OPEN-FILE REPORT 00-02

Geologic Map of the Idaho Springs Quadrangle, Clear Creek County, Colorado

Description of Map Units, Structural Geology, Economic Geology, and References

By Beth L. Widmann, Robert M. Kirkham, and Steven T. Beach

DOI: https://doi.org/10.58783/cgs.of0002.zipu4060

Colorado Geological Survey
Division of Minerals and Geology
Department of Natural Resources
Denver, Colorado / 2000

OPEN-FILE REPORT 00-2

Geologic Map of the Idaho Springs Quadrangle, Clear Creek County, Colorado

Description of Map Units, Structural Geology, Economic Geology, and References

By Beth L. Widmann, Robert M. Kirkham, and Steven T. Beach

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey STATEMAP program of the National Geologic Mapping act of 1992, agreement No. 99HQAG0143. Partial funding for this project came from Colorado Severance taxes, which are derived from the production of oil, gas, coal, and minerals.

Colorado Geological Survey
Division of Minerals and Geology
Department of Natural Resources
Denver, Colorado / 2000

FOREWORD

The purpose of Colorado Geological Survey Open File Report 00-2, Geological Map of the Idaho Springs quadrangle, Clear Creek County, Colorado is to describe the geological setting and mineral resource potential of this 7.5 minute quadrangle located along the Interstate 70 corridor in the Front Range of north central Colorado. The staff of the Mineral Resources and Geological Mapping Section of the Colorado Geological Survey, Beth Widmann and Robert Kirkham, and a Colorado School of Mines graduate student, Steven Beach, completed the field work on this project from July 1999 to October 1999. The objective of this publication is to provide geological maps in areas impacted by residential and other infrastructure development, especially those areas containing significant geological hazards and mineral and construction material resources to engineering companies, government planners, resource developers, and other interested citizens.

Funding for this project came from the Colorado General Fund and Colorado Department of Natural Resources Severance Tax Operational Fund. Severance taxes are derived from the production of gas, oil, coal, and minerals. Matching funds were provided through a grant from the STATEMAP Component of the U.S. Geological Survey National Cooperative Geological Mapping Program. Mr. Beach received a grant from the EDMAP Component of the U.S. Geological Survey National Cooperative Geological Mapping Program.

James A. Cappa
Chief, Mineral Resources and Geological Mapping Section

Vicki Cowart
State Geologist and Director

INTRODUCTION

Geologic mapping of the Idaho Springs 7.5-minute quadrangle was undertaken by the Colorado Geological Survey (CGS) as part of the STATEMAP component of the National Cooperative Geologic Mapping Act, which is administered by the U.S. Geological Survey. Partial funding for this project came from Colorado Severance taxes, which are derived from the production of oil, gas, coal, and minerals. Geologic maps produced by the CGS through the STATEMAP program are intended as multi-purpose maps useful for land-use planning, geotechnical engineering, geologic-hazards assessment, mineral-resource development, and groundwater exploration. Figure 1 shows the current status of geologic mapping in the Idaho Springs area.

The Idaho Springs quadrangle is located in Clear Creek County in the Colorado Front Range about 30 mi west of downtown Denver. The part of the quadrangle northwest of Chicago Creek includes parts of the Idaho Springs, Freeland-Lamartine, and Chicago Creek mining districts, all of which were mapped by the U.S. Geological Survey at a scale of 1:6,000. Several 7.5-minute quadrangles to the north and east of Idaho Springs have been mapped by the U.S. Geological Survey. The Georgetown 15-minute quadrangle, which includes the Idaho Springs 7.5 minute quadrangle, was previously mapped by Spurr and others (1908). The Denver 1° x 2° quadrangle was mapped by Bryant and others (1981).

The Idaho Springs 7.5-minute quadrangle is characterized by rugged terrain ranging in elevation from about 7,500 to 12,600 ft. The town of Idaho Springs lies in the northeast corner of the quadrangle at an elevation of about 7,525 ft. Squaw Pass Road (State Highway 103) extends east-west across the quadrangle at an average elevation of 11,000 ft, and the 14,258-ft-high peak of Mount Evans is just southwest of the southwest corner of the quadrangle.

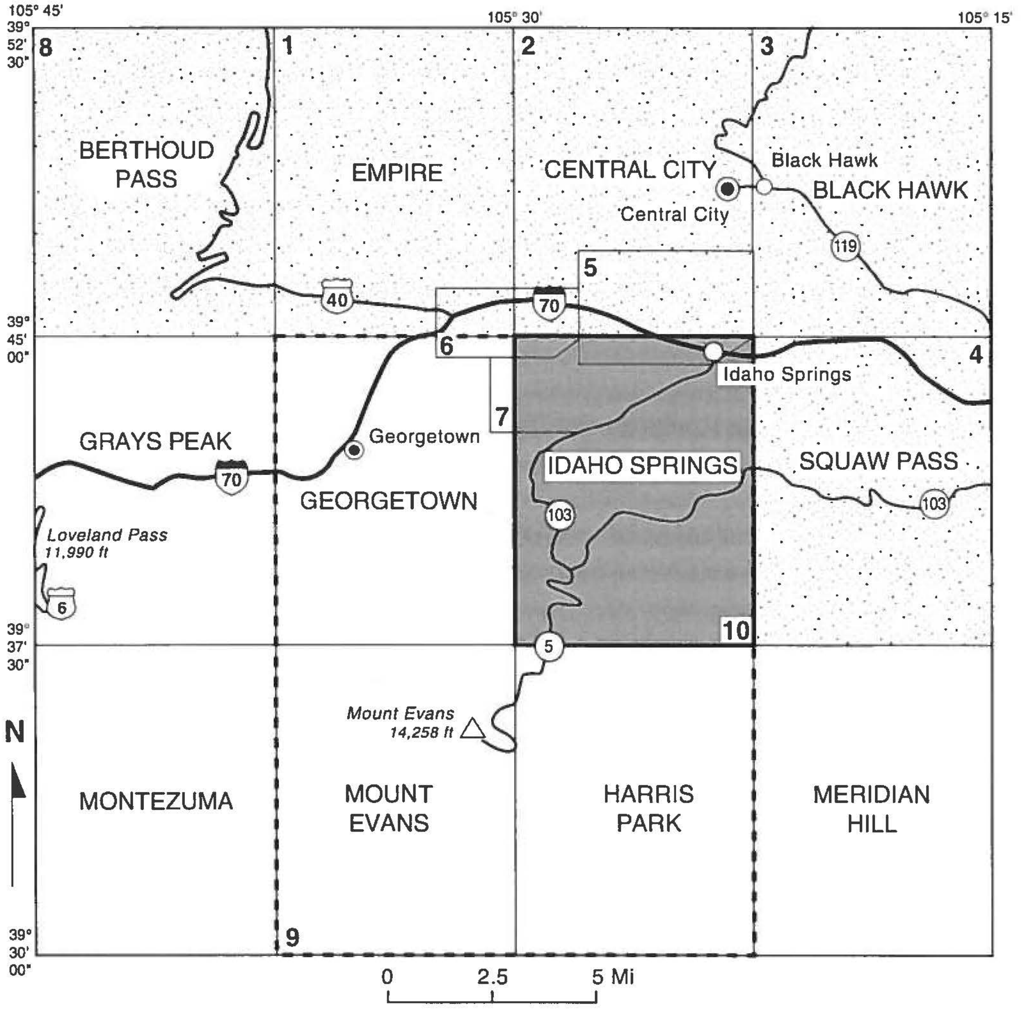
Most of the quadrangle is underlain by Proterozoic metamorphic and igneous rocks. The oldest are Early Proterozoic metasedimentary and metavolcanic rocks that were originally deposited more than 1,800 Ma (Tweto, 1987) and later metamorphosed during a period of intense deformation about 1,726 Ma (Selverstone and others, 1997). This metamorphic complex was subsequently intruded by granitic rocks of the Berthoud plutonic suite (Tweto, 1987) between about 1,448 and 1,420 Ma (Aleinikoff and others, 1993; Peterman and others, 1968). During the Laramide orogeny (Late Cretaceous to Paleocene), porphyry dikes and other small intrusive bodies were intruded primarily in the Proterozoic metamorphic complex along foliation planes northwest of Chicago Creek. The ore deposits of Idaho Springs were formed during the later stages of this intrusive event (Paleocene). The youngest deposits in the quadrangle include glacial till of probable Pinedale age and other Quaternary surficial deposits ranging in age from pre-Bull Lake to Recent.

ACKNOWLEDGEMENTS

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 Act of 1992, Agreement No. 99HQAG0143. Partial funding for this project came from Colorado Severance taxes, which are derived from the production of oil, gas, coal, and minerals.

We are extremely grateful for the wealth of knowledge that was shared with us by Bruce Bryant and Rich Madole. Members of the Idaho Springs Ranger District, U.S. Forest Service, were informative and helpful, providing access to the Mount Evans area. Vehicular access to the upper Chicago Creek area was approved by the Idaho Springs City Administrator Jack Russalesi. Jeff Coe, U.S.

Geological Survey, provided information on debris fans along the Interstate-70 corridor. Jim Maxwell, owner of the Indian Springs Hot Springs Resort, shared information regarding the hot springs at the resort. Jim Cappa, Colorado Geological Survey, and Eric Nelson, Colorado School of Mines, are thanked for their guidance and counseling throughout this investigation. We also express thanks to Susan Pacek, Planning Director, Clear Creek County, for supporting our work. John Keller, Colorado Geological Survey, was helpful in collecting and sending samples for geochemical analysis.



Index Map No.	Map Area and Reference
1	Empire quadrangle (Braddock, 1969)
2	Central City quadrangle (Sims, 1964)
3	Black Hawk quadrangle (Taylor, 1976)
4	Squaw Pass quadrangle (Sheridan and Marsh, 1976)
5	Idaho Springs mining district (Moench and Drake, 1966)
6	Freeland-Lamartine mining district (Harrison and Wells, 1959)
7	Chicago Creek mining district (Harrison and Wells, 1956)
8	Berthoud Pass quadrangle (Theobald, 1965)
9	Georgetown 15-minute quadrangle (Spurr and others, 1908)
10	Idaho Springs quadrangle (this publication)

EXPLANATION

▨	Current CGS 1:24,000-scale map
░	Completed USGS 1:24,000-scale map
⬚	Completed USGS 1:62,500-scale map
□	Completed USGS 1:6,000-scale map

Figure 1. Location map and index of published geologic maps near Idaho Springs.

DESCRIPTION OF MAP UNITS

BEDROCK

PRECAMBRIAN METASEDIMENTARY AND METAVOLCANIC ROCKS—These rocks were formerly called the Idaho Springs Formation (Ball, 1906). The designation of these rocks as a formation is, at this time, improper because both tectonic and magmatic deformation were so intense in the area that the stratigraphy of these rocks is uncertain. In his classification of the Precambrian rock units of Colorado, Tweto (1987) referred to these rocks simply as Proterozoic layered rocks or the Proterozoic gneiss complex. Premo and Fanning (1997) obtained U-Pb zircon ages ranging from 1,780 to 1,800 Ma for metavolcanic rocks. The metasedimentary and metavolcanic rocks were metamorphosed during accretion to the Archean Wyoming craton about 1,726 ± 15 Ma (U-Pb zircon age, Selverstone and others, 1997).

Xsb

Sillimanitic biotite gneiss (Early Proterozoic)—Medium- to dark-gray, well-foliated sillimanitic biotite gneiss is a mappable unit only in Trail Gulch, Soda Creek and along State Highway 103 at the eastern margin of the quadrangle. It generally contains numerous pegmatites, hence, contacts between sillimanitic biotite gneiss and migmatite (Xm) are locally subjective. Sillimanitic biotite gneiss consists primarily of biotite, sillimanite, and quartz. Microcline, muscovite, garnet, tourmaline, and cordierite are lesser constituents. Sillimanite is easily recognizeable either as cloudy white rods and bundles or flattened pods up to a few inches long that are elongate parallel to foliation. The pods of sillimanite are slightly more resistant to weathering than the surrounding biotite and form knobby surfaces on outcrops.

Sheridan and Marsh (1976) suggested that the protolith of this gneiss is alumina-rich shale. It is a potential source of riprap and crushed aggregate.

Xb

Biotite gneiss (Early Proterozoic)—Fine-grained, light- to medium-gray gneiss composed primarily of biotite, quartz, and plagioclase, and accessory magnetite, sillimanite, garnet, and/or cordierite. The rock typically weathers to a rusty brown. It's texture is typically equigranular which gives it a “salt and pepper” appearance in outcrop, although in places it is schistose. Foliation is generally parallel to lithologic layering. Discontinuous layers of amphibolite, felsic gneiss, and calc-silicate gneiss are common and are usually less than about 2 ft thick. Biotite gneiss is commonly interlayered with thin bands of pegmatite that tend to be less than one inch thick.

Sheridan and Marsh (1976) suggested that biotite gneiss originated as sandy shale or graywacke. The unit is a potential source of good-quality riprap and crushed aggregate, especially where it is equigranular and not schistose.

Xh

Hornblende gneiss and amphibolite (Early Proterozoic)—Medium- to dark-gray, fine-grained hornblende gneiss and dark-green to black, fine- to medium-grained amphibolite. Hornblende gneiss consists of hornblende and plagioclase with lesser amounts of quartz, biotite, and pyroxene. It is massive or well-banded with alternating thin, white layers of quartz and feldspar. Hornblende gneiss commonly grades to or is interlayered with calc-silicate gneiss. It is most abundant along the margins of felsic gneiss (Xf). Most of the amphibolite is massive, has a higher hornblende to plagioclase ratio than hornblende gneiss, and has almost no quartz, biotite, or pyroxene. In both rock types hornblende is altered to epidote or chlorite. These rocks probably originated as impure carbonates and mafic volcanic flows, sills, or tuffs, but some of the amphibolite bodies are intrusive (Spurr and others, 1908; Sheridan and Marsh, 1976; Tweto, 1987).

Hornblende gneiss and amphibolite are a minor potential source of riprap and aggregate.

Xhc

Interlayered hornblende gneiss and calc-silicate gneiss (Early Proterozoic)—Calc-silicate gneiss is commonly interlayered with hornblende gneiss and amphibolite (Xh). Fine- to medium-grained, dark-gray to light-green calc-silicate gneiss consists of alternating light layers rich in quartz and feldspar and darker layers rich in hornblende and diopside. Epidote, magnetite, and garnet are also common constituents. Calc-silicate gneiss usually forms layers only a few inches thick but is locally massive. Hornblende gneiss is more abundant and is typically more resistant to weathering than calc-silicate gneiss. Most of the calc-silicate gneiss does not crop out but is recognized only by relatively sparse, weathered, bright-green rock fragments in the soil. Calc-silicate gneiss may represent altered amphibolite (Moench, 1964) or, more likely, metamorphosed impure limestone and calcareous sandstone (Spurr and others, 1908).

Xf

Felsic gneiss (Early Proterozoic)—Fine- to medium-grained, white to light-gray or tan, moderately well-foliated microcline-quartz-plagioclase-biotite gneiss. It is almost entirely white to light-gray or dark-gray where containing little biotite; tan-colored where plagioclase and biotite are more equal in abundance; or white and dark-gray and composed of alternating biotite-rich and biotite-poor layers typically less than 0.25 in. thick. Magnetite, hornblende, or garnet are locally present, and chlorite from alteration of biotite locally creates light-green streaks parallel to the foliation defined by alignment of biotite crystals. Where weakly foliated and tan in color, this rock unit is difficult to discern from biotite-muscovite granite and quartz monzonite (Ygq). Discontinuous layers of biotite gneiss, amphibolite, and calc-silicate gneiss are locally common but are usually less than about 2 ft thick.

Felsic gneiss was first thought to have a magmatic origin. S.H. Ball, in Spurr and others (1908), suggested that this unit, which he called gneissoid granite, evolved from a granitic magma as irregular stock-like bodies and was subsequently "mashed" during regional metamorphism. Later, Sims and Gable (1967) postulated that the gneiss, which they called microcline gneiss, was metasedimentary and originated as an arkosic sandstone. Having evaluated other bodies of felsic gneiss throughout Colorado, Tweto (1987) stated that evidence strongly suggests the most plausible protoliths are rhyodacitic and quartz-latitic tuffs.

Felsic gneiss is a very good source of riprap and crushed aggregate, especially where it has a low biotite content. The unit tends to form cliffs, where it may cause rockfall hazards.

Xm

Migmatite (Early Proterozoic)—Rocks that have been heavily intruded by pegmatite or other granitic material and/or have been intensely deformed and heated to the point of partial melting are mapped as migmatite. Most commonly, migmatite is composed of biotite gneiss (Xb) or sillimanitic biotite gneiss (Xsb) that is stongly interlayered with pegmatite and granite. Layers of biotite or sillimanitic biotite gneiss may be several inches thick while pegmatite and granite layers tend to be less than one inch thick. The rock has a classic "swirled" look due to deformation under conditions of high ductility. The granitic component probably formed by partial melting of schist and gneiss and by segregation and intrusion of that melted material. Migmatite may also include layers or pods of granite, felsic gneiss, hornblende gneiss, and calc-silicate gneiss. Much of the migmatite in the area is considered to have formed between 1,700 to 1,750 Ma (Hedge, 1969).

This unit is a very good source of riprap and crushed aggregate. It may be prone to rockfall in areas where it is exposed in cliffs.

PRECAMBRIAN INTRUSIVE ROCKS—Precambrian intrusive rocks of the Colorado Front Range belong to three different groups (Tweto, 1987). The oldest igneous rocks belong to the Routt plutonic suite, which was emplaced about 1,700 Ma. Granitic intrusives centered around 1,400 Ma belong to the Berthoud plutonic suite. Those that intruded around 1,000 Ma include mafic and intermediate dikes, and rocks of the Pikes Peak batholith. Precambrian intrusive rocks in the Idaho Springs quadrangle belong only to the Berthoud plutonic suite.

YXp

Pegmatite, aplite, and related rocks (Middle and Early? Proterozoic)—Includes pegmatite, granite pegmatite, and aplite, all of which are composed of feldspar and quartz and accessory biotite, muscovite, magnetite, and hornblende. Pegmatite dikes consist of light-pink orthoclase or microcline and slightly smoky quartz with and small amounts of mica. Pegmatites commonly crop out at or near the contact between the Mount Evans batholith and Proterozoic metasedimentary and metavolcanic rocks. Granite pegmatite has a similar composition but has greater amounts of mica and magnetite. Biotite is more abundant than muscovite, and the two mica types usually occur in different pegmatite bodies, although they locally occur together within the same body.

Magnetite crystals tend to be anhedral and usually several inches in diameters. S.H. Ball, in Spurr and others (1908), referred to weathered-out magnetite crystals as excellent "sling-shot ammunition" frequently used by the local children. Granite pegmatite typically forms ridge-capping dikes and irregular bodies outside the Mount Evans batholith. Aplite dikes and veinlets, ubiquitous throughout the Mount Evans batholith, are light-pink and have a fine-grained sugary texture of quartz and feldspar.

Ygd

Granodiorite of the Mount Evans batholith (Middle Proterozoic)—The Mount Evans batholith takes its name from the 14,258-foot-high Mount Evans, which lies about 3.5 miles south-southwest of Echo Lake. The batholith crops out over an area of about 140 square mi (Aleinikoff and others, 1993), including most of the southwestern half of the Idaho Springs quadrangle, and consists of weakly to moderately foliated, medium- to coarse-grained, mottled black and white granodiorite. Primary mineral constituents are plagioclase, microcline, quartz, and biotite. Hornblende, magnetite, and sphene are accessory minerals. Where fresh, the unit has a characteristic blue tinge. Several zones of strongly decomposed rock crop out on road cuts along State Highway 103. At Devils Nose the granodiorite has been cataclastically deformed by a branch of the Kennedy Gulch fault system. Here, biotite has been almost completely replaced by hematite, causing dark-gray to rust-brown staining of the rock.

Rocks of the Mount Evans batholith were originally considered to belong to the Routt plutonic suite (1,700 Ma) of Tweto (1987) based on their mineralogical and textural similarity to the Boulder Creek granodiorite. Early rubidium-strontium dating of the granodiorite yielded an age of 1,660 ± 30 Ma (Bryant and Hedge, 1978), which seemed to coincide well with the 1,665 ± 40 Ma to 1,710 ± 40 Ma age calculated for the Boulder Creek granodiorite (Peterman and others, 1968; Bryant and Hedge, 1978). Sheridan and Marsh (1976) mapped equivalent rocks on the adjacent Squaw Pass quadrangle as Boulder Creek granodiorite (Xbc). However, more recent uranium-lead dates of zircon indicate that the Mount Evans batholith was emplaced 1,422 ± 2 Ma and is not equivalent to the Boulder Creek granodiorite (Aleinikoff and others, 1993). The granodiorite of Mount Evans therefore belongs to the Berthoud plutonic suite.

Where unaltered, the Mount Evans granodiorite is a good source of riprap and aggregate. It is also prone to rockfall.

Ygr

Rosalie granite (Middle Proterozoic)—Pinkish-gray, massive, microcline-quartz-biotite granite that crops out only along the southern margin of the quadrangle. This granite contains salmon to light-pink, Carlsbad-twinned microcline phenocrysts locally as much as two inches long. Other major minerals include medium- to coarse-grained smoky quartz, white feldspar, and black to dark-brown biotite. Zircon, apatite, and magnetite are the common accessory minerals (Spurr and others, 1908).

The Rosalie Granite occurs as several small plutons within the Mount Evans batholith. The granite has a U-Pb zircon date of 1,448 ± 9 Ma and is essentially the same age as the batholith (Aleinikoff and others, 1993). However, cross-cutting relationships indicate that the Rosalie Granite intrudes the granodiorite of Mount Evans leading Aleinikoff and others (1993) to interpret the Rosalie Granite as a secondary intrusive phase of the Mount Evans batholith.

This unit may be acceptable as riprap and aggregate, although access to the unit within the quadrangle is limited.

Ygq

Biotite-muscovite granite and quartz monzonite (Middle Proterozoic)—Gray to pinkish-buff, massive to weakly foliated intrusive rock composed primarily of microcline, plagioclase, and quartz, and lesser amounts of biotite and muscovite. It is usually medium-grained but is locally fine-grained or coarse-grained and gradational to pegmatite. It commonly has a seriate porphyritic texture defined by alignment of microcline phenocrysts, many of which exhibit Carlsbad twinning. The largest body crops out in the Alps Mountains, and dikes and small irregular bodies are found throughout the quadrangle. The granite is the youngest of the Proterozoic intrusives in the area and cuts all other Proterozoic rocks. Where weakly foliated and equigranular the unit is difficult to distinguish from some types of felsic gneiss (Xf). This unit mineralogically and texturally resembles the Silver Plume Granite, the type locality of which is near the town of Silver Plume about 5 miles east of the Alps Mountains. The Silver

Plume Granite has been dated at 1,420 ± 30 Ma by Peterman and others (1968) using rubidium-strontium techniques.

An unusual outcrop of this unit on the north side of West Chicago Creek, about 1,850 ft from the junction with State Highway 103 at Chicago Creek, is brecciated, coarse-grained, biotite-muscovite granite that has been stained dark-pink to dark-red by hematite that has replaced biotite. The rock is intensely fractured and silicified, and light- to dark-purple fluorite fills many of the fractures. This is the only known occurrence of fluorite in the quadrangle.

Where unaltered, this unit is a good source for riprap and aggregate.

EARLY TERTIARY AND UPPER CRETACEOUS INTRUSIVE ROCKS—Wells (1960) studied in detail the petrology of Laramide intrusive bodies in the Idaho Springs and adjacent mining districts and described as many as 13 different porphyries ranging from biotite-quartz latite to granodiorite porphyry. In the Idaho Springs quadrangle, bostonite dikes, many of which are porphyritic, are by far the most common Laramide intrusive body. Other intrusive bodies in the quadrangle are alkali syenite porphyry and quartz monzonite porphyry. In this study all Laramide intrusives are grouped together.

TKi **Intrusive porphyry and related rocks (early Tertiary and Upper Cretaceous)**—Includes various porphyry dikes and small intrusive bodies of Late Cretaceous to Paleocene age. These intrusives range in length from tens of feet to just over a mile and are typically less than about 15 ft wide. Bostonite is the dominant porphyry type, but some intrusive bodies are alkali syenite porphyry and quartz monzonite porphyry.

Bostonite is lilac to pinkish-gray where fresh but weathers to pale green or tan because of sericitization and oxidation. Porphyritic bostonite commonly appears pitted due to weathering and removal of feldspar phenocrysts. The rock consists primarily of orthoclase and plagioclase and contains lesser amounts of quartz, amphibole, and garnet. The groundmass is aphanitic and locally faintly trachytic. Phenocrysts are most commonly plagioclase crystals less than about 0.25 in. long and less commonly radiating aggregates of amphibole (Harrison and Wells, 1956).

Alkali syenite porphyry has a light-gray to tan aphanitic groundmass containing phenocrysts of alkali feldspar and, less commonly, pyroxene or amphibole. A short dike at the mouth of Soda Creek near the Indian Springs hot springs is an alkali syenite porphyry that may be responsible for the sodium enrichment of the hot springs (Spurr and others, 1908).

Quartz monzonite porphyry has a light- to medium-gray tending towards pale-violet, fine-grained groundmass. Phenocrysts are commonly plagioclase and sanidine, and, less commonly, amphibole.

These intrusives are particularly abundant within gneiss and migmitite northwest of Chicago Creek. However, there are also a few intrusives in gneiss, migmatite, and granodiorite southeast of Chicago Creek. The intrusives occur within the Colorado mineral belt, a major northeast-trending belt containing numerous porphyry intrusions and ore deposits, which extends from Boulder in the northeast to the San Juan Mountains in the southwest (Tweto and Sims, 1963). Throughout the Front Range, Laramide intrusive bodies range in age from 55 to 75 Ma. Similar intrusive rocks in the Central City district north of Idaho Springs range from 59 to 63 Ma (Rice and others, 1982). Biotite latite from Chicago Creek was dated at 68 to 69 Ma using rubidium-strontium methods (C.E. Hedge, oral communication, cited in Sheridan and Marsh, 1976). Mineralization in the Idaho Springs region occurred about 59 Ma based on potassium-argon dating by Rice and others (1982) and appears to be closely linked to the later stages of porphyry intrusion.

SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than about 5 ft thick, but may be thinner locally. Residuum and artificial fills of limited extent were not mapped. Contacts between surficial units may be gradational, and mapped units locally include deposits of another type. Divisions of the Pleistocene correspond to those of Richmond and Fullerton (1986). Age assignments for surficial deposits are based primarily upon the degree of erosional modification of original surface morphology, height above modern streams, and relative degree of clast weathering and soil development. Clast size is based on the modified Wentworth scale.

GLACIAL DEPOSITS—Gravel, sand, silt, and clay deposited by ice.

Qti

Till (late and late middle Pleistocene)—Heterogenous deposits of gravel, sand, silt, and clay deposited by ice in lateral, end, and ground moraines in the upper reaches of Chicago Creek. Locally includes poorly developed rock-glacier and block field deposits. End and lateral moraines are commonly hummocky, steep sided, and bouldery. Closed depressions are common and may be areas of elevated groundwater. The lateral moraine crests are rounded but fairly well preserved. The terminal moraine has been obliterated by stream erosion, but glacial ice probably extended a short distance below the confluence of South Chicago Creek and the main stem of West Chicago Creek on the basis of till distribution and regional studies by Madole and others (1998). Remnants of the lowest end moraine in the quadrangle occur in Chicago Creek about 0.8 miles above State Highway 103.

The till of Chicago Creek is typically unsorted, unstratified, matrix-supported bouldery, pebble and cobble gravel in a matrix of silty sand. Stratified drift may be locally interbedded with till. Rock-glacier and block field deposits are clast-supported consisting primarily of boulder-size fragments of bedrock. Till, rock-glacier, and block field clasts are subangular to rounded, elongate to subspherical, and may reach more than 20 ft in diameter. Granodiorite is the predominant rock type, but clasts of various gneisses and other types of intrusive rocks are also present in the till. Maximum thickness of this unit may exceed 100 ft. Most of the unit is of Pinedale age, although a small remnant of till on the southwest side of Echo Lake and till at the down-valley limit of glaciation may be pre-Pinedale in age.

PERIGLACIAL DEPOSITS—Deposits formed in cold environments by solifluction, frost action, and nivation.

Qs

Solifluction deposits (Holocene and late Pleistocene)—Consist primarily of reworked, weathered granodiorite deposited in alpine and sub-alpine basins near Goliath Peak and on the west side of the upper Chicago Creek valley. The deposits are characterized by hummocky terrain, ground cracks and fissures up to several inches wide, and numerous seeps and springs. Solifluction deposits result from the slow downslope flowage of surficial deposits that are water saturated and subject to seasonal freezing. Frost creep and melt-water transport are also important factors in the formation of solifluction deposits in the quadrangle. The deposits consist of angular to subrounded pebbles, cobbles, and large boulders in a chiefly sandy matrix. They are typically less than about 15 ft thick. Shallow groundwater and future, small-scale slope movement may be associated with these deposits.

LACUSTRINE AND ALLUVIAL DEPOSITS—Units mapped together in areas where adjacent individual units are too small to be mapped or where boundaries between units are not clearly defined. Peat, clay, silt, sand, and gravel deposited in basinal areas of Echo Lake and Doolittle Ranch.

Qla

Lacustrine and alluvial deposits (Holocene and late Pleistocene)—Lacustrine and alluvial deposits at Echo Lake and Doolittle Ranch consist of interbedded sand, gravel, peat, organic sandy silt and silty sand, and silty clay. Echo Lake was initially dammed by the lateral moraine on the east side of the late Pleistocene Chicago Creek glacier. This natural dam has subsequently been raised slightly by humans. The broad meadow at Doolittle Ranch was also at least partially dammed by a late Pleistocene lateral moraine, but later erosion apparently removed much of the natural dam. Between 1988 and 1992, J.P. Doerner collected and analyzed seven sediment cores from the meadow at Echo Lake, the bottom of Echo Lake, and Doolittle Ranch (Doerner, 1994). Several core samples were submitted for radiocarbon dating. The following description summarizes his work.

Two cores only a few feet long were collected from the meadow above Echo Lake. Both cores contained abundant peat which, towards the base of each core, was frozen. The longest of three cores recovered from Echo Lake was 10.6 ft long. It was collected from the deepest part of the lake where the water depth was 6.5 ft. This core consisted primarily of gyttja, a pulpy, freshwater mud rich in organic matter, to a depth of 7.2 ft. Inorganic silty clay, glacial flour, sand, and pebbly gravel were found in the lower part of the core. The longest of two cores extracted from Doolittle Ranch was 8.2 ft long. It consisted primarily of interlayered organic sandy silt and silty sand, sand and pebbly gravel, and organic material.

A radiocarbon age of 18,470 ± 460 yr BP (lab number Beta-31628) was obtained from organic material from the base of the Echo Lake core and suggests that the lake initially formed at about that time during the Pinedale glaciation. Organic material at a depth of 5.2 ft in the Doolittle Ranch core was radiocarbon dated at 7,020 ± 70 yr BP (lab number CAMS-5404). The Doolittle Ranch core consists of interlayered organic material and sand and gravel, suggesting the meadow area was only periodically part of a marsh or lake environment during the Holocene and perhaps late Pleistocene.

Pollen analysis and other radiocarbon dates throughout the cores indicated that the Pinedale glacier in Chicago Creek began receding around 14,000 yr BP. The modern meadow at Doolittle Ranch was probably established by 1,500 yr BP (Doerner, 1994).

COLLUVIAL DEPOSITS—Silt, sand, and gravel on valley sides and floors. Material mobilized, transported, and deposited primarily by gravity, but commonly assisted by sheetwash, freeze-thaw action, and water-saturated conditions that affect pore pressure.

Qco

Older colluvium (Pleistocene)—Includes two small, dissected remnants of formerly more extensive deposits on the southeast valley wall of Chicago Creek above the Idaho Springs cemetery. Texture, bedding, and clast lithology are similar to colluvium (Qc). Maximum exposed thickness of the unit is about 80 ft. Areas generally not subject to future colluviation, exept where adjacent to steep, eroding hillslopes.

Qt

Talus deposits (Holocene and late Pleistocene)—Angular, cobbly and bouldery rubble derived from bedrock that was transported downslope by gravity principally as rockfalls, rock avalanches, rock topples, and rockslides. Downslope movement may have been locally aided by water and freeze-thaw action. This unit typically lacks matrix material. The thickest talus deposits are probably in the upper reaches of Chicago Creek and are estimated at about 50 ft thick. Other talus deposits are probably only up to about 25 ft thick. Areas where talus have been mapped are subject to severe rockfall, rocktopple, and rockslide hazards. This unit may be a source of medium- to high-quality riprap and aggregate, but access to most talus deposits in the mapped area is limited.

Qls

Landslide deposits (Holocene)—Unsorted, unstratified deposit composed of glacial till (Qti) and angular to subangular fragments, less than about 2 ft in diameter, of granodiorite in Chicago Creek west of the Idaho Springs reservoir. This slide area is characterized by an arcuate scarp near the top of the slope, hummocky terrain, ground cracks several inches wide, and dislocated and toppled trees in some areas. The rate of movement is very slow and the depth of failure is probably less than about 15 ft. Movement is defined by several small, individual slope failures rather than a single landslide event. This landslide is currently active and very prone to future movement.

Qc

Colluvium (Holocene and late Pleistocene)—Includes weathered bedrock fragments that have been transported downslope primarily by gravity. Colluvium ranges from unsorted, clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported gravelly, silty sand. It is generally unsorted to poorly sorted with angular to subangular clasts. Clast lithology is variable and dependent upon types of rocks occurring within the provenance area. Locally, this unit may include debris-flow deposits that are too small or too indistinct on aerial photography to be mapped separately. Colluvium commonly grades into and interfingers with alluvium (Qa), alluvium and colluvium (Qac), and debris-flow deposits (Qf). Maximum thickness of this unit is probably about 30 ft, but may be greater in the broad basins north of Squaw Pass road. Areas mapped as colluvium are susceptible to future colluvial deposition and locally are subject to debris flows, rockfall, and sheetwash. Colluvial deposits are a potential source of medium-quality aggregate.

ALLUVIAL AND COLLUVIAL DEPOSITS—Units mapped together in areas where adjacent individual units are too small to be mapped or where boundaries between units are not clearly defined. Includes silt, sand, and gravel in stream channels, and on flood plains, debris fans, and lower reaches of adjacent hillslopes. Depositional processes in stream channels and on flood plains are primarily alluvial, whereas colluvial and sheetwash processes are predominant on debris fans and along the hillslope/valley floor boundary.

Qcs

Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene)—Colluvium occurs on steeper slopes and sheetwash deposits are on gentler slopes. Colluvium ranges from clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported gravelly sand. It is generally unsorted to poorly sorted and contains angular to subangular clasts. Sheetwash deposits typically consist of pebbly, silty sand, and sandy silt. Deposits of colluvium and sheetwash are gradational or intertonguing. The deposits range in thickness up to about 10 to 15 ft.

Qac

Alluvium and colluvium, undivided (Holocene and late Pleistocene)—Includes stream-channel, low-terrace, and flood-plain deposits along valley floors, and colluvium and sheetwash on valley sides, where adjacent units are too small to be mapped or contacts are poorly defined. Locally, this unit may also include small debris-flow deposits or lacustrine deposits associated with human-made reservoirs and lakes and topographic depressions dammed by glacial deposits. Alluvial deposits are typically composed of poorly sorted to moderately sorted, moderately stratified, interbedded sand, pebbly sand, and sandy gravel, but colluvium ranges to very poorly sorted, unstratified or poorly stratified, silty sand and bouldery sand. The clast lithologies are varied, depending on the type of rocks within the source area. This unit is typically less than about 15 ft thick. Low-lying areas are subject to flooding. Valley sides are prone to small debris flows, rockfall, and sheetwash. The unit is a potential source of aggregate.

Qf

Debris-fan deposits (Holocene and late Pleistocene—Sediments deposited by debris flows, hyper-concentrated flows, streams, and sheetwash on active fans. Debris-flow deposits range from poorly sorted to moderately sorted, matrix-supported, gravelly, sandy silt to clast-supported, pebble and cobble gravel in a sandy silt or silty sand matrix. Clasts are mostly angular to subround with varied lithologies dependant upon local source rock. The maximum estimated thickness for debris fans along Clear Creek is as much as 60 ft. Elsewhere, fan thickness is typically less than 30 ft. Debris-flow areas are subject to flooding and to future debris-flow, hyperconcentrated-flood, and alluvial deposition following intense rainstorms.

ALLUVIAL DEPOSITS—Silt, sand, and gravel deposited in stream channels, on flood plains, terraces, and minor debris fans, and in sheetwash areas along Clear Creek, Chicago Creek, Soda Creek, and their tributaries.

Qto

Older terrace alluvium (middle Pleistocene)—Stream alluvium underlying terrace remnants on the south side of Clear Creek. The terrace surfaces are about 180 ft above modern stream level. The unit is composed of poorly sorted, clast-supported, pebble and cobble gravel in a sandy matrix. Clasts are mainly subrounded to rounded and consist of a variety of lithologies such as granodiorite, migmatite, granite, and felsic gneiss, reflecting the diversity of the source rock in the drainages. Clasts, especially those composed of granodiorite, are moderately to strongly weathered. Iron staining associated with clast weathering is locally present. The unit is probably pre-Bull Lake in age, based on its height above modern stream level and the degree of clast weathering. Maximum exposed thickness is about 23 ft. It is a potential source of sand and gravel.

Qtm

Intermediate terrace alluvium (late and/or late middle? Pleistocene)—Includes a single terrace remnant above the U.S. Forest Service ranger station near the mouth of Chicago Creek. Intermediate terrace alluvium consists chiefly of poorly sorted, clast-supported, bouldery pebble and cobble gravel in a sandy matrix. Clasts are mainly subrounded to rounded and consist of a variety of lithologies such as granodiorite, migma-tite, granite, felsic gneiss, and biotite gneiss, reflecting the diversity of the source rock in the drainages. The original terrace surface has been extensively modified by placer mining, but appears to have been about 50 ft above modern Clear Creek. Intermediate terrace alluvium was probably deposited during the Bull Lake glaciation, but possibly as recently as the Pinedale glaciation. Thickness of the unit ranges from about 15 to 25 ft. It is a potential source of sand and gravel and may contain placer gold.

Qty **Younger terrace alluvium (late Pleistocene)**—Includes deposits of stream alluvium and glacial outwash underlying terraces ranging from about 8 to 20 ft above modern stream level. The most extensive terrace remnant lies about 10 to 15 ft above modern Clear Creek. Much of the town of Idaho Springs is built either on this terrace or on debris fans that were deposited over it. Many original terrace surfaces, especially those in the town of Idaho Springs, have been extensively modified by placer mining and construction activities. Younger terrace alluvium composed of poorly sorted, clast-supported, bouldery pebble and cobble gravel in a sandy matrix. Boulders are spherical to elongate and range in size up to about 6 or 7 ft along the longest axis. Clasts are mainly subrounded to rounded and are composed of a variety of lithologies such as granodiorite, migmatite, granite, felsic gneiss, and biotite gneiss, reflecting the diversity of the source rock in the drainages.

At two locations along Chicago Creek, thin remnants of younger terrace alluvium are exposed in road cuts. The remnants are typically only a few feet thick and rest on Proterozoic bedrock about 10 to 15 ft above modern stream level. They are overlain by thick deposits of colluvium. Because of their limited areal extent, these deposits are shown by a line symbol on the geologic map.

Younger terrace alluvium was probably deposited during the Pinedale glaciation. Thickness varies from about 3 to 15 ft. It is a potential source of good-quality sand and gravel and may contain placer gold.

Qa **Stream-channel, flood-plain, and low terrace alluvium (Holocene)**—Includes organic-rich mud, peat, sand, and gravel underlying Clear Creek, Chicago Creek, and Soda Creek and adjacent flood plains and low terraces up to about 10 ft above modern stream level. The unit is mostly clast-supported, interbedded sandy to bouldery pebble and cobble gravel and is commonly overlain by silty sand and organic-rich sandy silt. Clasts are subangular to well rounded, and their varied lithology reflects the diverse types of bedrock within their provenance. This unit may be interbedded with younger debris-flow deposits where the distal ends of fans extend into modern river channels and flood plains. Areas mapped as alluvium may be prone to flooding and sediment deposition. The unit is a potential source of sand and gravel.

HUMAN-MADE DEPOSITS

mw **Mine and mill waste (latest Holocene)**—Waste rock excavated from mines and pits and mill tailings resulting from milling operations. Mine waste typically consists of pebble- to cobble-size angular fragments of altered biotite gneiss, migmatite, felsic gneiss, granite, and pegmatite, whereas mill tailings are generally composed of sand and smaller-sized material. Mill tailings are as much 80 ft thick; mine waste deposits are usually only a few feet to a few tens of feet thick. There may be environmental problems, such as contamination of ground water, associated with mine and mill waste.

rm **Reclaimed mine waste (latest Holocene)**—Consists of rock debris and surficial deposits that have been reclaimed at or removed from three mining and milling sites. All three reclaimed sites are part of the Central City–Clear Creek Superfund Study Area defined by the U.S. Environmental Protection Agency (EPA). Information regarding this superfund site was obtained through oral and written communication from Armstrong Data Services, which contracts with the EPA.

Deposits along Chicago Creek, about 1.75 mi southwest of Idaho Springs, include mill tailings from the Black Eagle mill. The mill was intermittently active from 1934 to the late 1970s operating as a selective flotation mill where tailings were deposited by water slurry. Elevated levels of arsenic, lead, and zinc were found in the approximately six-acre tailings site. The site was graded and revegetated in 1994.

The Little Bear waste site is located on Little Bear Creek about 1.5 mi south of Idaho Springs. The waste pile was up to 35 ft thick, had an estimated volume of 7,000 cubed yards, and contained heavy metals including arsenic, cadmium, and lead. Reclamation of this site was cooperatively undertaken in 1998 by the U.S. Forest Service, Colorado Department of Public Health and Environment, and the EPA. The waste material was removed by the Coors Energy Company to their Keenesburg ash facility in eastern Colorado. Approximately 1,000 cubed yards of fill, topsoil, and compost was brought to the site and revegetated.

In the early 1900s, mine waste from the Big Five tunnel, located at the west end of Idaho Springs, was deposited along the south bank of Clear Creek upstream of the mouth of Chicago Creek. The Colorado Department of Public Health and Environment and the EPA are currently reclaiming this site. The waste pile has been regraded and will be capped and reseeded by the spring of 2000.

Reclamation of the large tailings pile associated with the Argo mill in Idaho Springs (mapped as mine waste) is scheduled to begin in 2001.

Reclaimed materials may be prone to settlement or erosion. Environmental problems related to these sites have been reduced or eliminated by these projects.

lf

Landfill (latest Holocene)—Municipal trash deposited in a landfill adjacent to the confluence of Barbour Creek and Soda Creek. Maximum thickness is about 30 ft. The site may be subject to severe settlement. Materials placed in landfills may generate biogenic methane gas as organic materials decay, which can create explosive hazards, and may pose environmental risk to Soda Creek.

af

Artificial fill (latest Holocene)—Fill and waste rock deposited by humans during the construction of Interstate Highway 70, State Highway 103, and the Idaho Springs reservoir. Artificial fill is composed mostly of unsorted silt, sand, and rock fragments, but may include recycled construction materials. The maximum thickness of unit is about 25 ft. It may be subject to settlement when loaded if not adequately compacted.

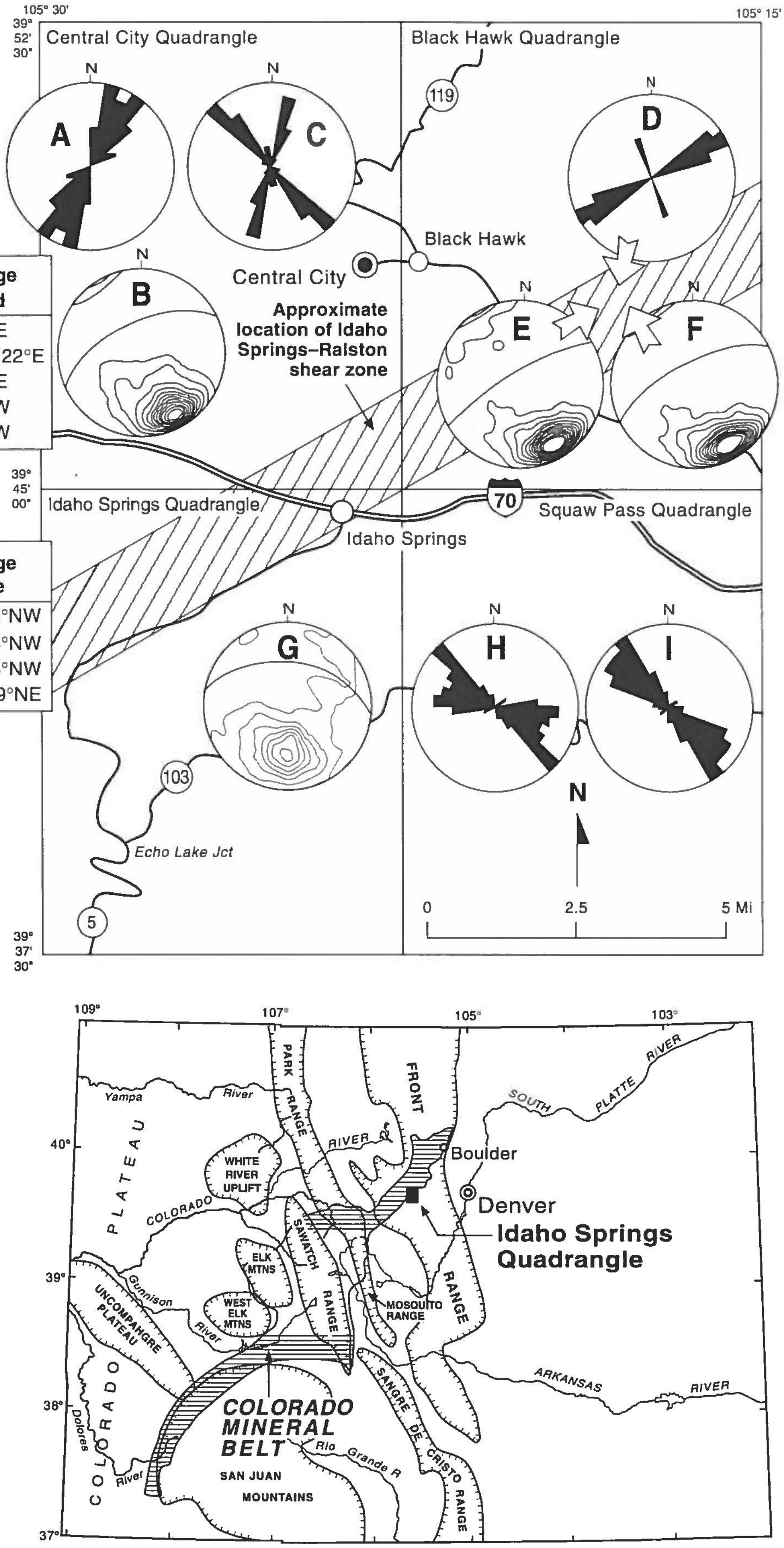
STRUCTURAL GEOLOGY

REGIONAL STRUCTURE

Rocks in the Idaho Springs region were deformed during both Proterozoic and Laramide times. Evidence of the oldest deformation is preserved in the Proterozoic metamorphic complex and is characterized by deep-seated, plastic deformation, which formed large-scale (1.25-mi wavelength), open to overturned folds. Southeast of Chicago Creek these folds and associated foliations trend roughly northwest, whereas northeast of Chicago Creek they trend northeast (Fig. 2). A later event occurred during regional peak metamorphism, U-Pb zircon dated at 1,726 ± 15 Ma (Selverstone and others, 1997), creating an intensely folded and sheared narrow zone that extends southwest-northeast through the Idaho Springs quadrangle. This 1- to 2-mi-wide zone of intense deformation formed the Idaho Springs anticline, which trends and plunges to the northeast. The anticline is strongly asymmetric with a northwestern limb that dips steeply to the northwest and a southeastern limb that dips moderately to the northeast. Tweto and Sims (1963) named this zone of deformation the Idaho Springs-Ralston shear zone.

The Idaho Springs-Ralston shear zone (ISRSZ) is the dominant structure in the Idaho Springs quadrangle. It is the northeasternmost of several Precambrian shear zones that coincide with the 250-mi-long Colorado mineral belt, which extends from near Boulder southwest to the San Juan Mountains (Fig. 2). As defined by Tweto and Sims (1963), the ISRSZ is about 23 mi long but only a few miles wide. It appears to die out south-west of Idaho Springs but may link up with another smaller shear zone southwest of Georgetown. Within the quadrangle its southeastern margin generally coincides with the segment of Chicago Creek extending northeast from the confluence with West Chicago Creek to Idaho Springs. The northwest margin is gradational but appears to die out near the mouth of Fall River in the Central City quadrangle. The ISRSZ terminates to the northeast near the mountain front at Coal Creek.

Deformation within the ISRSZ was probably most intense during regional peak metamorphism 1,726 ± 15 Ma (Selverstone and others, 1997). Motion along the ISRSZ was dextral as early as 1,700 Ma (Graubard, 1991), as evidenced by older, northwest-trending, overturned folds and associated foliations southeast of Chicago Creek that bend to the northeast and exhibit a right-lateral sense of drag as they approach the ISRSZ (Pl. 1). Subsequent sinistral movement along the ISRSZ occurred syntectonically with the emplacement of



Rose Diagram	Type of Data	No. of Data Points	Average Trend
A	Fold axes	N=70	N28°E
C	Faults	N=34	N41°W, N22°E
D	Joints	Schematic	N62°E
H	Fold axes	N=67	N67°W
I	Faults	N=80	N43°W

Stereo-net	Type of Data	No. of Data Points	Average Plane
B	Foliation	N=1265	N58°E 65°NW
E	Veins	N=402	N62°E 65°NW
F	Foliation	N=708	N60°E 78°NW
G	Foliation	N=914	N75°W 49°NE

Figure 2. Map showing location of the Idaho Springs–Ralston shear zone and orientation of foliation, fold axes, and faults northwest and southeast of the shear zone, and foliation, joints, and veins within the shear zone. Poles to planes of foliation and veins contoured on lower hemisphere of stereographic projections; line shows average orientation of planar surface. Orientation of fold axes, faults, and joints shown on rose diagrams; black arrows indicate average orientation. Foliation, fold, and fault data were compiled from field studies and the following reports: Sheridan and Marsh (1976); Taylor (1976); Sims (1964); Harrison and Wells (1959). Vein data are from Moench and Drake (1966). Joint data in rose diagram D was modeled after Harrison and Moench (1961). Inset tables list number of data points and average orientations. Inset map shows relative position of the Idaho Springs quadrangle to the Colorado mineral belt.

the Mount Evans batholith, part of the Berthoud plutonic suite, at about 1,440 Ma (Graubard and Mattinson, 1990).

By the Late Proterozoic, the regional deformation style was less ductile and produced major zones of cataclasis rather than large-scale folding. The Idaho Springs fault is one such zone of cataclasis that is believed to have originated in the Precambrian sometime after the formation of the ISRSZ (Tweto and Sims, 1963). The fault offsets Early Proterozoic metamorphic rocks in a manner that suggests initial left-lateral, strike-slip movement. Regional Laramide deformation occurred in a shallower environment and is characterized by normal movement and breccia rather than strike-slip movement and cataclasis (Tweto and Sims, 1963). The Idaho Springs fault is thought to have been reactivated in a normal sense during the Laramide on the basis of breccia reefs that have been found along its trace (Tweto and Sims, 1963).

The Kennedy Gulch fault is another Precambrian zone of cataclasis that appears to have originated as a strike-slip fault. Reactivation of the fault in a normal sense was suggested by G.R. Scott (1975) who calculated more than 980 ft of offset on the Kennedy Gulch fault since the Eocene on the basis of displacement of Tertiary gravels capping the late Eocene erosional surface to the east of the Idaho Springs quadrangle.

Throughout the Mesozoic and Paleozoic the ISRSZ probably absorbed minor regional strain but there is no evidence in the Idaho Springs quadrangle of large-scale deformation during this time. It was not until the Late Cretaceous and early Tertiary that tectonic activity again produced significant deformation in the area. During the Laramide orogeny, porphyry bodies were intruded generally parallel to foliation in the Proterozoic metamorphic host rocks. The majority of these porphyry bodies are northeast-trending dikes that are northwest of Chicago Creek. There are only a few northeast- and northwest-trending dikes southeast of Chicago Creek. Shortly thereafter, and primarily within the ISRSZ, northeast- to east-trending conjugate fracture sets developed, many of which contain the valuable ore deposits for which Idaho Springs is known. These fractures dip primarily to the north, cut all but the youngest early Tertiary to Upper Cretaceous dikes, and commonly cut each other. The latter indicates they formed at about the same time (Moench and Drake, 1966). Slickensides associated with these fractures indicate initial strike-slip movement and later normal movement. Base metal precipitation occurred about 59 Ma along many of these fractures (Rice and others, 1982). Later deformation in the area is indicated by a few conjugate fractures indicating north-south compression. These fractures contain no base metals and cut all other fractures. These relationships suggest the fractures may be post-Laramide in age (Beach, in press).

MICROSTRUCTURE OF THE IDAHO SPRINGS-RALSTON SHEAR ZONE

The ISRSZ is a N 50° E-trending Precambrian structure that hosts the majority of the mineralized, Laramide-age veins in the Idaho Springs region and defines the boundary of a major change in the regional trend of foliation and folding (Fig. 2). Despite this striking change in regional structural trend, the ISRSZ is difficult to recognize in outcrop. It is most readily defined at a macroscopic scale by the overall alignment of foliation and lithologic contacts in the vicinity of Chicago Creek. However, analysis of thin sections collected within and outside of the ISRSZ revealed that its boundaries can also be fairly well defined at the microscopic level.

Thin section analysis of metamorphic and igneous rocks in the quadrangle was conducted along two transects sub-perpendicular to the trend of the ISRSZ (Fig. 3) to define the margins of the ISRSZ. Sixteen samples were collected from the northeastern transect which extends through Proterozoic metamorphic rocks from Fall River road in the Central City quadrangle to Little Bear Creek road in the Idaho Springs quadrangle. Eight samples were collected from a second transect to the southwest, which extends through Proterozoic igneous rocks from the Mount Evans road to Cascade Creek.

Several microscopic features can be used to define the margins of the ISRSZ. The distinguishing features associated with each thin section are listed in Table 1. The principle minerals of rocks in the Idaho Springs region are feldspar, quartz, and biotite. Outside the ISRSZ biotite is coarse grained and either tabular or extensively crenulated (Fig. 4a). Biotite in the ISRSZ is fine grained

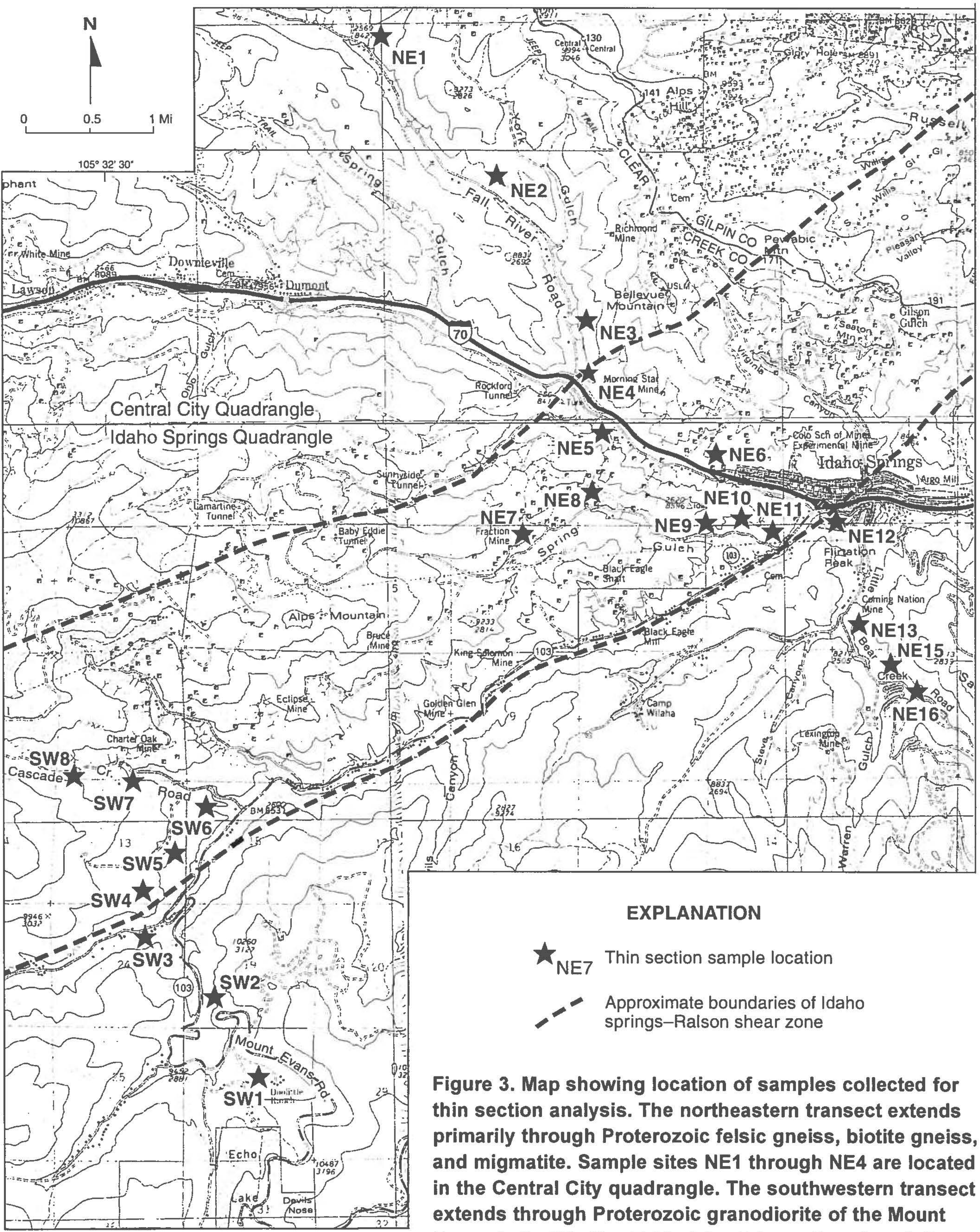


Figure 3. Map showing location of samples collected for thin section analysis. The northeastern transect extends primarily through Proterozoic felsic gneiss, biotite gneiss, and migmatite. Sample sites NE1 through NE4 are located in the Central City quadrangle. The southwestern transect extends through Proterozoic granodiorite of the Mount Evans batholith. See Table 1 for thin section descriptions.

and crenulations have been sheared out. Feldspar and quartz crystals within the ISRSZ are coarse grained and relatively unaltered (Fig. 4b). Sericitization is weakly developed in rocks outside the ISRSZ but is usually strongly developed in rocks within the ISRSZ (Fig. 4c). Evidence of both ductile and brittle deformation is found in rocks within the ISRSZ, whereas evidence of ductile deformation is characteristic of rocks outside the ISRSZ. Fracturing, grain-size reduction,

Table 1. Table shows sample number, rock unit from which sample was collected, brief description of each thin section, and general location of each sample in relation to the Idaho Springs-Ralston shear zone. Photomicrographs of samples NE4, NE5, NE9, NE15, and NE16 are shown in Figure 4.

	NORTHEASTERN TRANSECT		
	Sample	**Unit**	**Brief description of thin section**
	NE1	Xb	Moderate sericitization; some quartz and feldspar strained; quartz fractured.
	NE2	Xm	Weak sericitization; some quartz recrystallized; minor strain apparent in feldspar.
	NE3	Xf	Weak sericitization; strained quartz.
?	NE4	Xf	Little sericitization; strained feldspar, recystallization, and-grain size reduction of quartz; microcline twinning of feldspar. Photomicrographs Figs. 4E and F.
	NE5	Xf	Little sericitization; strained feldspar, minor recystallization and grain-size reduction of quartz; microcline twinning of feldspar. Photomicrograph Fig. 4D.
	NE6	Xb	Moderate sericitization; strained quartz.
Shear	NE7	Xb	Moderate sericitization; strained, fractured, and recrystallized quartz.
zone	NE8	Xb	Strong sericitization; grain-size reduction and recrystallization of quartz.
	NE9	Xb	Strong sericitization in places; recrystallization and minor strain apparent in quartz; fractured feldspar. Photomicrograph Fig. 4C.
	NE10	Xf	Strong sericitization; strained, fractured, and slightly recrystallized quartz.
↓	NE11	Xb	Strong sericitization; intensely altered and weathered; microcline twinning of feldspar.
	NE12a	Xf	Moderate sericitization; fractured quartz; minor recrystallization.
	NE12b	Xb	Moderate sericitization; biotite crenulations preserved; recrystallization and minor fracturing of quartz.
	NE13	Xf	Weak deformation throughout; some recrystallization of quartz; microcline twinning of feldspar.
	NE15	Xf	Minimal deformation and strain. Photomicrograph Fig. 4B.
	NE16	Xb	Moderate sericitization; biotite crenulations preserved; weak microcline twinning of feldspar. Photomicrograph Fig. 4A.

	SOUTHWESTERN TRANSECT		
	Sample	**Unit**	**Brief description of thin section**
	SW1	Ygd	Minor sericitization; minimal deformation and strain.
?	SW2	Ygd	Minor sericitization; minimal deformation and strain.
	SW3	Ygd	Moderate sericitization; minor grain-size reduction of quartz.
Shear	SW4	Ygd	Weak sericitization; fracturing of feldspars.
zone	SW5	Ygd	Recrystallized quartz; some strained quartz.
	SW6	Ygd	Moderate sericitization; recrystallization of quartz.
↓	SW7	Ygd	Ductile deformation of feldspar; grain-size reduction of feldspar; minimal sericitization.
	SW8	Ygd	Minor sericitization; fracturing and recrystallization of quartz.

recrystallization, and pressure shadows are common features found in feldspar and quartz crystals within the ISRSZ (Figs. 4d, 4e). Microcline-twinned plagioclase is found within the ISRSZ and adjacent to the Idaho Springs fault (Fig. 4f). This cross-hatched twinning occurs as twins propagate through individual orthoclase crystals in response to an applied stress. This type of strain-induced twinning occurs under ductile to brittle-ductile conditions at temperatures between 475–600°C and is typically more prevalent near major fault zones (Wilson and Coats, 1972).

Thin sections of rocks collected from the northeastern transect provide the best evidence of increased deformation within the ISRSZ. Rocks of this transect include biotite gneiss (Xb) and felsic gneiss (Xf). The northwest margin of the ISRSZ cannot be determined conclusively from thin section analysis. Samples NE1 to NE3 northwest of the ISRSZ are generally weakly sericitized, exhibit minor to moderate deformation, but have no biotite crenulations preserved. Between Chicago Creek and the mouth of Fall River, rocks are clearly affected by the ISRSZ. Samples NE4 and NE5 are near the northwestern boundary of the ISRSZ and exhibit only weak sericitization but also contain microcline-twinned feldspar. Samples NE6 to NE11 define the ISRSZ best. Sericitization is moderate to strong in these samples and biotite crenulations have been obliterated by shearing such that foliation defined by biotite rarely deviates from the northeast trend of the ISRSZ. Grain-size reduction and recrystallization of quartz is widespread, and larger quartz crystals are strongly strained and fractured.

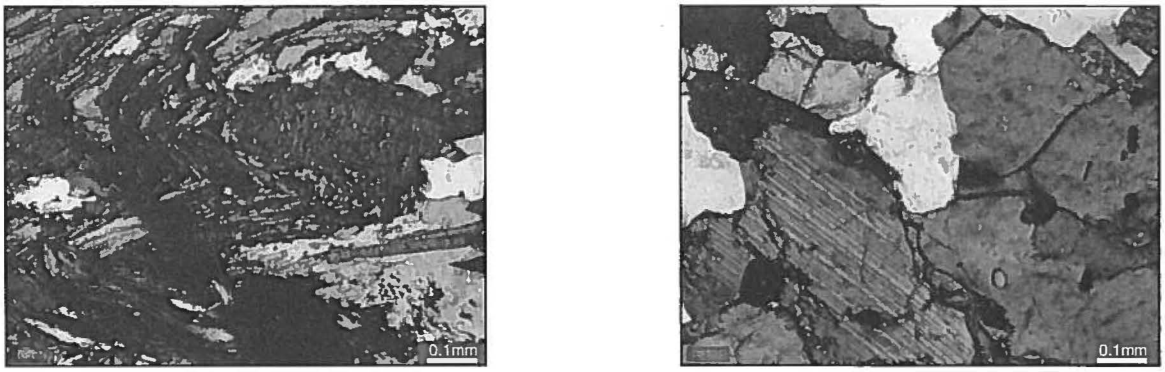
Microcline twinning is present in feldspars of several samples both within the ISRSZ and adjacent to the Idaho Springs fault but is not found in the thin sections of rocks collected outside the ISRSZ. Locally microcline twinning may be indicative of intense strain under ductile or brittle-ductile conditions (Wilson and Coats, 1972). The proximity of this type of twinning to the Idaho Springs fault suggests that it could have been active during the later stages of ductile deformation associated with the ISRSZ. Samples NE12 to NE16 are south of Chicago Creek and are only weakly to moderately sericitized and deformed. Samples NE12 and NE16 have preserved biotite crenulations indicating that the southeastern margin of the ISRSZ probably coincides closely with Chicago Creek.

Samples collected from the southern transect are granodiorite of the Mount Evans batholith. Samples SW4 to SW8 are within the ISRSZ northwest of Chicago Creek and are moderately to strongly sericitized. Feldspar is sheared slightly in a ductile fashion, but angular fragments of feldspar indicate brittle deformation as well. Quartz grains commonly show grain-size reduction and recrystallization. Pressure shadows are present in some fractured quartz grains, and quartz appears to replace feldspar in some places. Samples SW1 to SW3 are southeast of Chicago Creek. They are relatively pristine and show little deformation and only minor to moderate sericite alteration. These characteristics indicate that the southeastern margin of the ISRSZ coincides roughly with Chicago Creek.

Thin section analysis along both transects clearly demonstrates a dramatic increase in deformation adjacent to and northwest of Chicago Creek, thus defining Chicago Creek as the approximate southeastern boundary of the ISRSZ. Grain-size reduction and fracturing indicate brittle deformation within the ISRSZ, wheras recrystallization and possibly microcline twinning suggest a component of ductile deformation.

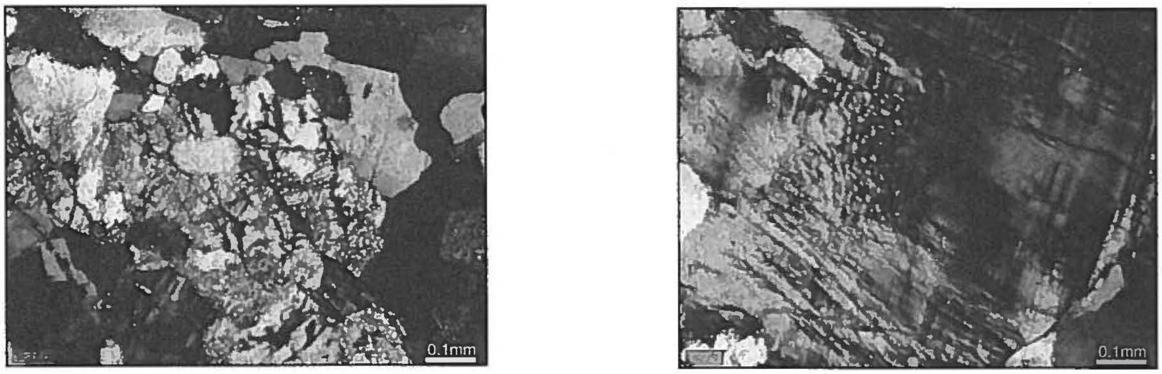
STRUCTURAL CONTROL OF MINERALIZATION

Although mineralized veins in the Idaho Springs district are largely a product of the Laramide orogeny, the orientations of these veins were influenced by Precambrian structures. The Precambrian development of significant zones of weakness and strong northeast-oriented foliation in the Proterozoic basement rocks of the Front Range was the first step in the formation of the northeast-trending Colorado mineral belt. In the Idaho Springs region, this zone of weakness is the ISRSZ. The formation of deep-seated, northwest-trending faults occurred syntectonically, or slightly thereafter. An essential control of ore formation was a deep magmatic source which served to circulate these fluids (Rice and others, 1982). Early Tertiary and Upper Cretaceous porphyry dikes and small intrusive bodies, ranging in age from 69 to 59 Ma (Rice and others, 1982; C.E. Hedge, oral communication, cited in Sheridan and Marsh,



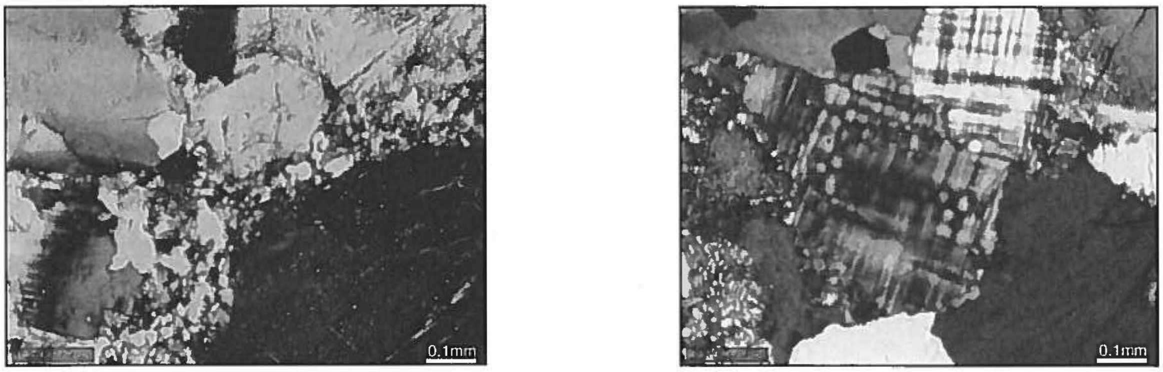
A. Sample NE16, biotite gneiss from north-eastern transect. Biotite crenulations are preserved indicating this rock has not been sheared.

B. Sample NE15, felsic gneiss from north-eastern transect. Relatively unaltered, coarse-grained feldspar and quartz.



C. Sample NE9, biotite gneiss from north-eastern transect. Brittle deformation and strong sericitization (brown).

D. Sample NE5, felsic gneiss from north-eastern transect. Strained feldspar with weak twinning and deformed cleavage planes.



E. Sample NE4, felsic gneiss northeastern transect. Grain size reduction and recrys-tallization of quartz (light) at a feldspar grain boundary (dark).

F. Sample NE4, felsic gneiss from north-eastern transect. Microcline twinning of orthoclase.

Figure 4. Photomicrographs of selected thin sections from the northestern transect. A and B samples collected southeast of the Idaho Springs-Ralston shear zone. C through F samples collected within the shear zone.

1976), were injected along the Precambrian zone of weakness, generally parallel to foliation and the overall trend of the ISRSZ. Northeast-oriented Laramide compressional stress induced north-northeast- to east-trending fractures in the already weakened and strongly foliated ISRSZ. The fractures predominate in the more competent rock units such as migmatite (Xm), pegmatite (YXp), and felsic gneiss (Xf). Biotite gneiss (Xb) in the ISRSZ has very few fractures, probably because most of the stress was absorbed by slip along foliation planes. Southeast of the ISRSZ there are few such fractures; the rocks here experienced significantly less strain, and foliation tends to be oriented northwest, roughly perpendicular to Laramide compressive stresses. Hydrothermal fluids, probably associated with early Tertiary and Upper Cretaceous magmas, flowed along deep-seated, northwest-trending Proterozoic faults to shallower, generally northeast-trending Laramide fracture openings and junctions (Harrison and Wells, 1959; Lovering and Goddard, 1950). As pressure and temperature decreased, and where restricted channels flowed into open spaces, ore minerals precipitated (Lovering and Goddard, 1950). The origin and location of Laramide fracture sets is therefore of great significance.

During the Laramide the average direction of horizontal compression in the Front Range was N 72° E (Erslev and Selvig, 1997). Theoretically, when a conjugate fracture model is used, strike-slip fractures should occur between 30° and 45° from a given maximum compressive stress. When a maximum stress orientation of N 72° E is assumed (Erslev and Selvig, 1997), predicted fractures should occur as right-lateral fractures oriented between N 27° E and N 42° E and as left-lateral fractures oriented between N 63° W and N 78° W.

Detailed investigation of Laramide fractures in the Central City-Idaho Springs area by Harrison and Moench (1961) indicated a horizontal compression direction trending roughly N 70° E. Stereographic diagrams of their data collected near Idaho Springs show a predominance of fractures (cross and diagonal joints) oriented between N 50° E and N 75° E and fractures generally perpendicular to the maximum compressive stress (longitudinal joints) oriented between N 20° W to N 40° W (Harrison and Moench, 1961, Fig. 10). In the Idaho Springs district mineralized veins have strikes with a range of orientations but average about N 62° E (Moench and Drake, 1966). The majority of the veins occur along right-lateral fractures (cross and diagonal joints), whereas fewer veins occur along left-lateral fractures (longitudinal joints). These fracture orientations do not coincide fully with predicted fracture orientations, but the predominance of right-lateral fractures oriented at an average of N 62° E suggests that the strongly developed, N 60° E-striking foliation within the ISRSZ played an important role in fracture development and mineralization.

ECONOMIC GEOLOGY

MINERAL RESOURCES

The mineral resources of Idaho Springs have been well described by Rice and others (1982), Schwochow (1975), Moench and Drake (1966), Harrison and Wells (1959; 1956), Lovering and Goddard (1950), Burbank (1947), and Spurr and others (1908). A brief summary of these reports is given herein.

Parts of three precious- and base-metal mining districts lie within the Idaho Springs quadrangle (Fig. 1), and each has been mapped and described in detail. The mining areas include the Idaho Springs district (Moench and Drake, 1966), the Freeland-Lamartine district (Harrison and Wells, 1956), and the Chicago Creek district (Harrison and Wells, 1959). The principal ore metals are gold, silver, lead, zinc, and copper, listed in order of decreasing importance (Streufert and Cappa, 1994). Ore minerals are pyrite, sphalerite, galena, chalcopyrite, and tennantite, small amounts of various silver-bearing minerals, and trace amounts of metallic gold (Schwochow, 1975). Mineralization took place about 59 Ma near the end of the early Tertiary to Late Cretaceous period of porphyry intrusion (Rice and others, 1982). The ores occur as lodes in generally northeast-trending fracture-filled veins in the Proterozoic basement rocks northwest of Chicago Creek and as placer deposits along Clear Creek. Minor ore metals include uranium, molybdenum, and iron (magnetite).

Ore bodies in the Idaho Springs area have been mined since their discovery in 1859 (Spurr and others, 1908). Mining, especially of gold, was most productive prior to 1942 but has been episodic since. For example, production figures for the Idaho Springs, Chicago Creek, and Freeland-Lamartine districts during the years 1932 to 1945 totaled 124,642 oz of gold (Vanderwilt, 1947), whereas from 1946 to 1958 production of gold in all of Clear Creek County was only 34,586 oz (Del Rio, 1960). Davis and Streufert (1990) estimated a total of 730,000 oz of gold produced in the Idaho Springs, Freeland-Lamartine, and Chicago Creek mining districts from 1859 to 1990. For more mine production figures in the area, the reader is referred to the U.S. Bureau of Mines Minerals Yearbooks.

The Little Warrior Mine (also called the April Fool Mine) produced small amounts of uranium ore in 1960 and 1961 from a pegmatite body on the south side of Squaw Pass Road at the east end of Warrior Mountain (Mason and Arndt, 1996). A sample of this pegmatite collected during this investigation contains 97 parts per million (ppm) uranium; it also has an anomalously high molybdenum content of 321 ppm (written communication, Intertek Testing Services, 1999). Some pegmatite bodies contain magnetite crystals up to several inches in diameter. Pegmatite east and southeast of Idaho Springs, on the Squaw Pass quadrangle, has been mined for muscovite, microcline, beryl, and columbite (Hanley and others, 1950).

Industrial mineral and construction material resources in the Idaho Springs region include sand and gravel, crushed aggregate, and riprap. Sand and gravel resources are in modern stream channels and Quaternary terrace and moraine deposits primarily along Chicago Creek, Clear Creek, and Soda Creek. Many of the Proterozoic rocks are potential sources of good quality crushed aggregate and riprap.

GEOTHERMAL RESOURCES

The Indian Springs Resort is located on the east side of the mouth of Soda Creek. The hot springs that serve this resort were first developed commercially for bathing and swimming in 1863 (Repplier and others, 1982) and are the only known hot springs in the area. The resort is fed by three springs and three hot water wells, the most recent of which was drilled in 1996 (J. Maxwell, oral communication, 1999). Temperature of the geothermal waters ranges from 68° to 127° F, and flow rates are between 1 and 36 gpm (Repplier and others, 1982). At the time of this report, a total of about 100 gpm of hot water was available to the resort, and the average water temperature was about 120° F (J. Maxwell, oral communication, 1999).

The areal extent of the geothermal waters has been estimated at only 1.52 sq mi (Pearl, 1979). The hot springs are thought to be fault controlled (Repplier and others, 1982). The southern extension of the Idaho Springs fault lies just south of the hot springs and may serve as the conduit for these geothermal waters. It has not been determined if the waters represent deeply recirculated meteoric waters or if they originated as magmatic fluids associated with Laramide intrusives (Repplier and others, 1982). The geochemistry and geothermal characteristics of the hot springs have been described by Barrett and Pearl (1978), Pearl (1979), Coe and Zimmerman (1981), Repplier and others (1982), and Cappa and Hemborg (1995).

SELECTED REFERENCES

Aleinikoff, J.N., Reed, J.C., Jr., and DeWitt, Ed, 1993, The Mount Evans batholith in the Colorado Front Range; revision of its age and reinterpretation of its structure: Geological Society of America Bulletin, v. 105, p. 791–806.

Ball, S.H., 1906, Precambrian rocks of the Georgetown quadrangle, Colorado: American Journal of Science, 4th series, v. 21, p. 371–389.

Barrett, J.K. and Pearl, R.H., 1978, An appraisal of Colorado's geothermal resources: Colorado Geological Survey Bulletin 39, 224 p.

Beach, S.T., in press, Structural and kinematic analysis of mineralized veins in the northern Idaho Springs quadrangle, central Colorado: Golden, Colorado, Colorado School of Mines, Master's thesis.

Braddock, W.A., 1969, Geology of the Empire quadrangle, Grand, Gilpin, and Clear Creek Counties, Colorado: U.S. Geological Survey Professional Paper 616, 56 p.

Bryant, Bruce, and Hedge, C.E., 1978, Granite of Rosalie Peak, a phase of the 1700-million-year-old Mount Evans pluton, Front Range, Colorado: U.S. Geological Survey Journal of Research, v. 6, no. 4, p. 447–451.

Bryant, Bruce, McGrew, L.W., and Wobus, R.A., 1981, Geologic map of the Denver 1° x 2° quadrangle, north-central Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1163.

Burbank, W.S., 1947, Summaries of mining districts and mineral deposits, Part II of Mineral resources of Colorado: Prepared under the supervision of J.W. Vanderwilt for the State of Colorado Mineral Resources Board, Denver, Colorado, Colorado Mining Association, p. 291–470.

Cappa, J.A., and Hemborg, H.T., 1995, 1992-1993 Low temperature geothermal assessment program, Colorado: Colorado Geological Survey Open-File Report 95-01, 20 p.

Coe, B.A., and Zimmerman, J., 1981, Geothermal energy opportunities at four Colorado towns: Colorado Geological Survey Open-File Report 81-2, 59 p.

Davis, M.W., and Streufert, R.K., 1990, Gold occurrences of Colorado: Colorado Geological Survey Resource Series 28, 101 p.

Del Rio, S.M., 1960, Mineral resources of Colorado, Part I of Mineral resources of Colorado: Prepared under the supervision of S.M. Del Rio for the State of Colorado Mineral Resources Board, Denver, Colorado, Publishers Press, p. 3–308.

Doerner, J.P., 1994, The late-Quaternary environmental history of Mt. Evans; Pollen and stratigraphic evidence from Clear Creek, Colorado: Denver, Colorado, University of Denver, Ph.D. dissertation, 216 p.

Erslev, E.A., and Selvig, B., 1997, Thrusts, backthrusts and triangle zones; Laramide deformation in the northeastern margin of the Colorado Front Range, *in* Bolyard, D.W., and Sonnenburg, S.A., eds., Geologic history of the Colorado Front Range: Fieldtrip guidebook No. 7, Rocky Mountain Section of the American association of Petroleum Geologists, p. 65–76.

Graubard, C.M., 1991, Extension in a transpressional setting; Emplacement of the mid-Proterozoic Mt. Evans batholith, central Front Range, Colorado: Geological Society of America Abstracts with Programs, v. 23, no. 4, p. 27.

Graubard, C.M., and Mattinson, J.M., 1990, Syntectonic emplacement of the ~1440 Ma Mt. Evans pluton and history of motion along the Idaho Springs-Ralston Creek shear zone, central Front Range, Colorado: Geological Society of America Abstracts with Programs, v. 22, no. 2, p. 12.

Hanley, J.B., Heinrich, E.W., and Page, L.R., 1950, Pegmatite investigations in Colorado, Wyoming, and Utah, 1942–1944: U.S. Geological Survey Professional Paper 227, 125 p.

Harrison, J.E., and Moench, R.H., 1961, Joints in Precambrian rocks, Central City-Idaho Springs area, Colorado: U.S. Geological Survey Professional Paper 374-B, 14 p.

Harrison, J.E., and Wells, J.D., 1956, Geology and ore deposits of the Freeland-Lamartine district, Clear Creek County, Colorado: U.S. Geological Survey Bulletin 1032-B, 127 p.

_____1959, Geology and ore deposits of the Chicago Creek area, Clear Creek County, Colorado: U.S. Geological Survey Professional Paper 319, 92 p.

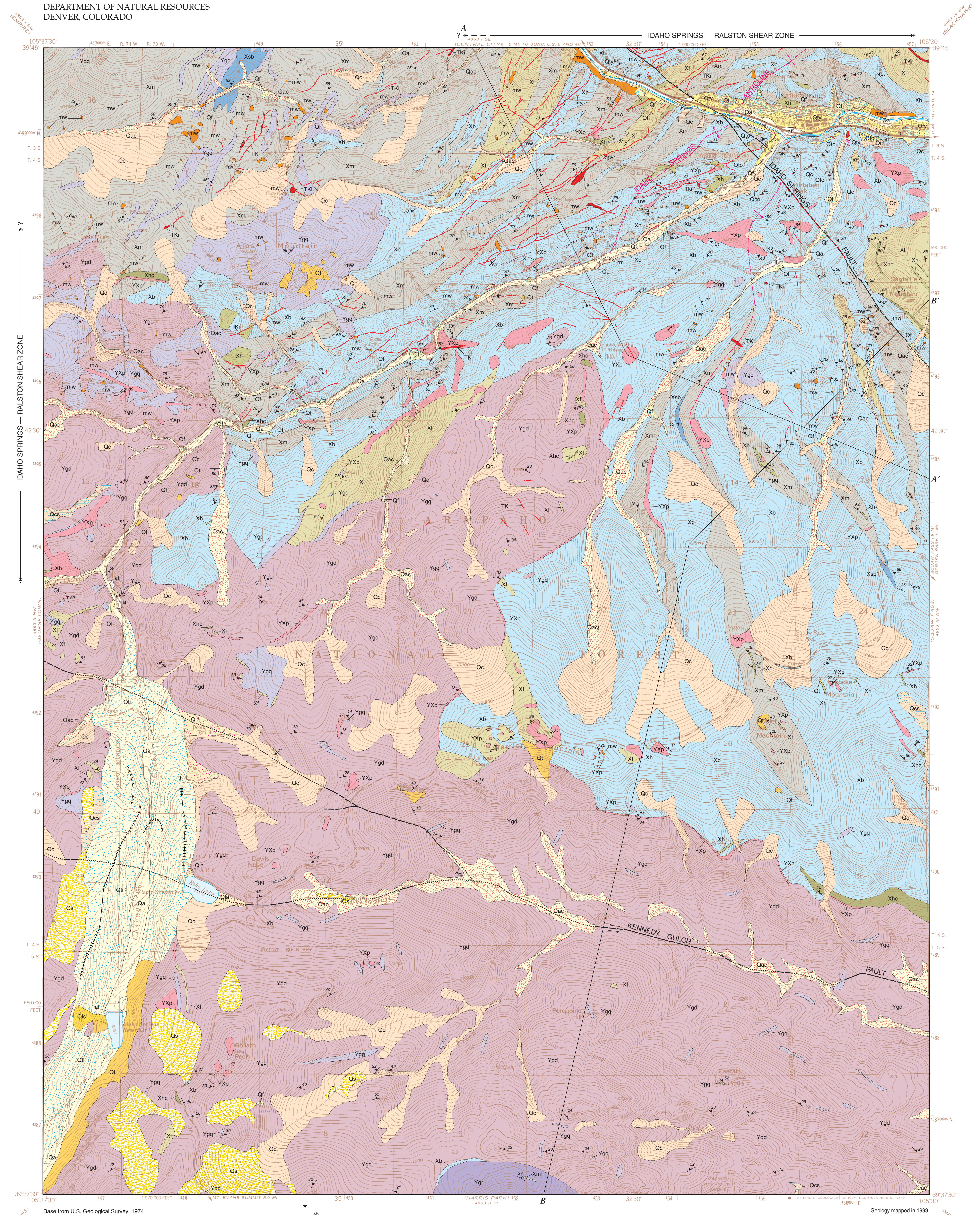
Hedge, C.E., 1969, A petrogenetic and geochronologic study of migmatites and pegmatites in the central Front Range: Golden, Colorado, Colorado School of Mines, Ph.D. dissertation, 158 p.

Lovering, T.S., and Goddard, E.N., 1950, Geology and ore deposits of the Front Range, Colorado: U.S. Geological Survey Professional Paper 223, 325 p.

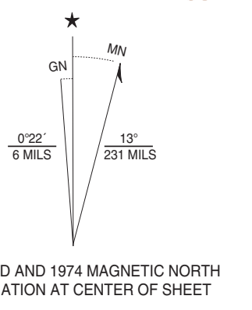
Madole, R.F., 1991, Surficial geologic map of the Walden 30′ x 60′ quadrangle, Jackson, Larimer, and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-1824.

COLORADO GEOLOGICAL SURVEY
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

OPEN-FILE MAP 00-2
GEOLOGIC MAP OF THE IDAHO SPRINGS QUADRANGLE
CLEAR CREEK COUNTY, COLORADO
Booklet accompanies map

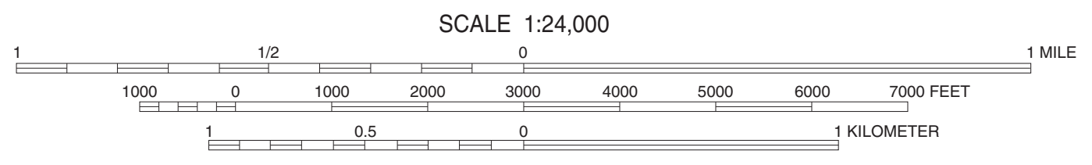


Base from U.S. Geological Survey, 1974
10,000-foot grid based on Colorado coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

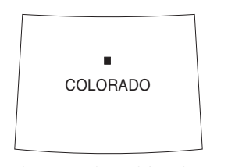


UTM GRID AND 1974 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000

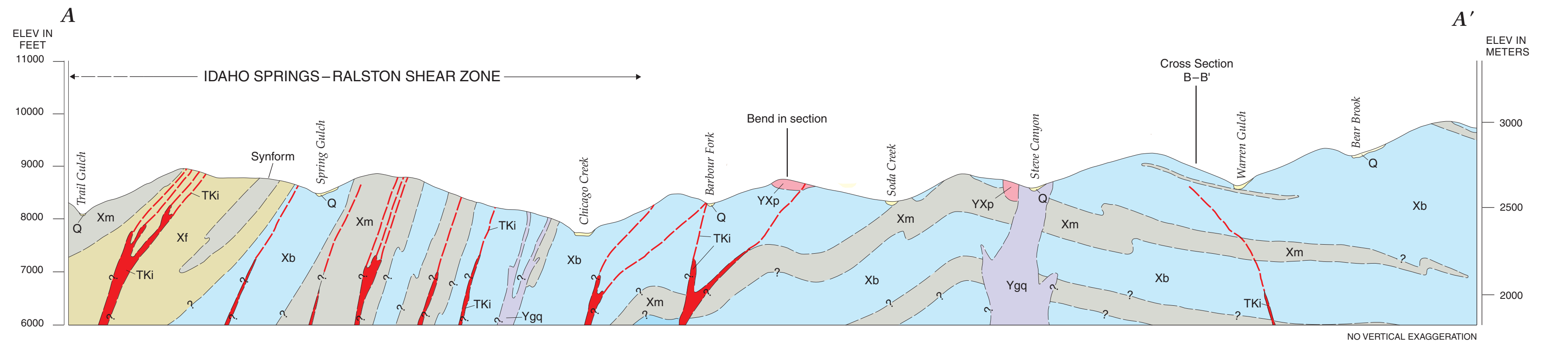


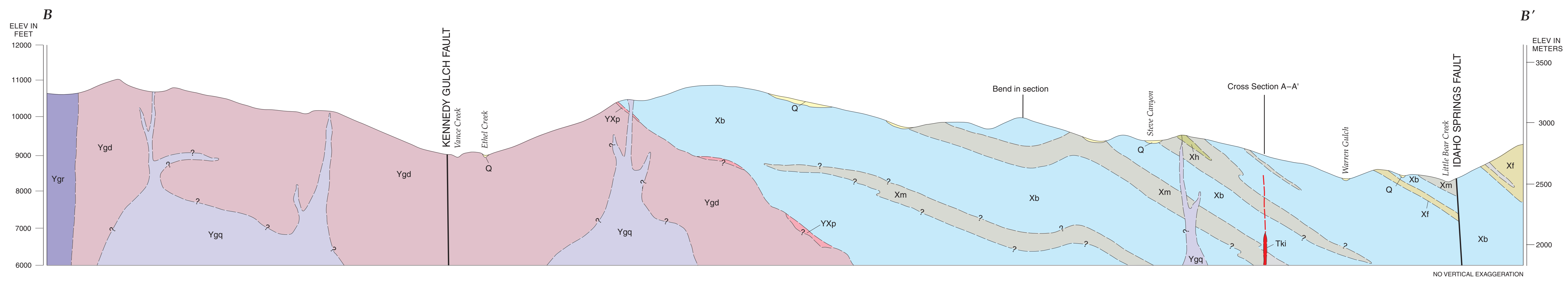
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION

Geology mapped in 1999
Digital cartography by Cheryl Brchan





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)**
lf	**Landfill (latest Holocene)**—Municipal trash in a landfill near Soda Creek
rm	**Reclaimed mine waste (latest Holocene)**—Various types of rock debris and surficial deposits that have been reclaimed at three mining and milling sites
mw	**Mine and mill waste (latest Holocene)**—Includes mill tailings and mine waste

ALLUVIAL DEPOSITS—Sediments deposited in stream channels, on flood plains, terraces, and minor debris fans, and in sheetwash areas

Qa	**Stream-channel, flood-plain, and low terrace alluvium (Holocene)**—Mostly clast-supported, sandy to bouldery pebble and cobble gravel interbedded and often overlain by silty sand. Includes organic-rich mud, peat, sand, and gravel underlying terraces up to about 10 ft above modern stream level
Qty	**Younger terrace alluvium (late Pleistocene)**—Mostly poorly sorted, clast-supported, bouldery pebble and cobble gravel in a sandy matrix. Includes deposits of stream alluvium and glacial outwash underlying terraces ranging from about 8 to 20 ft above modern stream level
Qtm	**Intermediate terrace alluvium (late and/or late middle? Pleistocene)**—Includes a single terrace remnant near the mouth of Chicago Creek. Unit is texturally similar to younger terrace alluvium (Qty). Terrace surface is about 50 ft above Clear Creek
Qto	**Older terrace alluvium (middle Pleistocene)**—Poorly sorted, clast-supported, pebble and cobble gravel in a sandy matrix. Micaceous clasts moderately to severely weathered. Upper surface is about 180 ft above modern stream level

COLLUVIAL DEPOSITS—Silt, sand, and gravel on valley sides and floors transported and deposited primarily by gravity

Qc	Colluvium (Holocene and late Pleistocene)—Ranges from clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported gravelly, silty sand
Qls	Landslide deposits (Holocene)—Single deposit west of Chicago Creek near the Idaho Springs reservoir. Consists of unsorted bedrock fragments and glacial till (Qti)
Qt	Talus deposits (Holocene and late Pleistocene)—Bedrock-derived angular, cobbly and bouldery rubble transported as rockfalls, rockslides, rock avalanches, and rock topples
Qco	Older colluvium (Pleistocene)—Texturally similar to colluvium (Qc). Occurs as dissected hillslopes on the valley walls of Chicago Creek above the Idaho Springs cemetery. Generally not subject to future deposition

ALLUVIAL AND COLLUVIAL DEPOSITS—Sediments in stream channels and on flood plains, debris fans, and lower reaches of adjacent hillslopes

Qf	**Debris-fan deposits (Holocene and late Pleistocene)**—Range from poorly sorted to moderately sorted, matrix-supported, gravelly, sandy silt to clast-supported, pebble and cobble gravel in a sandy silt or silty sand matrix. Includes debris-flow, hyperconcentrated-flow, fluvial, and sheetwash deposits on debris-flow fans and in drainage channels
Qac	**Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Poorly sorted to moderately sorted, stratified, interbedded sand, pebbly sand, and sandy gravel to poorly sorted, unstratified or poorly stratified, silty sand and bouldery sand
Qcs	**Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene)**—Colluvium on steeper slopes, sheetwash on gentler slopes. Colluvium ranges from unsorted to poorly sorted, clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported gravelly sand. Sheetwash deposits typically consist of pebbly, silty sand and sandy silt

LACUSTRINE AND ALLUVIAL DEPOSITS—Sediments deposited in lakes, stream channels, and sheetwash areas, and on flood plains

Qla	**Lacustrine and alluvial deposits (Holocene and late Pleistocene)**—Lacustrine deposits and alluvium at Echo Lake and Doolittle Ranch composed of interbedded sand, gravel, peat, organic sandy silt and silty sand, and silty clay. Echo Lake probably formed about 18,470 ± 460 yr BP (Doerner, 1994) when it was dammed by the east-side lateral moraine of the Chicago Creek glacier

PERIGLACIAL DEPOSITS—Boulder- to clay-size fragments transported primarily by solifluction and creep

Qs	**Solifluction deposits (Holocene and late Pleistocene)**—Consist of pebbles, cobbles, and large boulders in a sandy matrix transported down slope by solifluction and frost creep

GLACIAL DEPOSITS—Gravel, sand, silt, and clay deposited by ice

Qti	**Till (late and late middle Pleistocene)**—Heterogenous deposits of gravel, sand, silt, and clay deposited by ice in the upper reaches of Chicago Creek. Also includes a poorly developed rock-glacier deposit south of the Idaho Springs reservoir

UNDIFFERENTIATED DEPOSITS

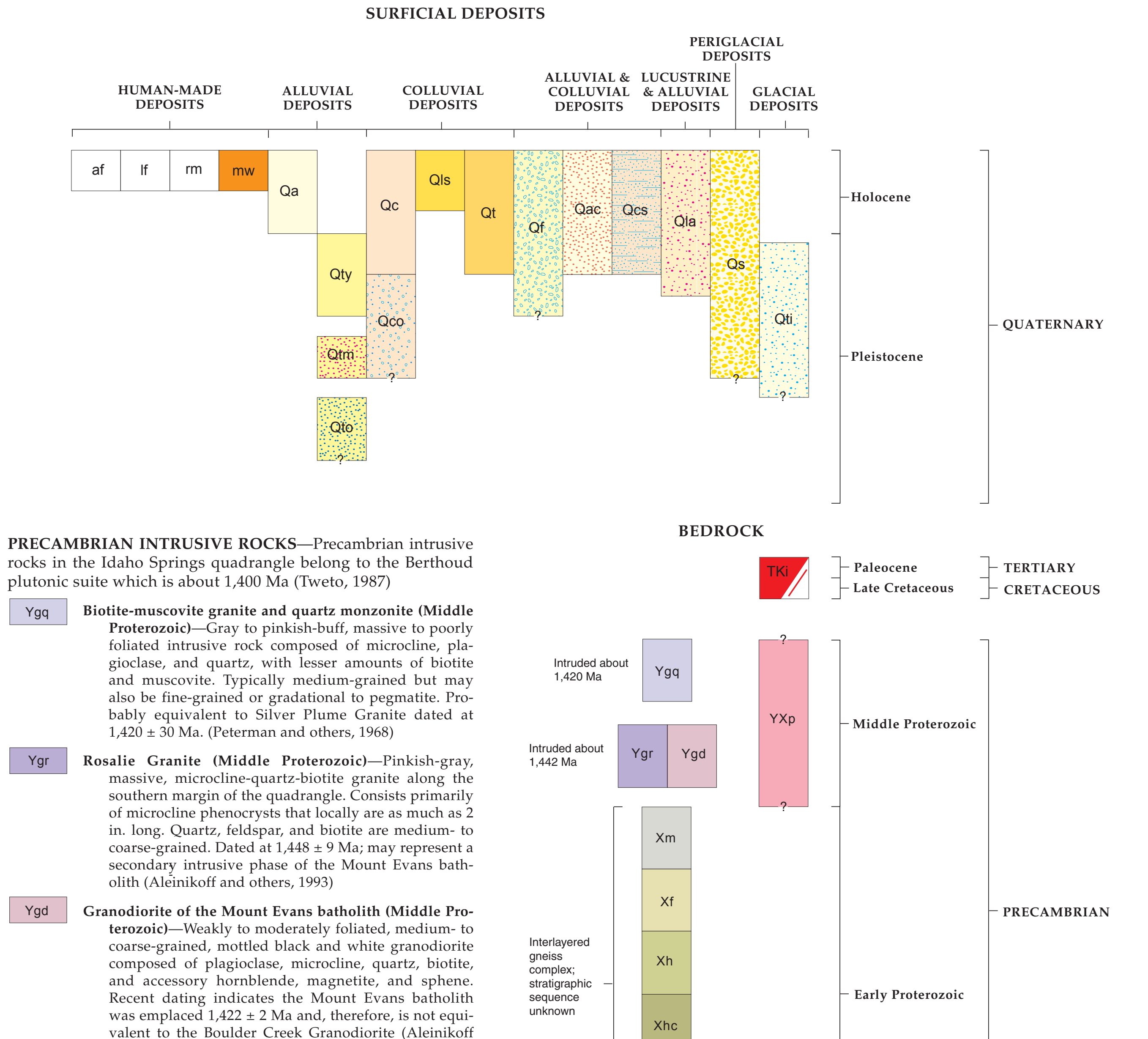
Q	**Undifferentiated surficial deposits (Quaternary)**—Shown only on cross section

BEDROCK

EARLY TERTIARY AND UPPER CRETACEOUS INTRUSIVE ROCKS

TKi	**Intrusive porphyry and related rocks (early Tertiary and Upper Cretaceous)**—Includes various porphyry dikes and small intrusive bodies primarily of bostonite, alkali syenite porphyry, and quartz monzonite porphyry. Bostonite is a lilac to pinkish-gray rock with an aphanitic groundmass composed of orthoclase and plagioclase and phenocrysts of plagioclase, and less commonly amphibole and garnet. Alkali syenite porphyry has a light-gray to tan aphanitic groundmass with phenocrysts of alkali feldspar and occasional pyroxene or amphibole. Quartz monzonite porphyry has phenocrysts of plagioclase, sanidine, and less commonly, amphibole set in a light- to medium-gray, fine-grained groundmass. A porphyry from Chicago Creek was dated at 68 to 69 Ma using rubidium-strontium methods (C.E. Hedge, oral com-munication, cited in Sheridan and Marsh, 1976). Similar intrusive rocks in the Central City district to the north range from 59 to 63 Ma (Rice and others, 1982). Porphyry dikes are generally less than 15 ft wide. Intrusive bodies less than about 40 ft wide are shown as a single dashed line on this map

CORRELATION OF MAP UNITS



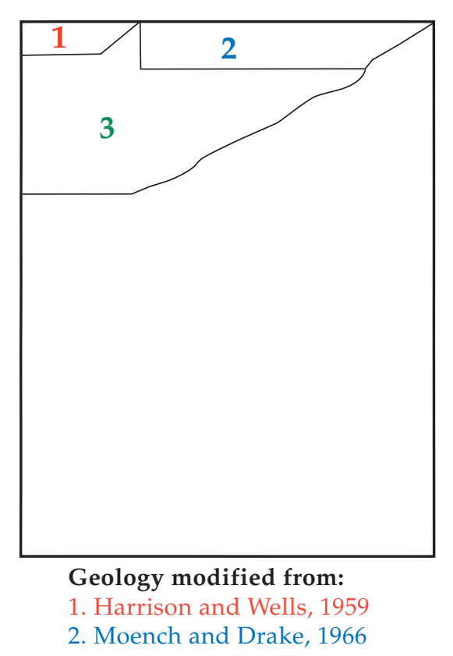
PRECAMBRIAN INTRUSIVE ROCKS—Precambrian intrusive rocks in the Idaho Springs quadrangle belong to the Berthoud plutonic suite which is about 1,400 Ma (Tweto, 1987)

Ygq	**Biotite-muscovite granite and quartz monzonite (Middle Proterozoic)**—Gray to pinkish-buff, massive to poorly foliated intrusive rock composed of microcline, plagioclase, and quartz, with lesser amounts of biotite and muscovite. Typically medium-grained but may also be fine-grained or gradational to pegmatite. Probably equivalent to Silver Plume Granite dated at 1,420 ± 30 Ma. (Peterman and others, 1968)
Ygr	**Rosalie Granite (Middle Proterozoic)**—Pinkish-gray, massive, microcline-quartz-biotite granite along the southern margin of the quadrangle. Consists primarily of microcline phenocrysts that locally are as much as 2 in. long. Quartz, feldspar, and biotite are medium- to coarse-grained. Dated at 1,448 ± 9 Ma; may represent a secondary intrusive phase of the Mount Evans batholith (Aleinikoff and others, 1993)
Ygd	**Granodiorite of the Mount Evans batholith (Middle Proterozoic)**—Weakly to moderately foliated, medium- to coarse-grained, mottled black and white granodiorite composed of plagioclase, microcline, quartz, biotite, and accessory hornblende, magnetite, and sphene. Recent dating indicates the Mount Evans batholith was emplaced 1,422 ± 2 Ma and, therefore, is not equivalent to the Boulder Creek Granodiorite (Aleinikoff and others, 1993)
YXp	**Pegmatite, aplite, and related rocks (Middle and Early? Proterozoic)**—Includes pegmatite, granite pegmatite, and aplite, all of which consist of quartz and feldspar with various amounts of biotite, muscovite, magnetite, and hornblende. Granite pegmatite is medium-grained to pegmatitic. Aplite dikes and veinlets are composed of fine-grained quartz and feldspar

PRECAMBRIAN METASEDIMENTARY AND METAVOLCANIC ROCKS—Metavolcanic rocks have U-Pb zircon age of 1,780 to 1,800 Ma (Premo and Fanning, 1997)

Xm	**Migmatite (Early Proterozoic)**—Rocks that have been heavily intruded by pegmatite or other granitic material, and/or intensely deformed and heated to the point of partial melting. Most commonly characterized by biotite gneiss (Xb) or sillimanitic biotite gneiss (Xsb) strongly interlayered with pegmatite. Less commonly, includes layers or pods of granite, felsic gneiss, hornblende gneiss, and calc-silicate gneiss. Migmatization probably occurred between 1,700 to 1,750 Ma (Hedge, 1969)
Xf	**Felsic gneiss (Early Proterozoic)**—Fine- to medium-grained, white to light-gray or tan, moderately well-foliated microcline-quartz-plagioclase-biotite gneiss. Light- or dark-gray where biotite is lacking; tan where biotite content is greater; banded white and dark-gray where both biotite-rich and biotite-poor layers occur. Magnetite, hornblende, or garnet present at some localities. Tweto (1987) suggested felsic gniess represents metamorphosed rhyodacitic and quartz latitic tuff
Xh	**Hornblende gneiss and amphibolite (Early Proterozoic)**—Medium- to dark-gray, fine-grained, massive or well-banded hornblende gneiss, and dark-green to black, fine- to medium-grained amphibolite. Hornblende gneiss is composed of hornblende and plagioclase and lesser amounts of quartz, biotite, and pyroxene. Amphibolite is composed almost entirely of hornblende and plagioclase with almost no quartz, biotite, or pyroxene. Rocks originated as impure carbonate rocks and mafic volcanic flows, sills, or tuffs (Sheridan and Marsh, 1976). Some amphibolites are intrusive (Spurr and others, 1908; Tweto, 1987)
Xhc	**Interlayered hornblende gneiss and calc-silicate gneiss (Early Proterozoic)**—Fine- to medium-grained, dark-gray to light-green calc-silicate gneiss composed of alternating light layers rich in quartz and feldspar and darker layers rich in hornblende and diopside. Interlayered with hornblende gneiss and amphibolite (Xh). Probably originated as impure limestone and calcareous sandstone (Spurr and others, 1908)
Xb	**Biotite gneiss (Early Proterozoic)**—Fine-grained, light- to medium-gray gneiss composed primarily of biotite, quartz, and plagioclase, with minor magnetite, sillimanite, garnet, and/or cordierite. Typically equigranular and "salt and pepper" in appearance, though schistose in some areas. Originated as sandy shale or graywacke (Sheridan and Marsh, 1976)
Xsb	**Sillimanitic biotite gneiss (Early Proterozoic)**—Medium- to dark-gray, strongly foliated gneiss composed primarily of biotite, sillimanite, and quartz, with minor microcline, muscovite, garnet, tourmaline, and cordierite. Sillimanite is easily recognizeable either as cloudy white rods and bundles or flattened pods up to a few inches long and elongate parallel to foliation. Protolith is alumina-rich shale (Sheridan and Marsh, 1976)

SOURCES OF GEOLOGIC DATA



Geology modified from:
1. Harrison and Wells, 1959
2. Moench and Drake, 1966
3. Harrison and Wells, 1956

MAP SYMBOLS

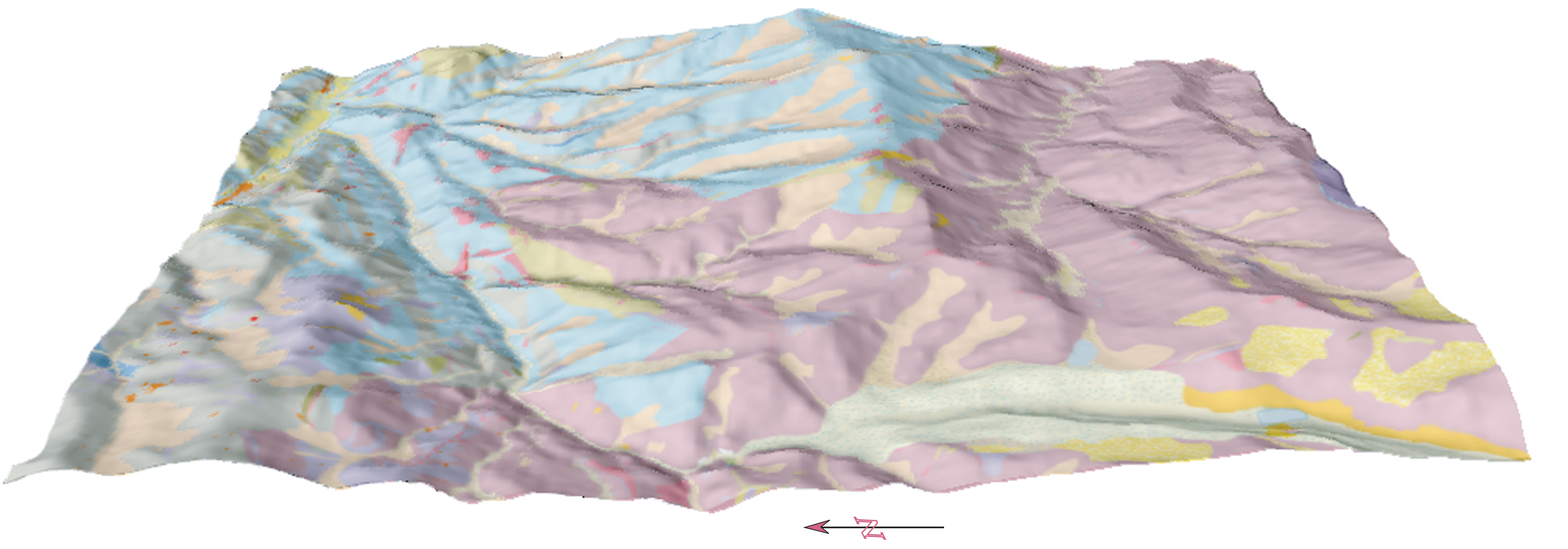
—•••	**Geologic contact**—Dashed where approximately located. Small red dots indicate locations where a thin veneer of younger terrace alluvium (Qty) is exposed in road cuts. Unit rests on bedrock 10 to 15 ft above Chicago Creek and is overlain by colluvium (Qc)
⇌	**Fault**—Dashed where approximately located; dotted where concealed. Arrows show apparent direction of relative movement
↕→	**Anticline**—Showing axial trace; dashed where approximately located; dotted where concealed
20 →	**Trend and plunge of minor fold—**Showing axial trace of minor folds in Proterozoic metamorphic rocks
—	**Intrusive porphyry dike—**Dashed where approximately located, dotted where concealed
++++++++++	**Moraine crest**—Crest of prominent lateral and terminal moraines in Chicago Creek valley
	Strike and dip of foliation or compositional layering—Foliation is typically parallel to compositional layering in Proterozoic metamorphic rocks
35 ┴	**Inclined**
◆	**Vertical**
35 ■	**Strike and dip of joint**
♀	**Geothermal spring (at mouth of Soda Creek)**
A ——— A'	**Alignment of cross section**

ACKNOWLEDGEMENTS

This mapping project was funded jointly by the Colorado Geological Survey and U.S. Geological Survey through the STATEMAP pro-gram of the National Cooperative Geologic Mapping Act of 1992, Agreement No. 99HQAG0143. Partial funding for this project came from Colorado Severance taxes, which are derived from the production of oil, gas, coal, and minerals.

We are extremely grateful for the wealth of knowledge that was shared with us by Bruce Bryant and Rich Madole. Members of the Idaho Springs Ranger District, U.S. Forest Service, especially Deb Ekstrand, were informative and helpful, providing access to the Mount Evans area. Vehicular access to the upper Chicago Creek area was approved by the Idaho Springs City Administrator Jack Russalesi. Jim Maxwell, owner of the Indian Springs Hot Springs Resort, shared information regarding the hot springs at the resort. Jim Cappa, Colorado Geological Survey, and Eric Nelson, Colorado School of Mines, are thanked for their guidance and counseling throughout this investigation. We also express thanks to Susan Pacek, Planning Director, Clear Creek County, for supporting our work. John Keller, Colorado Geological Survey, was helpful in collecting and sending samples for geochemical analysis.

SHADED-RELIEF MAP OF THE IDAHO SPRINGS QUADRANGLE WITH GEOLOGY OVERLAY; OBLIQUE VIEW LOOKING EAST



GEOLOGIC MAP OF THE IDAHO SPRINGS QUADRANGLE, CLEAR CREEK COUNTY, COLORADO

By Beth L. Widmann, Robert M. Kirkham, and Steven T. Beach

2000

Idaho Springs v15 11/1/00