OPEN-FILE REPORT 05-4

Geologic Map of the Como Quadrangle, Park County, Colorado

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

By

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Denver, Colorado
2005

FOREWORD

The Colorado Department of Natural Resources is pleased to present the Colorado Geological Survey Open File Report 05-4, *Geologic Map of the Como Quadrangle, Park County, Colorado.* Its purpose is to describe the geologic setting and mineral resource potential of this 7.5-minute quadrangle, the majority of which is located in Park County. 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 ground-water exploration. Field work for this project was conducted during the summer of 2004 by CGS staff geologists Beth L. Widmann and John W. Keller, consulting geologist Robert M. Kirkham, and field assistants Joel T. Poppert and Jason B. Price.

This mapping project was funded jointly by the U.S. Geological Survey through the STATEMAP component of the National Cooperative Geologic Mapping Program which is authorized by the National Geologic Mapping Act of 1997, Agreement No. 04HQOAG0075, and the Colorado Geological Survey using the Colorado Department of Natural Resources Severance Tax Operational Funds. The CGS matching funds come from the severance tax paid on the production of natural gas, oil, coal, and metals.

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INTRODUCTION

LOCATION AND GENERAL GEOLOGY

The Como quadrangle is located at the northern edge of South Park, just a few miles northeast of Fairplay in Park County, central Colorado (fig. 1). The small town of Como is in the east-central part of the quadrangle. U.S. Highway 285 traverses the southern half of the quadrangle. Several creeks and tributary streams flow south to southeast across the quadrangle and are part of the South Platte drainage basin. Within the quadrangle, the principal streams are Tarryall Creek and Trout Creek. Topography ranges in elevation from roughly 9,500 feet in the southeastern part of the quadrangle to nearly 13,600 feet on the eastern flank of Mount Silverheels in the northwestern part of the quadrangle. The forested land in the northwest part of the quadrangle is administered by the U.S. Forest Service (Pike National Forest). To the southeast, ranch lands are privately owned or controlled by the U.S. Bureau of Land Management or State Land Board. Numerous small parcels of land within the Forest Service boundaries along Tarryall Creek and in the northwest corner of the quadrangle are also privately owned.

The oldest rocks exposed in the Como quadrangle are the east-dipping Pennsylvanian to Permian redbeds of the Minturn, Maroon, and Garo Formations, which crop out in the western part of the quadrangle. The overlying sequence of rocks youngs eastward and includes the Jurassic Morrison Formation and the Cretaceous Dakota Sandstone, Benton Group, Niobrara Formation, Pierre Shale, Fox Hills Sandstone, and Laramie Formation, listed from older to younger. The Garo Formation and Dakota Sandstone form a north-trending hogback cut through by Red Hill Pass in the western third of the quadrangle. The low topography on either side of the hogback is due to the erosion of the less resistant fine-grained siltstone of the Maroon Formation to the west and Pierre Shale to the east. The Morrison Formation, Benton Group, and Niobrara Formation rarely crop out and are mapped on the basis of relative stratigraphic position and their characteristic residuum. Upper Cretaceous to Paleocene volcanic rocks of the South Park Formation form Reinecker Ridge and other low knobs in the southeast corner of the quadrangle. Clastic sedimentary rocks of the same formation overlie the volcanic rocks at Reinecker Ridge in the southern part of the quadrangle. Even younger Paleogene intrusive rocks crop out as sills, plugs, and stocks throughout the quadrangle. Most of these intrusive bodies are monzonite to quartz monzonite in composition and represent a period of intense magmatism about 41 to 43 Ma. Quaternary surficial deposits are widespread throughout the quadrangle and include modern stream alluvium and several older, broad alluvial surfaces, glacial deposits representing multiple glaciation events, alluvial fans, and mass-wasting deposits such as colluvium, talus, and landslide debris. Nearly everywhere above tree line (approximately 11,600 feet), bedrock is mantled by periglacial felsenmeer, which is a type of residuum resulting from freeze-thaw processes. These deposits were not mapped due to their ubiquity.

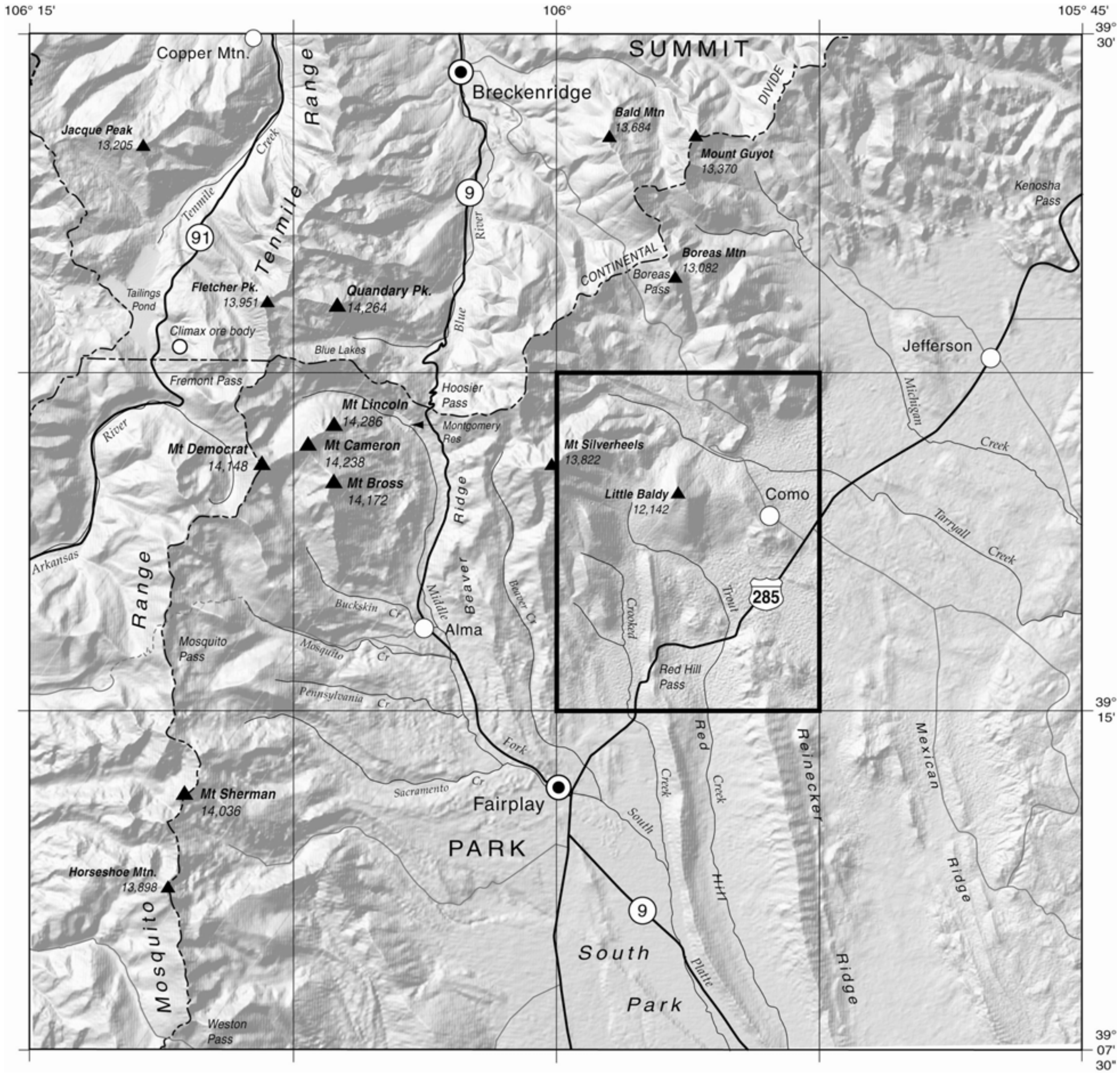

Figure 1. Shaded relief map of the region surrounding the Como quadrangle.

Numerous faults offset the rocks in the Como quadrangle. The dominant strike of these structures is northwest; a few faults trend north or northeast. The majority of the faults are interpreted as high-angle normal faults. However, faults cutting through the Como area and some of the faults on the east and northeast flanks of Reinecker Ridge are likely high-angle reverse faults. Most fault structures are considered to have originated in Laramide and younger time.

SCOPE OF WORK

The present study focuses on geologic mapping of the Como 7.5-minute quadrangle. Field work for the Como quadrangle was undertaken during the summer and fall of 2004. The geology was mapped on U.S. Forest Service color aerial photographs (1:24,000-scale) taken in September 1997. The majority of the bedrock mapping was completed by B. Widmann and field assistant J. Poppert. The Upper Cretaceous and Paleogene volcanic and sedimentary rocks of the South Park Formation were mapped by J. Keller and field assistant J. Price. Quaternary deposits were mapped by R. Kirkham. Map unit contacts were transferred from photogrammetric models of annotated aerial photographs to the topographic map of the Como quadrangle using the ERDAS (Earth Resource Data Analysis System) stereographic program. Bedrock units and surficial deposits that have maximum thickness of 5 feet or dimensions of less than about 75 feet were generally not mapped. Thin bedrock units, such as limestone beds and Tertiary dikes and sills are represented on the map as single lines because they add to the stratigraphic and structural understanding of the geology in the area. The cultural features of the topographic base map were revised in 1994. Thus, roads, reservoirs, and buildings constructed after 1994 are not on the map base, and human-made deposits that postdate the 1997 aerial photography also are not on the map.

PREVIOUS STUDIES

The South Park region has been the focus of numerous studies over the years. Because the region was part of the central Colorado trough during Pennsylvanian-Permian time the region has been discussed in various papers focusing on the geology of the trough (e.g. DeVoto, 1965b; 1980). The geology and origin of South Park proper has been closely examined by Stark and others (1949) and DeVoto (1961; 1971; 1972). The Park was studied in the 1960s to 1970s for oil and gas exploration, the chronicles of which are outlined by Clement and Dolton (1970). Bryant and others (1981a) focused primarily on the Tertiary intrusive rocks and obtained numerous potassium-argon and fission-track ages that helped constrain the timing of events in the South Park-Breckenridge areas. Geophysical studies of the South Park basin have been carried out by faculty and students from the University of Texas, El Paso. Their results will be published in an upcoming American Geophysical Union Monograph (Treviño and Keller, *in press*). Students from the Colorado School of Mines also conducted numerous geophysical studies of the basin, though few incorporate the area within the Como quadrangle (Beggs, 1977; Durrani, 1980; Fatti, 1974; Shoffner, 1974). A recent book by McGookey (2002) provides a good overview of the geology in South Park, complete with road logs. Raynolds (2003) examined sediments of the South Park Formation in a study that correlated these deposits with time equivalent deposits in the Denver Basin.

Several geologic maps of the area surrounding the Como quadrangle have been published by the Colorado Geological Survey or U.S. Geological Survey (fig. 2). The Como quadrangle is on the western margin of the Denver 1° x 2° geologic map, which was mapped by Bryant and others (1981b). Tweto (1974a) mapped the Mount Lincoln 15-minute quadrangle, the southeast margin of which abuts the Como quadrangle. Numerous 7.5-minute quadrangles in the area have also been mapped. They are Alma (Widmann and others, 2004), Breckenridge (Wallace and others, 2002), Milligan Lakes (Wyant and Barker, 1976), and Jefferson (Barker and Wyant, 1976). Within the Como quadrangle, previous studies are older and focus principally on the geology as it pertains to mineralization.   Mine claims and placer workings in the northwest part of the quadrangle are part of the Tarryall (or Beaver-Tarryall) mining district, which is characterized by pervasive skarn and sulfide mineralization. One of the earliest studies of this area was by Muilenberg (1925), who focused primarily on the nature of the Tertiary intrusive rocks and character of mineralization in the area. Later studies by Singewald (1942, 1950) expanded on this early work and provided a more in depth account of the geology and mineral resources in the area.

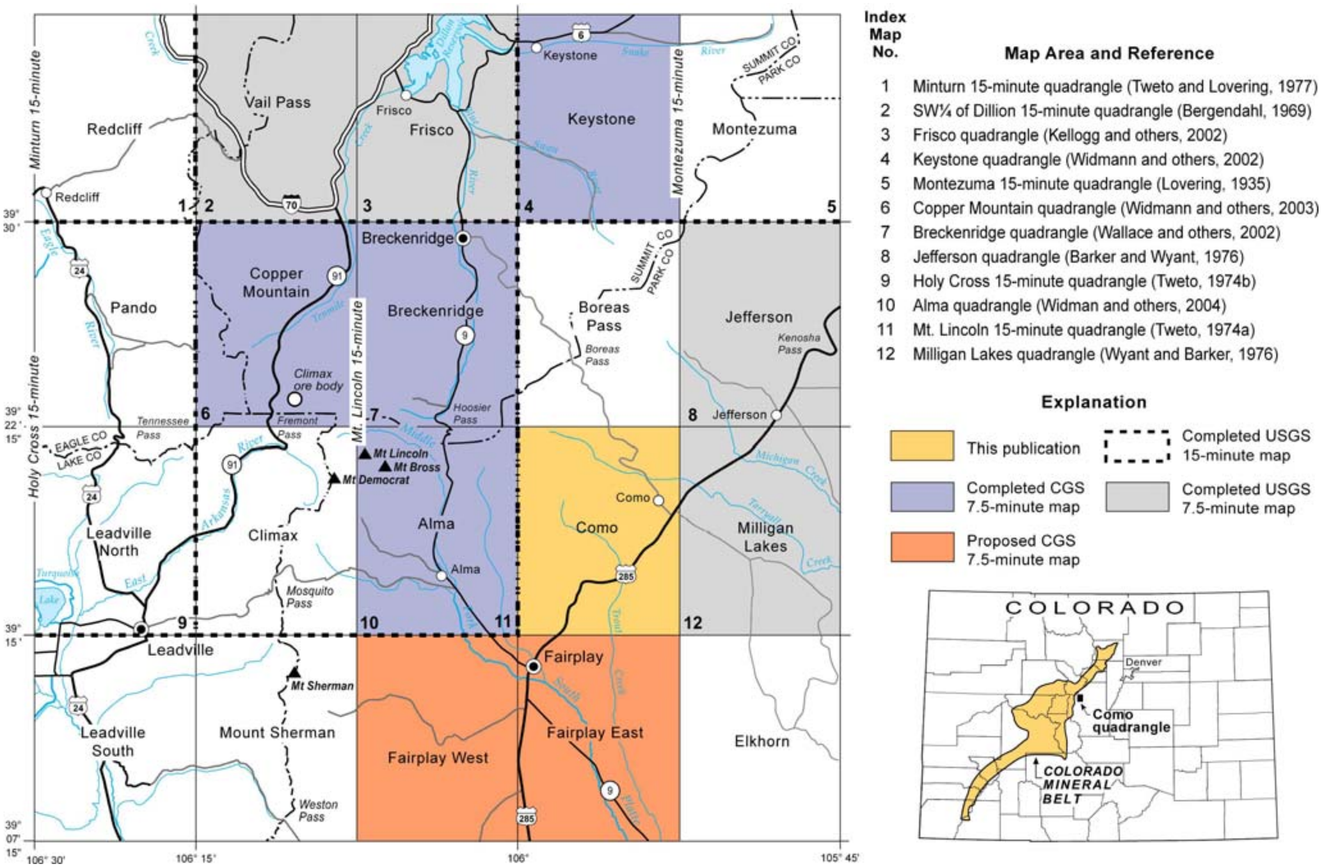

Figure 2. Location map and index of selected published geologic maps in the vicinity of the Como quadrangle. Inset map shows the location of the Como quadrangle in relation to the Colorado Mineral Belt.

ACKNOWLEDGMENTS

This mapping project was funded jointly by the Colorado Geological Survey and U.S. Geological Survey through the STATEMAP program of the National Cooperative Geologic Mapping Program under agreement no. 04HQOAG0075. Van Cullar and his wife Laura are warmly thanked for allowing access to the Carter Trust property, which encompasses much of the Tarryall mining district in the northwest part of the quadrangle. Mr. Cullar is a mining and geological consultant and is the present caretaker of the Carter Trust. He graciously provided us with numerous unpublished private reports from past industry exploration projects in the district.

The reports contain a wide variety of data including geochemistry and economic viability of potential lode gold mining projects. Additionally, we thank the numerous land-owners and caretakers who granted us permission to access their properties. Alex Ebel (Red Hill Ranch), John Sweetland, Dr. Brantigan (Como Roundhouse), Russ Skinner, Mr. and Mrs. Campling, Holly Reavis and the staff at the Como church camp were especially helpful. Special thanks are extended to Bruce Bryant (USGS) who provided a thorough review of the report. Jane Ciener acted as our technical reviewer. Jason Wilson and Larry Scott (CGS) were instrumental in the completion of maps, figures, cross-sections, and the final CD-ROM publication of this report.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial geologic deposits of the Como quadrangle are subdivided into map units, first on the basis of either genesis or landform, then on relative age. Most of the surficial deposits in the mapped area are not well exposed. The best exposures result from human activities and are found in features such as road cuts, foundation excavations, utility trenches, and unreclaimed mines. These types of exposures sometimes are available for examination only for very short time periods because they may be promptly backfilled. Natural exposures of the surficial deposits, for example those in the eroded banks of streams, are sparse. Because of the limited exposures, the physical attributes of these units, such as thickness, texture, stratification, and composition, are based on observations made at only a few locations, and their origin is often deduced using only geomorphic characteristics.

Surficial units shown on the map generally are more than 3 to 5 feet thick. Deposits associated with distinct landforms locally may be thinner than 3 feet. Surficial deposits with a mapped width of about 75 feet or less usually are not shown on the 1:24,000-scale map. Surficial deposits formed by the in-place weathering of bedrock, such as residuum and felsenmeer, are not mapped. Contacts for many surficial units were located using geomorphic characteristics; some contacts are gradational.

Table 1 illustrates the divisions of the Quaternary used in our study. Absolute ages have not been obtained on any of the surficial deposits in the mapped area. Characteristics such as stratigraphic relationships, position in the landscape, clast weathering, and pedogenic soil development were used to estimate the relative ages of the surficial deposits.

Formal time divisions		Informal time divisions	Informal nomenclature for glacial deposits	Approx. age (sidereal years)
Quaternary Period	Holocene Epoch			
	Pleistocene Epoch	late Pleistocene	— ? — ? — ? — ? — Pinedale — ? — ? — ? — ? —	11,680 55,000
		middle Pleistocene	— ? — ? — ? — ? — Bull Lake — ? — ? — ? — ? —	128,000
		early Pleistocene	Pre - Bull Lake	778,000
Tertiary Period (part)	Pliocene Epoch			1,806,000

Table 1. Time terminology applied to glacial deposits in the Como quadrangle (from Widmann and others, 2004, modified after Fullerton and others, 2003).

Grain-size terminology used for sedimentary deposits follows the modified Wentworth scale (Ingram, 1989). This classification system describes pebbles, cobbles, and boulders as differing sizes of gravel, and it does not imply a genetic origin for the clasts. The general term "gravel" also is commonly used by many geologists for rounded clasts deposited in fluvial or beach environments. We herein use the terms gravel, pebbles, cobbles, and boulders to describe the size of the clasts, not the genetic origin. Terms used for sorting are those of Folk and Ward (1957). Sedimentary clasts are defined in this study as rock fragments larger than 2 mm in diameter, whereas matrix refers to surrounding material that is 2 mm or less in diameter (sand, silt, and clay). In clast-supported deposits, the majority of the material consists of clasts that are in point-to-point contact. Matrix-supported deposits are composed predominantly of material smaller than 2 mm, and most clasts are separated by or embedded in matrix. Soil-horizon names used here are those of the Soil Survey Staff (1975) and Guthrie and Witty (1982), and the stages of secondary carbonate morphology are from Gile and others (1966), with the modifications of Machette (1985).

HUMAN-MADE DEPOSITS **–** Earth materials placed by humans

mw **Mine waste (Historic) –** Includes materials that resulted from mining operations; located in the drainage of Tarryall Creek and in the northeast corner of the quadrangle. Most mine waste in the quadrangle consists of hummocky light-brown piles of cobbles, pebbles, and boulders with minor sand and silt that resulted from gold placer operations. Dredge tailings comprise much of the mine waste along Tarryall Creek near and downstream of the abandoned town site of Hamilton. Hydraulic mining was utilized in many of the tributary drainages. Operations at the Silverheels gold mine contributed much of the mine waste in Montgomery, Deadwood, and Little French Gulches. The permit for this mine was revoked in 1985 and part of the disturbed mining area was reclaimed during the late 1980s using the forfeited bond. The reclaimed land is included in this unit. Small medium- to dark-gray to orange piles composed of sedimentary rock fragments between the town of Como and the Como cemetery resulted from underground coal mining. Mine waste in the northeast corner of the quadrangle resulted from the mining of peat. Non-earthen materials may locally occur in mine waste. Maximum thickness of mine waste is 30 to 40 feet.

af **Artificial fill (Historic) –** Earth materials used as fill in road, railroad, and dam construction. Artificial fill consists chiefly of sand, silt, rock debris, and clay that is at most about 40 feet thick.

ALLUVIAL DEPOSITS **–** Gravel, sand, silt, and clay transported and deposited by flowing water. This sediment was deposited in channels or braided outwash surfaces and as sheetwash and unconfined runoff.

Qa1 **Alluvial unit one (Holocene) –** Mainly poorly sorted, clast-supported, unconsolidated, sandy gravel of all sizes, gravelly sand, silty sand, and sandy silt in modern channels, flood plains, and adjacent low-lying terraces that are about 3 to 5 feet above modern channels. Deposits are typically stratified, may have cut-and-fill channels, and locally are organic rich. These deposits may also include interbedded or overlying very poorly sorted, matrix-supported gravelly silt and sand that probably were deposited by debris flows from tributary drainages. Sediment includes material eroded from Tertiary intrusive rock, sedimentary bedrock, and metamorphosed sedimentary bedrock. Most clasts are fresh and sound, and they typically are subround to subangular, although a few are round or angular. These alluvial deposits have only weakly developed pedogenic soil horizons. Deposition was during oxygen isotope stage 1, perhaps during episodes of Holocene neoglaciation or flooding. The base of the unit is not exposed; it probably averages 3 to 20 feet thick.

Qa2 **Alluvial unit two (upper Pleistocene) –** Stratified, poorly sorted, clast-supported, sandy cobble and pebble gravel, gravelly sand, silty sand, and sandy silt that locally are rich in organic material and peat. Clast lithologies are similar to those in unit Qa1, and most clasts are unweathered or very slightly weathered. These glacial outwash deposits generally underlie terrace surfaces that range from about 3 to 20 feet above adjacent streams. However, in the South Branch of Park Gulch, deposits of unit Qa2 converge with the valley floor and eventually are buried by younger sediment. During most and perhaps all of the late and middle Pleistocene, as alluvial units two and three were deposited, Trout Creek flowed in a paleovalley that approximately followed the modern valley of the South Branch of Park Creek (see geologic map for location of the late Pleistocene paleovalley). The Trout Creek paleovalley was abandoned either during the early Holocene or latest Pleistocene, and a new channel was cut about 40 to 50 feet deep below the aggradational surface of unit Qa2. Pedogenic soils formed in unit Qa2 have weakly to moderately well developed Bw horizons and very weak and thin argillic Bt horizons, and very thin calcareous Cca horizons with stage I to weak stage II carbonate morphology. These deposits grade upstream to glacial till of unit Qti1 in Tarryall and Trout Creeks. This stratigraphic relationship, along with the degree of soil development and clast weathering, suggests unit Qa2 is Pinedale in age (oxygen isotope stage 2) and is probably about 13 to 35 ka (table 1). Thickness of this unit may be as much as 30 feet, but it typically is 5 to 15 feet thick.

Qa **Alluvial units one and two, undivided (Holocene and upper Pleistocene) –** Includes deposits of alluvial unit one and alluvial unit two where they are indistinguishable, or where they cannot be mapped separately at a scale of 1:24,000.

Qa3 **Alluvial unit three (upper middle Pleistocene) –** Glacial outwash deposits similar to unit Qa2, but which are older and usually higher in the landscape than unit Qa2. Unit Qa3 underlies terrace and fan surfaces; it is widespread along Tarryall Creek, Trout Creek, Holthusen Gulch, and the South Branch of Park Gulch, which have incised 5 to 50 feet deep beneath the surface of alluvial unit three. The depth of incision is greatest in the vicinity where stream piracy captured the late Pleistocene paleovalley of Trout Creek in the south half of sec. 6, T. 9 S., R. 76 W. Most gravel clasts are slightly or moderately weathered. Pedogenic soils usually have moderately well-developed argillic Bt horizons with blocky or sometimes very weak prismatic structure and stage I carbonate morphology; Cca horizons have stage II to very weak stage III carbonate morphology. Where relatively thin deposits of unit Qa3 overlie the Pierre Shale, better developed and thicker carbonate horizons have formed. Unit Qa3 deposits are correlated with morainal deposits of unit Qti2, which are interpreted as Bull Lake-equivalent deposits that are late middle Pleistocene (oxygen isotope stage 6). Unit Qa3 is typically 3 to 25 feet thick.

Qa4 **Alluvial unit four (middle Pleistocene) –** Sediment in alluvial unit four is similar to that contained in alluvial unit two, however, many of the gravel clasts within the deposit are moderately to strongly weathered. Deposits of Qa4 underlie high-level surfaces on drainage divides (fig. 3). These surfaces, though widely separated, have strikingly accordant altitudes, which suggests a broad and perhaps continuous apron of alluvial sediment flanked the southeast side of the mountains when alluvial unit four was deposited. These surfaces now stand about 50 to 80 feet above Tarryall Creek, 80 feet above the North Branch of Park Gulch, and 120 to 160 feet above Trout Creek. Stark and others (1949) described these in their discussion of the "Como surfaces". Unit Qa4 is likely correlative with their Como surface no. 1. Pedogenic soils formed on unit Qa4 are similar to those on unit Qa3, except calcareous horizons typically have weak to moderate stage III morphology. Kratochvil (1978) correlated unit Qa4 deposits with the Slocum Alluvium of Scott (1963). Thickness of this unit averages about 5 to 20 feet.

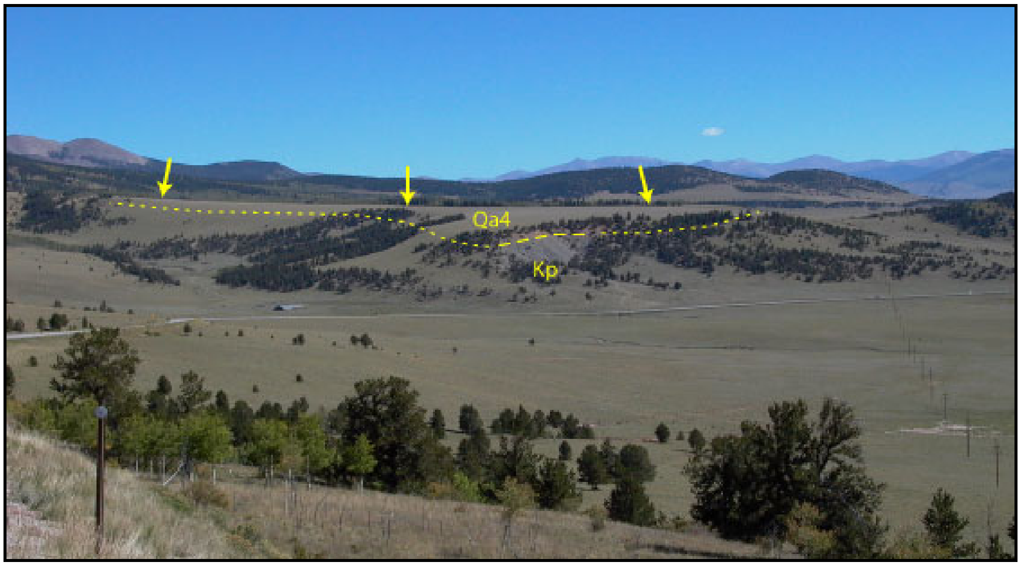

Figure 3. The broad, gently southeast-sloping surface marked by arrows is underlain by a thin veneer of gravel (Qa4). The gravel lies unconformably on Pierre Shale (Kp). Surface is north of U.S. Highway 285 near Red Hill Ranch.

MASS-WASTING DEPOSITS **–** Deposits on hillslopes and adjacent valley floors that were transported downslope primarily by gravity and not transported within, on, or under another medium such as flowing water or wind (Jackson, 1997). Water can be an important element in mass wasting, and it commonly triggers the movement. However, water is merely a part of the moving mass, not the transporting agent. Colluvium, landslide deposits, and talus are the principal types of mass-wasting deposits in the quadrangle. The classification system of Cruden and Varnes (1996) is used to describe the type of slope movement.

Qc **Colluvium (Holocene and upper Pleistocene) –** Deposits of poorly sorted, sandy or silty, fine to coarse gravel and gravelly sand and silt that are on or at the foot of hillslopes. Colluvium can be rich in boulders where near cliffs and steep slopes with rocky outcrops. As used here, colluvium generally follows the definition of Hilgard (1892) in that it (1) is derived locally and transported only short distances, (2) is not distributed by channelized water flow, (3) contains clasts of varying size, (4) has little or no sedimentary structures or stratification, which are typically caused by channelized flow of water, and (5) may include minor amounts of sheetwash and debris-flow deposits. Unit Qc also locally includes landslide deposits and talus.

Clast lithology within colluvial deposits depends on the source area. Tertiary intrusive rocks and Paleozoic sedimentary rocks are the primary clasts in colluvium in the mountainous northwestern half of the map area. In the southeastern half of the area Mesozoic sedimentary lithologies and Tertiary igneous rocks comprise most clasts. Clasts are typically angular to subangular, except in areas where the bedrock or surficial deposits in source areas for the colluvium contain well-rounded clasts. Maximum thickness is estimated at about 30 feet.

Qta **Talus (Holocene and upper Pleistocene) –** Chiefly angular rock debris deposited below the base of cliffs that are held up by well-indurated bedrock. The debris came from the cliffs as rockfalls, rock slides, rock topples, and snow avalanches. Most talus is of cobble, small boulder, and pebble sizes, but boulders as large as 8 to 10 feet in diameter locally are common. Talus typically lacks matrix material, at least at shallow depths. Talus is widespread on the south wall of the glaciated valley of Montgomery Gulch and on the flanks of Little Baldy Mountain. Tertiary intrusive rocks, Paleozoic sedimentary rocks, and the Dakota Sandstone are the principal sources of talus. Maximum estimated thickness is about 35 feet.

Qls **Landslide deposits (Holocene and upper Pleistocene) –** Landslide deposits consist of heterogeneous, mostly unsorted and unstratified debris that commonly is characterized by hummocky topography and lobate form. Translational landslides occur in the surficial deposits and shaly bedrock that overlie the Dakota Sandstone on the dip slopes east of Red Hill. They typically involve colluvium that overlies the Cretaceous sedimentary bedrock. The basal slip plane for many of these landslides is at or near the colluvium-bedrock contact. Landslides are also relatively common in Deadwood Gulch and Little French Gulch. These landslides are small complex slides that involve the Maroon Formation and Tertiary intrusive rocks as well as the surficial deposits that overlie them. The bedrock in this area is strongly altered, which probably explains the higher landslide density. A prominent landslide in a cirque on the east side of Mount Silverheels (summit is about 1,400 feet west of quadrangle) in the SE¼ of sec. 21, T8S, R77W probably failed after glacial ice melted out of the cirque at the head of the tributary following the last major glaciation (fig. 4). A landslide at the northwest end of Reinecker Ridge formed in the Pierre Shale and Reinecker Ridge Volcanic Member of the South Park Formation. The toe of this landslide is exposed in a road cut along Highway 285. Landslide deposits range up to about 50 feet thick, but most are thinner.

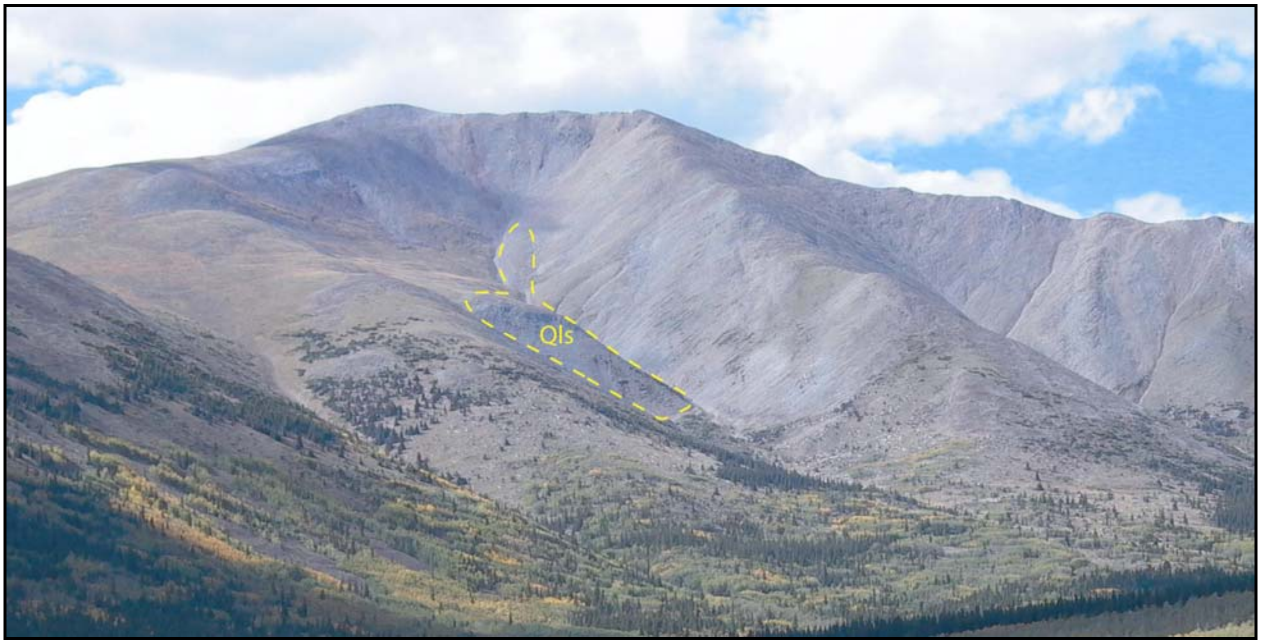

Figure 4. Photograph of the east flank of Mount Silverheels (summit is about 1,400 feet west of quadrangle). Note large slump block or relatively intact rock in cirque at center. Block probably slid after glacial ice melted out of the cirque in the latest Pleistocene. The steep toe of the slump block was eroded by runoff that is channelized along the south (left) side of the slump block. Photograph taken from U.S. Highway 285 near Como looking west.

Qlso **Older landslide deposits (Pleistocene) –** Includes landslide deposits that have subdued morphologic features and no evidence of recent activity, which suggests the deposits are pre-Holocene in age. A single older landslide deposit is preserved in the quadrangle; it lies on the southeast flank of Little Baldy Mountain in the headwaters of the South Branch of Park Gulch. No exposure of this deposit was observed. Angular to subangular cobbles and boulders derived chiefly from the Dakota Sandstone are locally abundant on the surface of this older landslide deposit. In some areas these large clasts comprise all the material exposed at the surface. Either the fine-grained matrix was removed by the winnowing effect of wind or washed away by water, or the larger clasts rose to the surface by frost heave. M. Stelling (2004, personal communication) stated that the older landslide deposits exposed several years ago in foundation excavations on his property consisted mostly of unsorted and unstratified debris, but fine-grained organic rich deposits that probably accumulated in closed depressions within the landslide complex also were encountered. The estimated maximum thickness of unit Qlso may exceed 80 feet locally.

Qco **Older colluvium (Pleistocene) –** Three deposits of older colluvium were observed in the quadrangle. One deposit caps a north-south-trending linear ridge that is south of Little Baldy Mountain on the south side of Trout Creek; a second deposit mantles the saddle on the east side of Little Baldy Mountain; and the third is an elongate deposit on the northwest side of Little Baldy Mountain. These deposits are interpreted as remnants of ancient debris-slope systems that once formed the flanks of Little Baldy Mountain, similar to the older talus flatirons of Gutiérrez Elorza and Sesé Martínez (2001) or the older pediment flatirons of Schmidt (1996). Angular to subangular boulders and cobbles of chiefly sandstone that probably were eroded from the Dakota Sandstone on Little Baldy Mountain are abundant on the surfaces of the older colluvial deposits; clasts with different lithogies are sparse or absent. All three areas of older colluvium are now depositionally inactive. The valley of Trout Creek separates the deposit of older colluvium south of Little Baldy Mountain from its original debris source. Stratigraphic and geomorphic relationships indicate the deposit south of Little Baldy Mountain predates the deposition of alluvial unit 4 (Qa4) during the middle Pleistocene. The maximum thickness is estimated at 40 feet.

ALLUVIAL AND MASS-WASTING DEPOSITS **–** These deposits include alluvial and colluvial material that are mapped as a single unit because they are juxtaposed and are too small to show individually, or they have contacts that are not clearly defined. Fan deposits are classified as mixed alluvial and mass-wasting deposits because in addition to alluvium, they also include significant volumes of sediment from debris flows, which are considered to be a form of mass wasting (e.g., Cruden and Varnes, 1996; Hungr and others, 2001).

Qf **Fan deposits (Holocene and upper Pleistocene) –** Includes sediment in small, geomorphically distinct fans at the mouths of tributary valleys and large, coalesced fan complexes along the hillslopes on the east side of Reinecker Ridge and near the former Fremont School in the northeast part of the quadrangle. The deposits are chiefly poorly sorted, clast-supported sandy gravel and gravelly sand deposited as alluvium, but locally they include debris-flow deposits that generally are composed of matrix-supported, poorly sorted silty or sandy gravel. Clasts are mainly subangular to subround. Maximum thickness is estimated at 40 feet, but commonly the deposits are thinner.

Qac **Alluvium and colluvium (Holocene and upper Pleistocene) –** Consists of sediment deposited in (1) channels, flood plains, and low terraces in tributary drainages, and (2) colluvium and sheetwash along valley margins and sidehills. The alluvial component of the unit is very poorly sorted to well sorted and ranges from sandy pebble, cobble, and boulder gravel to stratified fine sand and silt. Clasts in the alluvial component are angular to subround. The colluvial component consists of very poorly sorted, unstratified or poorly stratified, gravelly to silty sand, sandy to silty gravel and gravelly sandy silt. Clasts in the colluvial component are chiefly angular to subangular. A narrow, elongate deposit of matrix-free angular boulders of Dakota Sandstone occurs in unit Qac near and a short distance west of the unnamed tributary in the center of the south half of sec. 1 and north half of sec. 12, T. 9 S., R. 77 W. The boulders may represent a lag deposit that was created as the underlying easily eroded Pierre Shale was removed by water flowing around and beneath the boulders. The unit also locally includes debris-flow deposits. Thickness is estimated to range from 3 to 25 feet thick.

Qfo **Older fan deposits (Pleistocene) –** Older fan deposits are similar in genesis and sedimentological properties to fan deposits (unit Qf), but are associated with inactive fans, inactive fan complexes, and fan remnants. Older fan deposits were observed on the east side of Reinecker Ridge, where they overlie the Pierre Shale. Most clasts consist of angular to subround volcanic rocks eroded from the Reinecker Ridge Volcanic Member and conglomeratic member of the South Park Formation (TKsr, Tsc). Estimated maximum thickness is about 30 feet, but commonly they are much thinner.

Qaco **Older alluvium and colluvium, undivided (Pleistocene) –** Physical characteristics of older alluvium and colluvium are similar to those of unit Qac, except deposits of older alluvium and colluvium are found on drainage divides and hilltops that are not subject to modern deposition. Deposits of older alluvium and colluvium exist south and southwest of the town of Como. Angular to subround clasts of volcanic rock derived from the Reinecker Ridge Volcanic Member of the South Park Formation comprise much of the coarse-grained clastic material within the unit. Thickness of the unit is generally 3 to 15 feet.

GLACIAL DEPOSITS **–** Includes sediment deposited by or adjacent to glacial ice. These deposits are mapped as till, which is nonsorted and nonstratified sediment deposited directly by ice without reworking by glacial meltwater, but the unit locally includes stratified sediment and mass-wasting deposits. Stratified sediment may occur in ground and end moraines and in tributaries dammed by glacial ice. Locally, the unit may contain mass-wasting deposits in the end and lateral moraines. Most glacial deposits in the quadrangle are in Tarryall Creek and its tributaries; less extensive glacial deposits are preserved on the east flank of Mount Silverheels.

Qti1 **Till unit one (upper Pleistocene) –** Heterogeneous sediments deposited in lateral, terminal, end, recessional, and ground moraines in the valleys of Tarryall Creek, Montgomery, Deadwood, and French Gulches, and the unnamed tributary in the headwaters of Trout Creek. Unit consists chiefly of nonsorted and nonstratified subangular to subround boulders, cobbles, and pebbles in a sandy or silty matrix. Sand-sized and smaller particles commonly comprise more than 50% of the deposit, although gravel-sized material locally is more abundant. Stratified, thinly bedded sand and fine gravel occurs in places in the end and terminal moraines, and mass-wasting deposits of both landslide and colluvial origin may mantle the flanks of lateral, end, and terminal moraines. Clasts are generally unweathered to slightly weathered and consist chiefly of Tertiary intrusive and late Paleozoic and Mesozoic sedimentary lithologies, some of which have been contact metamorphosed. Pedogenic soils typically have weakly to moderately developed Bw horizons or very weak and thin, argillic Bt horizons enriched with illuvial clay. Unit Qti1 is tentatively correlated with deposits of the Pinedale glaciation, which formed between about 12 and 35 ka (table 1) during oxygen isotope stage 2. The unit may attain a thickness of about 80 feet in some areas, but typically it is thinner.

Qti2 **Till unit two (upper middle Pleistocene) –** Includes deposits of till in the valleys of Tarryall and North Tarryall Creeks that are similar to unit Qti1, but are older. They are either down valley from or further from the valley center than sediment in the younger till unit one. The moraine crests and hummocky knob-and-kettle landforms associated with till unit two are less distinct than those present on till unit one, and the weathering rinds on clasts in till unit two are thicker than those on clasts in till unit one. Pedogenic soils in till unit two are thicker, more oxidized, and contain more illuvial clay than those in till unit one. Unit Qti2 is tentatively correlated with sediment deposited during the Bull Lake glaciation (oxygen isotope stage 6), which ended about 130 ka (table 1). Maximum thickness is estimated at about 100 feet, but usually it is thinner. For example, the till in the lateral moraine between Tarryall and North Tarryall Creeks is in many areas only a 3- to 10-feet-thick veneer of glacial sediment over bedrock; in places, small unmapped windows of bedrock protrude through the till.

Qti3 **Till unit three (middle Pleistocene) –** A single, poorly exposed deposit on the south side of the Tarryall Creek southwest of the abandoned town site of Hamilton. This deposit appears to be similar to, but more weathered than, till units one and two (Qti1, Qti2). The deposit is more than one mile south of the terminal moraine for unit Qti2, which indicates till unit three is older than till unit two. In the absence of any other age criteria, we assign a middle Pleistocene age to this deposit, which has an estimated thickness of 5 to 15 feet.

PERIGLACIAL DEPOSITS – Deposits formed in cold environments by freeze-thaw action, solifluction, and nivation.

Qrgw **Valley-wall rock glacier deposits (Holocene) –** Includes two deposits on the south wall of Montgomery Gulch. These upper part of these deposits consist of a veneer (several feet thick) of angular boulders that lacks fine-grained matrix. The lower part of these deposits is much thicker and consists of rock rubble in a fine-grained matrix. The lower part may contain interstitial ice and ice lenses or be perennially frozen. The valley-wall rock glacier, also known as a lobate rock glacier, has a hummocky surface that sometimes includes curvilinear ridges and furrows that approximately parallel the valley wall. The estimated maximum thickness of these deposits is 30 to 40 feet.

PERIGLACIAL AND MASS-WASTING DEPOSITS – Undifferentiated deposits resulting from periglacial and mass-wasting processes.

Qcs **Colluvium and solifluction deposits, undivided (Holocene and upper Pleistocene) –** Intermixed colluvium and solifluction deposits that are mapped jointly because they are either too small to map individually or lack distinct contacts because the deposits grade from one type to the other. This unit is widespread in the higher elevations of upper Trout Creek and in a tributary to Crooked Creek. Solifluction deposits consist of angular to subrounded pebbles, cobbles, and large boulders in a chiefly sandy matrix that is deposited in the more poorly drained parts of alpine and subalpine areas. Solifluction deposits resulted from the slow, viscous, downslope flowage of water-saturated surficial deposits over frozen ground. Frost action, augmented by meltwater from alternate freezing and thawing of snow and ice, often initiates the movements. Solifluction deposits are characterized by hummocky terrain, linear swales and ridges, and numerous seeps and springs. Minor ground cracks and fissures also may be present. On open hillslopes, solifluction processes often produce lobes or terracettes, with small ledges or benches that can be several feet high. Refer to the unit description of unit Qc for the characteristics of colluvium. Thickness of unit Qcs is estimated to range from about 3 to

20 feet.

BEDROCK

TERTIARY INTRUSIVE ROCKS – At least three discernable types of porphyritic intrusive rock were emplaced during Eocene time: monzonite, quartz monzonite, and megacrystic quartz monzonite. Monzonite and quartz monzonite in the western part of the quadrangle are associated with intrusion of the Montgomery Gulch stock. Quartz monzonite in the northeastern part of the quadrangle is part of a large intrusive body centered on Bald Mountain, which is north of the quadrangle. At Bald Mountain, the intrusion is described as a massive sill that is generally parallel to bedding (Bryant and others, 1981a). However, in the northeastern corner of the Como quadrangle the intrusive contact cuts across stratigraphy and is suggestive of a large stock rather than a sill. Herein, we refer to this body as the Bald Mountain stock, but recognize that the intrusion is more sill-like to the north. Locally, these rocks range from diorite to granodiorite. Elsewhere in the quadrangle, most of the intrusions are in the form of sills that are generally concordant to bedding and range in thickness from several feet to several hundreds of feet. Other intrusions are in the form of dikes, stocks, plugs, and possible laccoliths. The rocks comprising Reinecker Ridge are conglomeratic sedimentary strata and trachyandesite, andesite, and dacite flows and breccias of the Upper Cretaceous and Paleocene South Park Formation. Names for intrusive rocks were assigned in accordance with the quartz-alkali feldspar-plagioclase (QAP) diagram of Streckeisen (1976), and a variant of the QAP diagram developed for use with whole-rock geochemical analyses of igneous rocks (La Roche, 1992). Whole-rock geochemical analyses were plotted on QAP diagrams using the IGPET computer program of Terra Softa, Inc.

Tqpm Quartz monzonite porphyry – megacrystic variety (Eocene)—Light-gray to light-bluish-gray, orange-brown-weathering quartz monzonite porphyry that contains prominent large phenocrysts (megacrysts) of orthoclase 2 to 5 cm long and, in many places, rounded bipyramids of quartz 5 to 15 mm in diameter (fig. 5). These phenocrysts are set in a porphyritic matrix composed of anhedral grains 2 to 5 mm long of plagioclase, quartz, orthoclase, and abundant biotite, set in a bluish-gray aphanitic matrix. This unit crops out as a single north-northwest-striking sill a few hundred feet thick north of Como in secs. 20, 21, and 28, T. 8 S., R. 76 W. Hand samples of this dike are similar in lithology and appearance to the Lincoln porphyry of the Leadville region (Pearson and others, 1962) and megacrystic quartz monzonite mapped in the adjacent Alma, Brecken-ridge, and Copper Mountain quadrangles (Widmann and others, 2004; Wallace and others, 2002; Widmann and others, 2003). Age determinations for megacrystic quartz monzonite porphyry in the region are inconclusive. The Lincoln porphyry has been assigned an age of 64.6 Ma by Bookstrom (1983) on the basis of a K-Ar date from a sample on the adjacent Alma quadrangle. Another K-Ar date from a similar porphyry in the Leadville area yielded an age of 64.7 ± 1.79 Ma (McDowell, 1971). However, megacrystic porphyry was dated in the Frisco quadrangle to the north at 44.1 ± 1.6 Ma by the K-Ar method (Marvin and others, 1989). Apatite and zircon fission-track dating of two samples of identical-appearing megacrystic porphyry from the Copper Mountain quadrangle to the northwest yielded ages of 36.7 ± 3.9 Ma (apatite) and 41.5 ± 3.7 Ma (zircon), and 48.6 ± 6.6 Ma (apatite) and 40.1 ± 3.9 Ma (zircon), respectively (Mach, 1992). $^{40}Ar/^{39}Ar$ dating of a sample (CO197) collected from the sill north of Como resulted in an age of 43.12 ± 0.26 Ma (Esser, 2005). Megacrystic quartz monzonite porphyry in the region may be the product of two separate intrusive events around 64 Ma and 40 to 44 Ma. Whole rock geochemical analysis of this same sample shows it to be locally granodioritic. It is chemically similar in composition to the granodiorite component of the Bald Mountain stock (Tqp; sample CO184; table 2).

Figure 5. Typical example of megacrystic quartz monzonite porphyry (Tqpm). Note large orthoclase phenocrysts (white), and smaller, somewhat rounded quartz phenocryst (gray).

Sample		SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	Cr2O3	TiO2	MnO	P2O5	SrO	BaO	LOI	Total
Tqp	CO184	66.55	15.4	3.8	2.79	1.09	3.82	3.18	<0.01	0.44	0.07	0.2	0.08	0.15	2.38	99.9
Tqpm	CO197	63.93	14.08	5.08	2.65	2.01	3.67	3.75	0.02	0.61	0.1	0.31	0.08	0.14	1.93	98.3

Table 2. Geochemical whole-rock analysis of selected Tertiary intrusive rocks in the Como quadrangle. Analyses were performed by ALS Chemex, Sparks, NV. using the XRF method. Values listed in weight percent. See geologic map for sample locations.

Tqp **Quartz monzonite porphyry (Eocene)—**Grayish-tan- to orangish-brown-weathering porphyritic quartz monzonite comprised primarily of quartz, plagioclase, orthoclase, biotite, and hornblende. Orthoclase phenocrysts comprise as much as 20 percent of the rock and quartz phenocrysts about 10 percent. Euhedral biotite forms 1 to 3 percent of the rock volume and is much more abundant than sparse hornblende. Hornblende is locally oriented and may be up to 2.5 cm in length. Quartz monzonite of the Montgomery Gulch stock is highly variable and commonly grades in and out of monzonite porphyry. Singewald (1942) described the stock as having margins of monzonite or diorite and a core of quartz monzonite. Phenocrysts of quartz are typically only a few millimeters in diameter but in coarser varieties may exceed 1 cm (fig. 6). A large contact metamorphic aureole associated with this stock has altered sedimentary rocks of the Minturn and Maroon Formations to hornfels. Cross-cutting field relationships indicate that the quartz monzonite is slightly younger than the monzonite sills (Tmp). Quartz monzonite of the Bald Mountain stock is less porphyritic and has a somewhat more equigranular texture than the quartz monzonite of Montgomery Gulch (fig. 7). Whole rock geochemical analysis of a sample collected from this stock during this study indicates it is granodioritic (sample CO184, table 2). Other geochemical analyses show the stock ranges from potassic diorite to quartz monzonite (Bryant and others, 1981a). The Bald Mountain stock weathers in slabs a few inches thick (fig. 8) to produce a rounded topography mantled by felsenmeer, which is a type of residuum resulting from repeated freeze-thaw events. These weathered slabs form an extensive and locally thick mantle on the flanks of the peaks in the northeast corner of the quadrangle. Similar ages of about 41 Ma were obtained using K-Ar and fission-track methods from samples collected from the Bald Mountain stock (Bryant and others, 1981a).

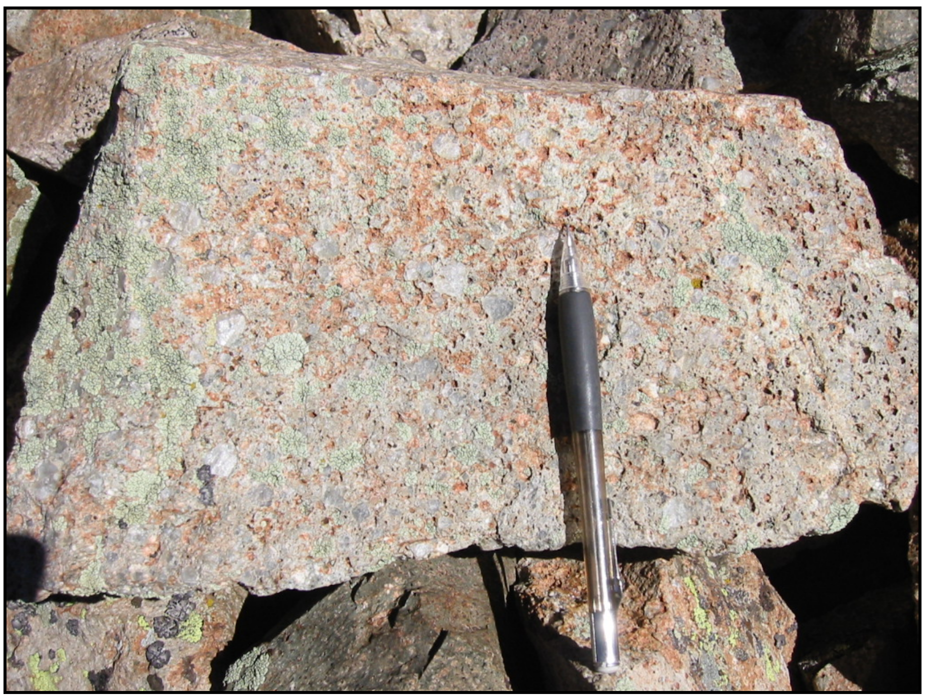

Figure 6. Coarse-grained variety of quartz monzonite porphyry (Tqp) from the Montgomery Gulch stock. Quartz phenocrysts are white and gray. Vugs represent areas where these phenocrysts have been plucked or removed through weathering.

Figure 7. Quartz monzonite porphyry (Tqp) of the Bald Mountain stock, which is more equiqranular than the quartz monzonite porphyry of the Montgomery stock.

Figure 8. Characteristic slabby weathering of quartz monzonite porphyry (Tqp). These slabs thickly mantle the slopes in the northeast corner of the quadrangle.

Tmp **Monzonite porphyry (Eocene)—**Pale-gray or green to tan monzonite porphyry with a pervasive characteristic green tinge due to the presence of the propylitic alteration minerals chlorite and epidote (fig. 9). Phenocrysts are 10 percent plagioclase 1 to 5 mm across, 3 to 5 percent hornblende laths 1 to 4 mm long, 3 percent biotite 2 mm across, and 0 to 3 percent quartz 2 to 5 mm in diameter. Phenocrysts are set in a fine-grained, nearly aphanitic, holocrystalline matrix dominated by plagioclase and quartz but also including biotite, augite, hypersthene, hornblende, magnetite, apatite, allanite, and zircon (Ransome, 1911). Biotite and hornblende are commonly chloritized or altered to epidote, quartz, or calcite. Adjacent to the Montgomery Gulch stock, feldspar phenocrysts are altered to epidote and/or calcite. Rounded quartz grains were observed in thin section to contain melt inclusions, which suggests rapid growth of quartz phenocrysts. Locally, the unit grades to or is intruded by quartz monzonite (Tqp). The monzonite porphyry is characterized by sills and small stocks in the western part of the quadrangle and is most abundant in the Montgomery Gulch-Mount Silverheels area. The sills are likely related to the quartz monzonite stock in Montgomery Gulch and appear to have been contemporaneous with or slightly in advance of stock emplacement.

Figure 9. Monzonite porphyry (Tmp) from the Mount Silverheels area. Note fine-grained texture, presence of mafic minerals (dark), and chloritized fracture surface (green).

UPPER CRETACEOUS AND TERTIARY VOLCANIC AND SEDIMENTARY ROCKS OF THE SOUTH PARK FORMATION – Sawatsky (1967) designated all of what he interpreted as Tertiary rocks in South Park, including the andesitic volcanics on Reinecker Ridge, as the South Park Formation. Wyant and Barker (1976) applied the formal name Reinecker Ridge Volcanic Member to andesitic volcanics and conglomeratic sediments in the lower part of the South Park Formation. They included conglomeratic strata, which in the Como quadrangle form the crest of Reinecker Ridge south of the road that traverses the ridge (herein referred to as Reinecker Ridge road), in their description of the Volcanic Member. Because the conglomeratic strata are lithologically and genetically distinct from the underlying andesitic flows and breccias, we mapped the units separately in accordance with Bryant and others (1981b).

Johnson (1935) correlated rocks now assigned to the South Park Formation with the Denver Formation on the basis of fossil leaf impressions. Paleontological age control is poor, however. No fossil pollen data and no vertebrate fossils have been described from the South Park Formation (Raynolds, 2003). A new $^{40}Ar/^{39}Ar$ age of 66.94 ± 0.25 Ma (Esser, 2005) was obtained from hornblende in the lowest exposed volcanic flow on the west side of Reinecker Ridge (sample JP300). This is considered the minimum age of eruption of the lowest flows of the sequence and shows that these flows are Upper Cretaceous rather than Paleocene as previously reported by Sawatsky (1967), who obtained a K-Ar date of 56 ± 2.6 Ma from the same exposure. K-Ar dates from tuffs interbedded with conglomeratic strata in the South Park Formation on the adjacent Milligan Lakes and Elkhorn quadrangles indicate a Paleocene age of 56 to 65 Ma (Bryant and others, 1981a).

Stark and others (1949) described the sub-types of the Reinecker Ridge volcanics in detail, calling the sequence the Basin Ridge group. As part of that group, they described a rhyolite unit overlying the andesitic rocks on Reinecker Ridge. Our mapping does not confirm this, nor did mapping by Sawatsky (1967). Rhyolite is not exposed in outcrop on the Como quadrangle but is found as cobble-sized clasts within the conglomeratic member of the South Park Formation (unit Tsc), which overlies the Reinecker Ridge volcanics. The texture of the rhyolite clasts is fine-grained equigranular but not aphanitic. Texturally and compositionally, the rhyolite clasts are similar to dikes mapped in the Alma, Breckenridge, and Copper Mountain quadrangles (Wallace and others, 2002; Widmann and others, 2003; Widmann and others, 2004). These same dikes are termed "later white porphyry" by Singewald and Butler (1941) for exposures in the Lincoln Amphitheater northwest of Alma.

South Park Formation (Upper Cretaceous and Paleogene)

Tsc **Coarse conglomeratic member (Paleogene)—**This unit is exposed on the crest and eastern slope of Reinecker Ridge, south of Reinecker Ridge road. The unit consists of polymictic pebble, cobble, and rare boulder conglomerate interbedded with arkosic sandstone and siltstone, and gray, biotite-bearing crystal-lithic tuff. The unit is poorly to moderately consolidated and is poorly exposed. Weathering produces a surface strewn with sub-angular to well-rounded pebbles, cobbles, and locally, boulders. Boulders as large as 6 feet in diameter observed on the east flank of Reinecker Ridge indicate a very high-energy depositional environment. Conglomerate clasts have deeply weathered surfaces and are often broken. Clast lithologies include quartz monzonite porphyry (possibly units Tqp and Tqpm), very light-tan to light-gray intrusive rhyolite with sparse quartz and biotite phenocrysts, Reinecker Ridge andesite (TKsr), Pennsylvanian and Permian "red bed" sandstones (Pℙm, ℙm), hornfels and skarn derived from contact-metamorphosed Pennsylvanian and Permian rocks (altered units Pℙm, ℙm, ℙml), Dakota Sandstone (Kd), and black, cherty pebbles from an undetermined formation. Silicified wood is present but not abundant. Small fragments of Proterozoic crystalline rock are extremely rare. Clasts of Reinecker Ridge andesite are abundant near the base of the formation but become increasingly scarce up section. The estimated maximum thickness of the coarse conglomeratic member of the South Park Formation in the Como quadrangle is 1,200 feet.

The hornfels and garnet-bearing skarn clasts in conglomerate beds appear identical to contact-metamorphosed rocks adjacent to the Montgomery Gulch stock in the northwest corner of the Como quadrangle and the northeast part of the Alma quadrangle. The Montgomery Gulch stock is 7 to 9 miles northwest of an excavated exposure of conglomerate containing porphyry, hornfels, and skarn clasts in the NW¼ of sec. 21, T. 9 S., R. 76 W. at the base of Reinecker Ridge. The various porphyry intrusive clasts are mesoscopically similar to intrusive rocks in the northern and northwestern part of the quadrangle as well. This indicates that the sediment was transported from the north or northwest as suggested by Wyant and Barker (1976).

The reported age for the South Park Formation is Paleocene, constrained mainly by age dates of volcanic rocks east of the Como quadrangle (Sawatsky, 1967; Bryant and others, 1981a). However, the presence of clasts of various intrusive and volcanic rocks within the coarse conglomeratic member may conflict with these previously reported ages. A new ^{40}Ar/^{39}Ar age of 64.08 ± 0.11 Ma (Esser, 2005) was obtained from biotite in a sample of a rhyolitic intrusive clast (sample JK365) from conglomerate on Reinecker Ridge. Thus, the absolute maximum age of the conglomerate is Paleocene. A whole-rock chemical analysis of the dated rhyolite clast is given it table 3. Clasts of other rock types will be dated in the Fairplay East quadrangle in 2005-2006, and these may indicate a younger age for the conglomerate. The reported ages of nearly all of the Tertiary intrusive rocks in the South Park-Breckenridge region are Eocene and range from about 35-51 Ma (Bryant and others, 1981a). Intrusives in the Mosquito Range near Leadville have been dated as early Paleocene. The Lincoln porphyry was dated at 64.6 Ma by Bookstrom (1983) on the basis of a K-Ar date from a sample in the Alma quadrangle. McDowell (1971) obtained a K-Ar date of 64.7±1 Ma from biotite in "Laramide porphyry" in the Leadville North quadrangle. However, similar porphyritic units have been dated in the Copper Mountain and Frisco quadrangles to the northwest at 36 to 48 Ma using K-Ar and apatite and zircon fission-track methods (Marvin and others, 1989; Mach, 1992). The clasts of quartz monzonitic intrusive rock that we observed in the conglomerates are variable in texture and composition but do not look similar to Lincoln porphyry, which has abundant feldspar megacrysts.

TKsr **Reinecker Ridge Volcanic Member (Upper Cretaceous and Paleocene)—**This unit is exposed on Reinecker Ridge and on the unnamed group of hills directly west of the town of Como. It consists predominantly of a sequence of trachyandesite, andesite, and dacite flows and breccias. The color of the unit varies from purplish gray, purplish brown, greenish gray, to deep red and light-gray mottled. It is usually porphyritic, with small phenocrysts of plagioclase, hornblende, and locally augite in an aphanitic groundmass. Hornblende typically forms the most conspicuous phenocrysts, but some flows contain augite and little or no hornblende. A few thin, discontinuous, medium-gray to green-gray, fossiliferous, tuffaceous sandstone and siltstone lenses were observed as inter-flow deposits within the volcanic sequence, but these are rare and poorly exposed. A new $^{40}Ar/^{39}Ar$ age of 66.94 ± 0.25 Ma (Esser, 2005) was obtained from hornblende in the lowest exposed flow of trachyandesite porphyry (sample JP300). According to Esser (2005), this should be considered a minimum age for the eruption of the sampled andesite. K-Ar and fission-track ages from tuffs near the base of the South Park Formation east of the Como quadrangle indicate ages ranging from 65.5±1.6 Ma to 59.3±8.1 Ma (Bryant and others, 1981a).

Flow breccia horizons are more prevalent than the dense, massive unbrecciated flows in the Reinecker Ridge volcanics. The flow breccias are monolithologic with matrix material being compositionally identical to the angular to sub-rounded clasts. The flow breccia texture was created by auto-brecciation of the andesitic flows as they cooled and differentially solidified while in motion. Some flow horizons contain an unusual texture characterized by leucocratic andesitic spheroids set in a dark reddish-brown to dark-gray andesitic matrix (fig. 10). These spheroids weather to distinctive round to oval pellets averaging about 0.25 to 0.5 inch in diameter (fig. 11). Thin section observations show that individual phenocrysts of plagioclase and hornblende are continuous across the boundaries between the leucocratic spheroids and the darker matrix. Whereas the spheroids are unaltered, the matrix has a muddy appearance from partial chloritization. In addition, only the matrix stains yellow with sodium cobaltinitrite suggesting the presence of potassium feldspar that is absent within the spheroids. The fact that the phenocrysts are unbroken indicates that this ‘pelleted’ volcanic unit is not a volcanic breccia but is a textural variant of non-fragmental andesite flows. We interpret the presence of spheroids to be the product of alteration and partial metasomatism as opposed to brecciation. This andesitic subunit was termed “variolitic” by Stark and others (1949), who recognized that the leucocratic spheroids were probably not true varioles as described by earlier petrologists. The term variole is a descriptive field term for cm-scale leucocratic spheroids and globules that are visible on weathered surfaces of mafic volcanic rocks (Fowler and others, 2002).

Figure 10. Variolitic texture in outcrop of Reinecker Ridge Volcanic Member of the South Park Formation. The small, light-colored blebs form spheroidal pellets that erode out of outcrops and locally cover the soil surface.

Figure 11. Spheroidal pellets derived from the erosion of variolitic andesite in the Reinecker Ridge Volcanic Member of the South Park Formation.

Another distinctive subunit within the Reinecker Ridge Volcanic Member was termed “red and white breccia” by Stark and others (1949). This subunit is a true volcaniclastic breccia. The matrix of this fragmental rock is dark red to reddish brown, consisting of tiny lithic fragments, broken crystal fragments, and abundant hematite. Clasts are whitish-gray, angular, equidimensional fragments of dacite that range from approximately 0.05 to 3.0 inches in diameter. Along with plagioclase, both biotite and hornblende phenocrysts are present in the dacitic clasts of “red and white breccia”. Biotite was not observed in the trachyandesite or andesite flows and breccias. Biotite grains are commonly surrounded by a halo of fine-grained hematite. Outcrops of “red and white breccia” were too irregular and scattered to map separately in the available time. The subunit appears to occur as relatively thin lenses or layers within the overall package of volcanics. Stark and others (1949) called this subunit a tuff-breccia.

Thin sections of samples from flows and flow breccias show that phenocrysts comprise 40 to 60 percent of the rock in a fine, aphanitic groundmass. The typically small (0.03 to 0.08 inch) phenocrysts consist of plagioclase (20 to 35 percent), hornblende (less than 1 to 35 percent), augite (0 to 28 percent), and opaque minerals (1 to 4 percent). No quartz phenocrysts were observed. K-spar staining of the thin sections shows that the groundmass of hornblende-bearing trachyandesite flows contains potassium feldspar, but potassium feldspar is not present as phenocrysts. The groundmass is commonly hematite rich. Hematite, sometimes with chlorite, locally fills small, spheroidal vugs. Plagioclase phenocrysts are zoned and locally show evidence of very rapid crystal growth. Plagioclase is commonly partially altered to sericite. Hornblende phenocrysts are lath shaped and locally as long as 0.3 inches. In thin section, hornblende phenocrysts are usually patchy green and red-brown and are typically partly altered to chlorite and iron oxides. The rarer augite-bearing andesite flows are harder, denser, and less altered than the hornblende-bearing trachyandesites and contain little or no potassium feldspar in the groundmass.

Whole rock geochemical analyses of seven samples of Reinecker Ridge volcanics (table 3) show that the unit varies considerably in composition. The samples show two diffuse clusters when plotted on a total alkali-silica diagram (fig. 12), one in the trachyandesite field, the other in the dacite to trachydacite field. A single sample of a dark-gray, dense, augite-bearing flow of limited areal extent plots squarely in the andesite field, away from the more alkaline clusters (sample JP325, table 3). No distinct vertical chemical trend through the sequence of volcanics was observed as was earlier postulated by Stark and others (1949). Both trachyandesite and the more silicic dacite appear to occur throughout the sequence, sometimes in adjacent flows or breccias. The red and white hematitic breccia (sample JK354, table 3), which is generally found in the upper parts of the sequence, is the most silicic of the seven analyzed samples.

The Reinecker Ridge Volcanic Member forms steep-sided ridges that rise from the flat floor of South Park. Erosion of the unit produces an abundance of angular cobble- and pebble-sized detritus that mantles the lower slopes of ridges as colluvium and fan alluvium. This debris everywhere obscures contacts with the adjacent and underlying Pierre Shale. Nowhere was the contact with the Pierre Shale observed directly. On the basis of the few outcrops where volcanic layering is discernible, the volcanic rocks appears to dip gently to moderately east and northeast but display many local variations that may reflect the influence of paleotopography during extrusion, and deformation due to faulting after deposition. The generally east-dipping volcanic sequence thins from an estimated maximum of 1,000 to 2,000 feet near Como to 500 to 900 feet along the southern boundary of the Como quadrangle on Reinecker Ridge. The Reinecker Ridge Volcanic Member continues to thin southward until it pinches out completely 7.8 miles south of the Como quadrangle (Bryant and others, 1981b). Three water wells have been drilled in the NE¼ and SE¼ of sec. 17, T9S, R76W on the high, northern part of Reinecker Ridge. The wells range from 300 to 652 feet in depth. According to our interpretations of drill logs on file with the Colorado Division of Water Resources, all of these wells remained in Reinecker Ridge volcanics for their entire length and did not encounter Pierre Shale. The lowest elevation penetrated by the deepest well is approximately 9,600 feet. The anomalously wide area of exposure of Reinecker Ridge volcanics directly south of U.S. Highway 285 may be due, in part, to repetition of volcanic strata by faulting.

Sample		SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	Cr2O3	TiO2	MnO	P2O5	SrO	BaO	LOI	Total
TKsr	JP300	54.01	16.95	7.5	5.35	3.13	4.25	1.83	<0.01	0.71	0.15	0.42	0.14	0.11	5.16	99.7
TKsr	JP301	60.4	16.43	5.62	4.32	1.67	3.19	3.24	<0.01	0.64	0.2	0.39	0.05	0.12	3.35	99.6
TKsr	JP325	54.5	16.16	9.67	7.85	4.46	2.83	1.02	0.01	0.95	0.18	0.34	0.07	0.09	1.7	99.8
TKsr	JP392	61.28	16.24	5.79	4.43	1.85	3.6	2.52	<0.01	0.67	0.17	0.37	0.08	0.12	2.5	99.6
TKsr	JK354	63.75	15.8	5.94	3.18	0.57	2.68	4.74	<0.01	0.59	0.12	0.39	0.06	0.14	1.67	99.6
TKsr	JK363	54.95	18.14	8.95	5.09	1.32	4.91	2.61	0.01	0.99	0.14	0.76	0.06	0.09	1.52	99.5
Tsc (rhyolite clast)	JK365	72.6	14.95	1.39	1.84	0.24	3.44	4.03	<0.01	0.14	0.06	0.06	0.07	0.15	0.72	99.7
TKsr	JK430	54.59	17.42	8.5	3.44	3.23	5.82	2.64	<0.01	0.91	0.17	0.49	0.08	0.11	2.06	99.5

Table 3. Whole-rock analysis of selected rocks of the Reinecker Ridge Volcanic Member of the South Park Formation. Analyses were performed by ALS Chemex, Sparks, NV. using the XRF method. Values listed in weight percent. See geologic map for sample locations.

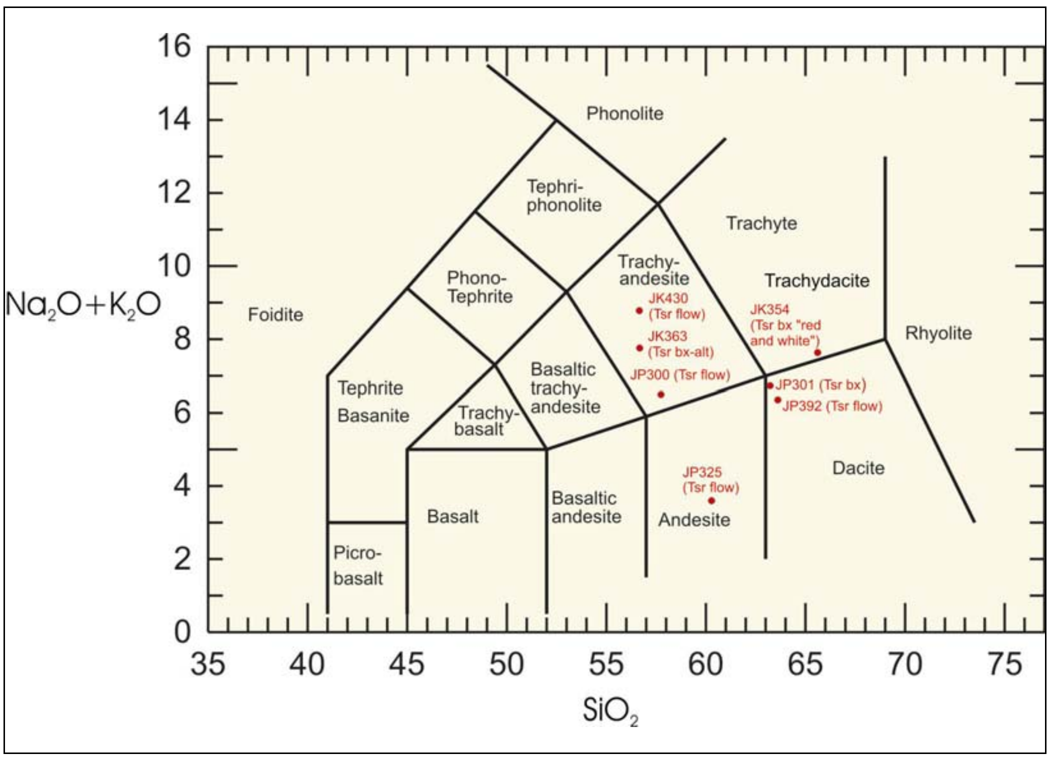

Figure 12. Total alkali-silica diagram of samples collected from the Reinecker Ridge Volcanic Member in the Como quadrangle. Classification scheme by Le Bas and others (1986). Values are in weight percent.

MESOZOIC AND PALEOZOIC SEDIMENTARY ROCKS – Mesozoic and Paleozoic rocks in the Como quadrangle strike generally north, dip 20° to 50° to the east with few exceptions, and range from Pennsylvanian to Cretaceous in age. Triassic rocks are absent from this sequence within the quadrangle, although they have been recognized in outcrop near Boreas Pass just a few miles north of the quadrangle (Poole and Stewart, 1964).

The oldest sedimentary stratigraphic units are in the western part of the quadrangle and include the Pennsylvanian to Permian rocks of the Minturn and Maroon Formations. The contact between these two formations is debatable. Recent mapping in areas near the Como quadrangle (Kellogg and others, 2002; Scott and others, 2002; Widmann and others, 2003) relied on the definition set forth by Tweto (1949), which sets the contact at the top of the Jacque Mountain Limestone Member of the Minturn Formation. In central and northwestern Colorado, this member is typically the last significant (widely mappable) limestone bed of the Pennsylvanian-Permian stratigraphic sequence. Unfortunately, recognition of the Jacque Mountain Limestone Member is difficult outside the type locality. DeVoto (1980) recognized this problem but still concluded that the Minturn/Maroon contact is best represented by the Jacque Mountain Member or its correlative time-stratigraphic datum. This led Widmann and others (2004) to map the Minturn/Maroon contact in the adjacent Alma quadrangle at the uppermost limestone bed with the caveat that this stratigraphic horizon may or may not coincide with that of the Jacques Mountain Limestone but that it does represent, at least locally, a change in depositional environment.

In the South Park basin, Stark and others (1949) placed the Minturn/Maroon contact at the top of what they termed the Coffman conglomerate. This unit is much lower in the section than the Jacque Mountain Limestone Member. If used as the contact, then numerous limestone beds are included in the Maroon Formation and the contact ignores changes in the depositional environment. In the Antero basin area south of the Como quadrangle, DeVoto (1980) showed the contact much higher in section, yet still depicted a few limestone beds within the Maroon Formation on some schematic cross sections. It appears then, that while locally very useful, the uppermost limestone bed is not necessarily always the best indicator of the Minturn/Maroon contact. A detailed analysis of faunal evidence in the numerous limestone beds in the southwestern part of the quadrangle may serve to better constrain the contact between the two formations. In the meantime, the contact is herein drawn at the top of the uppermost mappable limestone bed as was done in the adjacent Alma quadrangle (Widmann and others, 2004). The few limestone beds mapped within the Maroon Formation on the east flank of Mount Silverheels are thin (less than 10 to 12 inches) and highly discontinuous and likely represent only localized marine (or lacustrine) incursions.

Overlying the Maroon Formation is the Garo Sandstone. This formation lacks the fossils and other types of datable material that are needed to accurately determine age, and its stratigraphic relationships with overlying and underlying rocks are not well understood. Stark and others (1949) recognized an unconformity both above and below the Garo Formation. They ruled out correlation with Triassic rocks, but found similarities between the Garo and Jurassic Entrada Formation, which led them to tentatively assign the Garo Formation to the Jurassic. However, DeVoto (1965a, 1972, 1980) favored a Permian interpretation, citing an "excellent" exposure south of the Como quadrangle where facies relationships indicated that the Garo was deposited at the same time that nearby shales of the Maroon Formation were deposited. Herein, the Garo Formation is assigned to the Permian.

The remainder of the stratigraphic sequence in the quadrangle is fairly straightforward. The Jurassic Morrison Formation rests unconformably on the Garo Sandstone. An unconformity separates the Morrison Formation from the overlying, hogback-forming, Upper Cretaceous Dakota Sandstone. The Benton Group is conformable to the Dakota Sandstone and includes the black shale and minor limestone sequence between the Dakota Sandstone and Niobrara Formation. Exposures of this unit were so poor that delineating units within the Benton Group (Carlisle Shale, Greenhorn Limestone, and Graneros Shale) as mapped in the adjacent Jefferson and Milligan Lakes quadrangles (Barker and Wyant, 1976; Wyant and Barker, 1976) was not possible. Barker and Wyant (1976) and Wyant and Barker (1976) noted a questionable unconformity between the Upper Cretaceous Niobrara Formation and the underlying Benton Group. Limited exposure of these formations in the Como quadrangle prohibited observation of this contact. The Upper Cretaceous Pierre Shale predominates in the eastern half of the quadrangle. A small outcrop of Upper Cretaceous Fox Hills Sandstone is exposed beneath alluvium (Qa4) in a road cut on U.S. Highway 285 roughly 0.3 miles northeast of the Como turnoff, but this formation is otherwise not observed to crop out within the quadrangle. Near the Como coal mines, only a few fragments of highly weathered sandstone attest to Fox Hill Sandstone underlying the surficial deposits in that area. The Upper Cretaceous Laramie Formation is nowhere exposed in outcrop, but Laramie sandstone and coal fragments are readily observable in the mine waste piles of the Como coal mines, indicating this formation is present beneath the surface.

Kl **Laramie Formation, undivided (Upper Cretaceous)—** Though nowhere exposed in outcrop, blocks of the Laramie Formation are present in the waste piles of the Como coal mines. Here, light-gray, fine-grained sandstone riddled with small, spherical iron concretions predominates (fig. 13). Coal fragments in the waste piles were derived from a 5- to 6-foot-thick coal seam within the Laramie Formation that was worked in the late 1800s or early 1900s (Washburne, 1910). Elsewhere in South Park, Stark and others (1949) also noted shale and volcanic tuff in the Laramie Formation. Thickness of this unit is uncertain, but it probably does not exceed 150 feet in the Como quadrangle. A sandstone unit previously mapped as Laramie Formation near Peabody's (Stark and others, 1949) is herein reassigned to the Pierre Shale on the basis of its similarity to sandstone at the base of the Pierre Shale at Red Hill Ranch and the observed stratigraphic continuity (Morrison Formation to Pierre Shale, see geologic map plate) between the Fortune Placer Mine to the north and Peabody's site.

Figure 13. Light-gray, fine-grained sandstone of the Laramie Formation. Note the abundance of iron oxide concretions.

Kf **Fox Hills Sandstone (Upper Cretaceous)—** Single small area mapped only in a road cut on Highway 285 roughly 0.3 miles northeast of the Como turnoff. Additionally, a few fragments of probable Fox Hill Sandstone were found (fig. 14) just west of the Como coal mines. However, bedrock is obscured here by surficial deposits. The Fox Hills Sandstone, as described by Stark and others (1949), is a light-gray to yellow and orange-brown, well-sorted, fine-grained, poorly cemented sandstone. Cross-bedding and concretions are common. In the adjacent Milligan Lakes quadrangle, the sandstone is locally sparsely fossiliferous (Wyant and Barker, 1976). Thickness of the sandstone within the quadrangle is unknown; south of the quadrangle the Fox Hills Sandstone reaches 350 feet (Stark and others, 1949).

Figure 14. Orange-brown fragments of the poorly cemented, fine-grained Fox Hills Sandstone.

Kp **Pierre Shale (Upper Cretaceous)—**Predominantly medium-gray to black, fissile shale with zones of brownish-gray calcareous sandstone or sandy shale. Shale is best exposed in drainages or cut slopes. Bedding orientation within the shale is highly variable and often difficult to discern; bedding is best defined by thin, sandy layers less than an inch or two thick. Fossils are generally scarce except for a few notable horizons. Near Red Hill Ranch, numerous fossils (primarily *baculites* and *inoceramus*) are found in the shale exposed in the SE¼ of sec. 12, T. 9 S., R. 77 W. Other horizons are marked by abundant elongate concretions of hard, dense calcareous and non-calcareous shale commonly 4 to 8 inches and up to one foot in maximum dimension. These concretions exhibit spheroidal weathering and, when broken apart, may yield fossil shell fragments (fig. 15). Near the Bald Mountain stock (Tqp) in the northeast part of the quadrangle, Pierre Shale is contact metamorphosed and locally contains pyrite nodules with quartz halos.

Figure 15. Concretions in the Pierre Shale exhibit spheroidal weathering and commonly contain shell fragments (white diagonal lines in concretion halves of lower picture).

Shale at the base of the formation is conformable with the underlying Niobrara, and near Red Hill Ranch, the contact is expressed as a slight break in topography and a change in vegetation from aspen trees to prairie grasses. The shale quickly gives way to a zone of sandy shale and fine- to medium-grained, locally calcareous sandstone roughly 100 to 150 feet thick well exposed in the SE¼ of sec. 12, T. 9 S., R. 77 W. Carbonized plant fragments are common and a few burrow horizons were observed. This same sandy unit is also exposed near Peabody's site where it has been metamorphosed by the nearby quartz monzonite intrusion (Tqp). Here, the sandstone is very hard, locally calcareous, and also carbonaceous. One horizon contains numerous spherical iron oxide concretions up to about 0.25 inches in diameter. A few shaly layers are interbedded throughout the sandy unit.

Total thickness of the Pierre Shale is uncertain. Although the shale underlies most of the eastern half of the quadrangle, the section has undoubtedly been repeated through faulting. Stark and others (1949) reported a speculative thickness of less than 3,000 feet, which seems unusually thin, for the South Park area. In a report on oil and gas exploration in South Park, cross sections tied to well logs just south of the Como quadrangle indicate that the Pierre Shale is between 4,200 and 4,500 feet thick (Clement and Dolton, 1970). Within the Como quadrangle, cross section B-B' at the south edge of the quadrangle indicates the shale is at least 5,300 feet. Since the upper part of the section is missing in this area, the total estimated thickness is likely closer to the 6,000 feet observed in the adjacent Jefferson and Milligan Lakes quadrangles (Barker and Wyant, 1976; Wyant and Barker, 1976).

Kn **Niobrara Formation (Upper Cretaceous)—**Includes the upper Smoky Hill Shale Member and the lower Fort Hays Limestone Member, which are not mapped separately herein. The lower member is unconformable with the underlying Benton Group and consists of light-gray, chalky limestone roughly 40 to 50 feet thick. The upper member is medium-gray, hard, platy, calcareous shale that weathers to light gray or white and forms a distinctive yellow soil (fig. 16). A subtle though discernable break in topography marks where the limestone transitions to the overlying shale. Near Red Hill Ranch, this break in slope is also accompanied by a change in vegetation from grasses and Gambel's oak to aspen trees. Exposures of the limestone and shale are minimal; both are mapped on the basis of soil color, rock chips, and stratigraphic position. Colluvium derived from or down slope of the Niobrara Formation often exhibits calcium carbonate coatings. Total thickness is about 350 feet.

Figure 16. Yellow soil characteristic of the Niobrara Formation in the Como quadrangle.

Kb **Benton Group (Upper Cretaceous)—**Very poorly exposed, dark-gray to black, fissile shale, dark-gray fossiliferous limestone, and dark-brownish-gray fetid sandstone. Shale in the Benton Group is typically darker in color than the Pierre Shale, is widely calcareous, and may contain thin streaks or crystals of gypsum. Bentonite beds over two feet thick were reported in the Benton Group south of the quadrangle (Stark and others, 1949). This unit rests conformably on the Dakota Sandstone. The contact is well marked by a sharp break in topography from the ridge-forming Dakota Sandstone to the low, rolling slopes of the Benton Group. Overall thickness in the quadrangle is about 250 feet.

Kd **Dakota Sandstone (Lower Cretaceous)—**White to light-gray, fine- to medium-grained, well-sorted, ridge-forming quartzite and quartzose sandstone. Weathers white, orange-brown, or purplish-black. Locally, some beds are arkosic. Cross-bedding is ubiquitous throughout and borrows are common. Thin beds of black shale and light-colored clay are found in the middle part of the formation and can be seen in the exposure at Red Hill Pass. Lenses of conglomerate occur at the base of the formation. Conglomerate clasts are typically composed of quartz and are pebble sized and well rounded. Rip-up clasts derived from the underlying Morrison Formation were observed near the base of the formation. These angular clasts are also relatively small (only a few inches long or less) and are typically composed of chert, limestone, and clayey shale. This conglomeratic basal unit is well exposed on Little Baldy Mountain where it has been intensely metamorphosed by the nearby quartz monzonite (Tqp) stock (fig. 17). Average thickness of the Dakota Sandstone is 400 to 450 feet.

Figure 17. White quartz pebbles contrast with the greenish-gray, fine-grained matrix of the metamorphosed basal conglomerate of the Dakota Sandstone on Little Baldy Mountain.

Jm **Morrison Formation (Upper Jurassic)—**Multi-lithologic unit containing fine- to medium-grained sandstone, sandy shale, shale, siltstone, and limestone. This unit weathers to various shades of greenish-gray, red, orange, and yellow. Discontinuous beds and lenses of limestone less than 2 feet thick are prevalent in the lower part of the formation. Limestone and shale units are typically medium to dark gray but commonly weather to brown or light gray. The field term “M&M unit” was coined to designate areas where small colluvial fragments showed a characteristic weathering pattern that is dark on the inside and colorful on the outside. The formation grades progressively from limestone, shale, and mudstone at its base to interbedded shale and well-sorted, fine-grained, quartz-rich sandstone near the top. On Little Baldy Mountain, the upper sandstones have been metamorphosed to quartzite and are virtually indistinguishable from the overlying quartzites of the Dakota Sandstone. The Morrison Formation is about 200 feet thick along Red Hill but is about 350 feet thick north of Little Baldy Mountain.

Pg **Garo Formation (Permian)—**Unit forms the red cliffs observed at Red Hill Pass. Red to pink, well-sorted, fine- to medium-grained, calcareous, quartz-rich sandstone and, locally, conglomerate. Quartz grains are generally rounded and are frosted where more coarse grained.   The Garo Formation differs from the Maroon Formation in that the Garo Formation is generally non-micaceous and is more calcareous. Cross bedding and ripple marks are common and some beds are heavily bioturbated. “Nodule beds” may be representative of mud or fecal pellets deposited in bioturbated zones (fig. 18). Calcite and/or barite crystals are prevalent on fracture surfaces. Early reports assigned the Garo Formation to the Triassic or Jurassic Period on the basis of its stratigraphic position and similarity to Triassic redbeds or sandstones of the Jurassic Entrada Formation (Singewald, 1942; Stark and others, 1949). Stark and others (1949) noted unconformities both above and below the Garo Formation. However, DeVoto (1965a) reported an unconformity only above the Garo Formation. He also claimed there is conclusive evidence near Badger Spring (south of the quadrangle) that the Garo Formation was deposited at the same time as the upper part of the Maroon Formation, and that both are Permian in age. DeVoto’s theory was based on observed facies relationships and a Permian alga that was found in a dolomitic limestone 80 feet stratigraphically below the Garo Formation. Thesis work by Lozano (1965) in the Garo area supported the Permian age assignment put forth by DeVoto (1965a). Herein, the Garo Formation is considered to be Permian in age in accordance with DeVoto (1965a). However, we concede that more detailed work may be needed to fully constrain the age of the Garo Formation, although the lack of fossil evidence in this formation may be an obstacle. This unit is about 225 feet thick at Red Hill Pass, but it appears to thin and pinch out to the north near Selkirk Campground.

Figure 18. The Garo Formation at Red Hill Pass is riddled with calcite veins (upper photo). "Nodule Beds" consisting of possible remnant fecal pellets are ubiquitous in this formation (lower photo).

PꟼPm Maroon Formation (Lower Permian to Upper Pennsylvanian)—Predominantly light- to orange-red, fine-grained micaceous sandstone and thinly laminated siltstone and mudstone, pinkish-gray pebble- to cobble-conglomerate, and a few thin (less than one foot thick), discontinuous layers of dark-gray to reddish-gray limestone or limey siltstone and mudstone (labeled "*l*" on the geologic map). Sandstone beds are arkosic, highly micaceous, and commonly exhibit tabular and trough cross-stratification and sub-parallel laminations. Fine-grained sandstone predominates in the southern part of the quadrangle. Conglomerate is more prevalent in the northern part of the quadrangle. Clast lithologies in the conglomerate include granite, quartzite, gneiss, vein quartz, limestone, and sandstone. In the vicinity of Mount Silverheels and the Montgomery Gulch stock (Tqp), the Maroon Formation is intensely hornfelsed. Siltstone horizons have abundant epidote, chlorite, and iron oxide-stained interstitial clay and are typically dark-red or multicolored (greenish gray, bright green, purple, fleshy pink, pinkish gray, and black) (fig. 19). Sandstone layers are generally dark red, whereas conglomerate ranges from pinkish red to pinkish gray but is locally bleached white. The thin, discontinuous limestone units locally contain skarn minerals such as epidote, calcite, and andradite garnet. Near Iron Mountain, a thin, discontinuous limestone bed has been extensively altered to magnetite and now has an iron concentration of 43.6 percent. Other ore minerals at this location include sphalerite, chalcopyrite, and pyrrhotite. Thickness of the Maroon Formation in the western part of the quadrangle is approximately 3,300 feet, but the formation likely thins eastward as it is absent in the adjacent Milligan Lakes quadrangle (Wyant and Barker, 1976).

Figure 19. Multicolored hornfelsed siltstone of the Maroon Formation near Iron Mountain in the northwest corner of the quadrangle.

Pm **Minturn Formation (Middle Pennsylvanian)—**Predominantly buff or pinkish-gray, arkosic, micaceous pebble- and cobble-conglomerate and dark-red siltstone and fine- to coarse-grained sandstone interbedded with dark-gray limestone beds (some mapped separately as Pml, described below) typically less than about 10 feet thick. Sandstone beds tend to be planar where fine grained and trough cross-stratified where coarser grained. Conglomerate is anomalously abundant on the southeast flank of Mount Silverheels in the north half of sec. 27 in T. 8 S., R. 77 W. and may be indicative of a paleovalley or basin margin. Most of the conglomerate contains well-rounded to sub-angular pebble-size clasts in an arkosic sandy matrix. Locally, cobble-size clasts are abundant, particularly within deep (several feet) channels cut into underlying beds. The prevailing clast lithologies, listed in decreasing order of abundance, include: granite, quartzite, gneiss, vein quartz, limestone, and sandstone. The base of the Minturn Formation is not exposed within the quadrangle; total thickness exposed within the quadrangle is about 2,400 feet. Mapping on the adjacent Alma quadrangle (Widmann and others, 2004) suggests overall thickness of the Minturn Formation is more than 6,000 feet.

Pml **Limestone beds—**Includes limestone or dolomite beds interspersed throughout the Minturn Formation. Where fresh, limestone is nearly everywhere dark to medium gray. However, individual beds have weathered or been altered to gray, black, dark reddish gray, and tan. Limestone texture is micritic to fine grained. Fossil shell fragments were observed in a few limestone beds; thin section analysis suggests possible *echinodermata* and *gastropoda*, though an extensive study was not undertaken. Immediately northwest of the quadrangle the uppermost limestone beds in the Minturn Formation are contact metamorphosed to hornfels by the Montgomery Gulch stock and are almost completely replaced by epidote, calcite, chlorite, and andradite garnet. Thin section analysis indicates earliest crystal growth was of long, prismatic crystals of actinolite-tremolite. These crystals were subsequently replaced by chlorite and calcite in a preferred orientation along the long axis of the host crystal. Calcite and garnet were also observed locally as vein material. Limestone beds are typically 2 to 10 feet thick but may range up to about 40 feet thick.

STRUCTURAL GEOLOGY

SOUTH PARK

The Como quadrangle is situated in the northern part of South Park, a generally north-south elongated, intermontane topographic and structural basin in central Colorado. The basin is bound on the west by the Mosquito Range, on the north and east by mountains of the Front Range and the Elkhorn thrust, and on the south by the Thirtynine Mile volcanic field (fig. 1). The synclinal axis plunges to the south. Several north-south-trending intra-basinal ridges interrupt the low valley floor. Within the quadrangle, Reinecker Ridge and Red Hill are two such ridges (fig. 20). The ridge at Red Hill is a hogback formed by the resistant Dakota Sandstone. Reinecker Ridge is underlain by Upper Cretaceous and Paleocene volcanic and conglomeratic rocks, which are more resistant to weathering than the surrounding Pierre Shale.

Faults control the east side of the ridge. Although much of the present day topography in South Park is Laramide or younger, the geologic history of the basin extends much farther back in time.

Figure 20. View of South Park looking south from the summit of Little Baldy Mountain. Reinecker Ridge (left) is a resistant landform underlain by Upper Cretaceous and Tertiary volcanic and conglomeratic rocks of the South Park Formation. Red Hill (right) is a hogback formed by the Dakota Sandstone and Garo Formation. Highway 285 can be seen winding through the gap in Red Hill. Rock debris in the foreground is characteristic of the felsenmeer deposits that mantle many of the slopes in the quadrangle.

Precambrian rocks are exposed along both the western and eastern margins of South Park, but in the central part of South Park, Precambrian rocks are buried beneath several thousand feet or more of Paleozoic and Mesozoic sedimentary strata. Cambrian to Mississippian rocks are present on the western margin of South Park along the east flank of the Mosquito Range; these rocks were removed from the eastern margin of the basin during pre-Pennsylvanian erosion. During Pennsylvanian and Permian time, the South Park region was part of the central Colorado trough, a major structural depression extending from south-central Colorado to northwestern Colorado. The thick sequence of Pennsylvanian-Permian rocks along the western side of South Park was shed primarily eastward from uplifted highlands to the west (possibly an ancestral Sawatch uplift; DeVoto, 1972). These rocks thin eastward and onlap Precambrian basement rocks beneath the cover of South Park; they are absent along the eastern margin of South Park. There is no record of Triassic or early Jurassic sedimentation within the South Park basin, although Triassic rocks crop out at Boreas Pass just north of the northern margin of the basin. The Morrison Formation was deposited during late Jurassic time. As Colorado gradually became part of a vast continental depression, the Cretaceous Western Interior Seaway began to inundate most of Colorado. Eolian and beach sands of the Dakota Sandstone were quickly transgressed by several thousand feet of marine mud and sand, represented by the Benton Group, Niobrara Formation, and Pierre Shale. Renewed orogenesis (the Laramide orogeny) that began towards the end of the Cretaceous again elevated Colorado and forced an eastward withdrawal of the great Cretaceous sea leaving behind the regressive sands of the Fox Hill Sandstone and coastal plain deposits of the Laramie Formation. The Sawatch Range and Front Range emerged and the structural basin of South Park was largely developed. Thick deposits of synorogenic strata were shed into the South Park basin during this time. Raynolds (2003) reported more than 7,800 feet of volcanic flows, volcanoclastic debris, and erosional sediments were emplaced contemporaneously with Laramide uplift and associated subsidence of the South Park basin. Widespread igneous activity was also concurrent with orogenesis and resulted in the emplacement of numerous generally calk-alkaline stocks, plugs, dikes, and sills. A period of quiescence followed the Laramide orogeny, during which time erosion caused basin areas to be filled and many highland areas to be beveled to low hills. A pulse of volcanic activity formed the Thirty-nine Mile volcanic field (~29 to 35 Ma; Epis and Chapin, 1968), which defines the southern margin of the South Park basin. Modern South Park has been is the product of renewed Miocene and younger rifting, uplift, and erosion. Several Miocene and younger faults are documented in the southern part of South Park, the youngest of which last moved 30 to 15 ka (Widmann and others, 2002).

BEDDING and FOLDS

On the whole, stratigraphic layering in the Como quadrangle consistently strikes north-south and dips eastward 35° on average. The Dakota hogback at Red Hill and the numerous Tertiary sills on the flank of Mount Silverheels illustrate this trend clearly. Changes in bedding orientation were only observed near faults, the Bald Mountain stock, and the intrusion at Little Baldy Mountain (Tqp). A broad, asymmetrical anticline and tight syncline pair are well developed in the north-central part of the quadrangle. The structure is likely a Laramide-age fold that formed prior to the Eocene intrusive bodies in the area. The fold, termed the Boreas Pass-Little Baldy Mountain fold by Singewald (1942), plunges to the south and is best delineated by the ridge-forming Dakota Sandstone, which crops out on either side of Tarryall Creek near Peabody’s site (fig. 21). Near the mouth of Silverheels Creek, the west limb of the anticline is faulted, and highly silicified Dakota Sandstone forms a near-vertical fin (fig. 22). The fold dies out in Pierre Shale to the south and is cut out by faulting to the north. Both limbs are cut by strain accommodation faults; the eastern limb is truncated by the Bald Mountain stock. The structure is further complicated by additional faulting and the intrusion at Little Baldy Mountain (Tqp), which displace Dakota Sandstone in the nose of the anticline by at least 1,000 feet.

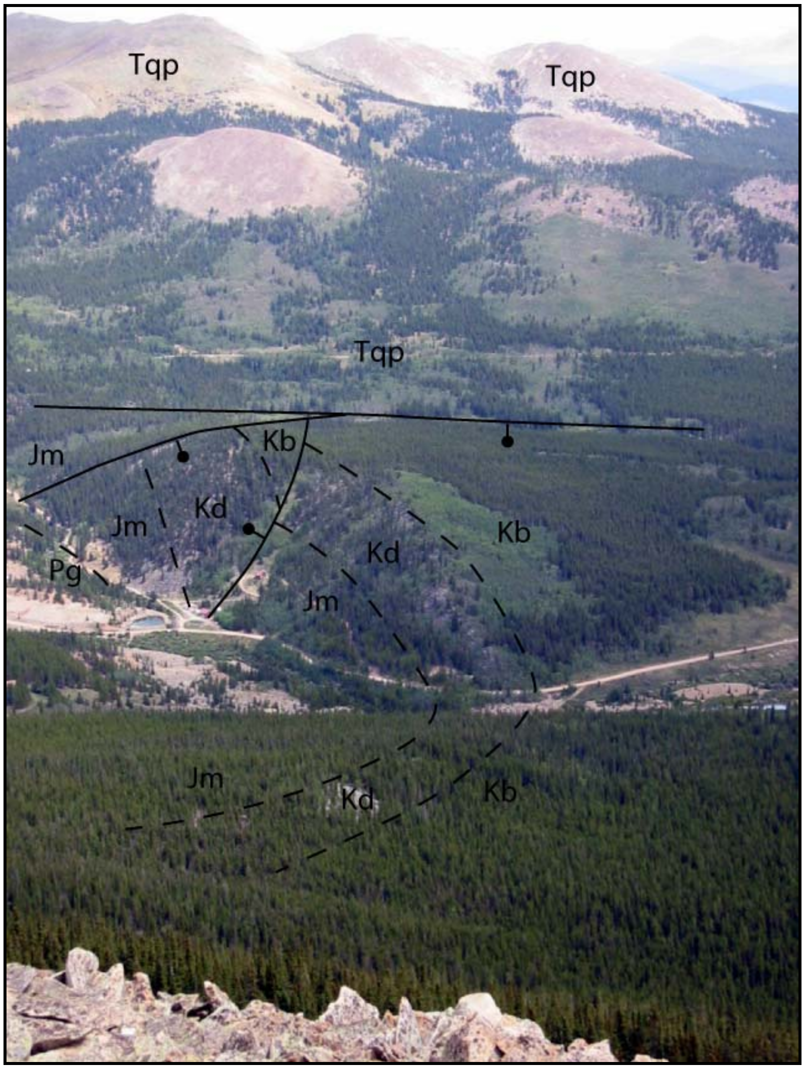

Figure 21. Generalized bedrock geology of the Boreas Pass-Little Baldy Mountain fold. Faults cut the eastern limb, which is truncated by the Bald Mountain stock (Tqp). View is looking northeast from summit of Little Baldy Mountain.

Figure 22. Silicified and faulted Dakota Sandstone on the west limb of the Boreas Pass-Little Baldy Mountain anticline forms a ridge, or fin, near Silverheels Creek. Geologist J. Keller climbs to inspect more closely.

In the southern part of the quadrangle, previous workers have showed a syncline in the Upper Cretaceous and Paleogene South Park Formation at the northern end of Reinecker Ridge (e.g., Sawatsky, 1967; Clement and Dolton, 1970). Our mapping does not support this structure, at least within the younger coarse conglomeratic member of the South Park Formation (Tsc). Fresh excavations in the area indicate that sedimentary layering in the conglomeratic unit strikes north-south and dips about 30° to the east. No evidence of west- or south-dipping South Park Formation sedimentary strata was found. Volcanic layering in the Reinecker Ridge Volcanic Member of the South Park Formation is generally east dipping; local variations in dip are interpreted to be due to the influence of paleotopography during extrusion and deposition of the flows. Bedding attitudes in Pierre Shale directly east of Reinecker Ridge define a pair of folds that strike north-south. Attitudes in Pierre Shale near the northwest and northeast flanks of Reinecker Ridge suggest that the volcanics may have been deposited within a preexisting syncline in the shale.

FAULTS

The most striking fault pattern in the Como quadrangle is defined by a series of northwest-trending faults. These faults are Laramide and younger as indicated by cross-cutting relationships with the presumed Laramide-age Boreas Pass-Little Baldy Mountain fold and numerous Eocene porphyries. Very few of these faults are readily visible in outcrop. Most are mapped on the basis of stratigraphic offset, local joint patterns, and topographic slope breaks.

South Park Fault

Numerous references have been made to the South Park fault, a generally north to north-northwest-oriented reverse or thrust fault extending along most of the eastern margin of Reinecker Ridge (Clement and Dolton, 1970; Stark and others, 1949; Washburne, 1910). Drill logs south of the quadrangle indicate the fault dips moderately to the east and brings Pierre Shale into contact with younger Cretaceous rocks and/or deposits of the Upper Cretaceous and Paleogene South Park Formation (Clement and Dolton, 1970). Clement and Dolton (1970) interpreted the structure to be a thrust fault with several thousand feet of displacement and an associated west-verging fault propagation fold in overlying Cretaceous rocks (fig. 23). Stark and others (1949) depicted the fault to be a moderate- to high-angle reverse fault. Geophysical studies by students from the Colorado School of Mines suggest the South Park fault and other similar faults in the area are reverse in nature and dip 45° or more to the east (e.g., Sawatsky, 1967; Shoffner, 1974).

Within the Como quadrangle, the trace of the South Park fault is difficult to discern. Washburne (1910) and Stark and others (1949) mapped the fault as truncating the northeast margin of Reinecker Ridge and extending to the northwest along Trout Creek. Bryant and others (1981a; 1981b) followed suit and further extended the fault northward over Boreas Pass towards Bald Mountain. They termed this extensive structure the Boreas Pass-South Park fault zone and concluded there had been significant pre-Laramide movement on the fault but that the most recent fault activity had occurred after deposition of the South Park Formation (Upper Cretaceous and Paleogene) and before emplacement of the Bald Mountain stock (41 Ma). Clement and Dolton (1970) showed the South Park fault as instead continuing north through Como and chose to curve the northwest-trending fault in Trout Creek down to the south and end it on the west side of Reinecker Ridge. DeVoto (1972) similarly extended the South Park fault through Como. Alluvial deposits conceal the bedrock between Reinecker Ridge and Como, making it virtually impossible to trace through-going faults without geophysical or well log data. Additionally, colluvial debris masks the stratigraphic and structural relationships on the east side of the ridge and the nature of faulting (normal or reverse) cannot clearly be deduced. Wide variations in dip angle of the Pierre Shale east of the ridge may be evidence of fault-propagation folding over a west-verging reverse fault in that area. Ultimately, we have chosen not to map any one particular fault in the quadrangle as the South Park fault. Rather, we feel that the South Park fault as it exists to the south dies out or splits and transfers strain to northwest-striking faults near the northern margin of Reinecker Ridge.

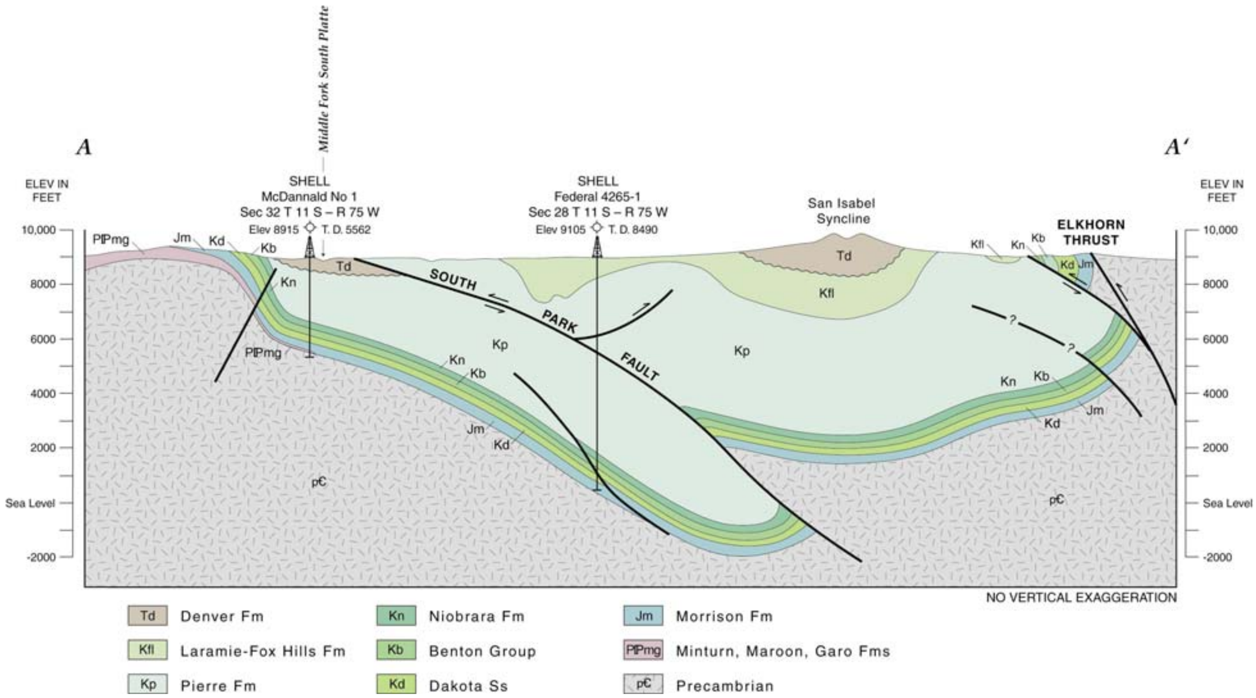

Figure 23. Cross section drawn on the basis of well log data indicates significant displacement along the South Park fault south of the Como quadrangle (modified from Clement and Dolton, 1970). Within the Como quadrangle, the South Park fault is not exposed, but stratigraphic relationships suggest it is a high-angle structure.

Farther to the north and in the vicinity of Como, faulting is apparent despite minimal bedrock exposures. The coal mined from the east-dipping (45°) Cretaceous Laramie Formation near Como was reportedly truncated by an east-dipping fault at a depth of about 300 feet (McConnel, 1945). Unfortunately, no other information on the orientation of bedding or the fault was provided in the report. Examination of surface materials and mine waste indicate a repetition of strata in this area. Pierre Shale and fragments of the Fox Hill Sandstone were found southwest of the Como coal mines. Pieces of the Laramie formation were found along a northwest strike in line with the coal mines. The Pierre Shale was again found northeast of the mines. Additional structures are needed to explain the apparent juxtapositioning of Pierre Shale against the younger Laramie Formation. Stark and others (1949) interpreted these relationships as a syncline (the Como syncline). Our field mapping does not support this structure because Pierre Shale was found in outcrop (road cut and well exploration pit) where Fox Hill Sandstone had previously been mapped by Stark and others (1949) and no evidence of Fox Hill Sandstone or Laramie Formation was found beyond the immediate vicinity of the coal mines. It is our interpretation that a west-verging reverse fault, or series of such faults, brings Pierre Shale into contact with the Laramie Formation near the Como coal mines.

<u>Northwest Faults</u>

Outside of the Reinecker Ridge and Como areas, most northwest-striking faults are normal and several show evidence for movement that is post-Eocene or younger. The faults in Tarryall and North Tarryall Creeks form a northwest-trending, down-dropped block that cuts diagonally across and offsets the Boreas Pass-Little Baldy Mountain fold by several hundred feet. While some of this movement may have taken place contemporaneously with or shortly after Laramide development of the fold structure, most of the movement probably occurred in conjunction with or following intrusion of the Bald Mountain stock and other intrusive bodies in the area (syn- or post-41 Ma). Normal faults in the southwest quarter of the quadrangle also follow a northwest structural grain and are considered to have moved during or since Eocene time. This is evidenced at a few localities where faults offset monzonite porphyry (Tmp), which is thought to be only slightly older than quartz monzonite of the Bald Mountain stock (about 41 Ma; Bryant and others, 1981a). Displacement on these faults is typically less than about 50 feet.

Other Faults

Strain accommodation faults associated with the Boreas Pass-Little Baldy Mountain fold are variably oriented. The complexity of this deformation zone is only hinted at on the accompanying map plate. While the resistant Dakota Sandstone is not generally difficult to trace, surrounding strata are not as well preserved. The lack of good exposure limits the degree of detail that can be achieved in this particular area. Other faults on Little Baldy Mountain are shallow structures that appear to affect only the Morrison and Dakota Formations. These faults formed contemporaneously with and in response to the quartz monzonite porphyry intrusion (Tqp) on the north side of Little Baldy Mountain. The north-striking fault on the west flank of Little Baldy Mountain may have originated during Laramide time the under intense deformational strain that formed the Boreas Pass-Little Baldy Mountain fold. This fault may also have been activated (or reactivated) to accommodate the Little Baldy Mountain intrusion (Tqp). Displacement on this structure is over 1,400 feet.

Numerous east-west-oriented fracture surfaces were observed in the Maroon Formation (PIPm) and intrusive sills (Tmp) on the north flank of Mount Silverheels above Montgomery Gulch (fig. 24). Offset along these fractures ranges from only a few inches to several tens of feet. While no fault could be clearly identified either on the valley floor or wall, the abundance of the fractures clearly indicates a structural zone of some significance. Therefore, a fault is tentatively drawn roughly coincident with Montgomery Gulch and slightly oblique to the trend of the numerous fracture surfaces. This fault, and another northwest-trending fault in Little French Gulch, may represent the structural boundaries of the Montgomery stock.

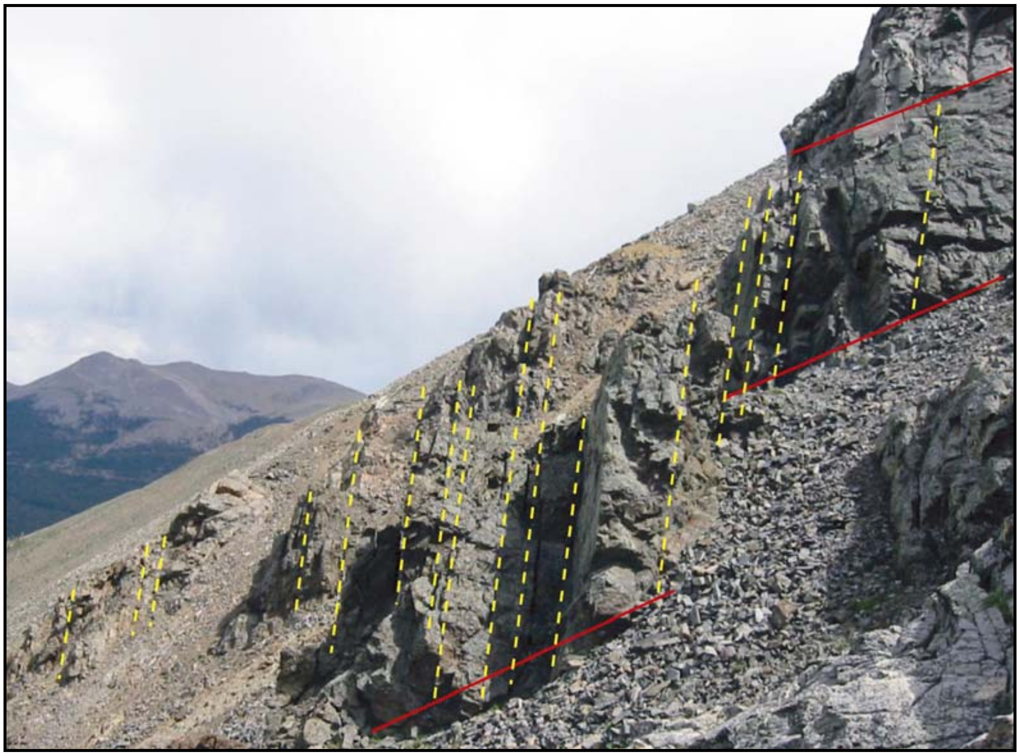

Figure 24. View looking east from the northern flank of Mount Silverheels. Sedimentary rocks of the Maroon Formation and Tertiary sills dip 30° to 50° east (red lines). Numerous east-striking fractures dip 80° to 90° north (yellow dashed lines). Offset along fracture surfaces ranges from a few inches to a few tens of feet. Distance between upper two red lines is about 10 feet.

OTHER STRUCTURES

In the southwestern part of the quadrangle, more than a dozen limestone beds were observed in the Minturn Formation; most could be traced over 1.5 miles. North of Crooked Creek, that number is reduced to only a few. Accompanying this lithologic break is a change in bedding orientation, noted particularly immediately south of Crooked Creek. As discussed previously, the South Park region was part of the central Colorado trough during Pennsylvanian-Permian time. As such, it was subject to deposition of thick sequences of shale, conglomerate, sandstone, and siltstone. Intermittently, marine waters flooded the area and carbonate beds were deposited. The anomalously high number of limestone beds in the southwestern part of the quadrangle suggests the area was once a sub-basin within the central Colorado trough and was thus more frequently inundated by marine waters. The observed change in strike near Crooked Creek takes place primarily in coarse-grained to conglomeratic channel sands typical of many basin margins (see cross sections in DeVoto, 1965b). The limestone beds accordingly pinch out or are obliterated in this high-energy channel sand environment. The Minturn Formation intertongues with and transitions to the Maroon Formations near this margin.

ECONOMIC GEOLOGY

Mines in the Como quadrangle have produced gold, iron ore, coal, gravel aggregate, and peat (fig. 25). No mines of any kind, however, are currently active. The quadrangle and surrounding area have been the target of oil and gas exploration in the past and encouraging shows were found, but there has so far been no hydrocarbon production. Potential exists in the quadrangle to develop additional gold, coal, and coarse aggregate resources. Potential for oil and gas in this part of South Park basin is low (Groth, 1985).

METALS

Placer Gold in the Tarryall Creek District

Historically, the most significant economic mineral resource in the Como quadrangle has been placer gold. Placer gold was mined from deposits of Quaternary glacial and fluvial gravels along Tarryall Creek and some of its upper tributaries. Most of the historic production was from late middle Pleistocene deposits. Gold was discovered in the late summer of 1859 near the confluence of the three forks of Tarryall Creek, near the Peabody's site (Parker, 1992). The placer deposits were worked mainly on a small scale from the time of discovery until the 1890s. In 1890, John Fortune began mining on the Fortune placer and large-scale hydraulic mining was soon used there (Muilenburg, 1925). Miles of ditches and steel pipe were used to transport water to the hydraulic "giants" that washed the gold-bearing gravel from the hillsides.

Henderson (1926) cited an early report by R.W. Raymond that estimated Tarryall Creek and its tributaries produced about $1 million worth of placer gold between 1859 and 1872. At $20 per ounce gold, that equates to 50,000 ounces. No specific production data is available for the district from 1872 to 1904. From 1905 to 1937, the district produced 4,971 ounces of gold (Singewald, 1942). According to Vanderwilt (1947), the Tarryall Creek district produced 11,314 ounces of gold from 1938 through 1942. Thus, the estimated minimum production of placer gold from the district is 66,000 ounces, and this does not include production from 1873 to 1904, or production after 1942.

The Fortune and Peabody placers along Tarryall Creek are the most extensive of the early mines in the district (Singewald, 1950). The Peabody placer is adjacent to and directly downstream from the Fortune placer and together they form a nearly continuous belt of workings extending for two miles along Tarryall Creek. Cline Bench placer also yielded considerable quantities of gold. Cline Bench is on an apron of outwash gravel (unit Qa3) on the floor of South Park, about three miles downstream from Peabody's on the eastern edge of the Como quadrangle. Gold-bearing gravels were also mined intermittently on the adjacent Milligan Lakes quadrangle for another 6 miles downstream of Cline Bench. Singewald (1950) studied the placer deposits of the Tarryall Creek region in detail and produced maps showing the locations of the main mining areas and geologic features of the deposits.

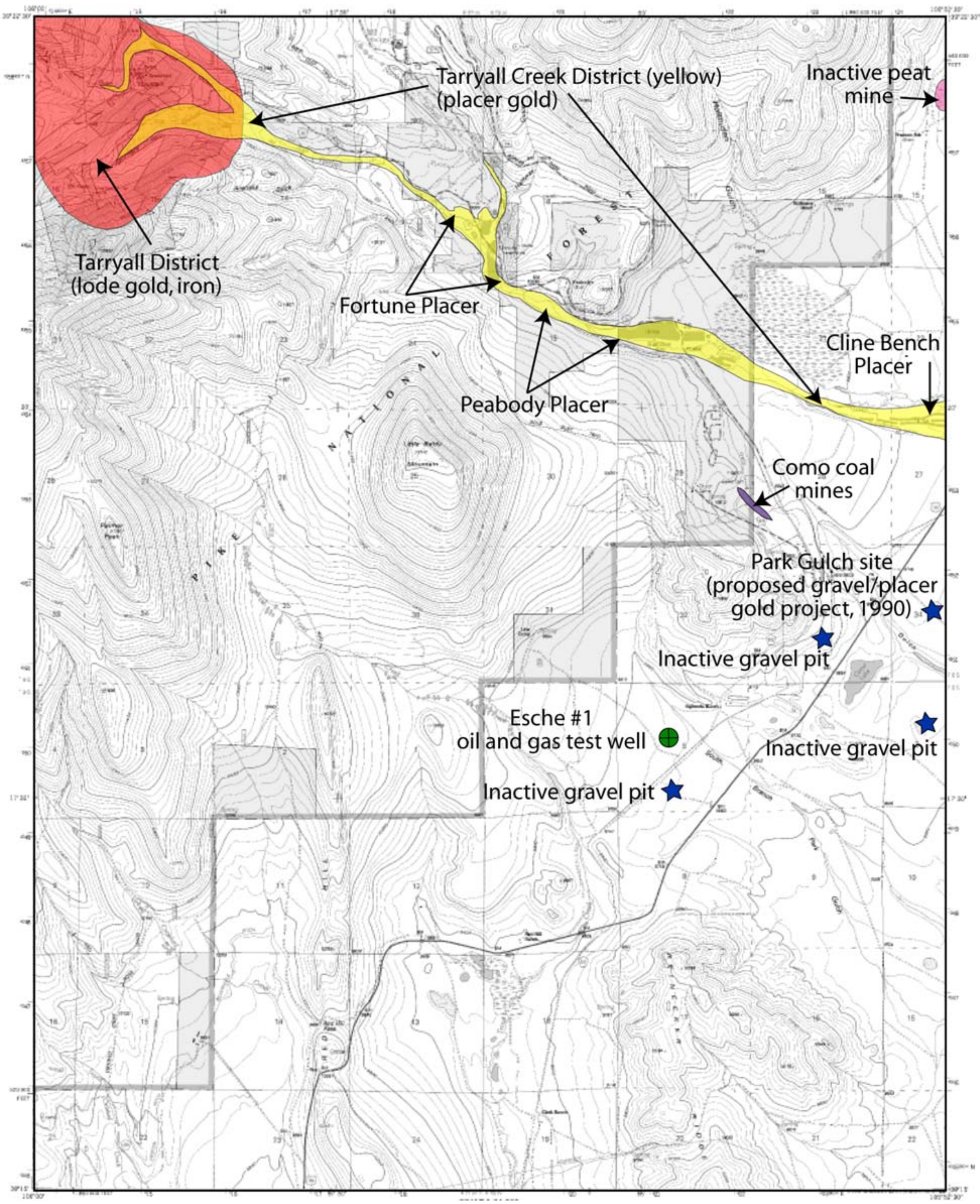

Figure 25. Overview of historically mined resources in the Como quadrangle.

The early placer mining era in Tarryall Creek came to a halt in 1917 when labor costs became prohibitive, and South Park ranchers succeeded in having an injunction placed against the Fortune Placers Gold Mining Company because the clastic debris from hydraulic mining was clogging their irrigation ditches (Muilenburg, 1925). However, the Great Depression helped spur the revival of placer mining in the Tarryall Creek region in the 1930s and 1940s. A dragline dredge was set up and operated near Peabody's and on Cline Bench in 1941-1942 and again in 1946-1947 (Parker, 1992). During this time, extensive placer mining was also being done upstream in Little French Gulch. Smaller placer gold deposits were also exploited in Montgomery Gulch and Deadwood Gulch (fig. 26).

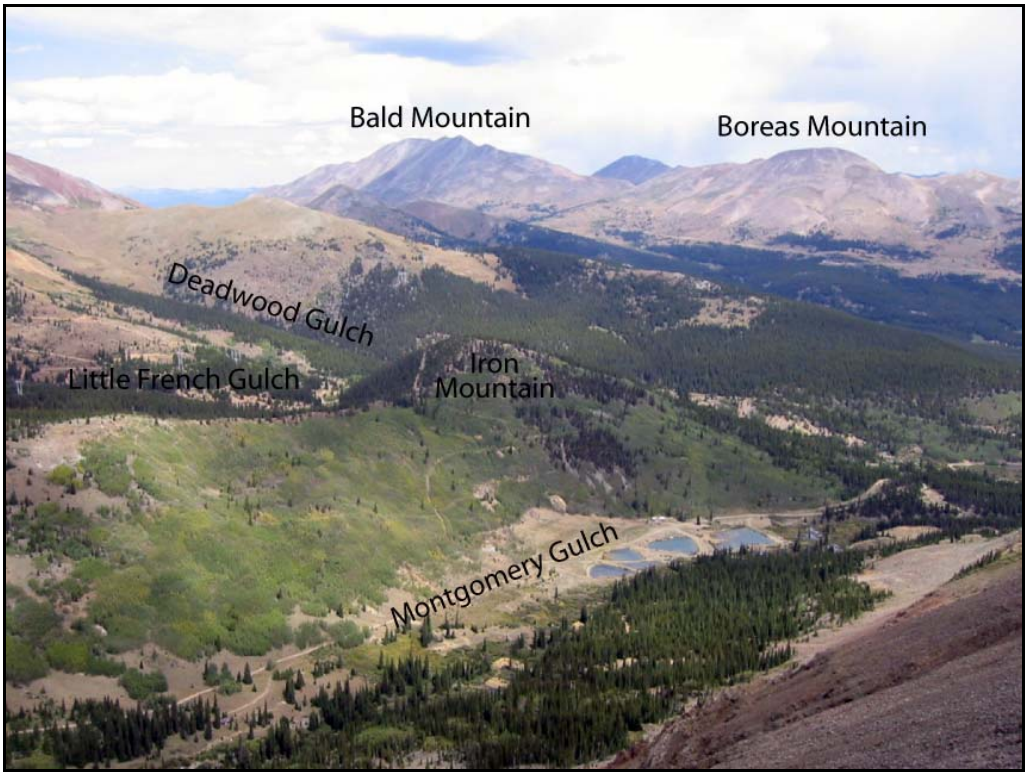

Figure 26. Overview of the Carter Trust lands, which encompass much of the Tarryall mining district in the northwestern corner of the Como quadrangle. Placer mining was carried out in the early to mid 1900s in Montgomery Gulch, Little French Gulch, and Deadwood Gulch. Mining was briefly renewed in Montgomery Gulch in the 1980s. Small lode deposits were also mined throughout the district. The bodies of water seen in the center part of the photo are settling ponds from historic mining and milling operations. View is from the northern flank of Mount Silverheels looking northeast. Boreas Pass road can bee seen on the lower flank of Boreas Mountain.

According to unpublished mining reports provided to CGS by V. Cullar, geologist/mining consultant and caretaker of the Carter Trust (northwestern corner of the quadrangle), the Silver Heels placer claims in the Montgomery Gulch area were evaluated by several mining companies in the 1950s and 1960s. Numerous backhoe pits and shallow drill holes were used to sample the glacial gravels in the area for gold content. Texas Mining Corp. operated the Silver Heels open-pit placer mine in the early 1980s in parts of secs. 10, 11, and 15, T. 8 S., R. 77 W. in Deadwood, Little French, and Montgomery Gulches. The reclamation bond and mining permit were revoked by the Colorado Mined Land Reclamation Division (now called the Division of Minerals and Geology) in 1985, and the site was reclaimed using the forfeited bond in 1992.

In 1990, Antra Resource Corp. of Denver proposed the “Park Gulch Gold Aggregate Project” to mine coarse gravel aggregate and to simultaneously recover placer gold from deposits of glacial outwash gravel of middle Pleistocene age (Qa4) at a site in sec. 34, T8S, R76W, east of the town of Como near U.S. Highway 285. V. Cullar of the Carter Trust provided CGS with access to an unpublished technical report produced by Antra in 1990. Antra estimated that the Park Gulch project area contains 18.2 million tons of coarse aggregate containing 62,654 ounces of recoverable gold (average grade of 0.003 to 0.004 ounces gold per ton). The proposed project never came to fruition, however.

The placer gold deposits of the Tarryall Creek district are hosted in glacial moraines and associated outwash gravels of Pleistocene age, as well as in younger stream alluvium. The greatest production has been from the outer parts of terminal moraines and the proximal parts of their outwash aprons (Singewald, 1950). Typically, the richest material was found along the bedrock/gravel contact. The bedrock source of the placer gold is the mineralized area around the Montgomery Gulch stock (Tqp) between Montgomery and Deadwood Gulches (Singewald, 1950; Parker, 1992). The richest gold-bearing gravels in all of the main placers contain an abundance of green contact-metamorphosed rock that was clearly derived from that area.

Lode Deposits in the Tarryall District

A few small lode mines and numerous prospects are located in the northwestern part of the Como quadrangle. The area on the lower northern slopes of Mt. Silverheels is known as the Tarryall district (Muilenburg, 1925) or the Beaver-Tarryall area (Singewald, 1942). Unpublished mining company reports on exploration activities in recent decades sometimes refer to the area as the Silverheels district. The small mines in the district were never very productive, and only a few hundred tons of ore were shipped from the district (Singewald, 1942).

Lode mining in the district began in the 1870s and several stamp mills were built. All of these ventures turned out to be “disastrous”, and all of the mine workings were abandoned and largely inaccessible by 1923 (Muilenburg, 1925). Lode gold deposits in the district have been systematically explored by several companies in recent decades, but there has been no production (V. Cullar, 2004, personal communication).

The small district is centered on the Montgomery Gulch stock (Tqp) and encompasses the area of Montgomery Gulch, Little French Gulch, and Deadwood Gulch. The district includes Iron Mountain and extends west into the Beaver Creek drainage in the Alma quadrangle. The small mines and prospects are principally hosted within Pennsylvanian-Permian sedimentary rocks (Minturn and Maroon Formations) that were affected by contact metamorphism associated with intrusion of the stock (fig. 27). A few mines and prospects are hosted in Tertiary intrusive rocks. The gold deposits consist of three main types: (1) pyrite-quartz veins and veinlets that formed in open fissures and fractures, (2) small replacement bodies adjacent to veins in limestone beds, and (3) stockwork-like deposits composed a network of pyrite veinlets in areas of fractured intrusive rock (Singewald, 1942). The district contains a tremendous number of mineralized veins and veinlets, but these rarely exceed 6 inches in width or 100 feet in length, and gold grades are usually low. Pyrite and quartz, in variable quantities, are the chief constituents of the veins. The veins occur as intermittent lenses within narrow fault zones. The zones of stockwork veinlets in areas of fractured porphyry are spatially and genetically associated with the larger pyrite-quartz veins. The highest gold concentrations occur where pyrite has been oxidized to limonite (Singewald, 1942). Sphalerite, chalcopyrite, and pyrrhotite are present at a few of the prospects, but nowhere do they constitute a significant resource of zinc or copper. Pyrrhotite is abundant at two mines that shipped small tonnages of iron ore (Singewald, 1942). Mineralized quartz-pyrite veins often crosscut and overprint older skarn (contact metamorphic) mineralization, indicating that the veins are younger than the contact metamorphic event. Skarn zones occur in thin limestone beds and consist of epidote, garnet, perovskite, specular hematite, and magnetite. Coarse calcite and tremolite-actinolite are also present locally.

Although gold has been the focus of most of the prospecting and exploration, iron ore may have been the most valuable commodity that was actually produced in the district from lode mines. Zinc (sphalerite), copper (chalcopyrite), and lead (galena) sulfides are present in small quantities locally, and this doubtlessly spurred some interest in the base-metal potential of the district as well. Galena, when present, usually carries some silver. Singewald (1942) described the most significant of the historic mines and prospects in the district in moderate detail.

<u>Modern-era Gold Exploration in the Tarryall District</u>

The district has been explored in varying levels of detail by several companies including Alma American Mining Co., Homestake Mining Co, and Antra Resources Corp. In addition, Phelps Dodge, Kennecott, ASARCO, and AMAX made reconnaissance-level examinations of the district and the exploration data acquired by other companies but did not conduct detailed exploration programs. Unpublished reports by these companies are held by V. Cullar, mining and geological consultant and present caretaker of the Carter Trust. The reports contain a wide variety of data including geochemistry and economic viability of potential lode gold mining projects in the district. Information provided in these reports is summarized below.

Alma American conducted the most recent and most extensive of the modern-era gold exploration programs. Their work was conducted between 1988 and 1991 and included detailed geologic mapping, surface geochemical sampling, drilling several core and reverse-circulation drill holes, re-opening the “Mascotte” adit for sampling and mapping, and conducting magnetometer surveys. The objective of the program was to find and develop (1) high-grade vein deposits to help feed the company’s mill near Alma, (2) find shallow, low-grade ore bodies amenable to open-pit/heap-leach methods, and (3) demonstrate the potential for deeper, larger, higher-grade sulfide bodies that could justify developing a major underground mine in the future. The company was not successful in finding sufficient mineralization to warrant further exploration expenditures. Out of 1,200 feet of core drilling, no intervals assayed over 0.01 ounces per ton gold. As the old-timers had discovered, the lode deposits in the Tarryall district are small and the grade too low and sporadic. Alma American terminated its property position in the district in 1991 when it could not interest a major mining company in a joint venture on the property.

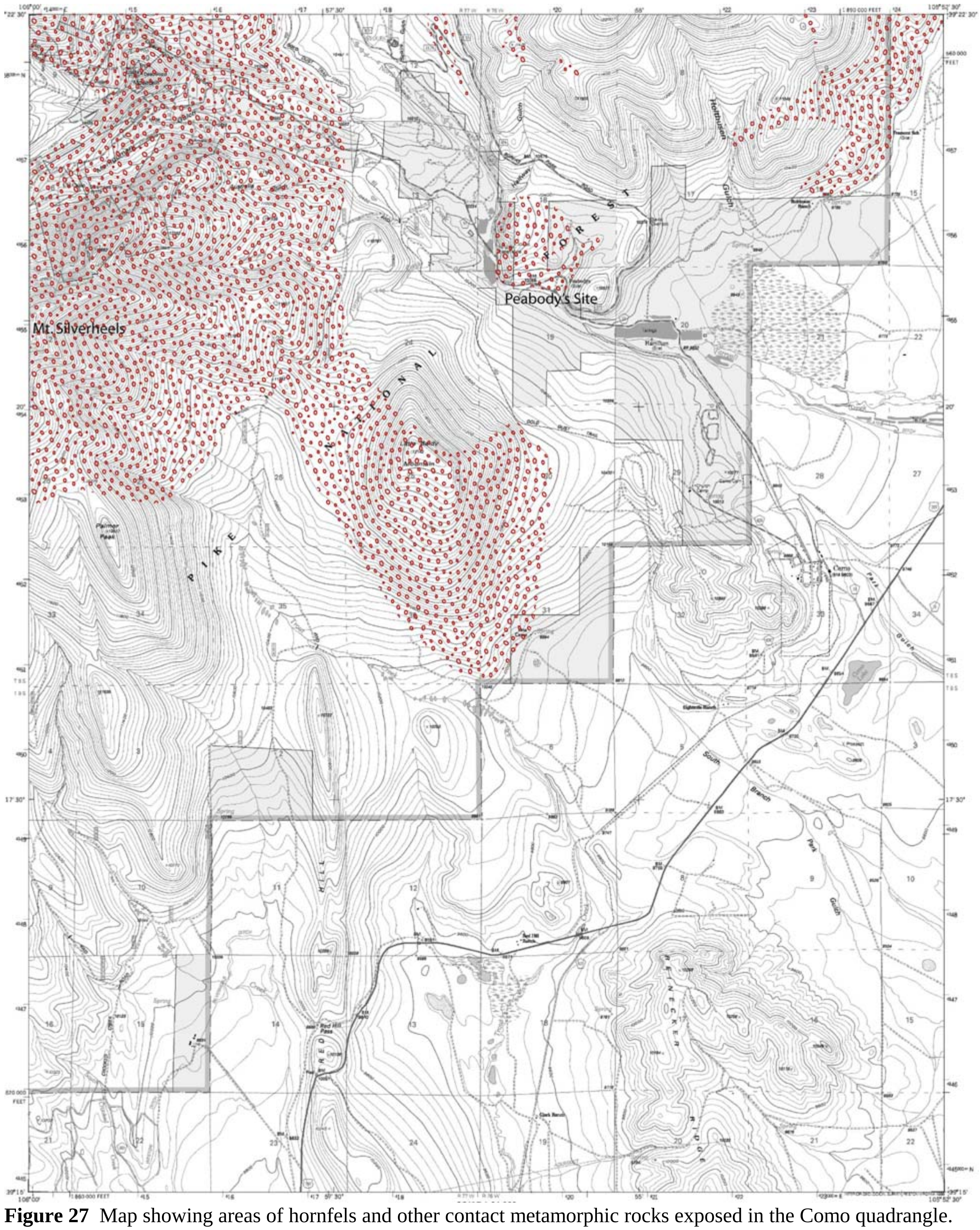

Figure 27 Map showing areas of hornfels and other contact metamorphic rocks exposed in the Como quadrangle.

On the basis of their detailed exploration work, Alma American geologists interpreted that Montgomery and Little French Gulches are topographic expressions of structurally controlled, altered, and less-resistant contact zones between the Montgomery Gulch stock and Minturn Formation strata to the north and south. They suggested that these two gulches, with potentially mineralized bedrock concealed under Quaternary stream and glacial deposits, represent the best targets for further gold exploration. Geochemical analyses for a few samples collected from the area are listed in table 4.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Cr_2O_3	TiO_2	MnO	P_2O_5	SrO	BaO	LOI	Total
CO288	19.57	4.28	64.11	7.73	1.2	0.25	0.05	<0.01	0.28	0.11	0.17	0.02	0.01	0.71	98.48
BW6	48.24	6.89	26.89	0.51	0.14	0.05	0.3	0.01	0.41	0.02	0.12	0.04	0.02	16	99.63

Sample	Ag	Al	As	Au	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ga
	ppm	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm
CO288	2.42	2.13	14	0.271	10	11.7	2.16	4.89	0.2	46	15	46	0.14	379	43.6	16.6
BW6	4.88	3.31	1345	0.898	20	1.87	0.68	0.34	6.56	37.6	9.8	49	1.61	61.6	18.8	8.42

Sample	Ge	Hf	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Rb	Re
	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
CO288	1.64	0.5	1.305	0.03	20.9	3.6	0.35	617	0.45	0.03	5.9	18.6	760	11.7	0.7	<0.002
BW6	0.25	1.4	0.831	0.21	17	76.7	0.1	176	8.48	0.01	7.2	16.1	530	49.8	12.7	0.003

Sample	S	Sb	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
CO288	1.38	0.54	1	2.5	135	0.56	0.42	5.1	0.136	0.04	10.5	96	69.5	13.3	62	14.9
BW6	>10.0	141.5	1	4.8	57	0.54	0.51	7.7	0.169	19.9	4.7	42	28.1	6.7	1000	42.6

Table 4. Whole-rock geochemistry, trace element analysis, and gold assay values for selected samples from the Como quadrangle. Whole-rock analyses were conducted using the XRF method. Gold was analyzed by fire assay and ICP-AES. An ICP-MS method was used for trace-element analyses. Whole-rock analyses shown in weight percent. All analyses were performed by ALS Chemex, Sparks, NV. Sample CO288 – limestone bed in the Maroon Formation; sample BW6 Minturn Formation sandstone. See geologic map for sample locations.

<u>Copper Deposits in the Dakota Sandstone</u>

In the northern part of the quadrangle, the Dakota Sandstone locally exhibits weak copper oxide mineralization. Malachite was found principally as a fracture coating in several small exploration pits on the unnamed ridge just southwest of the Gold Dust Trail in the SE¼ of sec. 11, T. 8 S., R. 77 W. Sparse azurite accompanied the malachite at a few localities. However, economic potential of these deposits appears to be low.

INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS

<u>Sand and Gravel Construction Aggregate</u>

Abundant sand and gravel aggregate resources exist in the Como quadrangle. Coarse gravel is particularly abundant. Large- and medium-sized deposits of glacial outwash and stream alluvium form terraces along Tarryall Creek, Trout Creek, and South Branch Park Gulch. Mapped units Qa, Qa1, Qa2, and Qa3 are all potential sources of aggregate in the quadrangle. Unit Qa4 is also a potential source for gravel but moderate clast decomposition slightly reduces the quality of this particular resource. Schwochow (1981) shows that two gravel pits existed in the quadrangle, both near U.S. Highway 285 south and southwest of Como. Currently there are no active gravel pits in the quadrangle. Large outwash gravel deposits, similar to those in the Como area, are currently being mined at several places along the South Platte River near Fairplay and Alma (Guilinger and Keller, 2004). Talus (Qta) and rock glacier (Qrgw) deposits are potential sources of riprap.

Gravel deposits in the region have potential to yield significant amounts of placer gold in addition to coarse aggregate. In 1990, Antra Resource Corp. proposed a major mining project for both coarse gravel aggregate and placer gold from a site on Park Gulch east of Como (see "placer gold" section, above). The project never became operational and their application for a mining permit from the Colorado Division of Minerals and Geology (DMG) was withdrawn. Also in 1990, DMG records show that a mining permit was issued to APAN Joint Venture to mine gravel and gold at the proposed Fremont Pit in the NW¼ of sec. 22, T. 8 S., R. 76 W., on the eastern edge of the Como quadrangle north of Tarryall Creek. In 1989, a mining permit was issued to Allen Drilling and Excavating of Fairplay to mine gravel from the old Cline Placer tailings along Tarryall Creek in the NW¼ of sec. 27, T. 8 S., R. 76 W.

<u>Peat</u>

Several peat mines are present in Park County, though none are currently active. Peat was mined as recently as the early 1990s at the Ohler Gulch mine about three miles northeast of the Como quadrangle and at the Branaman Pond mine west of Fairplay. A small, inactive peat mine is located along and east of the eastern boundary of the Como quadrangle in sec. 10, T. 8 S., R. 76 W, but no information is available about this mine and it is not in the state mine permit database. Peat resources locally overlie Quaternary alluvial deposits and are found in low-lying boggy or marshy areas in the South Park region. Peat is primarily used in potting soil mixtures and as a soil conditioner.

<u>Clay</u>

The Pierre Shale and the Laramie Formation may contain useable deposits of clay in the Como quadrangle. Fire clay reportedly underlies coal seams in the Laramie Formation at some of the abandoned mines in the Como coal district (Washburne, 1910; McConnell, 1945). In addition, the Laramie and Pierre in the Como quadrangle may contain resources of common clay as is presently mined along the base of the Front Range near Denver. Clay from these formations is used mainly for manufacturing bricks and tiles. Additionally, certain horizons in the Pierre Shale are mined and processed for use as lightweight aggregate at a facility near Boulder.

<u>Stone</u>

The Dakota Sandstone is present on the Como quadrangle and has been quarried elsewhere in the state for use as dimension stone, silica sand, and crushed-rock aggregate (Schwochow, 1981). Currently, the Dakota Sandstone is being mined primarily for use as riprap at the Table Mountain quarry southwest of Colorado Springs. Clay is mined from the Dakota at places along the eastern base of the Front Range. No significant clay zones are known to exist in the Dakota Sandstone in the Como area, however.

Tertiary intrusive rocks present on the quadrangle (Tqp, Tmp) also are a potential source of crushed-rock aggregate. The abundance of easily mined stream gravel deposits makes it unlikely that potential crushed rock sources on the Como quadrangle will be exploited anytime soon.

Limestone

Limestone in the Niobrara Formation has been quarried in small quantities in the South Park basin for lime (Stark and others, 1949). Limestone beds in the Niobrara are often very pure, but these beds are seldom greater than one foot in thickness (Stark and others, 1949). The Niobrara is poorly exposed, and there are no active or former limestone quarries on the Como quadrangle.

Garnet

Garnet is present in skarns developed in Maroon Formation limestone beds within the contact metamorphic aureole around the Montgomery Gulch stock (Tqp) in the northwestern part of the quadrangle. A particularly garnet-rich skarn is present near the head of Little French Gulch. The garnet is a variety of andradite (Muilenburg, 1925) and is usually massive, although well-formed, euhedral crystals are sometimes found. Some of the crystals are black with an adamantine luster, and these may be melanite, a chromium-bearing variety of andradite. The garnet here commonly occurs with magnetite, epidote, specular hematite, and coarse calcite.

OIL AND GAS

South Park basin, particularly the eastern portion, has been the target of sporadic oil and gas exploration since the early 1930s. No significant commercial production has so far been established. The principal potential reservoir units in the basin are the Cretaceous Dakota Sandstone, Fox Hills Sandstone, and sandstone subunits within the Pierre Shale such as the Apache Creek member (Clement and Dolton, 1970). The Permian Garo Sandstone is also a potential hydrocarbon reservoir.

One exploratory wildcat well was drilled in the Como quadrangle, and several others have been drilled just east and south of the quadrangle. All of the wells were dry, but at least two had oil and gas shows. One test well 13 mi. southeast of the Como quadrangle on the Hartsel anticline, the State #1 well drilled by the South Park Oil & Gas Company, reportedly produced over 5,000 barrels of oil (Cappa and others, 1999).

In 1934, a well was drilled and abandoned by the South Park Oil & Gas Company on the Esche Lease in the SE¼ SE¼ NW¼ of sec. 5, T.9 S., R.76 W. in the vicinity of the Circle V Bar Eightmile Ranch in the Como quadrangle. The well was drilled to a depth of 3,043 feet and was collared in an area underlain by Pierre Shale. Further geologic data from the well is not available, and the well was dry.

Two exploratory wells drilled just east of the northeastern corner of the Como quadrangle encountered oil and/or gas shows. The Milligan #1 well was drilled to 3,228 feet by South Park Oil & Gas in 1934 in the NE¼ NE¼ SE¼ of sec. 13, T. 8 S., R. 76 W. and encountered an oil and gas show in the Dakota Sandstone. The Teter #1 well was drilled to 7,475 feet by Tennessee Gas Transmission Company in 1957 in the SW¼ SE¼ NW¼ of sec. 11, T. 8 S., R. 76 W. Colorado Oil and Gas Conservation Commission records indicate that a gas show was encountered in what was interpreted as the Hygiene Member of the Pierre Shale, a hydrocarbon-producing sandstone unit in the Denver Basin. The Hygiene Member was later called the Apache Creek member in South Park. A third well in the area, the Shattinger #3, was drilled to a depth of 2,200 feet in the SW¼ NE¼ of sec. 10, T.8 S., R.76 W. by the Geary Oil Company in 1977. The well bottomed in Pierre Shale and was dry.

In 1978 and 1982 Amoco Production Company drilled wildcat wells just south of the Como quadrangle on Reinecker Ridge. The target was the Cretaceous Dakota Sandstone. The well drilled in 1978 in the SW¼ SW¼ NW¼ of sec. 10, T.10 S., R.76 W. deviated from the target structure and was terminated at a depth of 9,010 feet while still in the Pierre Shale (Groth, 1985). The well drilled in 1982 in the NE¼ SW¼ NW¼ of sec. 34, T.9 S., R.76 W. was apparently successful in testing the Dakota because the well was terminated at a total depth of 7,611 feet in the underlying Jurassic Morrison Formation. Vitrinite reflectance data indicated that the Reinecker Ridge structure is unlikely to be productive because it formed after oil generation, and this part of South Park basin has low potential for oil and gas (Groth, 1985).

COAL

The South Park coal field extends for about 20 miles, from about one mile north of the town of Como south into the Hartsel quadrangle. The Como district encompasses the only historically productive mines in the South Park coal field and consists of several mines and prospects that were active between 1870 and 1905 (Washburne, 1910). An unpublished 1945 report from the U.S. Geological Survey shows that coal was mined as recently as 1926 from at least one area in the district, and coal prospecting was conducted in the early 1930s (McConnell, 1945). Coal from the district was used mainly by the Union Pacific Coal Company as a fuel source for steam locomotives, but it may also have been used locally for space heating.

The Como district produced a reported 58,997 tons of coal by 1905 (Washburne, 1910). Three coal beds were exploited in the district, all from the Upper Cretaceous Laramie Formation. The lowest of the coal beds rests directly on the Fox Hills Sandstone. The beds are mostly subbituminous and vary from less than 1 foot to over 8 feet in thickness (Washburne, 1910). The coal was difficult to mine. McConnell (1945) reported the following statement by Union Pacific Coal Company officials who were relaying information about coal quality by former employees familiar with the mines in the Como district:

> "This was a low moisture, low ash, and very good quality fuel. The mine conditions were very difficult due to large quantities of water which had to be handled, soft fire clay floor, a soft shale roof, numerous faults, steeply pitching seams and very gassy condition, the fire clay discoloring the coal so that in cold weather it was very difficult to separate the coal from the rock."

Analysis of coal from the South Park Coal Company mine in sec. 26, T.8 S., R. 76 W. in the Milligan Lakes quadrangle east of Como is shown in table 5. E.H. Denny (U.S. Bureau of Mines) collected the sample from the face of a drift in 1929. The analysis was later reported by McConnell (1945). This may be the same location as the Judge Foote prospect referred to by Washburne (1910).

Moisture	15.5 %		Sulfur	0.5 %
Volatile	32.4 %		Hydrogen	5.6 %
Fixed carbon	45.7 %		Carbon	58.6 %
Ash	6.4 %		Nitrogen	1.1 %
Btu	9,780		Oxygen	27.8 %

Table 5. Analysis of a coal sample collected east of the Como quadrangle in the Como district (after McConnell, 1945). Thickness of main coal seam is 7.2 feet.

The largest mines in the Como district, collectively known as the King mines, are located about three miles southeast of the town of Como in the Milligan Lakes quadrangle. The Como mine was the only producing coal mine in the Como quadrangle. The mine is in the SE¼ of sec. 29 and SW¼ of sec. 28, T. 8 S., R.76 W. near the church camp northwest of Como. The mine extended along strike for about 0.5 mile (McConnell, 1945). The mine was abandoned in 1883 and nothing remains of the workings except two small waste rock piles (fig. 28) and three small subsidence pits. No bedrock is exposed at the site. At the Como mine, the Laramie Formation coal bed is 5 to 6 feet thick, dips 45 degrees to the east, and is truncated by a down-to-the-west fault at a depth of about 300 feet (McConnell, 1945). Vanderwilt (1947) estimated that the South Park coal field contains reserves of 18 million tons. More recent unpublished estimates by the Colorado Division of Minerals and Geology indicate a total coal resource of 135 million tons above a depth of 3,000 feet (Cappa and others, 1999).

Figure 28. All that remains of the southern of the two Como coal mines is this small waste pile. The town of Como and the distant Mosquito Range are seen in the background. View is to the southwest.

GEOLOGIC HAZARDS AND ENGINEERING CONSTRAINTS

Geologic hazards and engineering constraints in the Como quadrangle include sediment-laden flooding, debris flows (mudslides), rockfall, landslides, problematic soils, earthquakes, and perhaps sinkholes. Areas underlain by alluvial unit one (Qa1), alluvial units one and two, undivided (Qa), and alluvium and colluvium (unit Qac) are prone to flooding, including sediment-laden flood waters. Debris flows, mudflows, and sheet flooding may affect areas mapped as fan deposits (unit Qf) and alluvium and colluvium (unit Qac).

Rockfall, rock topples, and rock slides are a hazard on and beneath cliffs of hard rock, such as those found along the south wall of Montgomery Gulch and the flanks of Little Baldy Mountain. Areas mapped as talus (unit Qta) and some areas mapped as colluvium (unit Qc) are particularly prone to rockfall. Minor rockfall hazards may exist anywhere a cliff or rocky outcrop occurs on a steep slope.

Although landslides are not abundant in the quadrangle, several large landslide deposits and many smaller ones are present in the quadrangle. They occur in a variety of geologic environments, but they are most common on the east side of Red Hill where east-dipping Cretaceous shales comprise the bedrock and in the glaciated headwaters of Little French Gulch that are underlain by strongly altered rocks in the Maroon Formation. Other significant landslides in the quadrangle include one on the east side of Mount Silverheels in a cirque that probably failed when the glacier in the cirque melted at the end of the last glaciation; another is on the northwest side of Reinecker Ridge (fig. 29) and involves the Pierre Shale and Reinecker Ridge Volcanic Member of the South Park Formation.

Figure 29. Landslide on northwest side of Reinecker Ridge. Tree-covered hills in upper right are underlain by the Reinecker Ridge Volcanic Member of the South Platte Formation (TKsr); Pierre Shale (Kp) underlies the gently rolling, grass-covered slopes. Toe of landslide is exposed in road cut along U. S. Highway 285 in left center of photograph. Renewed movement of a landslide like this one could close the highway. View is to the east.

No evidence of historic landslide activity was documented during this study. Many landslide deposits in the quadrangle may have last moved during the Pleistocene or early Holocene and appear to be stable or quasi-stable under present conditions. However, natural events such as intense rainfall, rapid snowmelt, ground shaking during earthquakes, and changes in ground-water levels can destabilize slopes and trigger landslides. Human activities, including excavations and earth fills on slopes and changes to the hydrologic environment from irrigation, septic systems, and water impoundments and diversions, also can contribute to slope failure. Future landsliding may not be restricted to areas mapped as landslide deposits (unit Qls); other areas in favorable geologic environments, particularly those where human activities reduce slope stability, may also experience slope failures.

Surficial deposits derived from shale-rich Cretaceous formations, especially the Pierre Shale, may have high shrink-swell potential, which can be detrimental to foundations, roads, and other works of humans. Heaving bedrock may also be a problem in areas underlain by beds of steeply dipping Cretaceous shale, as along the east side of Red Hill. Fine-grained sediments deposited in fan environments and on colluvial slopes may create conditions favorable for hydrocompaction and piping. Such sediments may be found in units Qf, Qc, and Qac.

Several closed topographic depressions of unknown origin occur in the quadrangle and are denoted on the geologic map. The depressions range in size from a few tens of feet to hundreds of feet in diameter and from a few feet to tens of feet deep (fig. 30). Some are water-filled. These features are geomorphically similar to a cluster of at least 50 sinkholes about 8 to 12 miles south of the quadrangle that are described by Shawe and others (1995) and attributed to collapse over dissolution voids in evaporite beds in the Minturn Formation. However, the Minturn Formation is not known to contain evaporite strata within the Como quadrangle. Furthermore, all the closed depressions in the Como quadrangle formed in the Pierre Shale or in surficial deposits that overlie it. Additional study is required to determine the origin of the closed depressions within the quadrangle. If they resulted from collapse into dissolution voids, then they pose a potential hazard to roads, buildings, and other developments. Other parts of the quadrangle could also be prone to sinkholes, if dissolution of bedrock caused the depressions. Other possible explanations of the closed depressions include undocumented sand and gravel mining, gold placer mining, meteorite impact craters, deflation by wind, and buffalo wallows.

Three small subsidence pits were noted over the underground workings of the Como coal mines about 0.7 miles northwest of Como. Because of their close proximity to one another, all three pits are encircled by a single polygon on the geologic map. The extent of the underground workings is unknown, therefore an investigation of the subsidence potential of these mine workings should be completed prior to future development of the area.

Figure 30. Photograph of the closed topographic depression in the SE¼ of sec. 4, T. 9 S., R. 76 W. Depression is approximately 100 feet wide, 200 feet long, and 6 feet deep; it formed in outwash gravels of alluvial unit 4 (Qa4) that overlie Pierre Shale. Note fence posts for scale. View is to the north.

Although no active faults are known to exist within the quadrangle, earthquakes resulting from the surface rupture of nearby faults, like those at Spinney Mountain (Shaffer and Williamson, 1986) or in the upper Arkansas Valley (Ostenaa and others, 1981; Lettis and others, 1996), could cause moderately strong ground motion in the quadrangle. A random or “floating” earthquake along a fault that is deep in the crust and does not rupture the ground surface also could generate moderately strong ground motion. It is recommended that structures at least be designed and built to the standards of the current International Building Code or other appropriate building code. Earthquakes can also trigger secondary effects, such as liquefaction, rockfall, and landslides, which potentially can cause great damage.

WATER RESOURCES

SURFACE WATER

The Como quadrangle is located in the northern part of the South Park drainage basin (fig. 31) and is part of the South Platte watershed. The quadrangle includes the headwater areas of Crooked Creek, Trout Creek, and Tarryall Creek. Trout Creek flows southward between Red Hill and Reinecker Ridge to the town of Garo where it joins the Middle Fork of the South Platte River (MFSPR). Similarly, Crooked Creek joins the MFSPR on the west side of Red Hill. Water from the South Platte River is captured and stored in the Spinney Mountain and Eleven Mile Canyon Reservoir southeast of Hartsel. Beyond these reservoirs, the river changes to a northeasterly course, eventually flowing through and beyond Denver. Tarryall Creek also merges with the South Platte River, but not until well east of South Park.

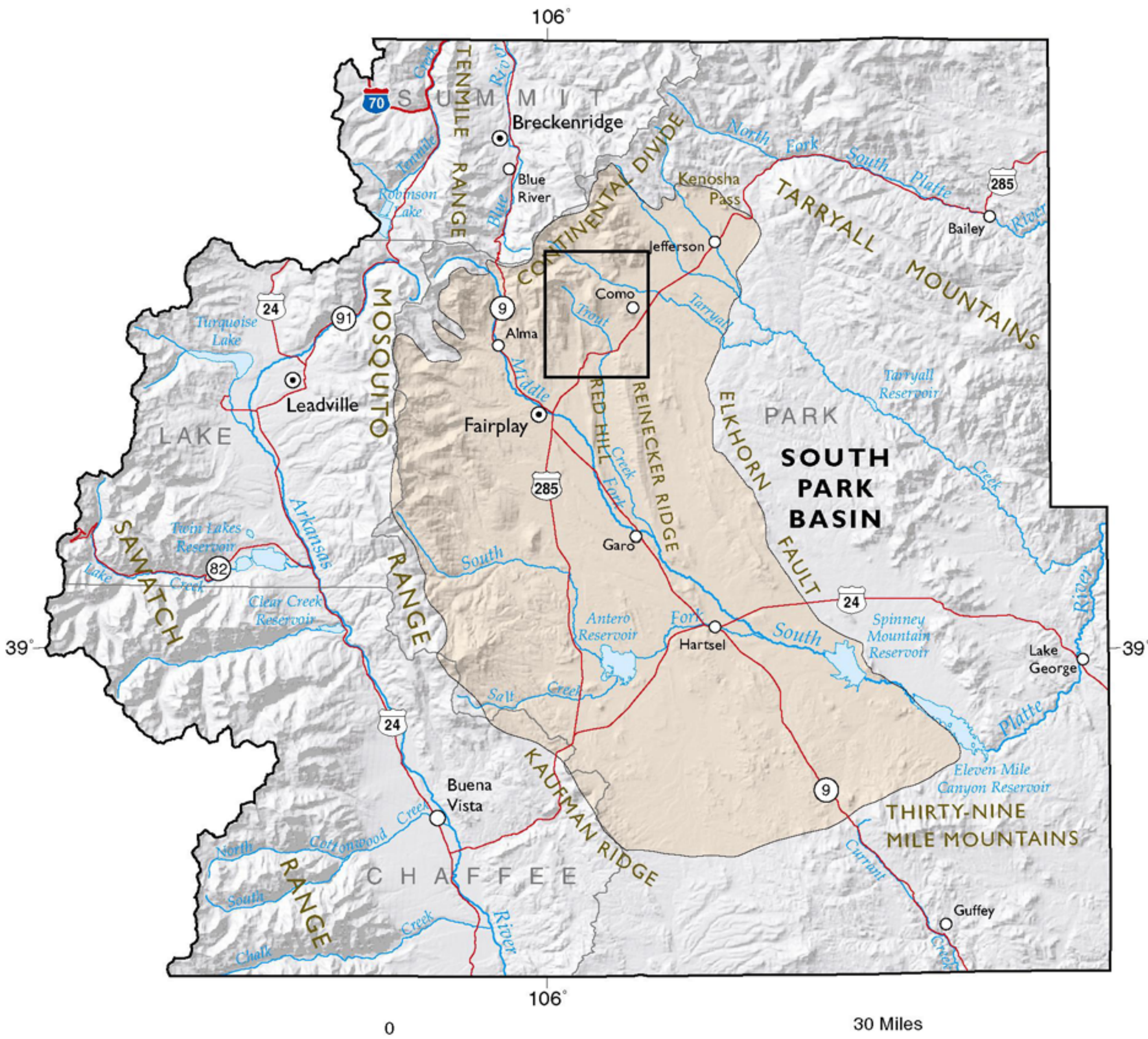

Figure 31. Map showing relationship of the Como quadrangle to the South Park watershed.

The Tarryall Creek watershed has a somewhat larger drainage area than Trout Creek and experiences greater average discharge. Tarryall Creek houses two USGS streamflow stations (site numbers 06696980 and 06697100) in the vicinity of the Como quadrangle. Peak flows occur in the warm summer months of May, June, and July (fig. 32) as a result of snowmelt and storm runoff. Peak flows at the upper station near the base of Boreas Pass Road can exceed 100 cubic feet per second (cfs), with winter base flows in the vicinity of 3 cfs. Fishing conditions on both creeks are excellent and widely renowned. Most of the Tarryall Creek drainage within the Como quadrangle is privately owned, however, and public access is minimal. Conversely, a good portion of Trout Creek is within National Forest Service boundaries and is accessible for public use.

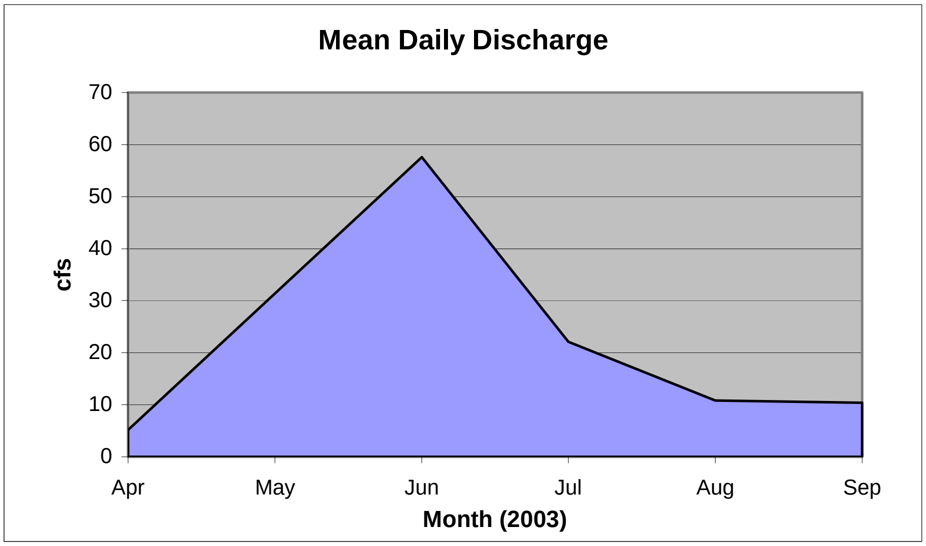

Figure 32. Mean daily discharge in cubic feet per second (cfs) for Tarryall Creek. Data is from the U.S. Geological Survey Water Resources Data website (U.S. Geological Survey, 2004).

GROUND WATER

According to the Colorado Division of Water Resources, there are roughly 150 water wells completed in the Como quadrangle (fig. 33). Several alluvial terraces flank the Tarryall Creek drainage and the Late Pleistocene paleovalley of Trout Creek. These terraces are underlain by sand and gravel deposits ranging from 5 to 30 feet in thickness. Alluvial terraces commonly constitute good ground water aquifers. However, in the Como area, only about 20 water wells have been drilled to less than 60 feet. The mean depth of all water wells drilled in the Como area is about 160 feet, indicating that most wells likely draw from bedrock aquifers as opposed to alluvial aquifers. Locally, alluvial aquifers may be suitable for stock watering and some domestic uses.

The groundwater characteristics of bedrock aquifers in South Park are described in the Colorado Geological Survey's Ground Water Atlas of Colorado (Topper and others, 2003). The following information is derived primarily from this publication.

Within South Park, there are several potential bedrock ground water aquifers. Sandstone and conglomerate of the Oligocene to Pliocene Antero, Wagontongue, and Trump Formations comprise the uppermost aquifers within South Park. These deposits, however, are not present in the Como quadrangle. The underlying South Park aquifers (upper and lower) are within the Paleocene South Park Formation, which includes the Reinecker Ridge Volcanic Member. Due to its low porosity, the volcanic member acts as a confining unit, not an aquifer. It is the overlying sandstone and conglomerate that comprise the South Park aquifers. Again, in the Como quadrangle, sediments of the upper South Park aquifer are absent. Lower South Park aquifer sediments form only a thin mantle on the surface of Reinecker Ridge.

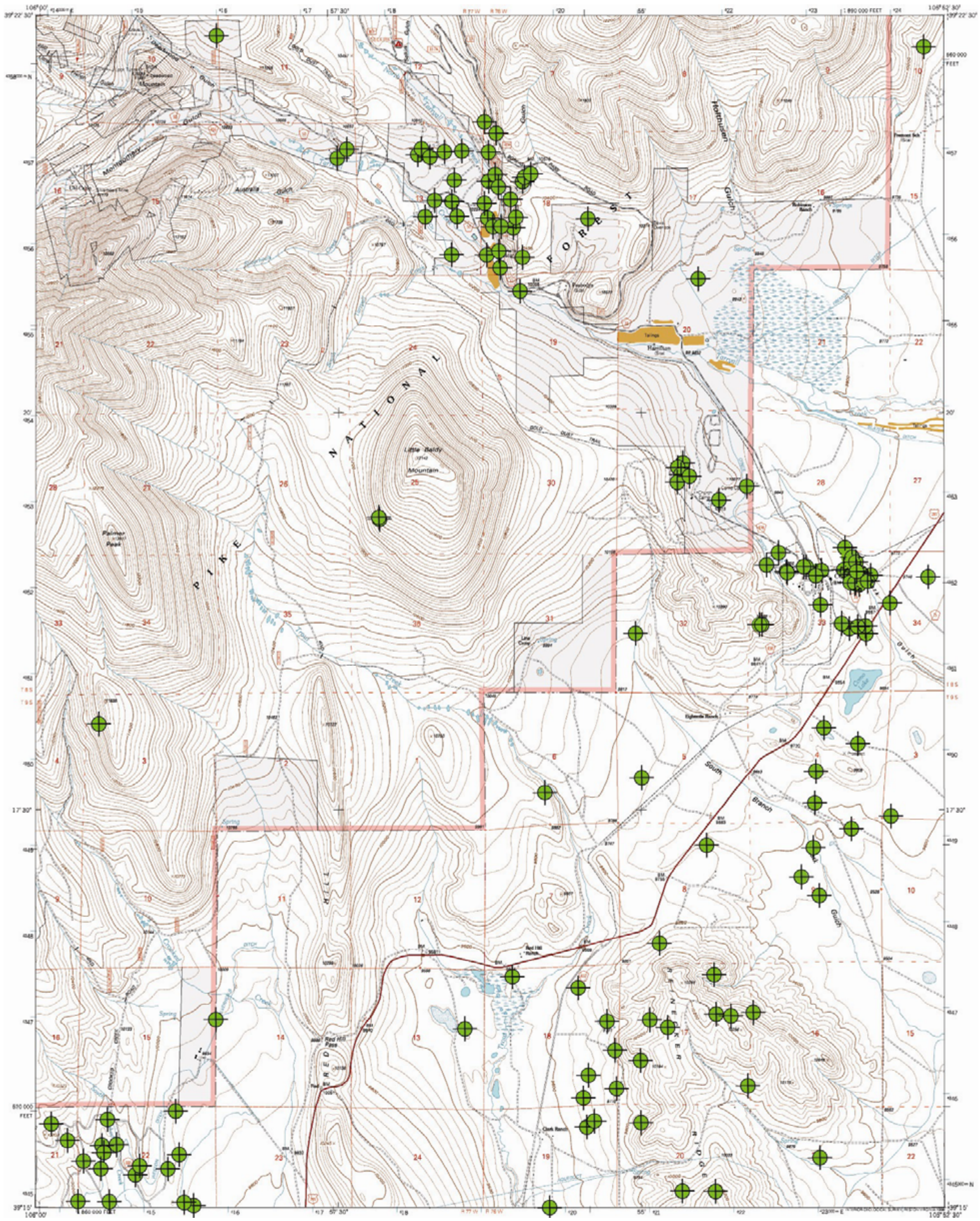

Figure 33. Map showing distribution of the nearly 150 water wells in the Como quadrangle. GIS shapefile of well locations from the Colorado Division of Water Resources.

The lack of significant saturated thickness precludes these sediments from acting as a reliable aquifer. Continuing down section, the Laramie and Fox Hills Formations are the next hydrogeologic units found in South Park. As discussed previously, these formations are limited to the area just northwest of Como and are at or very near the surface. It is likely that water resources in these deposits would be minimal. The remaining three aquifers in South Park are prime targets for ground water in Como quadrangle according to Topper and others (2003). They are the Cretaceous Dakota Sandstone, Permian Garo Sandstone, and conglomerate and sandstone beds of the Pennsylvanian Minturn Formation. Additionally, sandy horizons within the Cretaceous Pierre Shale are potential ground water aquifers. Many of the wells drilled near the town of Como and to the south likely draw Pierre Shale. Recharge to these aquifers is almost entirely through direct infiltration of rainfall and snowmelt. Recharge also occurs where porous rock units underlie saturated alluvium or through individual septic disposal systems. Discharge occurs at natural springs, as base flow in adjacent stream courses, and by ground water withdrawal from wells. The Como quadrangle contains a number of springs along the base of the mountain front at an elevation of about 10,000 feet. Ground water discharge in the form of springs also occurs along the basal flanks of Reinecker Ridge.

Ground water usage in South Park is primarily for domestic purposes and comprises only about 10 percent of total water consumption. Irrigation probably constitutes a significant portion of the remaining total water consumption but draws heavily from surface water as opposed to ground water. The majority of wells within the Como quadrangle are completed at depths less than 350 feet; mean depth is about 160 feet. Most wells reportedly yield 15 gallons per minute (gpm) or less. State statutes limit production from domestic and stock wells to 15 gpm, so the reported yields may be influenced by the regulatory limits. Water quality is generally suitable for most potable requirements.

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