

it is overlain, however, by two thinner tuffs of similar appearance that are mapped with the Mount Dutton

Formation; either or both of these tuffs could be correlative with, or belong to, the tuff of Ladybug.

brown, or green lava flows, volcanic mudflow breccia, and ash-flow tuff of apparent dacitic composition.

At least 500 m thick, but is poorly exposed and complexly faulted, so that its internal stratigraphy and its

relation with other formations is unknown. It doubtless is more extensive north and northwest of the

quadrangle. It is lithologically different from any known rocks in the Black Mountains, and probably

represents deposits of a local stratovolcano complex perhaps equivalent in time with the Horse Valley and Mount Dutton Formations. This unit was placed within the Isom Formation by Erickson and Dasch

(1963), but no beds within the volcanic rocks of Shauntie Hills can be correlated with the Isom Formation; some beds that superficially resemble Isom Formation are significantly different

petrographically. The unit consists of 15-20 percent plagioclase, 0-8 percent pyroxene, 1-4 percent

biotite, 0-1 percent hornblende, and 2-5 percent opaque minerals, in an aphanitic or tuffaceous matrix.

Most rocks are propylitically altered; some rocks are more intensely altered and silicified, especially along

faults and near plugs of the rhyolite of Dead Horse Reservoir, as noted by Erickson and Dasch (1963)

along the southern border of the quadrangle. At the southern edge of Little Horse Valley it consists of two

cooling units of ash-flow tuff, separated by a moderately resistant green sandy conglomerate about 3 m

thick that is correlated with the Bear Valley Formation (Anderson, 1971). The upper cooling unit is a

massive, white to pale-green, poorly welded moderately resistant tuff, about 5 m thick, containing about

3 percent volcanic rock fragments. It is crystal poor, containing 5 percent crystals of quartz, K-feldspar, plagioclase, and traces of ferromagnesian minerals. It is a local unit that petrographically resembles a tuff

mapped about 12 km east of the quadrangle, in the canyon east of Minersville (Rowley, unpub. data).

The lower cooling unit is a weak tan poorly welded crystal-poor ash-flow tuff about 3 m thick, containing

plagioclase, lesser quartz and sanidine, and minor biotite, hornblende, and opaque minerals; it is high in

red volcanic rock fragments (3 percent) and white autolithic(?) pumice fragments (15 percent) up to 1 cm long. The lower cooling unit is correlated with the Table Butte Tuff Member of the Leach Canyon

Formation (Williams, 1967; Anderson and Rowley, 1975); the upper cooling unit probably also is

correlative with the Table Butte Member. Where mapped elsewhere, most of the unit probably is correlated with the Table Butte Member, but some of the lower part may belong to the Narrows Tuff

Member of the Leach Canyon Formation (Williams, 1967; Anderson and Rowley, 1975). Near the southern border of the quadrangle, the formation is as much as 90 m thick. The Leach Canyon

Formation has a K-Ar age of about 24 m.y. old (Armstrong, 1970; Fleck and others, 1975). The Leach

Canyon Formation was first defined as a member of the Quichapa Formation (Mackin, 1960); later

elevated to formation status (Cook. 1965), and Quichapa elevated to group status (Williams, 1967;

units of resistant medium-brown, medium-tan, or medium-grayish-purple, densely welded crystal-poor

ash-flow tuff and some probable lava flow units containing plagioclase and minor pyroxene and opaque

minerals. Moderately to steeply dipping flowage structures characterize the tops of several upper cooling

units. Some units have thin light-gray ash-flow tuff lenticules as much as 0.6 m long, some tops are

vesicular and amyaloidal, and some contain large vesicles drawn out as much as 0.3 m by flowage.

Several cooling units contain black basal vitrophyres. K-Ar age is about 26-25 m.y. (Armstrong, 1970;

Baldhills Tuff Member and a lowermost unnamed member of similar rocks as mapped by Mackin (1960).

Thickness about 10 m in northeastern Horse Valley, thickening southward to about 105 m at the

light-gray, moderately welded crystal-rich ash-flow tuff containing plagioclase, hornblende, quartz,

biotite, and minor magnetite and sanidine. Contains white or pink, ash-flow tuff lenticules as much as 10

cm long and 5 cm thick. Consists in some places of two nearly identical cooling units, the lower one

having a dark-gray basal vitrophyre. The upper cooling unit is generally gray or light-reddish-purple

containing crystals that are smaller and less abundant than those in the lower cooling unit, which is

generally pink. These two cooling units are separated locally by a light-gray sandstone as much as 6 m

thick. Where mapped west of The Neck (sec. 11, T. 32 S., R. 12 W.) the formation consists largely of

reworked clasts of tuff in a green and tan conglomerate or volcanic mudfiow breccia, and partly of a thin

tuff bed. K-Ar age is about 29 m.y. (Armstrong, 1970). Defined by Mackin (1960). Lower contact poorly

lacustrine sedimentary rocks. The youngest of six members, as defined by Mackin (1947, 1954). Includes

at the top a weak white poorly welded crystal-poor ash-flow tuff, at least 15 m thick containing

plagioclase, quartz, and minor biotite and opaque minerals. This tuff is rich in autolithic(?) pumice

chunks, now weathered red or green and altered to a waxy appearance. In the quadrangle, the tuff is

exposed only in the northeastern Horse Valley area. It is correlated with a tuff that is mapped with

member E of the Claron Formation and exposed in a single place in the Enoch NW quadrangle (Rowley,

1976); this tuff probably is correlative to unit 2 of the Indian Peak Formation of Conrad (1969). The tuff is

overlain by a conglomerate containing pebbles of volcanic rocks that is the lag gravel described by Mackin

(1960), and the tuff is underlain by a coarse-grained tan, pink, and green sandstone, containing

abundant volcanic fragments. Most of the sedimentary rocks under the lag gravel are sandstone, and they

are poorly exposed. Thickness of the member is at least 60 m. Upper contact poorly exposed and

dotted where concealed, queried where uncertain. Bar and ball on downthrown side. Bar and ball not

bars. Shown where visible on aerial photographs or on the ground; elsewhere largely obliterated by

erosion or covered by Holocene sediments. Some shorelines in the vicinity of The Sink probably formed

grade that is higher than propylitic facies is mapped. Much of these altered and silicified rocks were

mapped by Erickson and Dasch (1963), who reported the presence of alunite and kaolinite. The only

metallic minerals reported are minor amounts of hematite, limonite, and pyrite (Erickson and Dasch

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Thickness zero to at least 30 m

Rowley and Anderson 1975)

southern border of the quadrangle

approximately located

originally by faulting

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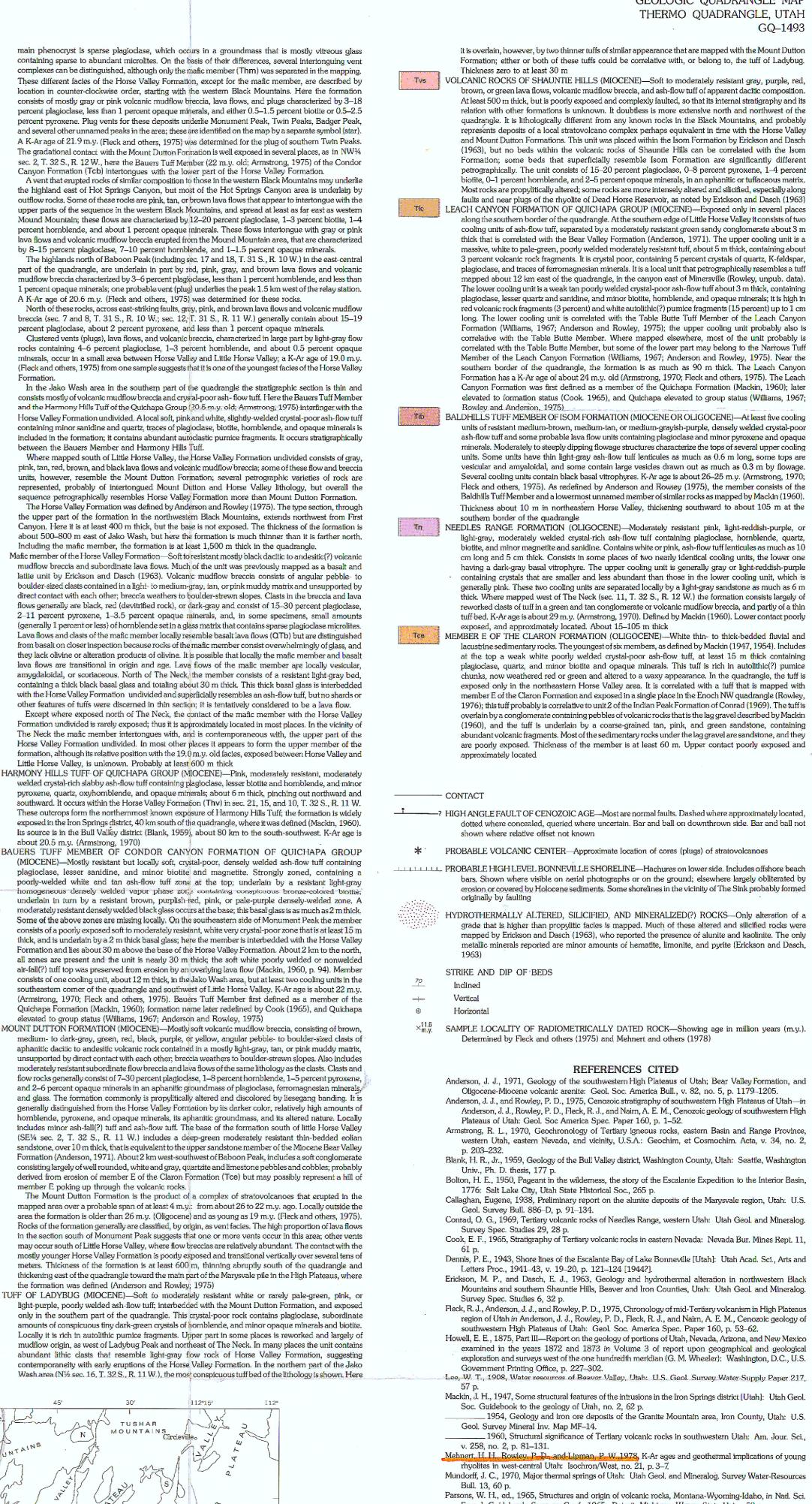
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shown where relative offset not known

exposed, and approximately located. About 15-105 m thick



underlying mostly aphanitic and dark-colored and commonly pro-Dutton Formation is gradational over 30 m or more of vertical section in most places. Volcanic mudflow breccia is the most abundant rock type in the vicinity of the contact and generally contains clasts of both Horse Valley Formation and Mount Dutton Formation lithologies; the amount of clasts of Horse Valley lithology increases upward. Generally the contact is poorly exposed and approximately located. Rocks of the Horse Valley Formation undivided consist of many phases that are similar in overall silicic character and phenocryst content; phases differ in color and in type of ferromagnesian minerals. The EXPLANATION B-Bear Valley Peak pluton G-Granite Mountain pluton -Iron Mountain pluton IP—Iron Point pluton -Nevershine Hollow pluton(?) P—Paradise pluton PP—Pinto Peak pluton S—Spry pluton SM—Stoddard Mountain pluton 0 5 10 15 20 MILES 0 5 10 15 20 KILOMETERS INDEX MAP SHOWING RELATION OF THE MAPPED AREA (SHADED) TO ADJACENT U.S. GEOLOGICAL SURVEY GEOLOGIC MAPS 1, Cedar Mountain; 2, Kanarraville; 3, Cedar City; 4, Avon SE; 5, Cedar City NW; 6, Enoch; 7, The Three Peaks; 8, Enoch

CORRELATION OF MAP UNITS

QUATERNARY

> TERTIARY

Oligocene

Oligocene

DESCRIPTION OF MAP UNITS

intermittent stream channels, on bordering flood plains, and in fans of major drainages. Contact

transitional with deposits of Escalante arm of Lake Bonneville (Qe) in some places. As much as 10 m thick

gravel from local sources deposited in alluvial fans and on pediments. Includes minor colluvium. Locally

deposits of two echelon mounds nearly 10 m high (sec. 21 and 28, T. 30 S., R. 12 W.) that overlie

north-striking fractures, probably faults (Petersen, 1973). The main rock type is resistant bulbous and

cavernous growths of tan and pale-green bedded opal (siliceous sinter), containing clasts of windblown

quartz sand and silt. Travertine also has been reported (Mundorff, 1970), and eolian sand occurs on the

emperatures as high as 90° C. and with an estimated average reservoir subsurface temperature of 200° C.

(Howell, 1875; Renner and others, 1976), issue from the tops and eastern sides of the mounds along the

avenues of escape for the water, and perhaps the water reservoir itself, appear to have formed from the

faults; east-striking faults occur east of the springs (Rowley and Lipman, 1975). The hot springs overlie

the broad east-trending Blue Ribbon lineament (Rowley and others, 1978), which makes up most of the

northern half of the quadrangle. East-striking faults of the lineament also localize most hydrothermal

alteration of rocks in the northern Black Mountains. Igneous centers occur along the lineament; two such

centers are the rhyolite of Thermo hot springs area (Trt) and rhyolite of Dead Horse Reservoir (Trd).

Thus the lineament may supply geothermal heat to the water and may express a long-lived (20 million

years or older) hydrothermal system (Rowley and others, 1978). The first discovery of the hot springs by

white men was made on October 10, 1776, when Father Escalante recorded their existence (Bolton

1950). Now the Thermo hot springs area has potential for geothermal energy and has been designated as

outlet channel deposits of a Pleistocene lake; this channel drained areas to the east and southeast

(Rowley, 1975, 1976), and carried water into Escalante Bay of Lake Bonneville. Only exposed in

southwestern part of quadrangle. Locally includes younger alluvium. Contacts approximately located. As

and pebble gravel deposited in, and on shorelines of, a Pleistocene lake (Escalante arm of Lake

Bonneville). Includes fluvial deposits from streams that emptied into the lake. Much of the unit, however,

consists of fluvial deposits formed during terminal drying up of the lake and draining of its water

northward to lower parts of the Lake Bonneville topographic basin. Thus most contacts may represent a

and lowest shoreline or outlet channel, and has an elevation of 1,530-1,540 m, sloping northward.

Locally includes Holocene alluvium. Contact with alluvium (Qa) and fan and pediment deposits (Qf)

Higher level Lake Bonneville shorelines are prominently exposed only locally, and are shown by a

separate map symbol (hachures). In most places these high level shorelines have been removed by

erosion or covered by younger alluvium (Qa) or fan and pediment deposits (Qf). Dennis (1943) noted

that these high level shorelines of Escalante Bay of Lake Bonneville occur at an average elevation of

about 1,555 m; shorelines at this approximate level also are shown by Snyder and others (1964). In the

quadrangle most high level shorelines occur at 1,545-1,550 m elevation. Shoreline gravels at the

western contact of the rhyolite of Thermo hot springs area (Trt) occur at about 1,550 m elevation, and

consist of rounded well-sorted rhyolite pebbles, 0.5-1 cm in diameter. Lake Bonneville deposits are at

primarily of fluvial origin; dissected by present streams. Most clasts are of Tertiary volcanic rocks, derived

from local sources. On the southern side of Little Horse Valley (NW4 sec. 5, T. 32 S., R. 10 W.), the unit

consists of well-indurated red sandstone containing numerous clasts of basalt and basaltic scoria. Upper

contact approximately located and probably transitional with fan and pediment deposits (Qf). Basal

contact with Horse Valley Formation (Thv) and, locally just south of the quadrangle (Rowley, 1975,

1976) with Mount Dutton Formation, is approximately located and probably transitional. Overlain in part

by a thin cover of Quaternary sediments. Approximately correlative with the Sevier River Formation of

the High Plateaus area (Callaghan, 1938), about 20 km east of the quadrangle. At least 30 m thick where

exposed, but probably makes up much of the valley fill in the quadrangle and thus is considerably thicker

medium-gray, commonly vesicular or amygdaloidal lava flows of basalt. Basalt generally contains spots

of antigorite(?), an alteration product of olivine. This unit also includes scoria and a 3 m thick white tuff

that underlies basalt in sec. 16 and 20, T. 31 S., R. 12 W. Some flows overlie and resemble rocks of the

mafic member of the Horse Valley Formation (Thm); in these places age and genesis of parts of the two

locally spherulitic crystal-poor dome and (or) lava flows of alkalic rhyolite that contain sanidine, quartz,

and plagioclase, and traces of biotite, opaque minerals, and homblende. Mostly devitrified except for a 2

m thick obsidian layer in the southwestern part of the exposure. Has a K-Ar age of 10.3 m.y., and is part of

an east-trending alignment of small plugs, domes, and lava flows of alkalic rhyolite (Rowley and others,

alkalic rhyolite that contain quartz, lesser sanidine and plagioclase, and minor biotite and opaque

minerals. Contains sparse vesicles in some places. Has a K-Ar age of 11.6 m.y. (Rowley and others,1978)

Horse Valley Formation, undivided-Gray or pink, or less commonly white, red, tan, black, purple, or

brown, soft to resistant, rhyodacite to dacitic lava flows, volcanic mudflow breccia, plugs, and minor

ash-flow tuff. Erupted from numerous clustered central vents, most of which are in the quadrangle. Unit is

generally poorly exposed, especially where composed of volcanic mudflow breccia, which weathers to

boulder-strewn slopes. Where well exposed, volcanic mudflow breccia consists of angular pebble- to

bolder-sized clasts of Horse Valley Formation lithology contained in a mostly light-gray or tan muddy

matrix, and unsupported by direct contact with each other. Lava flows and plugs are generally

flow-foliated. Most of the unit represents vent facies rock, using the terminology of Parsons (1965, 1969)

and Smedes and Prostka (1973). In the northern part of the Black Mountains, the Horse Valley

Formation undivided includes rocks that commonly were mapped as either rhyolite, hornblende

m.y.: from 22 m.y. ago, or older, to at least 19 m.y. ago. Locations of K-Ar ages of three samples (Fleck

and others, 1975) are shown on the map. The stratovolcano complex erupted, in part, simultaneously

with the dacitic to andesitic stratovolcano complex of the Mount Dutton Formation. The contact between

mostly fresh, vitreous, light-colored rocks of the Horse Valley Formation and the intertonguing and

The formation is the product of a complex of stratovolcanoes that erupted over a span of at least 3

BASALT LAVA FLOWS (PLEISTOCENE?, PLIOCENE, AND MIOCENE)-Resistant black to

RHYOLITE OF THERMO HOT SPRINGS AREA (MIOCENE) - Light-gray or black resistant flow-foliated,

RHYOLITE OF DEAD HORSE RESERVOIR (MIOCENE)—White or pink, resistant crystal-rich plugs of

POORLY CONSOLIDATED SEDIMENTS (PLEISTOCENE, PLIOCENE, AND MIOCENE)-Poorly

consolidated light-gray, tan, or red coarse-grained sandstone and sandy fine-pebble conglom

least several tens of meters thick and perhaps much thicker (Lee, 1908)

mapped units may be closely similar. As much as 15 m thick

andesite, or Isom Formation by Erickson and Dasch (1963)

HORSE VALLEY FORMATION (MIOCENE)

R. 10 W.

Geology mapped in 1968, 1969, and 1976

north-draining channel. Only the most prominent contact is shown; generally it represents the youngest

the Thermo Known Geothermal Resource Area (KGRA) by the Department of the Interior

VALLEY-BOTTOM DEPOSITS (PLEISTOCENE)—Clay, silt, and sand, mostly of alluvial origin. Made up of

DEPOSITS OF ESCALANTE ARM OF LAKE BONNEVILLE (PLEISTOCENE)-Includes clay, silt, sand,

intersection, at about 90° from each other, of north- and northeast-striking faults with nearly east-striking

main controlling faults. The water is high in hydrogen sulfide and dissolved silica (Lee, 1908), The

tops and flanks of the mounds. About 20 small hot springs, containing water with recorded surface

HOT SPRING DEPOSITS OF THE THERMO AREA (HOLOCENE AND PLEISTOCENE)-Hot spring

ALLUVIUM (HOLOCENE AND PLEISTOCENE)—Sand and less abundant pebble gravel deposited in

FAN AND PEDIMENT DEPOSITS (HOLOCENE AND PLEISTOCENE)—Silt, sand, and minor pebble

more than 30 m thick. Contacts approximately located

much as 10 m thick

locally transitional

DEPARTMENT OF THE INTERIOR

Base from U.S. Geological Survey, 1958

system, south zone

METERS

3000

SEA LEVE

10,000-foot grid based on Utah coordinate

1000-meter Universal Transverse Mercator

ESCALANTE DESER

Thickness of Quaternary surficial deposits exaggerated

grid ticks, zone 12, shown in blue

SCALE 1:62 500

CONTOUR INTERVAL 40 FEET

DOTTED LINES REPRESENT 10-FOOT CONTOURS

NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOLOGIC MAP OF THE THERMO 15-MINUTE QUADRANGLE, BEAVER AND IRON COUNTIES, UTAH

By

Peter D. Rowley

1978

4 KILOMETERS

HORSE VALLEY FAULT ZONE

MOUNTAINS

QUADRANGLE LOCATION

LITTLE HORSE VALLEY

FAULT ZONE

LHE'HHE

BLACK

APPROXIMATE MEAN DECLINATION, 1978

HHHHHHHH

UNITED STATES GEOLOGICAL SURVEY

NE, and 9, Enoch NW. Dashed line shows Wasatch front, separating Basin and Range province on the west from the

High Plateaus subprovince of the Colorado Plateaus province on the east

For sale by Branch of Distribution U.S. Geological Survey, Box 25286. Federal Center, Denver, CO 80225