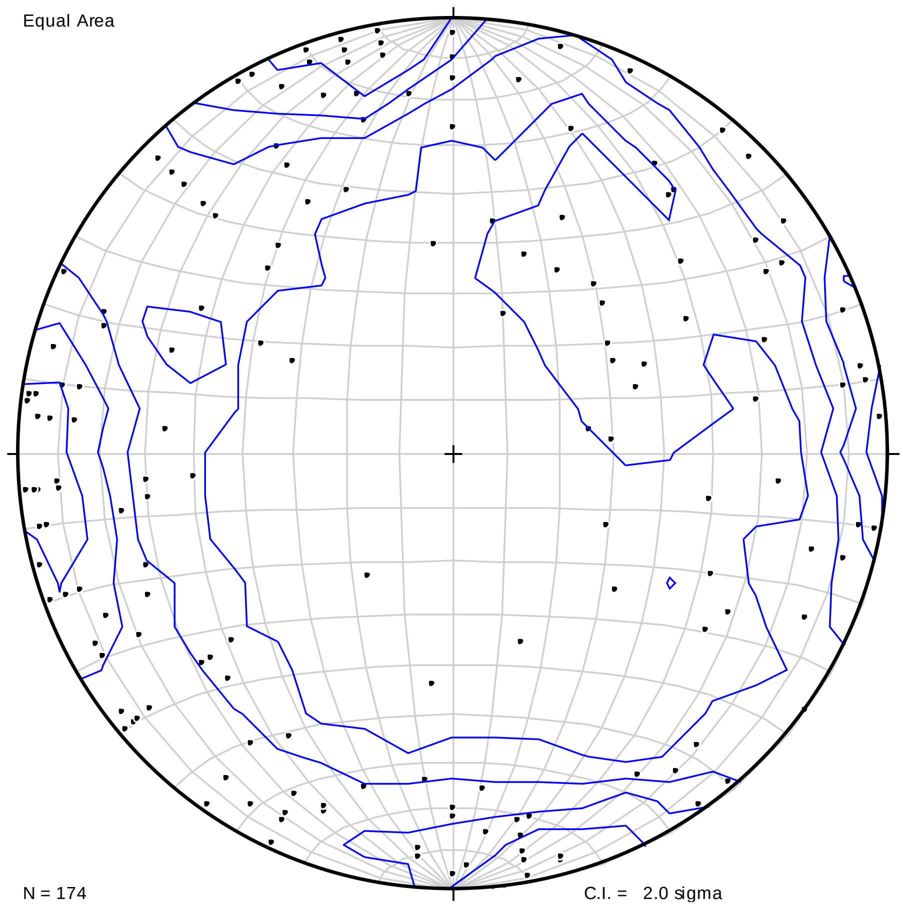


Figure 6. Stereonet diagram for 174 poles to fracture planes measured in the Proterozoic crystalline rocks in the Divide quadrangle. Lower hemisphere projection.

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 Divide quadrangle, floods may be triggered by heavy snowmelt runoff, but prolonged or intense rainstorms during the summer months are likely to produce the most serious flooding. The network of small, chiefly ephemeral streams in narrow valleys and gullies in the high-relief terrain can be expected to flood frequently, and the floods will impact roads or other structures that cross them. Where the Tertiary gravels are present in the east-central part of the quadrangle, 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 Divide quadrangle are widespread but small. Most areas are in the high-relief terrain made up of the Proterozoic crystalline rocks. 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. Some of these rock-fall deposits, however, may be relicts of Pleistocene glacial climates.

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 Divide 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 in the surrounding highlands that drain into the lower elevation grassy area where the Tertiary gravels are located. The soil and underlying Tertiary gravels in the lower grassy areas are coarse and highly permeable. Thus, they quickly become saturated during intense thunderstorms, and then surface runoff is high and the resulting erosion of the soil and gravel material can be severe. Debris flows in the Divide quadrangle are small, have little surface expression, and were not mapped separately.

Landslides

Landslide classifications include most forms of mass movement. Consequently, landslide has become a generic term 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 not present in the Divide quadrangle. 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 of the Divide quadrangle.

Earthquakes

The Oil Creek fault zone strikes north–south through the Divide quadrangle. Although dominant movement on this fault preceded deposition of the Tertiary gravels, minor adjustments are certainly possible. On January 6, 1979 a magnitude 2.9 earthquake was felt in the area of Divide. The earthquake produced two loud sounds audible in an area of more than 600 sq. km. and led to an extensive air search for an air crash or meteorite source for the event (Butler and Nicholl, 1986). The U.S.G.S. determined the epicenter to be near the town of Divide and assigned a depth of less than 5 km for the source. Kirkham and Rogers (1981) assign this event to the Oil Creek fault.

The Ute Pass fault zone strikes north-south through the western part of the Woodland Park quadrangle, which adjoins the Divide quadrangle to the east. Movement on this fault is primarily Laramide and older (Temple and others, 2007). However, subsequent movements have occurred 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 (Dickson and others, 1986). 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.

MINERAL RESOURCES

Pegmatites

Quartz and feldspar were mined in the past from open cuts on only one pegmatite body (unit Ypeg) in the Divide quadrangle. This operation was at the Black Cloud mine in the NW ¼ sec. 10 of T. 13 S., R. 70 W. All of this mined pegmatite was enclosed within the Pikes Peak Granite (unit Ypp). Bladed biotite crystals up to one foot long are common in some parts of the pegmatite. There has been no recent mining at the site and the permit is listed as inactive. Clean, white, crystalline quartz and pink microcline feldspar were mined from parts of this pegmatite. This pit is about two hundred feet long and one hundred feet wide (fig. 6).

Figure 7. A large open-cut abandoned pegmatite mine (Black Cloud Mine), west-central part of the Divide quadrangle (UTM83 481521, 4309782).

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 Divide quadrangle but is not presently being mined.

Metals

No metal mining operations are present in the Divide quadrangle. Several gold occurrences are reported in the U.S. Geological Survey's Mineral Resource Data System (MRDS) in the Signal Butte quadrangle to the north (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.

GROUND WATER RESOURCES

Ground water provides a primary resource for municipal and domestic water use throughout the Divide quadrangle. Ground water can be found in one, or a combination of two hydrogeologic units: (1) unconsolidated bedrock aquifers of Tertiary age sedimentary gravels, and (2) fractured crystalline rock aquifers of the Neoproterozoic Pikes Peak batholith.

Bedrock aquifers of Tertiary age sedimentary deposits are primarily confined to the Gravels at Divide in the central and east-central parts of the Divide quadrangle. These gravels have been shown to reach a thickness of at least 308 feet in the central region of the quadrangle based on a well drilled by PK Enterprises in the SW ¼ of sec 7, T. 13 S., R. 69 W., less than one mile south of the town of Divide. The initial flow rate for this well was 180 gallons per minute, which suggests very favorable porosities and permeabilities for these gravels.

The Proterozoic crystalline rock aquifer system is composed almost entirely of the Pikes Peak Granite with the possibility of minor zones of the Windy Point Granite. 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 5 document the high angles of fractures measured in the quadrangle. These fractures would enhance the infiltration of precipitation and snowmelt recharge. Water well information obtained from Black Mountain Drilling, a Divide area water drilling company, indicates that most wells in the crystalline rock aquifer in this area are completed between 100 and 400 feet in depth and yield from 1 to 10 gallons per minute.

Water-quality data for the Tertiary gravels 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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