Map Series 35

Geologic Map of the Shoshone Quadrangle, Garfield County, Colorado

By Robert M. Kirkham, Randall K. Streufert, and James A. Cappa

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Colorado Geological Survey
Denver, Colorado
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FOREWORD

The Colorado Department of Natural Resources is pleased to present the Colorado Geological Survey Map Series 35, *Geologic Map of the Shoshone Quadrangle, Garfield County, Colorado*. Its purpose is to describe the geologic setting of this 7.5-minute quadrangle which is located east of the city of Glenwood Springs.

This mapping project was funded jointly by the U.S. Geological Survey (USGS) and the Colorado Geological Survey (CGS). USGS funds are competitively awarded through the STATEMAP component of the National Cooperative Geologic Mapping Program (Agreement No. 1434-94-A-1225 and 01HQAG0094). The program is authorized by the National Mapping Act of 1992. The CGS matching funds come from the Severance Tax Operational Account that is funded by taxes paid on the production of natural gas, oil, coal, and metals.

Vince Matthews,
State Geologist and Director,
Colorado Geological Survey

Acknowledgments

The map produced as CGS Open-File Report 95-4 benefited from reviews by Jim Soule and Bruce Bryant. Jane Ciener served as the technical editor of the earlier map. Robin VerSchneider and Bill Loran provided samples of volcanic ash recovered from the drill hole in Spring Valley. Andrei Sarna-Wojcicki geochemically analyzed and correlated the tephra. Several other colleagues, including Ken Hon, Bruce Bryant, Pat Rogers, Mick Kunk, Jim Budahn, Mark Hudson, Bob Scott, Bill Perry, Dan Unruh, Jim Soule, Bruce Stover, and Tony Svatos, also contributed data or advice to us. Jim Messerich set photogrammetric models of our annotated aerial photographs on a Kern PG-2 plotter. We appreciate the many landowners and property managers who gave permission to enter their property. Hal Terrell, Craig Bair, Sue Rodgers, Calvin Cox, and Roger Lawrence were especially helpful. Peter L. Stelling served as our field assistant in 1994, and Vince Matthews collected additional structural attitudes on bedding planes in 2002. Colin A. Shaw and Joseph L. Allen provided new information on Proterozoic rocks in Glenwood Canyon.

CONTENTS

FIGURES

TABLE

APPENDIX

INTRODUCTION

OVERVIEW

Between 1993 and 2001 the Colorado Geological Survey (CGS) mapped the geology of twelve 7.5-minute quadrangles in the Glenwood Springs area in west-central Colorado (**Figure 1**). These maps were released to the public in varying formats, but many were "old-fashioned", hard-to-read, black-and-white diazo prints of hand-drafted, non-digital maps. During this same time period, map production involving computer-aided drafting and geographic information systems evolved rapidly.

This publication includes the digitally produced, full-color geologic map of the Shoshone 7.5-minute quadrangle. The digital map and accompanying booklet are slightly modified from an earlier publication released by the CGS as Open-File Report 95-4. The digital update was undertaken as part of the STATEMAP component of the National Cooperative Geologic Mapping Program, which is administered by the United States Geological Survey (USGS). In addition to the Shoshone quadrangle, six other quadrangles in the Glenwood Springs area are currently being digitally produced. They include the Glenwood Springs, Cottonwood Pass, Carbondale, Leon, Basalt, and Mount Sopris quadrangles (Fig. 1).

Most of the modifications to this updated digital geologic map of the Shoshone quadrangle relate to the discovery of widespread late Cenozoic evaporite collapse in the region (Kirkham, Scott, and Judkins, 2002) and to a collaborative investigation of that phenomenon by the CGS and USGS subsequent to the release of the CGS Open-File Report 95-4. The discovery of regional evaporite collapse was made early during the mapping program, and new evidence of the collapse was found as additional quadrangles were mapped

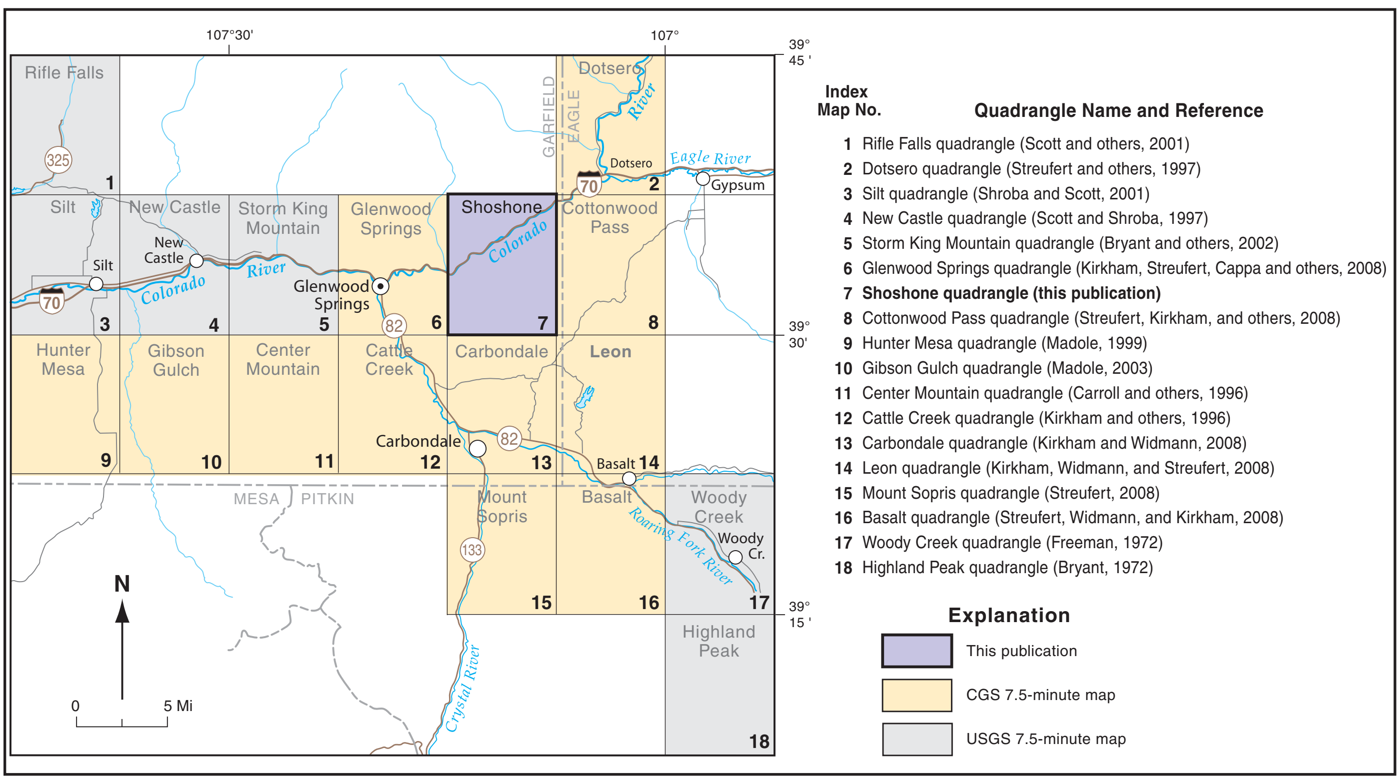

Figure 1. Geologic maps of 7.5-minute quadrangles in the vicinity of the Shoshone quadrangle.

and as the data from the collaborative CGS-USGS investigation were interpreted. The conceptual model of the collapse process also evolved considerably during this time, which caused us to re-evaluate some of the structures and mapped units within the Shoshone quadrangle.

A key part of the collaborative CGS–USGS investigation involved the correlation of Neogene basaltic rocks. Numerous samples of these igneous rocks were collected in the region and were analyzed and correlated using geochemistry, $^{40}Ar/^{39}Ar$ geochronology, magnetostratigraphy, paleomagnetism, and petrography subsequent to the publication of CGS Open-File Report 95-4 (Unruh and others, 2001; Budahn and others, 2002; Kunk and others, 2002; Hudson and others, 2002). Five samples of volcanic rocks from Shoshone quadrangle were studied during the collaborative CGS–USGS investigation; the correlation of these basaltic samples is briefly discussed in a later section.

Most other modifications to the map and booklet are a result of (1) edge matching the geology shown on the Shoshone quadrangle with adjacent recently mapped quadrangles; (2) interpretation of the geology of the mapped area with respect to the regional knowledge acquired by mapping contiguous quadrangles; (3) expansion of the booklet to develop a consistent format for all digitally updated maps; and (4) editorial corrections. In addition to producing a block of full-color geologic maps in uniform digital format, the seven edge-matched quadrangles have compatible stratigraphic nomenclature and consistently use formation colors, patterns, and symbols.

Geologic maps produced by the CGS through the STATEMAP program are useful for many purposes, including land-use planning, geotechnical engineering, geologic-hazards assessment, analysis and mitigation of environmental problems, and mineral-resource and ground-water exploration and development. The maps describe the geology of the quadrangle at a scale of 1:24,000 and serve as a good basis for more detailed research and for regional and broad-scale studies.

The Shoshone quadrangle covers about 58 square miles in Garfield County, which is in west-central Colorado. Interstate Highway 70 runs northeast to southwest across the northern half of the quadrangle, generally following the course of the Colorado River. Most of the land north of the Colorado River is public land administered by the U.S. Forest Service, whereas the land south of the river includes both private and public lands. The private land south of the river consists of ranches and subdivisions; the U.S. Forest Service and Bureau of Land Management are responsible for the public land south of the river. The 1:24,000-scale topographic base map of the quadrangle was first published in 1961 and later updated in 1987 using aerial photographs taken in 1983.

Mapping responsibilities for the geologic map of Shoshone quadrangle are as follows: R.M. Kirkham mapped all the surficial deposits in the quadrangle and the Eagle Valley Evaporite and younger bedrock formations south of the Colorado River; R.K. Streufert mapped the Paleozoic sedimentary rocks north of the Colorado River and the Belden Formation and older Paleozoic strata on the south wall of Glenwood Canyon; J.A. Cappa mapped the Precambrian rocks. R.M. Kirkham is responsible for the modifications to the original geologic map and booklet and for preparation of the updated digital product.

PRIOR GEOLOGIC MAPS

Previously published small-scale geologic maps of the Shoshone quadrangle include 1:500,000-scale maps by Burbank and others (1935) and Tweto (1979), and the 1:250,000-scale map of Tweto and others (1978). Bass and Northrop (1963) focused on the bedrock in their 1:31,680-scale map of the Glenwood Springs 30-minute quadrangle. The southern part of the quadrangle was mapped by F.M. Fox & Associates (1974) at a scale of 1:48,000. The 1:50,000-scale mapping of Soule and Stover (1985), which covered only the southwestern corner of our mapped area, emphasized surficial deposits. CGS originally mapped the Shoshone quadrangle at a scale of 1:24,000 and released it as Open-File Report 95-4 (Kirkham and others, 1995).

MAPPING METHODS AND TERMINOLOGY

Most field work in Shoshone quadrangle was conducted by the authors during the 1994 field season. The authors occasionally spent short periods of time in the field during ensuing years; most of this work related to the collaborative CGS–USGS investigation of basaltic rocks and evaporite collapse. Traverses were made along all public roads and many of the private road in the quadrangle. Numerous foot traverses were needed to access remote parts of the quadrangle. Mapping of the walls of Glenwood Canyon was frequently accomplished from vantage points with good views of nearby canyon walls. Aerial photography was used extensively during the project. Black and white photography with a scale of 1:40,000 was available for the entire quadrangle. 1:24,000-scale color aerial photographs flown for the U.S. Bureau of Land Management covered the southwestern part of the quadrangle; 1:16,000-scale color aerial photography flown for the U.S. Forest Service was utilized for the remainder of the mapped area. Geologic information collected in the field was plotted on the larger-scale photography using a pocket stereoscope. Geologic information drawn on the aerial photographs was transferred to a mylar base map using a Kern PG-2 plotter at the U.S. Geological Survey's photogrammetric facility in Denver.

Volcanic rocks are classified on the basis of the total alkali-silica diagram of Le Bas and others (1986). Grain-size terminology used herein for the sedimentary deposits follows the modified Wentworth scale (Ingram, 1989). This classification system describes pebbles, cobbles, and boulders as differing sizes of gravel. 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. Material smaller than 2 mm is dominant in matrix-supported deposits, and most clasts are separated by or embedded in matrix.

The divisions of geologic time and the age estimates of their boundaries that are used in this publication are shown in **Figure 2**.

Era	Period		Epoch		Age (Ma)
CENOZOIC	Quaternary		Holocene		0.0115
			Pleistocene	U/L	0.126
				Middle	0.781
				L/E	1.81 ± 0.005
	Tertiary	Neogene	Pliocene		5.33 ± 0.005
			Miocene		23.0 ± 0.05
		Paleogene	Oligocene		33.9 ± 0.1
			Eocene		55.8 ± 0.2
			Paleocene		65.5 ± 0.3
MESOZOIC	Cretaceous		Upper/Late		99.6 ± 0.9
			Lower/Early		145.5 ± 4.0
	Jurassic		Upper/Late		161.2 ± 4.0
			Middle		175.6 ± 2.0
			Lower/Early		199.6 ± 0.6
	Triassic		Upper/Late		228.0 ± 2.0
			Middle		245.0 ± 1.5
			Lower/Early		251.0 ± 0.4
PALEOZOIC	Permian		Upper/Late		260.4 ± 0.7
			Middle		270.6 ± 0.7
			Lower/Early		299.0 ± 0.8
	Carboniferous	Pennsylvanian	Upper/Late		306.5 ± 1.0
			Middle		311.7 ± 1.1
			Lower/Early		318.0 ± 1.3
		Mississippian	Upper/Late		326.4 ± 1.6
			Middle		345.3 ± 2.1
			Lower/Early		359.2 ± 2.5
	Devonian		Upper/Late		385.3 ± 2.6
			Middle		397.5 ± 2.7
			Lower/Early		416.0 ± 2.8
	Silurian		Upper/Late		422.9 ± 2.5
			Lower/Early		443.7 ± 1.5
	Ordovician		Upper/Late		460.9 ± 1.6
			Middle		471.8 ± 1.6
			Lower/Early		488.3 ± 1.7
	Cambrian		Upper/Late		501.0 ± 2.0
			Middle		513.0 ± 2.0
			Lower/Early		542.0 ± 1.0
PRECAMBRIAN	Proterozoic		Neoproterozoic		1,000
			Mesoproterozoic		1,600
			Paleoproterozoic		2,500
	Archean		Neoarchean		2,800
			Mesoarchean		3,200
			Paleoarchean		3,600
			Eoarchean		4,000

U. S. Geological Survey Geologic Names Committee, 2007, Divisions of geologic time - major chronostratigraphic and geochronologic units: U. S. Geological Survey Fact 2007-3015, March 2007.

Pleistocene internal ages from International Commision on Stratigraphy, 2007, International stratigraphic chart: downloaded December 2007 from www.stratigraphy.org/cheu.pdf

Figure 2. Geologic time scale.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

The surficial map units are classified by genesis and relative age. Surficial units shown on the map are generally more than about 5 ft thick. Deposits associated with distinct landforms may locally be thinner than 5 ft. Surficial deposits with a width of about 75 to 100 ft or less are not shown on the map because they cannot be depicted on a 1:24,000-scale map. Artificial fill of limited areal extent and residuum were not mapped. Contacts between many surficial units may be gradational and therefore should be considered as approximate boundaries.

Most of the surficial deposits in the Shoshone quadrangle are not well exposed. Therefore, the attributes of these units, such as thickness, texture, stratification, and composition, are based on observations made at only a few locations and on geomorphic characteristics. Since some of the intended users of this map will be interested in unconsolidated surficial materials and active surficial processes, the surficial deposits are subdivided into a relatively large number of map units compared to traditional bedrock-oriented geologic maps.

Characteristics such as the position in the landscape, degree of erosional modification of original surface morphology, and relative degree of weathering and soil development were used to estimate the relative ages of the surficial deposits. 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

af

Artificial fill (latest Holocene) — Fill placed by humans during construction projects. Most artificial fill consists of earthen materials used for the dams of reservoirs and ponds and for Interstate Highway 70. Unit af is composed chiefly of silt, sand, and rock fragments. Maximum thickness is about 30 ft.

ALLUVIAL DEPOSITS — Silt, sand, and gravel deposited in stream channels, flood plains, terraces, and sheetwash areas along the Colorado River and their tributary drainages.

Qa

Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene) — Includes modern alluvium and other deposits along the Colorado River, adjacent flood-plain deposits, and low-terrace alluvium that is up to about 15 ft above modern stream level. Unit Qa is mostly clast-supported, silty, sandy, occasionally bouldery, pebble and cobble gravel in a sandy or silty matrix. It is locally interbedded with and commonly overlain by sandy silt and silty sand. Gravel and sand beds within the unit are poorly to moderately well sorted and are moderately well to well bedded. Clasts are well rounded to subangular. The varied lithology of the clasts reflects the diverse types of bedrock within the provenance of the deposit. Unit Qa locally includes organic-rich deposits or lacustrine clay or silt that were deposited upstream of a rockfall dam that formed early during the Holocene in the vicinity of modern Shoshone dam (White and Kirkham, 1997). Maximum thickness of unit Qa may exceed 200 ft in Glenwood Canyon in the eastern half of the quadrangle (White and Kirkham, 1997). Flood-plain and terrace deposits included in this unit correlate with Holocene deposits in terrace T8 of the Carbondale-Glenwood Springs area of Piety (1981). ^{14}C dates on organic material within the thick section of lacustrine sediments deposited upstream of the rockfall dam ranged from 9,820 ± 130 to 3,890 ± 120 radiocarbon years B.P. (J.B. Gilmore, 1984, personal commun., cited in White and Kirkham, 1997).

Qsw

Sheetwash deposits (Holocene and late Pleistocene) — Bedded deposits locally derived from weathered bedrock and surficial materials that are transported chiefly by sheetwash and deposited in ephemeral and intermittent stream valleys, on gentle hill-slopes, or in small basins. Sheetwash deposits are common on gentle to moderate slopes underlain by limestone, shale, basalt, red beds, and landslide deposits. They typically consist of pebbly, silty sand and sandy silt. Locally, sheetwash deposits are gradational with unmapped colluvium on steeper hillslopes and with unmapped lacustrine or slackwater deposits in closed depressions. Maximum thickness of the unit is probably about 25 ft.

Qto **Older terrace alluvium (late middle Pleistocene) —** Includes a single deposit of stream alluvium on the north side of the Colorado River at the western edge of the quadrangle. The upper surface of this deposit is about 140 ft above the river. Unit Qto consists of clast-supported, cobble or pebble gravel in a sand matrix and matrix-supported, gravelly sand or gravelly silt. Small boulders may be present. Locally it may include fine-grained overbank deposits. Clasts within unit Qto are chiefly subround to round, with varied lithologies that reflect the heterogeneous nature of bedrock within the provenance area. Granitic and micaceous clasts are moderately weathered at shallow depths.

Unit Qto is tentatively correlated with terrace T5 in the Carbondale-Glenwood Springs area of Piety (1981), with terrace C of Bryant (1979) in the Aspen-Woody Creek area, and with older terrace alluvium of Bryant and others (1998). The unit was probably deposited during the late middle Pleistocene Bull Lake glaciation. Maximum thickness of unit Qto is about 100 ft.

QTg **High-level gravel (early Pleistocene or Pliocene) —** Includes remnants of gravelly deposits on hill and ridge crests on the south side of the Colorado River at heights ranging from 1,300 to 2,800 ft above modern river level. Unit QTg consists chiefly of subangular to rounded boulders, cobbles, and pebbles of basalt, red sandstone, and red conglomerate in a clayey or sandy silt matrix. Clasts eroded from evaporitic bedrock locally are present. Deposits of unit QTg in the eastern part of the quadrangle are rich in basalt clasts relative to the deposits that occur to the west. The best exposure of unit QTg is in the head scarp of a landslide in the SW¼ SW¼ of section 32, T. 5 S., R. 87 W., in a tributary to Devils Hole Creek. The unit was probably deposited in fluvial and debris-flow environments. Maximum thickness of unit QTg is estimated at about 80 ft.

MASS-WASTING DEPOSITS — Sediments on valley sides, valley floors, and hill slopes that were mobilized, transported, and deposited primarily by gravity.

Qlsr **Recent landslide deposits (latest Holocene)—** Includes materials deposited by active or recently active landslides with fresh morphological features such as ground fissures, scarps, ridges, hummocky ground, closed depressions, and water-saturated ground. Recent landslide deposits are heterogeneous, and they consist of unsorted, unstratified rock debris, gravel, sand, silt, and clay. Thickness of the unit is probably a maximum of about 40 ft.

Qc **Colluvium (Holocene and latest Pleistocene)—**Ranges from unsorted, clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported gravelly, clayey, sandy silt. Colluvium is derived from weathered bedrock and surficial deposits and is transported downslope primarily by gravity. Locally it grades downslope to unit Qac in some drainages. Deposits are usually coarser grained in the upper reaches of a colluvial slope and finer grained in distal areas where sheetwash processes may be important. Clasts typically are angular to subangular. Colluvium commonly is unsorted or poorly sorted with weak or no stratification. Clast lithology is variable and dependent upon types of rocks on the slopes beneath and above the deposit. Locally the unit may include talus, landslides, sheetwash, and debris flows that are too small or too indistinct on aerial photography to be mapped separately. Maximum thickness of colluvium is about 50 ft.

Qt **Talus (Holocene and late Pleistocene) —** Angular, cobbly and bouldery rubble on steep slopes that is derived from bedrock outcrops and transported downslope principally by gravity as rockfalls, rockslides, rock avalanches, and rock topples. Most talus in the quadrangle is derived from well-indurated Precambrian and lower Paleozoic rocks or basalt. Talus commonly lacks matrix material near the ground surface. Areas mapped as talus may locally include alluvium and colluvium (unit Qac), particularly on narrow valley floors where talus is mapped on both sides of the valley floor. Maximum thickness is estimated at about 80 ft.

Qls **Landslide deposits (Holocene and Pleistocene) —** Highly variable deposits consisting of unsorted, unstratified rock debris, sand, silt, clay, and gravel. Clast lithology is dependent upon the type of material in the original deposit prior to landsliding. Landslide deposits are associated with landforms that have recognizable, but sometimes subdued, geomorphic features such as hummocky ground, lobate form, headscarps, and closed depressions which are characteristic of slopes that have failed. The unit includes rotational and translational landslides, complex slump-earthflows, and extensive slope-failure complexes. The large landslide complex on the east side of Spring Valley probably is related to evaporite tectonism (Kirkham, Streufert, and others, 2002). Landslide deposits attain a maximum thickness of around 250 ft, but usually they are much thinner.

Qco

Older colluvium (Pleistocene) — Erosional remnants of formerly more extensive colluvial deposits found on the ridge line between Ike and Spruce Creeks and on a bench within Glenwood Canyon west of Blue Gulch. Genesis, texture, and bedding are similar to that of colluvium (unit Qc). Older colluvium ranges from about 5 to 40 ft thick.

Qlso

Older landslide deposits (Pleistocene and late Pliocene?) — Includes landslide deposits that are deeply dissected by erosion and that lack distinctive landslide morphologic features. Older landslide deposits are similar in texture, bedding, sorting, and clast lithology to landslide deposits (unit Qls). The type of landslide movement generally is not identifiable due to the eroded character of the deposits. Maximum thickness may exceed 120 ft in the deposit southwest of Tie Gulch.

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 also 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 generally considered to be a form of mass wasting (e.g. Cruden and Varnes, 1996; Hungr and others, 2001).

Qdfy

Younger debris-flow deposits (Holocene) — Sediments deposited by debris flows, hyperconcentrated flows, streams, and sheetwash on active fans and in stream channels. Younger debris-flow deposits range from poorly sorted, matrix-supported, gravelly, sandy, clayey silt to clast-supported, pebble and cobble gravel in a sandy, clayey silt or silty sand matrix. The unit commonly is very bouldery, particularly near fan heads. Distal parts of some fans are characterized by mudflow and sheetwash, and these distal fan deposits tend to be finer grained. Younger debris-flow deposits are locally interfingered or interbedded with modern alluvium adjacent to perennial stream channels. Clasts are mostly angular to subround sedimentary rock and basalt fragments up to about 6 ft in diameter. Original depositional surfaces are usually preserved on younger debris-flow deposits, except where they have been disturbed by human activities. Maximum thickness of younger debris-flow deposits is estimated at 40 ft.

Qac

Alluvium and colluvium, undivided (Holocene and late Pleistocene) — Unit Qac is chiefly stream-channel, low-terrace, and flood-plain deposits along the valley floors of ephemeral, intermittent, and small perennial streams, with colluvium and sheetwash common on valley sides. Locally, unit Qac includes younger debris-flow deposits, or it may grade to debris-flow deposits in some drainages. The alluvial fraction typically is composed of poorly sorted to well-sorted, stratified, interbedded pebbly sand, sandy silt, and sandy gravel. Colluvial beds commonly are unsorted, unstratified or poorly stratified, clayey, silty sand, gravelly sand, sandy gravel, and sandy silt. Thickness of unit Qac typically is 5 to 20 ft, and its maximum thickness is about 40 ft.

Qdfm

Intermediate debris-flow deposits (Holocene and late Pleistocene) — Similar in texture and depositional environment to younger debris-flow deposits (unit Qdfy). The geomorphic character of original depositional surfaces are commonly recognizable, but the surface is topographically about 10 to 20 ft above active debris-flow channels.

Qdfo

Older debris-flow deposits (Pleistocene) — Includes remnants of formerly extensive debris fans at the mouth of Ike Creek and in Spring Valley. Older debris-flow deposits have genetic, textural, and lithologic characteristics that are similar to younger debris-flow deposits (unit Qdfy). Deposits of unit

Qdfo that are east of the mouth of Ike Creek contain rounded basalt clasts, suggesting deposition in a fluvial environment associated with Ike Creek. The original debris-fan surfaces are fairly well preserved on older debris-flow deposits, although the fan surfaces locally may be mantled with loess. Elevation differences between the original depositional surface of the fan and the adjacent modern drainages range from 20 to 200 ft. The thickness of older debris-flow deposits generally are about 30 to 60 ft, but the deposits on the west side of Ike Creek locally attain thicknesses of about 150 ft.

QTbg **High-level basaltic gravel (early Pleistocene or late Tertiary?) —** Deposits of high-level basaltic gravel cap the ridge east of Ike Creek along the eastern edge of the quadrangle. The unit consists of slightly indurated, matrix-supported, gravelly and clayey sandy silt that probably was deposited as debris flows, earthflows, colluvium, or landslides. Clasts vary from pebble to boulder sizes and are primarily composed chiefly of very weathered, rounded to subangular basalt with minor amounts of red sandstone and conglomerate, quartzite, quartz, pink granite, and chert. The deposits are about 600 ft above Ike Creek. Maximum thickness is about 60 ft.

GLACIAL DEPOSITS — Gravel, sand, silt, and clay deposited by, adjacent to, or beneath ice in moraines.

Qm **Morainal deposits (late and/or late middle Pleistocene) —** Heterogeneous deposits of gravel, sand, silt, and minor clay deposited by ice in ground, lateral, and end moraines between East and West Dead Horse Creeks. Morainal deposits are dominantly unsorted or poorly sorted, unstratified or poorly stratified, matrix-supported bouldery, pebble and cobble gravel with a matrix of silty sand. The deposits may locally be clast-supported where composed mostly of gravel. Clasts contained within the morainal deposits typically are angular to round pieces of Precambrian and lower Paleozoic bedrock that occasionally exceed 10 ft in length. The unit may locally include glacio-fluvial deposits which is why the unit is called morainal deposits, not glacial till. The morainal deposits in the quadrangle were deposited by, adjacent to, or beneath glaciers that were part of an extensive ice cap that formed on the White River Plateau. The ice cap transitioned into valley glaciers that flowed down the stream valleys on the south side of the Plateau. The southernmost ends of these valley glaciers extended into the mapped area; the lower limit of glaciation was at an altitude of about 9,200 ft. Ages of the morainal deposits are not well constrained. The deposits are probably in part equivalent to the late Pleistocene Pinedale glaciation, but they may also in part be equivalent to the late middle Pleistocene Bull Lake glaciation. Maximum thickness of unit Qm is about 100 ft.

LACUSTRINE DEPOSITS — Sediments deposited in lakes.

Ql **Lacustrine deposits (Quaternary) —** Stratified deposits of light- to dark-gray, organic-rich, silty clay and silt, reddish-brown, well-sorted, fine to coarse sand, and light-gray volcanic ash in Spring Valley. The unit is very poorly exposed; most information on the lacustrine deposits is from drill hole SRV No. 6 in the SW1/4 NE1/4 of section 29, T. 6 S., R. 88 W. This test hole was drilled to a depth of about 570 ft by Wright Water Engineers and did not encounter bedrock (Robin Verschneider, 2001, oral commun.). Most material penetrated by the well was fine-grained silt and clay with gray and red-brown colors. From a depth of about 250 to 300 ft, the drilled sediments were rich in volcanic ash that was identified as the Lava Creek B ash (A. Sarna-Wojcicki, 2002, written commun.).

According to Calvin Cox (1994, oral commun.), a lake existed in Spring Valley until near the end of the last century. His ancestors hand excavated a ditch at the northwest end of Spring Valley to drain the lake and then farmed the exposed lake bottom to demonstrate agricultural use of the land for homesteading purposes. Land ownership was transferred from the federal government to his ancestor in 1896, therefore dewatering of the lake occurred prior to that year. The lake in Spring Valley did not result from landsliding or glaciation that blocked the outlet. The valley apparently formed in response to evaporite tectonism, either as a half graben or pull-apart structure (Kirkham, Streufert, and others, 2002). The lacustrine deposits in Spring Valley are at least 570 ft thick.

SINTER DEPOSITS—Chemical sediment deposited by a mineral spring.

Qtu

Tufa (Holocene and Pleistocene?) — Low-density, porous chemical sedimentary rocks consisting of calcium carbonate precipitated from mineral-charged spring, ground, and surface water. Tufa occurs as massive ledges and as a gravel-cementing material in Dead Horse Creek. A large tufa mound serves as the dam for Hanging Lake. Modern tufa deposition in the quadrangle is associated with cold-water springs. To the west in Glenwood Springs quadrangle, however, thermal springs were encountered during 1993 in excavations for homes at the base of a prominent tufa ledge. Tufa deposition may have initiated during the Pleistocene and has continued at one or another location intermittently to the present. Maximum thickness is estimated at about 30 to 40 ft.

COLLAPSE DEPOSITS — Complexly deformed deposits related to collapse caused by evaporite tectonism.

QTcd

Collapse debris (Quaternary and late Tertiary) — Heterogeneous deposits of moderately to severely deformed bedrock and overlying undeformed to moderately deformed surficial deposits. Collapse debris formed in complexly deformed areas within the central parts of the Carbondale Collapse Center in response to major differential vertical collapse or regional subsidence resulting from dissolution and flow of underlying thick beds of evaporite, primarily halite (Kirkham, Streufert, and others, 2002). Highly fractured and locally brecciated basalt and trachyandesite comprise the predominant type of bedrock within the collapse debris at the ground surface. The unit locally includes small blocks of intact but tilted volcanic rocks. Lesser amounts of deformed Maroon Formation locally occur within the collapse debris, and windows of evaporite may be present. Various types of surficial deposits, including sheetwash, alluvium, colluvium, loess, and talus, have been deposited over the collapsing debris at various times. These surficial deposits often were caught up within and incorporated into the deposit as it underwent further collapse. Collapse debris grades to folded and faulted bedrock where less deformed and to landslide deposits where the direction of collapse appears to have a significant horizontal component. Contacts between collapse debris and bedrock are very approximately located. Thickness of unit QTcd is unknown, but it probably exceeds 100 ft.

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q

Surficial deposits, undifferentiated (Quaternary) — Shown only on cross sections. Unit may include any of the above surficial deposits.

BEDROCK

Tta

Trachyandesite (Pliocene) —-Flows and breccias of basaltic trachyandesite and trachyandesite in the southeast part of the quadrangle. Two samples from unit Tta (SH267 and SH268) are included in geochemical compositional group 6b of Budahn and others (2002), and one sample (SH262) is included in group 6a′. Little Buck Point may be an eruptive center for unit Tta. Large xenocrysts of quartz, sanidine, and plagioclase are common in unit Tta. Small diameter phenocrysts of olivine also are present. The quartz xenocrysts are rounded, corroded anhedra that have a rim of pigeonite; they range in size from 0.4 to 8.0 mm. Sanidine crystals are fresh subhedra up to 8 mm in size. Inclusions of plagioclase and quartz exist within the sanidine xenocrysts. Plagioclase (An58) occurs as rounded, zoned, corroded anhedra and euhedra ranging in size from 0.2 to 4.0 mm. Olivine phenocrysts are fine euhedral and subhedral crystals that are weakly to strongly altered to hematite and iddingsite. The groundmass of unit Tta consists of fine, fresh laths of plagioclase, olivine, and pyroxene. Accessory minerals include biotite, hematite, and magnetite. A sample of sanidine from trachyandesite exposed on Little Buck Point (sample SH267) yielded an isochron $^{40}Ar/^{39}Ar$ age of 3.97 ± 0.08 Ma (Kunk and others, 2002).

Tb

Basaltic flows (Miocene) — Multiple flows of trachybasalt, basaltic trachyandesite, and probably basalt. In places the unit includes slightly indurated fluvial sandstone and siltstone and lacustrine claystone that is commonly calcareous and occasionally tuffaceous. Petrographically, most flows are olivine basalt; many are porphyritic. Flow rocks range from massive to highly vesicular;

amygdules of calcite and iron-rich clay are locally common. Phenocrysts typically are euhedral and subhedral olivine that range in size from 0.4 to 3.0 mm. The olivine phenocrysts are weakly to strongly altered to hematite and iddingsite. Plagioclase phenocrysts are present in some flows. The groundmass is dominantly plagioclase and pyroxene, with lesser but varying amounts of olivine, glass, pigeonite, augite, and magnetite. Trace minerals include apatite, iddingsite, and hematite. The flows in unit Tb may contain rare xenocrysts or xenoliths of quartz or quartzite.

Unit Tb flows comprise the extensive basaltic cap on Little Grand Mesa in the east-central and south-central parts of the quadrangle. These trachybasalt flows are tilted, deformed, and downdropped to the south along the Cottonwood Monocline, which forms the northern margin of the Carbondale Collapse Center. Budahn and others (2002) include the unit Tb flows on Little Grand Mesa (samples SH303 and SH341) in their geochemical group 5b, which have an average ^{40}Ar/^{39}Ar age of 7.75 Ma (Kunk and others, 2002). Although no geochemical data is available for the unit Tb flows in the southwest part of the quadrangle, hand specimens of these flows are similar to nearby flows in Glenwood Springs and Cattle Creek quadrangles that are ~10 Ma. Refer to a later section of this booklet for additional information on the age and geochemical correlation of the basaltic rocks in unit Tb. Individual flows in unit Tb commonly are 5 to 25 ft thick. Maximum thickness of the entire sequence of flows is around 200 ft on Little Grand Mesa, but are thinner elsewhere.

Pℙm

Maroon Formation (Lower Permian and Pennsylvanian) — Mainly red beds of sandstone, conglomerate, mudstone, siltstone, and claystone with minor, thin beds of gray limestone. The upper part of the formation, which includes the Schoolhouse Member of the Maroon Formation (Johnson and others, 1990), is not present within the quadrangle, having been stripped off by erosion during the middle or late Tertiary prior to eruption of the late Miocene volcanic flows of unit Tb. Conglomerate beds within the Maroon Formation contain subangular to rounded pebble- and cobble-sized clasts of quartz, feldspar, and granitic rock fragments. The formation commonly is arkosic and very micaceous. Within the quadrangle, the formation is very poorly exposed. Total thickness of the entire formation is about 3,000 to 4,000 ft in adjacent areas; however, only about the lower half of the formation is preserved in the quadrangle. The Maroon Formation was deposited in fluvial and perhaps eolian environments in the Central Colorado Trough between the ancestral Front Range and Uncompahgre Highlands.

ℙeu

Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian) — Includes the Eagle Valley Formation and Eagle Valley Evaporite on the south wall of Glenwood Canyon where heavy forest cover and a thick veneer of surficial deposits obscure the contact between these very poorly exposed units. The Eagle Valley Formation includes interbedded reddish-brown, gray, reddish-gray, and tan siltstone, shale, sandstone, gypsum, and carbonate rocks that represent a stratigraphic interval in which the red beds of the overlying Maroon Formation intertongue with the dominantly evaporitic rocks of the underlying Eagle Valley Evaporite. The Eagle Valley Formation includes rock types of both formations. The Eagle Valley Evaporite is a sequence of evaporitic rocks consisting mainly of gypsum, anhydrite, and halite that are interbedded with light-brown to medium-gray, fine-grained clastic rocks, thin carbonate beds, and sparse conglomerate. Beds within the Eagle Valley Evaporite commonly are intensely folded, faulted, and plastically deformed by diapirism and flowage associated with evaporite tectonism.

The combined thickness of the Eagle Valley Formation and Eagle Valley Evaporite within the mapped area is only a few hundred feet, significantly less than in adjacent areas. The contact with the overlying Maroon Formation is placed at the top of the uppermost evaporite bed or light-colored clastic bed and below the base of the thick sequence of red beds. The Eagle Valley Formation was deposited within the late Paleozoic Eagle Basin on the margin of an evaporite basin; most sediments with the formation accumulated in the distal end of a coalescing alluvial fan complex or in a submarine environment within the evaporite basin.

ℙb

Belden Formation (Lower Pennsylvanian)— Predominantly gray to black, calcareous shale and fossiliferous gray limestone with minor beds of fine- to medium-grained, micaceous sandstone, micaceous siltstone, and a few beds of faintly cross-bedded arkose. The Belden Formation also contains thin beds of gray, brown, and black chert in the lowermost part of unit. It also may contain thin discontinuous beds of evaporite which can occur anywhere in the formation. The upper portions of the formation include intertonguing beds of coarse-grained clastic rocks that are thought to be equivalent to the Minturn Formation. These intertonguing beds of lithic wacke and subarkose occurring near the top of the Belden Formation are well exposed to the northeast in the Dotsero quadrangle (Streufert and others, 1997). The Belden Formation is very fossiliferous. Bass and Northrop (1963) described 258 fossil species collected from the formation in the region, including algae, foraminifera, anthozoans, bryozoans, brachiopods, pelecypods, gastropods, scaphopods, cephalopods, annelids, trilobites, ostracods, blastoids, crinoids, echinoderms, and vertebrate remains.

The Belden Formation rarely forms discernable outcrops, except where it is subjected to rapid erosion. Normally, the formation underlies the vegetated slope immediately above the prominent cliffs of the underlying Leadville Limestone. The Belden Formation commonly is overlain conformably by a massive bed of gypsum that is the basal strata of the overlying Eagle Valley Evaporite (Mallory, 1971). Sediments of the Belden Formation were deposited in the Central Colorado Trough between the ancestral Uncompahgre and Front Range Highlands in a low-energy marine environment at a distance from their source. Strata equivalent to the Minturn Formation were most likely deposited in a series of coalescing alluvial fans, the distal ends of which intertongue with rocks of the Belden Formation. The unit is approximately 700 to 900 ft thick.

Ml

Leadville Limestone (Mississippian) — Light- to medium-gray, bluish-gray, massive, coarsely to finely crystalline, fossiliferous micritic, limestone and dolomite. The Leadville Limestone contains lenses and nodules of dark-gray to black chert in the lower one-third of the formation that are as much as 0.3 ft thick. Coarse-grained ooliths occur in the upper half of the formation. Carbonate veins with disseminated silt-sized quartz grains are common. A paleokarst surface developed at the top of the Leadville Limestone prior deposition of the overlying Belden Formation. Collapse breccias, a red to reddish-purple claystone regolith, and solution cavities, many of which are sediment-filled, occur at the top of the formation. The brightly colored regolith, known as the Molas Formation, is not a mappable unit at a scale of 1:24,000 in the quadrangle. The Leadville Limestone is very fossiliferous; crinoid and brachiopod fragments are locally abundant. The formation commonly forms a prominent cliff, and it frequently caps the bold cliffs that constitute the inner walls of Glenwood Canyon. The contact with the overlying Belden Formation is irregular and unconformable. The Leadville Limestone averages about 200 ft thick in the quadrangle. It formed in the sublittoral zone of a marine environment by chemical precipitation and through the accumulation of biogenic and oolitic sediment.

Dc

Chaffee Group (Upper Devonian)— Sequence composed of green shale, quartzite, dolomite, limestone, and dolomitic sandstone. It consists of three named formations, which from top to bottom are the Gilman Sandstone, Dyer Dolomite, and Parting Formation. Total thickness of the Chaffee Group in Glenwood Canyon is 252.5 ft (Soule, 1992).

The **Gilman Sandstone** consists of tan to yellow, laminated, fine- to very fine-grained quartz arenite and dedolomitic limestone. It is variable in lithology and thickness across the study area. Within the quadrangle, the Gilman Sandstone is chiefly a calcareous sandstone that averages about 16 ft thick. To the west it thins and transitions to an oxidized dolomite (dedolomite) with thickness less than 1 ft near Glenwood Springs. The sandstone phase consists of rounded to subrounded quartz grains that are well sorted. Laminae are generally less than 1 inch in thickness and consist of zones of fine sand that locally have weak planar-tabular cross-bedding and minor load structures. Some laminae contain discontinuous lenses of quartz arenite with visible relict casts of carbonate rhombohedron. Limestone beds in the Gilman consist of a greater than 99 percent pure calcite-bearing dedolomitic limestone with minor hematite and quartz. The contact with the overlying Leadville Limestone is unconformable. Tweto and Lovering (1977) suggested a water reworked, eolian origin for the Gilman Sandstone near the town of Gilman. Most likely it was deposited in a changing environment of very shallow water and periodic subaerial exposure in the supratidal (tidal flat) zone.

The **Dyer Dolomite** is divided into two members on the White River Plateau, an upper Coffee Pot Member and a lower Broken Rib Member. The Coffee Pot Member consists of crystalline, micritic dolomite, dolomitic gray shale, and micritic limestone. It is somewhat sandy, especially near the top and is fossiliferous in places. The Coffee Pot Member is characterized by abundant rip-up clasts, intraformational breccia, and bioturbated bedding (Soule, 1992). Together with the Gilman Sandstone it forms blocky slopes beneath the prominent cliff of overlying Leadville Limestone on the walls of Glenwood Canyon. It was deposited predominantly in the uppermost intertidal to supratidal (tidal flat) zones in a changing environment of periodic subaerial exposure with influxes of shallow marine conditions. The Broken Rib Member consists of gray, nodular, crystalline limestone. The Dyer Dolomite is very fossiliferous with brachiopods (Bass and Northrop, 1963). It forms a very distinctive "knobbly-weathering" gray ledge above blocky slopes of the underlying Parting Formation in canyon outcrops. The Dyer Dolomite formed in a shallow marine environment in the sub-littoral zone.

The **Parting Formation** consists of white to buff, well-cemented orthoquartzite with minor feldspar and rock fragments, micaceous green shale with discontinuous lenses of orthoquartzite, and sandy micritic dolomite. Thicknesses of orthoquartzite beds are consistent across study area, ranging from 0.5 to 1.0 ft. Other beds show much greater variation in thickness. The Parting Formation forms a blocky slope with distinct ledges above the prominent cliffs of the underlying Manitou Formation. Bass and Northrop (1963) collected fish fossils from the Parting Formation in Glenwood Canyon. It formed in a shallow marine environment.

MDr

Mississippian and Devonian rocks, undivided (Mississippian and Upper Devonian) — Includes the Leadville Limestone and Chaffee Group where it is not practicable to separate formations.

Om

Manitou Formation (Lower Ordovician) — Consists predominantly of medium-bedded brown dolomite at the top of the formation and thin beds of gray flat-pebble limestone interbedded with greenish-gray calcareous shale, sandstone, and brown-weathering limestone and dolomite in the lower part of the formation. In Glenwood Canyon the formation is 155.8 ft thick according to Bass and Northrop (1963) and 167.3 ft thick as measured by Soule (1992).

Two members comprise the Manitou Formation, an upper Tie Gulch Member and a lower Dead Horse Conglomerate Member. The **Tie Gulch Member** consists of massive, micritic, brown and orange-weathering, crystalline, somewhat siliceous dolomite and minor limestone that becomes slightly sandy near the top of the member. The Tie Gulch Member forms a consistent 50- to 90-ft thick, brown- to orange-colored cliff in Glenwood Canyon that rises above a gentler slope on the underlying lower Manitou and Dotsero Formations. Some beds in the Tie Gulch Member are slightly glauconitic. No fossils are known from the Tie Gulch Member. The contact with the overlying Devonian Chaffee Group is unconformable, occurring at a thin shale bed that may be the remains of a paleosol (Soule, 1992). Strong dolomitization and a lack of marine fossils suggests that sediments of the Tie Gulch Member accumulated in the upper intertidal and/or lowermost supratidal (tidal flat) environments.

The **Dead Horse Conglomerate Member** consists mostly of thin-bedded, gray, flat-pebble limestone conglomerate, thin-bedded limestone, shaly limestone, and two beds of massive dolomitic orthoquartzite. It is somewhat glauconitic, especially in the bottom part of the member. The Dead Horse Conglomerate Member contains a diverse Lower Ordovician fossil fauna (Bass and Northrop, 1963). The base of the member generally forms a continuous slope with underlying rocks of the Dotsero Formation. Strata in the upper parts of the member frequently form an unbroken cliff with the overlying rocks of the Tie Gulch Member in Glenwood Canyons, rendering close inspection of the upper contact difficult. The Dead Horse Conglomerate Member most likely was deposited under fluctuating conditions and varying water depths in the intertidal and shallow marine environments.

Ꞓd

Dotsero Formation (Upper Cambrian) — Includes four units, which in descending order are the Clinetop Bed, Glenwood

Canyon Member, Red Cliff Member, and Sheep Mountain Member (Myrow and others, 2003). The uppermost strata is a 5-ft thick sequence of matrix-supported limestone-pebble conglomerate with abundant rip-up clasts and an overlying bed of stromatolitic limestone with well-preserved algal-head crinkle structure that is now called the **Clinetop Bed** (Myrow and others, 2003). The **Glenwood Canyon Member** consists of approximately 50 ft of thin-bedded dolostone, dolomitic sandstone, conglomeratic limestone, coarse-grained fossiliferous limestone, and dolomitic shale. Dolomitic beds in the Glenwood Canyon Member are glauconitic, giving the beds a greenish hue. Worm tracks and worm burrow (fucoids) are common, especially in the middle third of the member. The **Red Cliff Member** is composed of approximately 22 ft of sandy dolostone, flat-pebble conglomerate, and dolomitic shale. It is locally glauconitic and/or bioturbated. Although it is a distinct member east of the quadrangle, the contact between the Red Cliff Member and overlying Glenwood Canyon Member is much less distinct within the quadrangle (Myrow and others, 2003). The basal unit of the Dotsero Formation is the **Sheep Mountain Member**, which rests on the white quartz-rich Sawatch Formation. The member consists of 5-6 ft of light-brown, very fine- to medium-grained, glauconitic, well-sorted sandstone and local dolomitic flat-pebble conglomerate.

The Dotsero Formation generally forms a vegetated slope above the prominent cliffs of the Sawatch Formation. However, beds within it can form cliffs, especially in the deeper portions of Glenwood, No Name, and Grizzly Canyons. The entire formation is about 80 ft thick. Variation in lithologies and sedimentary structures in the formation indicate a period of widely fluctuating depositional patterns ranging from near-shore shallow marine through intertidal to supratidal (tidal flat) environments.

€s

Sawatch Formation (Upper Cambrian) — White and buff to gray-orange, brown-weathering, vitreous quartz arenite in beds from 1 to 3 ft thick. Locally, the base of the Sawatch Formation contains beds of arkosic quartz-pebble conglomerate that rest unconformably on highly weathered Proterozoic rocks. Basal hematite-stained, planar to tabular cross-bedded sandstone interbedded with quartz arenite is also locally present in the quadrangle. The middle part of the formation includes beds of massive, brown, sandy dolomite, and white dedolomitic quartzite. Fossils are extremely rare to non-existent in the formation. The total thickness of the combined unit is 500 ft. Primary sedimentary structure is poorly preserved in the Sawatch Formation, which most likely originated as beach deposits or in shallow water of the littoral zone from sediment eroding off a highland in the vicinity of the Front Range (Tweto and Lovering, 1977).

Xbg

Biotite granite (Paleoproterozoic) — Generally dark-gray and white-speckled, medium to coarse-grained, equigranular granite and granodiorite. Primary constituents of unit Xbg are soda-rich anhedra of plagioclase, anhedra of microcline and perthite, and severely strained anhedra of quartz. Small blebs of quartz also occur within the feldspar crystals. Accessory minerals include interstitial anhedra of biotite and hornblende. Trace minerals include magnetite, apatite, sphene, epidote, chlorite, and zircon. Mafic xenoliths averaging about a foot in diameter are common in the granite. Samples of the granite examined in thin section have a weak gneissic foliation that is defined by the alignment of the biotite and hornblende crystals.

Biotite granite forms spectacular, well-jointed outcrops in Glenwood Canyon. The granite contains numerous dikes and sills of white to pink pegmatite and aplite. These dikes and sills range from an inch to 10 ft wide and have lengths as much as a few hundred feet. Lithological similarity of the biotite granite to granites exposed in the Aspen area (Bryant, 1979) and Sawatch Range (Wetherill and Bickford, 1965) suggest that the biotite granite is 1.6 to 1.7 Ga (Early Proterozoic).

Xgn

Mica schist and gneiss (Paleoproterozoic)— A heterogeneous unit composed of a variety of supercrustal metamorphic rocks. Mica schist and gneiss is the predominent rock type in most of the quadrangle. It consists of dark-gray to black, well- to poorly foliated, biotite-muscovite schist or gneiss composed primarily of fine-grained quartz, orthoclase, plagioclase, and as much as 35 percent biotite and muscovite. Biotite is commonly partially replaced by chlorite. In some localities the gneiss is coarse grained and contains distinct 1-inch diameter aggregates of white muscovite. Quartz and feldspar podiform segregations that range from a few inches to 3 ft long and from less than an inch to 0.5 ft wide are common throughout the gneiss. Migmatitic layers of granite gneiss in bands ranging from approximately 1 inch to 3 ft thick are locally abundant. White and pink pegmatite and aplite zones are common within the unit and can locally comprise most of the unit. Where pegmatite units are mappable, they are shown on the accompanying geologic map by a stippled pattern. Pegmatites are generally composed of large, white, euhedral feldspars; muscovite; anhedral to euhedral red garnets; dendritic aggregates and solitary crystals of black tourmaline; and oxidized specular hematite.

The mica schist and gneiss unit is intruded by and thus is older than the biotite granite.

GEOLOGIC SETTING

The rocks and surficial deposits of the Shoshone quadrangle record a long and diverse geologic history. The rocks are moderately to well exposed on the steep walls of Glenwood Canyon and its tributaries, but are less well exposed elsewhere in the quadrangle. Exposures are especially poor in the southern half of the quadrangle. The oldest exposed rocks (units Xgn and Xbg) date back to the Paleoproterozoic and are apparently related to arc magmatism and sedimentation in arc-related basins along the southern edge of the Archean Wyoming craton (Reed and others, 1987).

A spectacular nonconformity that is well exposed on the walls of Glenwood Canyon separates the Early Proterozoic igneous and metamorphic rocks from overlying lower Paleozoic sediments. Over a billion years of geologic time is represented by this erosion surface. Purple to dark-gray regolith locally present in the Proterozoic rocks beneath the nonconformity suggest that these older rocks were strongly weathered prior to deposition of the overlying lower Paleozoic sediments.

A sequence of Cambrian through Mississippi sediments above the nonconformity (includes strata of the Upper Cambrian Sawatch Formation through Mississippian Leadville Limestone) was episodically deposited in a shelf sequence environment. Disconformities within the Cambrian through Mississippian sequence represent more geologic time than do the preserved strata (Ross and Tweto, 1980). A long period of extended subaerial exposure occurred between deposition of the Leadville Limestone and overlying Lower Pennsylvanian Belden Formation. An extensive karst topography that included sinkholes, caverns, and limestone towers developed on the top of the Leadville Limestone during this time interval. A brightly colored regolith, the Molas Formation, formed on the karst topography and filled many of the sinkholes. Because the Molas Formation is thin and discontinuous in the quadrangle, it is lumped with the map unit of the Leadville Limestone.

Major elongate, northwest-trending uplifts began to form in Early or Middle Pennsylvanian time. These uplifts, commonly referred to as the Ancestral Rocky Mountains, developed both to the east of the quadrangle (Ancestral Front Range Highland) and to the west (Ancestral Uncompahgre Highland). As the uplifts rose, lower Paleozoic strata were stripped off, exposing the underlying Precambrian rocks. During the Pennsylvanian and Permian, clastic sediments eroded from the uplifts and accumulated in flanking basins such as the Central Colorado Trough (Brill, 1944; DeVoto, 1980). The Shoshone quadrangle, which lies within the Eagle Basin part of the Central Colorado Trough, received several thousand feet of sediment stripped from the uplifts.

Carbonaceous marine shales, thin limestones, and minor gypsum within the Belden Shale were the initial fill deposited in the Eagle Basin in the quadrangle. Evaporitic sediments of the Eagle Valley Evaporite, including halite and gypsum, accumulated over the Belden. Where exposed in the quadrangle, the Eagle Valley Evaporite is very thin relative to adjacent areas. This thinning probably is due to post-depositional flowage or dissolution. Highly soluble evaporite minerals like halite have not been observed in outcrop, but they have been encountered in oil test holes drilled in nearby areas. Red beds of sandstone, conglomerate, and siltstone of the Maroon Formation were deposited in fluvial and fan environments that prograded into and over the evaporitic sequence. An interval of interbedded red beds and evaporitic strata that separates the Eagle Valley Evaporite from the Maroon Formation is mapped as the Eagle Valley Formation. Thick sequences of Permian to Eocene sedimentary rocks overlie the Maroon Formation in adjacent areas, but these strata, as well as the upper part of the Maroon Formation, are absent in the quadrangle, probably a result of erosion during the Paleogene.

Tectonism and igneous activity associated with the Laramide orogeny initiated near the end of the Cretaceous. The White River Uplift, a broad domal structure whose southern flank is in the northern part of the quadrangle, formed late during the Laramide orogeny (Tweto, 1975). The structural axis of the domal uplift crosses Glenwood Canyon near the western margin of the quadrangle, in the area where the top of the uplifted Proterozoic rocks attains its maximum altitude. To the west of the mapped area, the Grand Hogback Monocline forms the western margin of the White River Uplift. Strata of the Paleocene and early Eocene Wasatch Formation are deformed by the Grand Hogback Monocline about as much as are older strata. The middle Eocene Green River Formation is tilted slightly by the monocline (Tweto, 1975), and the sandstones within this formation coarsen as they approach the White River Uplift (Donnell, 1961). This evidence suggests the White River Uplift was active chiefly in the Eocene.

Sometime after the Laramide orogeny, perhaps initially during late Eocene time (Scott, 1975) and possibly later modified by one or more subsequent periods of erosion (Kirkham, Kunk, and others, 2001; Steven, 2002), a broad angular unconformity was cut across the region. Miocene basaltic rocks were episodically erupted onto low-relief erosion surfaces in the quadrangle. Erosional remnants of these volcanic flows are widely distributed across the southern half of the quadrangle. Subhorizontal basaltic flows that are about 7.75 Ma cap Little Grand Mesa; these flows are abruptly tilted to the south by Cottonwood Monocline. Slightly older, ~10 Ma flows crop out in the southwestern part of the quadrangle.

During the Miocene, the Colorado River and its tributaries began to downcut through the low-relief erosion surface, creating younger and topographically lower erosion surfaces inset into the regional late Eocene-early Miocene erosion surface (Larson and others, 1975; Kirkham, Kunk, and others, 2001; Kunk and others, 2002). This incision triggered flow and dissolution of halite and gypsum that led to widespread collapse of the ground surface in the region (Kirkham, Streufert, and others, 2001, 2002; Lidke and others, 2002; Scott and others, 2002). The northern margin of the Carbondale Collapse Center, which coincides with Cottonwood Monocline, runs generally east-west through the southern half of the quadrangle.

Neogene basaltic lavas, which were originally erupted onto the low-relief subhorizontal erosion surface, provide critical evidence of evaporite collapse in the Carbondale Collapse Center and constrain the timing, rate, lateral extent, and amount of vertical collapse. For example, the 7.75 Ma flows that cap Little Grand Mesa are sharply tilted along the Cottonwood Monocline, losing about 1,000 ft in elevation from the mesa to the south edge of the quadrangle. Correlative 7.75 Ma basaltic flows exposed in the walls of the Roaring Fork River valley near the middle of the collapse center are downdropped 2,400 ft relative to those on Little Grand Mesa.

The ~4 Ma trachyandesite flows also provide critical control on the timing of evaporite collapse. Trachyandesite flows occur at altitudes as high as 9,020 ft within the collapse center, which is only about 200 ft below the 7.75 Ma flows on Little Grand Mesa. This elevation difference of 200 ft represents the maximum vertical collapse at this location that has happened during the nearly 4 million year time span between when the trachybasalts on Little Grand Mesa and the trachyandesites were erupted. Most of the evaporite collapse must have occurred after the eruption of the ~4 Ma trachyandesites, because the trachyandesite flows are lowered about 1,800 ft by evaporite collapse.

The structure responsible for Spring Valley in the southwest corner of the map is depicted as a half graben on the geologic map, but it may be a pull-apart structure related to evaporite tectonism (Kirkham, Streufert, and others, 2002). Volcanic ash encountered from about 250 to 300 ft below the ground surface in test well SRV No. 6 in Spring Valley (Robin VerSchneider, 2001, personal commun.) was identified as the Lava Creek B ash (A.M. Sarna-Wojcicki, 2002, written commun.), which was dated at 639 ka by Lanphere and others (2002). Based on the depth and age of the ash, the sedimentation rate in the valley is very high, especially considering that much of the sediment overlying the ash is clay and silt deposited in a lacustrine environment.

If Spring Valley is a pull-apart structure, then evaporite flow may be the primary mechanism responsible for creating the Spring Valley structure. The block of rock that underlies Los Amigos Mesa (a basalt-capped rolling surface west of Spring Valley; see Kirkham, Streufert, Cappa, and others, 2008, and Kirkham and others, 1996, for location) protrudes about one-half mile into the Roaring Fork River valley. This block may be moving or rafting towards the Roaring Fork River, as underlying evaporite flows westward (Kirkham, Streufert, and others, 2002). The large landslide complex on the east side of Spring Valley likely failed in response to removal of the toe of the slope as the Spring Valley pull-apart structure gradually widened.

The dissolved halite and gypsum that are responsible for the collapse eventually end up in the Colorado River. Chafin and Butler (2002) estimate that about 880,000 tons of salt are dissolved from the Eagle Valley Evaporite in the Carbondale and Eagle Collapse Centers every year. Yampa hot spring, which provides the water for the hot springs pool in the town of Glenwood Springs, discharges about 260 tons of dissolved halite and gypsum to the Colorado River daily (Barrett and Pearl, 1976). Many other hot springs in the area also discharge water that is enriched in dissolved evaporite minerals. These high salt concentrations are strong evidence that the evaporite dissolution and collapse is active.

Effects of Pleistocene glaciation are apparent in Glenwood Canyon and between and near the forks of Dead Horse Creek. Till and glacio-fluvio deposits underlie the moraines along the northern edge of the quadrangle in the vicinity of East and West Dead Horse Creeks. These morainal materials were deposited by valley glaciers shed southward off the ice that capped the White River Plateau. A single terrace underlain by gravelly Pleistocene glacial outwash deposited by the Colorado River is present along the western margin of the quadrangle.

CORRELATION AND AGE OF LATE CENOZOIC BASALTIC ROCKS

When the Shoshone quadrangle was initially mapped by the CGS during 1994, five samples of basaltic rock were collected in the quadrangle and analyzed for major elements (Appendix A). One sample (SH267) was dated using $^{40}Ar/^{39}Ar$ methods (Larry Snee, 1995, written commun.). Locations of these samples are shown on the accompanying geologic map.

Early during the collaborative CGS-USGS investigation of evaporite tectonism in the region, it was recognized that a thorough understanding of the late Cenozoic volcanic stratigraphy was needed to better characterize evaporite-related deformation. By tracing dated and correlated volcanic flows across the region, the lateral extent, amount of vertical deformation, and timing and rates of collapse could be assessed. To accomplish this goal, an extensive effort involving $^{40}Ar/^{39}Ar$ age dating of 133 samples (Kunk and others, 2002) and major-, minor-, and trace-element geochemical analysis of 220 volcanic rocks in the region (Unruh and others, 2001) was undertaken. This data, when combined with the geologic framework established by quadrangle mapping, enabled Budahn and others (2002) to identify 46 distinct compositional groups of volcanic rocks. These compositional groups were erupted during significant pulses of volcanic activity spread across the region during the time intervals from 24 to 22 Ma, 16 to 13 Ma, and 11 to 9 Ma. Smaller, more widely spaced eruptions occurred in the region about 7.8–7.7 Ma, 4 Ma, 3 Ma, 1.3 Ma, and 4 ka (Kunk and others, 2002).

Five samples of volcanic rocks were collected in the Shoshone quadrangle for geochemical analysis and the earlier $^{40}Ar/^{39}Ar$ date was re-evaluated as part of the collaborative CGS-USGS investigation. Locations of these samples are shown on the accompanying geologic map. Three of the compositional groups identified by Budahn and others (2002) were recognized in the Shoshone quadrangle (**Table 1**).

The unit Tb flows in the southwest corner of the mapped area probably are the oldest volcanic rocks in the quadrangle. Although no geochemical data or age dates are available for the unit Tb flows in the southwest part of the quadrangle, hand specimens of these flows are similar to nearby flows in Glenwood Springs and Cattle Creek quadrangles that are ~10 Ma. The unit Tb flows that cap Little Grand Mesa and that crop out in the south-tilted block within the Cottonwood Monocline (samples SH303 and SH341; Table 1) are geochemically correlated with the late Miocene rocks of compositional group 5b (Budahn and others, 2002), which elsewhere are dated at ~7.7 to 7.8 Ma (Kunk and others, 2002; Kirkham, Streufert, Cappa, and others, 2008; Streufert, Kirkham, and others, 2008). These late Miocene Ma flows are the most widely distributed flows in the quadrangle. The trachyandesites of unit Tta crop out in the southeast part of the quadrangle. These flows are included in compositional groups 6a′ (sample SH262) and group 6b (samples SH267 and SH268). A sample from compositional group 6b (SH267) yielded an isochron $^{40}Ar/^{39}Ar$ age of 3.97 ± 0.08 Ma (Kunk and others, 2002). No absolute ages are available for compositional group 6a′ rocks in the quadrangle, but their geochemistry suggests they are related to other Pliocene flows in the region (Budahn and others, 2002; Kunk and others, 2002).

Table 1. Compositional geochemical groups and preferred $^{40}Ar/^{39}Ar$ ages of volcanic rocks in the Shoshone quadrangle (from Budahn and others, 2002; Kunk and others, 2002). Sample locations are shown on the accompanying geologic map and are described in Appendix A.

Sample Number	Map Unit	Preferred Age (Ma)	Compositional Group
SH303	Tb		5b
SH341	Tb		5b
SH262	Tta		6a'
SH267	Tta	3.97 ± 0.08	6b
SH268	Tta		6b

GEOLOGIC HAZARDS AND CONSTRAINTS

A variety of geologic hazards and constraints affect the Shoshone quadrangle. Areas mapped as younger debris-flow deposits (unit Qdfy) are highly prone to future debris flows, mudflows, and flooding. Areas mapped as intermediate debris-flow deposits (unit Qdfm) are less prone to these hazards. Low-lying areas mapped as stream-channel, flood-plain, and low-terrace deposits (unit Qa) and as alluvium and colluvium, undivided (unit Qac) are subject to flooding.

White (2002) developed a geologic hazard map that characterizes collapsible soils in the adjacent Roaring Fork River valley; this effort relied heavily upon the units described and mapped in the CGS geologic maps in that area. The derivative approach used by White (2002) can be applied to the units in Shoshone quadrangle. The hydrocompaction potential of sheetwash deposits (unit Qsw), fine-grained colluvium (unit Qc) and alluvium and colluvium, undivided (unit Qac) is moderate to high. These deposits, along with lacustrine deposits (unit Ql), intermediate debris-flow deposits, and older debris-flow deposits (unit Qdfo), also have moderate to high potential for settlement and piping. Areas mapped as colluvium (unit Qc) are susceptible to future colluvial deposition and locally subject to sheetwash, rockfall, small debris flows, mudflows, and landslides.

Most landslides in the quadrangle involve strata of Pennsylvanian and Permian age, or the surficial deposits derived from them. Landslides are very common along the margins of Little Grand Mesa, particularly where basaltic flows cap the mesa. Spectacular slump blocks of nearly intact but broken and dislocated blocks of basalt exist along the north of edge of Little Grand Mesa in the headwaters of Ike Creek. An incipient tension crack in the basalt cap at the head of Ike Creek forebodes future slope stability problems in this area.

The large landslide complex on the east side of Spring Valley may be a result a evaporite tectonism. As the Spring Valley structure developed, the toe of the slope that supported the terrain between Spring Valley and Little Grand Mesa was gradually altered, which created oversteepened and unstable slopes east of the valley. The timing and the rate of slope movements in the landslide complex east of Spring Valley may be directly controlled by the timing and rate of evaporite tectonism in Spring Valley.

Sinkholes, which pose significant hazards, may occur in areas where the Eagle Valley Evaporite is present at or near the surface (Mock, 2002; White, 2002). Modern rates of ground movement related to evaporite collapse and diapirism are poorly constrained. If these rates are sufficiently high to pose hazards, then these types of deformation should be considered in engineering design, particularly where differential movement is possible, such as within Cottonwood Monocline. In addition to causing collapse hazards, the Eagle Valley Evaporite and surficial deposits eroded from it can be corrosive.

There is moderate to high potential for rockfall below cliffs of well-indurated bedrock throughout the quadrangle, especially in areas mapped as talus (unit Qt). Proterozoic crystalline rocks and lower and middle Paleozoic rocks in Glenwood Canyon and in steep-walled tributary valleys pose severe rockfall hazards. The basalt cliffs on the north margin of Little Grand Mesa also pose severe rockfall hazards. Large gravel clasts and boulders contained within surficial deposits can be hazardous when exposed in the walls of excavations and in roadcuts.

Historic earthquakes have shaken the region on numerous occasions (Kirkham and Rogers, 2000), and future earthquakes, some possibly strong enough to cause damage and trigger landslides and rockfall, may affect the mapped area.

ECONOMIC GEOLOGY

Mineral commodities with possible economic potential in the quadrangle include high-calcium limestone, sand and gravel, and to a lesser degree, base metals. Many of the surficial deposits have sand and gravel potential, including units Qa, Qto, QTg, Qdfy, Qac, Qaco, Qdfo, and Qm.

The Mississippian Leadville Limestone crops out extensively on the White River Plateau and has been suggested as a source of high-calcium limestone. There are quarries near the city of Glenwood Springs on the adjacent Glenwood Springs quadrangle where the Leadville Limestone was produced for aggregate and high-calcium limestone. CF&I Steel Corporation, Pueblo, identified an area about 2.5 mi north of the Shoshone quadrangle near Willow Peak that has been proven by core drilling to contain a sizeable resource of metallurgical limestone (Wark, 1980). Specific quality parameters pertaining to limestone feedstock for steel-making applications (calcium content = 97 percent $CaCO_3$; silica content < 1 percent SiO_2) are frequently attainable in the Leadville Limestone, particularly in its upper part where dolomitization is less prevalent and away from the chert-bearing lower zones. It is possible that zones of high-calcium limestone exist in the Devonian age Chaffee Group, but this is less likely. Any area within the quadrangle where the Leadville Limestone or other high-calcium rocks occur without appreciable overburden may be a target area for limestone development.

All of the Proterozoic units are potential sources of riprap and aggregate. The Sawatch Formation and some of the dolomite and limestone beds in other Paleozoic formations may be suitable for aggregate.

A small lead-zinc occurrence known as the Fort Defiance prospect is located approximately one mile north of the Colorado River on the divide between Wagon Gulch and Dry Gulch. The Fort Defiance prospect was described by Heyl (1964) as a weak stockwork in limestone controlled by easterly and northerly striking vertical fractures. The porous silicified breccia contains masses of cerrussite surrounding galena, chalcocite, malachite, limonite boxworks, and minor amounts of smithsonite.

Petrographic examination of a mineralized sample from the Fort Defiance prospect that was collected during this mapping program indicates that the breccia fragments consist of sparry calcite from limestone, and lesser amounts of chert and dolomite. The breccia matrix consists primarily of quartz, with lesser amounts of calcite and hematite. Ore minerals in the sample include cerrussite and galena, with trace amounts of chalcopyrite, covellite, and pyrite. One mineralized sample collected during this mapping program was analyzed by XRAL Laboratories for its metal content. The results are: 6 parts per billion (ppb) gold, 15.6 parts per million (ppm) silver, 44 ppm arsenic, 35 ppm antimony, 44 ppb mercury, 2,080 ppm copper, 75.3 ppm zinc; <1 ppm cadmium; and 2 ppm cobalt. Samples collected by the U. S. Bureau of Mines at the Fort Defiance prospect (Gese and Scott, 1993) contained as much as 36.4 ppm silver, 6,760 ppm lead, and 1,500 ppm zinc.

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APPENDIX A

Major-element, whole-rock XRF analyses of the Shoshone quadrangle. Sample locations are given in the lower table and are also shown on the accompanying geologic map.

	Weight Percent												
Sample ID	**SiO_2**	**Al_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**Fe_2O_3**	**MnO**	**Cr_2O_3**	**P_2O_5**	**TiO_2**	**LOI***	**Total**
SH262	55.21	15.89	5.84	4.66	3.37	3.63	8.27	0.13	—	0.44	1.340	0.71	99.6
SH267	54.50	15.10	7.31	4.12	3.17	3.20	7.76	0.15	0.01	0.57	1.290	3.20	100.4
SH268	54.40	15.10	6.23	5.27	3.34	3.48	8.36	0.14	0.02	0.59	1.320	0.45	98.7
SH300	54.00	15.10	6.00	5.07	3.39	3.65	8.09	0.13	0.02	0.54	1.310	0.70	98.0
SH301B	54.80	15.10	6.47	4.70	3.33	3.45	8.13	0.13	0.02	0.53	1.290	1.75	99.7
SH303	50.40	15.20	7.08	6.36	3.20	2.47	11.20	0.15	0.03	0.69	1.800	0.60	99.2
SH341	50.88	15.30	7.48	6.21	3.20	2.43	10.61	0.15	—	0.71	1.800	0.99	99.8
SCR1	61.60	15.10	4.34	3.44	2.96	3.20	6.69	0.10	<0.01	0.25	0.649	0.75	99.1
SHL2	73.20	14.30	1.18	0.57	3.34	4.33	2.38	0.03	<0.01	0.10	0.218	0.70	100.3
SHL5	69.30	13.80	1.13	1.83	1.99	3.03	6.49	0.05	<0.01	0.07	0.828	0.80	99.3

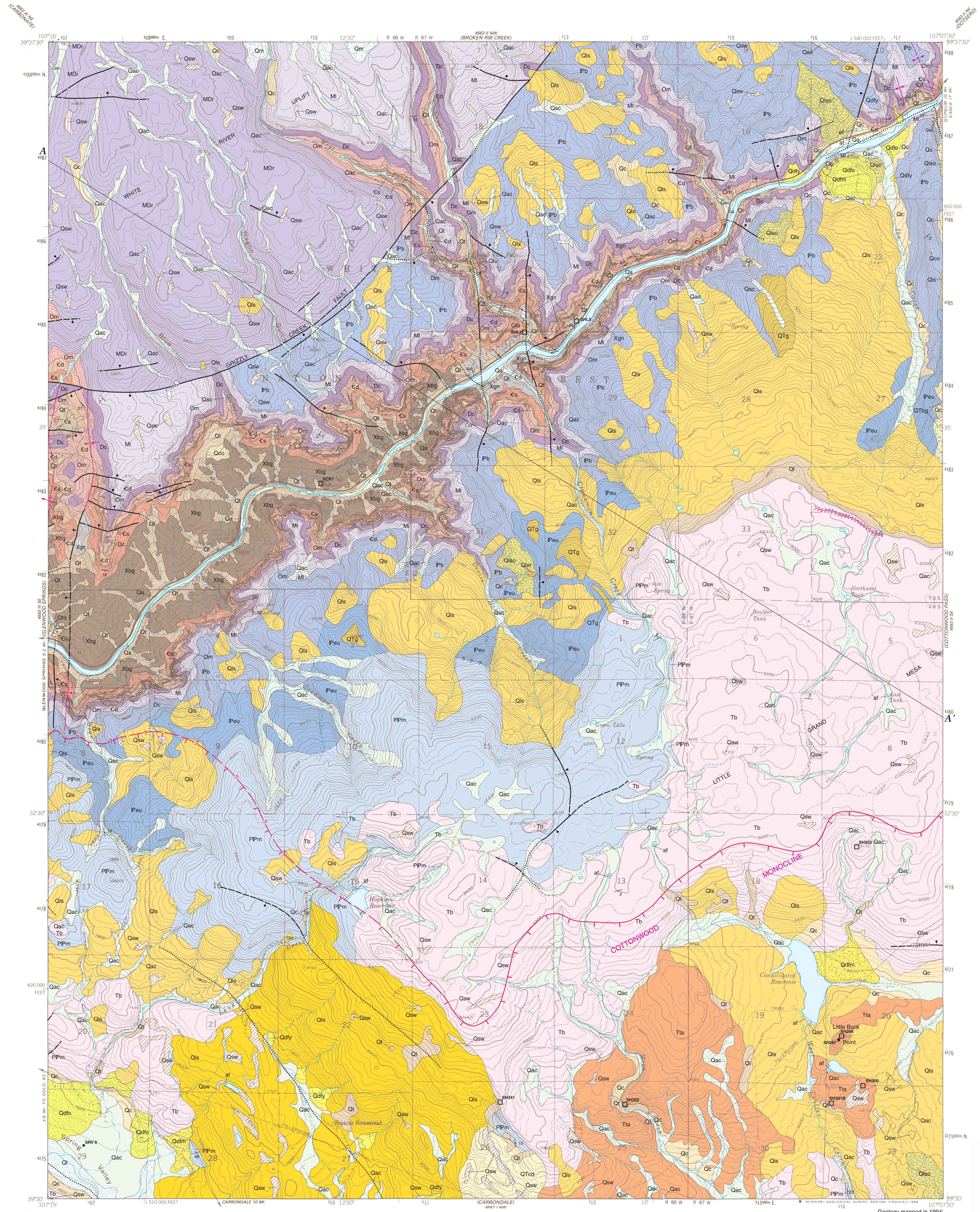
*Loss On Ignition
Samples SH262 and SH341 analyzed by the U.S. Geological Survey (Unruh and others, 2001)
All other samples analyzed by XRAL Laboratories, Denver, Colorado

Sample Locations (NAD27)

		Location	
Sample ID	**Map Unit**	**Latitude**	**Longitude**
SH262	Tta	39.5099°N	107.1694°W
SH267	Tta	39.5169°N	107.1395°W
SH268	Tta	39.5173°N	107.1391°W
SH300	Tta	39.5119°N	107.1360°W
SH301B	Tta	39.5101°N	107.1404°W
SH303	Tb	39.5379°N	107.1367°W
SH341	Tb	39.5099°N	107.1868°W
SCR1	Xg	39.5775°N	107.2121°W
SHL2	aplite dike in Xgn	39.5939°N	107.1837°W
SHL5	Xgn	39.5950°N	107.1764°W

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

MAP SERIES 35
GEOLOGIC MAP OF THE SHOSHONE
QUADRANGLE, GARFIELD COUNTY, COLORADO
Booklet accompanies map



Base from U.S. Geological Survey, 1961
Polyconic projection, 1927 North American datum
10,000-foot grid based on Colorado coordinate system, central zone

SCALE 1:24,000

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

Geology mapped in 1994;
assisted by P.L. Stelling in 1994 and V. Matthews in 2002;
digital cartography by Cheryl Brchan and Larry Scott

CONDENSED DESCRIPTION OF MAP UNITS

The complete description of map units and references is in the accompanying booklet.

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**

ALLUVIAL DEPOSITS

Qa — **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Mostly poorly sorted, clast-supported gravel in a sandy or silty matrix up to about 15 ft above modern stream level

Qsw — **Sheetwash deposits (Holocene and late Pleistocene)**—Bedded deposits of gravelly sand, sandy silt, and clayey silt

Qto — **Older terrace alluvium (late middle Pleistocene)**—Chiefly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel with a sand matrix. Underlies a terrace about 140 ft above modern stream level

QTg — **High-level gravel (early Pleistocene or Pliocene)**—Poorly sorted, basalt-rich boulder and cobble gravel on hill and ridge crests about 1,300 to 2,800 ft above modern river level

MASS-WASTING DEPOSITS

Qlsr — **Recent landslide deposits (latest Holocene)**—Includes active and recently active landslides with fresh morphological features. Heterogeneous unit consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay

Qc — **Colluvium (Holocene and late Pleistocene)**—Matrix- and clast-supported, pebble to boulder gravel in a sandy silt matrix. Locally fine grained

Qt — **Talus (Holocene and late Pleistocene)**—Angular, cobbly and bouldery rubble derived from bedrock outcrops and transported as rockfalls, rockslides, rock avalanches, and rock topples.

Qls — **Landslide deposits (Holocene and Pleistocene)**—Heterogeneous, mostly unsorted and unstratified debris that commonly is characterized by hummocky topography and lobate form

Qco — **Older colluvium (Pleistocene)**—Highly variable deposits texturally similar to colluvium (Qc), but generally not subject to future deposition

Qlso — **Older landslide deposits (Pleistocene and late Pliocene?)**—Landslide deposits dissected by erosion and lacking distinctive landslide morphology. Similar in texture to recent landslide deposits (Qlsr)

ALLUVIAL AND MASS-WASTING DEPOSITS

Qdfy — **Younger debris-flow deposits (Holocene)**—Poorly sorted to moderately well-sorted, clast- and matrix-supported, pebble, cobble, and boulder gravel in a sandy silt or silty sand matrix. Distal fan areas are finer grained. Deposited on active fans

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Moderately well-sorted to well-sorted, stratified, interbedded sand, pebbly sand, and sandy gravel to poorly sorted, unstratified or poorly stratified clayey, silty sand, bouldery sand, sandy silt, and silty clay

Qdfm — **Intermediate debris-flow deposits (Holocene and late Pleistocene)**—Poorly sorted gravels found 10 to 20 ft above adjacent streams. Similar in texture and lithology to younger debris-flow deposits (Qdfy)

Qdfo — **Old debris-flow deposits (Pleistocene)**— Remnants of inactive debris fans found on ridge lines, mesas, and valley floors 20 to 200 ft above adjacent streams. Similar in texture and lithology to younger debris-flow deposits (Qdfy)

QTbg — **High-level basaltic gravel (early Pleistocene or late Tertiary?)**—Slightly indurated, matrix-supported, cobbly, pebbly, and bouldery clayey, sandy silt. Occurs on eastern edge of map area, on south wall of Glenwood Canyon

GLACIAL DEPOSITS

Qm — **Morainal deposits (late and/or late middle Pleistocene)**—Heterogenous deposits of gravel, sand, silt, and minor clay deposited in lateral, end, and ground moraines

LACUSTRINE DEPOSITS

Ql — **Lacustrine deposits (Quaternary)**—Stratified deposits of medium- to dark-gray and reddish-brown, organic-rich, silty clay and silt, and medium-red-brown, well-sorted, coarse sand and volcanic ash in Spring Valley

SINTER DEPOSITS

Qtu — **Tufa (Holocene and Pleistocene?)**—Low-density, porous calcium carbonate precipitated from mineral-charged spring water

COLLAPSE DEPOSITS

QTcd — **Collapse deposits (Quaternary and late Tertiary)**—Heterogeneous deposits of moderately to highly deformed bedrock and overlying undeformed to moderately deformed surficial deposits within the Carbondale collapse center. Unit formed in response to differential collapse resulting from dissolution or flow of underlying evaporite

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q — **Undifferentiated surficial deposits (Quaternary)**—Shown only on cross section

BEDROCK

Tta — **Trachyandesite (Pliocene)**—Flows and breccias consisting of basaltic trachyandesite and trachyandesite. Xenocrysts consist of quartz, sanidine and plagioclase. Included in compositional group 6b, and perhaps group 6b", of Budahn and others (2002). $^{40}Ar/^{39}Ar$ age of 3.97 ± 0.08 Ma (Kunk and others, 2002)

Tb — **Basaltic flows (Miocene)**—Multiple flows of basaltic trachyandesite, trachybasalt, and probably basalt, interbedded with fluvial and lacustrine sediments. Includes flows in compositional group 5b, and perhaps group 5a, of Budahn and others (2002)

PIPm — **Maroon Formation (Permian and Pennsylvanian)**—Mainly reddish-brown sandstone, conglomerate, mudstone, siltstone, and claystone with minor thin beds of gray limestone

IPeu — **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)**—Includes the Eagle Valley Evaporite, which is a sequence of gypsum, anhydrite, and halite interbedded with light-colored, fine-grained clastic rocks, limestone, and conglomerate; and the Eagle Valley Formation, which is an intertonguing sequence of Maroon Formation and Eagle Valley Evaporite. Commonly intensely folded, faulted, and deformed

IPb — **Belden Formation (Lower Pennsylvanian)**—Medium-gray to black, calcareous shale and fossiliferous limestone with interbeds of fine-grained micaceous sandstone, gritstone, coaly shale, and gypsum

Ml — **Leadville Limestone (Mississippian)**—Gray to bluish gray, coarse to finely crystalline limestone and dolomite. Abundant chert nodules in lower part of formation

Dc — **Chaffee Group (Upper Devonian)**—Includes in ascending order: Parting Formation—white to buff orthoquartzite, green shale, and gray dolomite; Dyer Dolomite—limestone and dolomite; and Gilman Sandstone—tan to yellow, fine-grained dolomitic sandstone

MDr — **Mississippian and Devonian rocks, undivided (Mississippian and Upper Devonian)**

Om — **Manitou Formation (Lower Ordovician)**—Includes in ascending order the Dead Horse Comglomerate Member and Tie Gulch Member. Consists of flat-pebble, limestone conglomerate, brown and tan crystalline dolomite, and greenish-gray calcareous shale

€d — **Dotsero Formation (Upper Cambrian)**—Includes in ascending order the Sheep Mountain Member, Red Cliff Member, Glenwood Canyon Member, and Clinetop Bed (Myrow and others, 2003). Consists of thin-bedded, brown to tan sandy dolomite and dolomitic sandstone with abundant glauconite and pinkish-light-gray to light-gray algal limestone

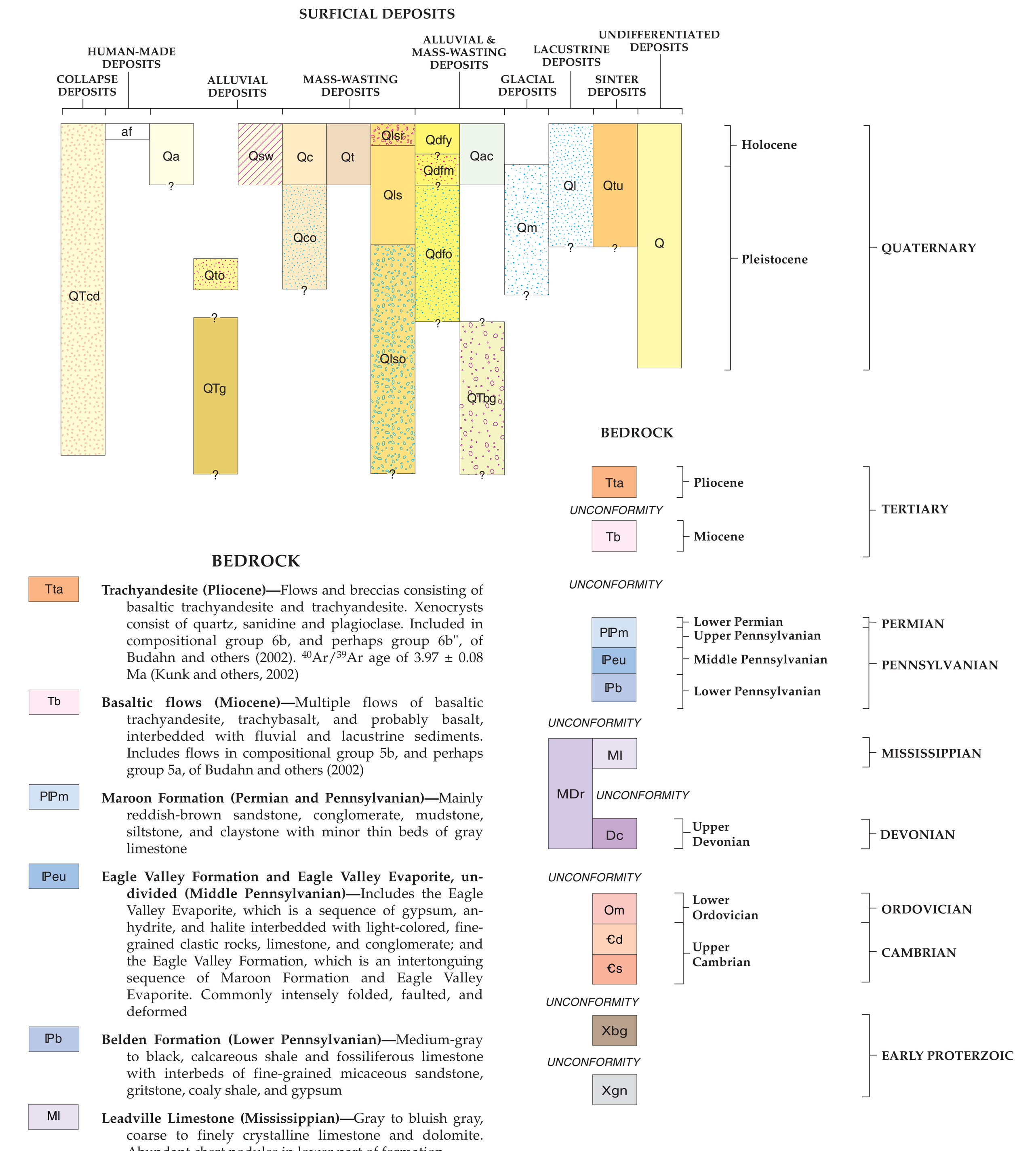
€s — **Sawatch Formation (Upper Cambrian)**—White to buff, massive, medium-grained quartz arenite and arkosic quartz-pebble conglomerate.

PRECAMBRIAN ROCKS

Xbg — **Biotite granite (Paleoproterozoic)**—Dark-gray and white-speckled, fine- to coarse-grained, equigranular granite and granodiorite

Xgn — **Mica schist and gneiss (Paleoproterozoic)**—Well-foliated to poorly foliated biotite-muscovite schist and gneiss, locally pegmatitic

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact—Dashed where approximately located

Fault—Dashed where approximately located; dotted where concealed; bar and ball on downthrown side

Anticline—Showing trace of crestline; dashed where approximately located; dotted where concealed

Syncline—Showing trace of crestline; dashed where approximately located; dotted where concealed

Monocline—Showing upper and lower fold axes; arrows indicate direction of dip; longer arrow indicates flatter dip; dashed where approximately located; dotted where concealed; monocline locally coincides with a mapped fault

Margin of late Cenozoic collapse area—Collapse caused by evaporite tectonism; dashed where approximately located; queried where uncertain (see Kirkham, Streufert, and others, 2001; and Kirkham, Scott, and Judkins, 2002, for description of collapse)

23 — **Strike and dip of beds**—Angle of dip shown in degrees; most attitudes in basalt were measured on top of flow surfaces

Strike and dip of foliations—Angle of dip shown in degrees

7 — **Inclined**

Vertical

SH303 — **Location and identification number of geochemical rock sample (see Table 1 and Appendix A in booklet; Unruh and others, 2001; Budahn and others, 2002)**

SH267 — **Location and identification number of rock sample with geochemical analysis and $^{40}Ar/^{39}Ar$ age date (see Table 1 and Appendix A in booklet; Unruh and others, 2001; Budahn and others, 2002; and Kunk and others, 2002)**

Tension fracture in basalt above landslide at head of Ike Creek

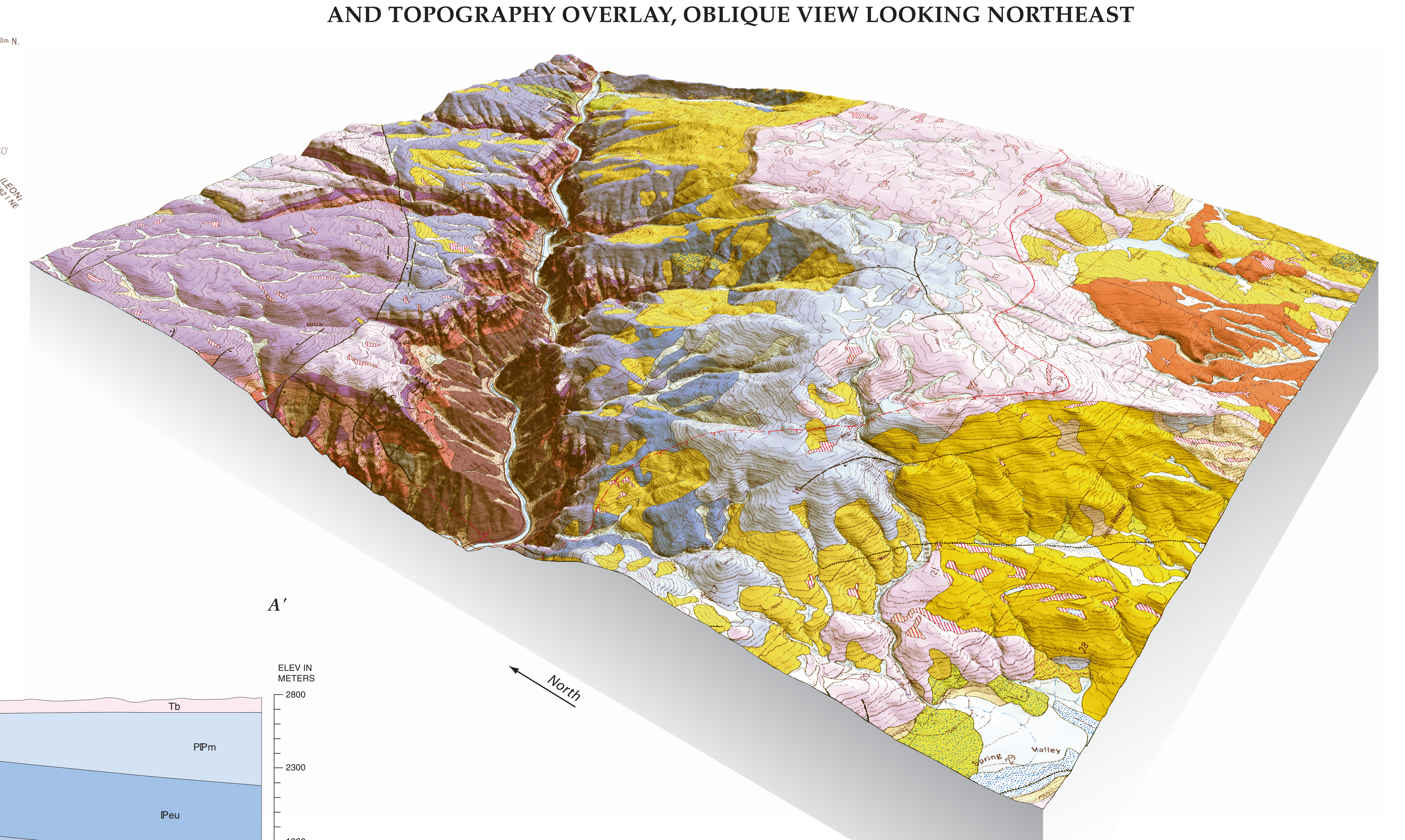
SVR#6 — **Location of test well, with identification number**

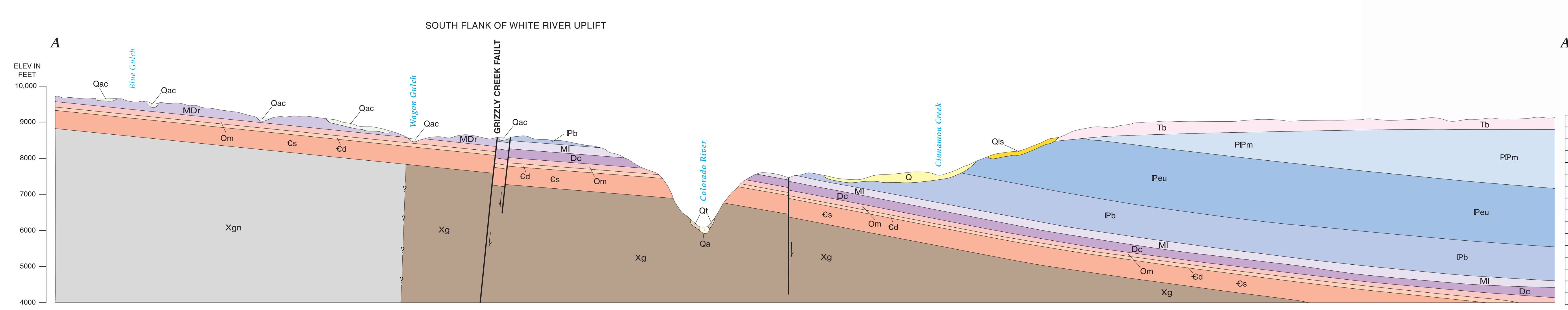
A——A′ — **Alignment of cross section**

ACKNOWLEDGEMENT

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program and by State of Colorado General Funds and Colorado Department of Natural Resources Severance Tax Operational Funds.

SHADED-RELIEF MAP OF THE SHOSHONE QUADRANGLE WITH GEOLOGY AND TOPOGRAPHY OVERLAY, OBLIQUE VIEW LOOKING NORTHEAST





GEOLOGIC MAP OF THE SHOSHONE QUADRANGLE, GARFIELD COUNTY, COLORADO

By Robert M. Kirkham, Randall K. Streufert, and James A. Cappa

2008

Bill Ritter Jr., Governor
State of Colorado

Harris D. Sherman, Executive Director
Department of Natural Resources

Vincent Matthews
State Geologist and Director
Colorado Geological Survey