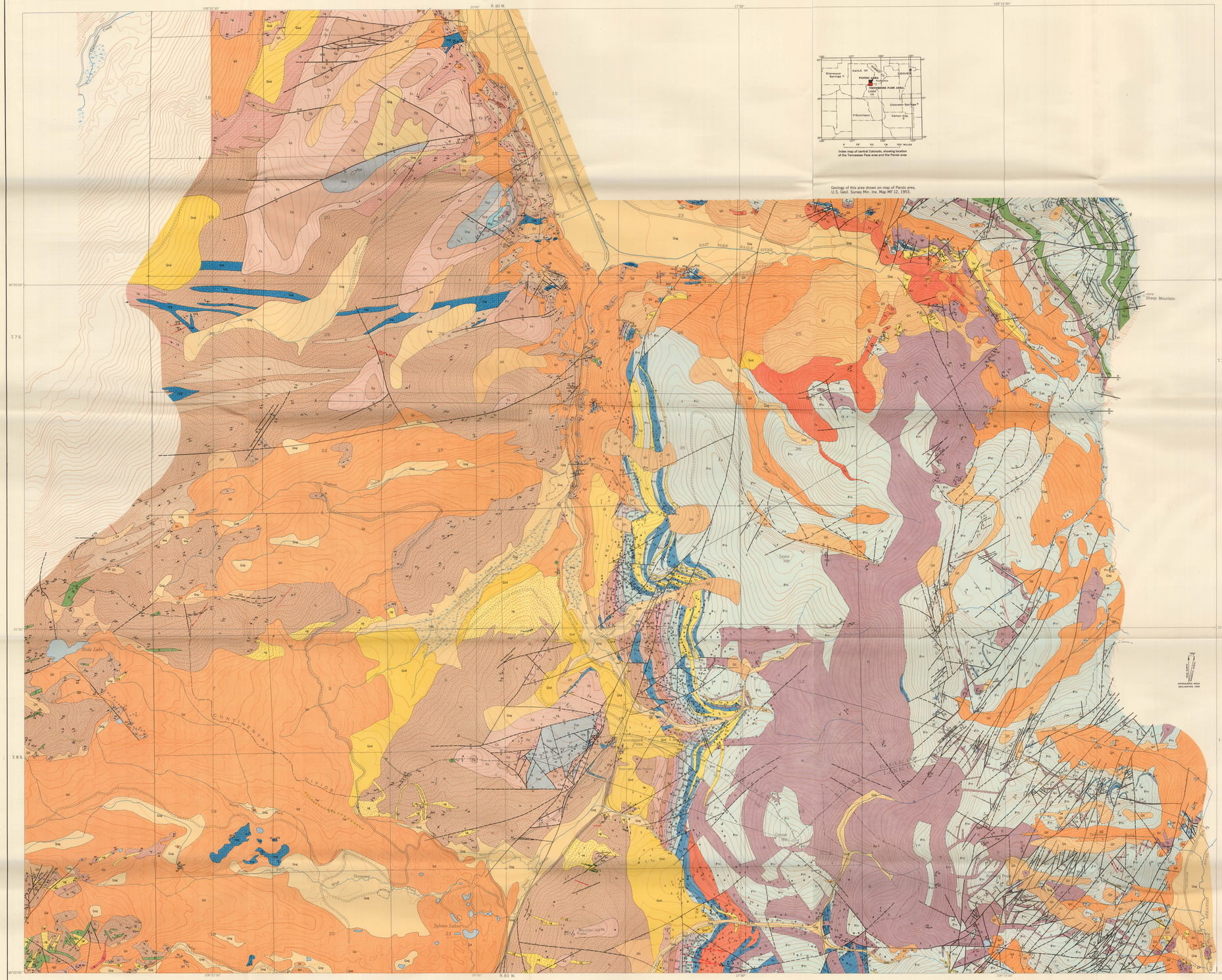
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR

PREPARED IN COOPERATION WITH
THE STATE OF COLORADO
COLORADO GEOLOGICAL SURVEY BOARD AND COLORADO METAL MINING FUND BOARD



Index map of central Colorado, showing location of the Tennessee Pass area and the Pando area

Sedimentary rocks of the Tennessee Pass area in Colorado				
Age	Formation	Member	Thickness (feet)	Character
			3,800 (measured)	Lower 1,000 feet predominantly quartzite and shale; above this, grit, conglomerate, shale, and arkose, with a few beds of dolomite, some of which are designated members, as shown below. Predominantly gray and buff.
Pennsylvanian (preserved part).	Minturn formation.	Resolution dolomite (highest preserved dolomite member).	85-100	Alternating limestone and shale, with minor amounts of sandstone and conglomerate. Limestone is dark-gray, fine-grained, thin-bedded, cherty dolomite. Shale is dark-gray, fissile, with thin layers of limestone.
		Dotsero limestone.	19-40	Alternating limestone and shale, with minor amounts of sandstone and conglomerate. Limestone is dark-gray, fine-grained, thin-bedded, cherty dolomite. Shale is dark-gray, fissile, with thin layers of limestone.
		Gypsum Creek member.	10-21	Alternating limestone and shale, with minor amounts of sandstone and conglomerate. Limestone is dark-gray, fine-grained, thin-bedded, cherty dolomite. Shale is dark-gray, fissile, with thin layers of limestone.
		Eagle Valley evaporite member.	75-100	Interbedded gray to black shale and thin-bedded dark limestone. Variicolored silty and cherty regolithic material in patches up to 50 feet thick at base.
Mississippian	UNCONFORMITY Leadville dolomite.		80-120	Massive, gray to blue-black, crystalline dolomite; locally cherty.
	UNCONFORMITY Gilman sandstone.		13-21	Sandstone, sandy dolomite, and chert and dolomite breccia, in lenticular beds.
Devonian	UNCONFORMITY Chaffee formation.	Dyer dolomite.	75-90	Dark-gray to black, fine-grained, thin-bedded dolomite.
		Parting quartzite.	45-60	White and tan quartzite, with local lenses of conglomerate.
Ordovician	UNCONFORMITY Harding quartzite.		0-40	Maroon and purplish shale and gritty sandstone; locally variicolored; local beds of greenish quartzite.
	UNCONFORMITY Manitou dolomite.		0-65	Light-colored, medium-bedded, crystalline dolomite and dolomitic limestone; white chert irregularly distributed.
Cambrian	UNCONFORMITY Peerless formation.		75-110	Thin-bedded, buff, green, and reddish sandy dolomite and dolomitic sandstone.
	Sawatch quartzite.		130-160	Medium-bedded, finer- to coarse-grained white quartzite; tan, or locally pink, near base; and generally some pink beds near top.

EXPLANATION

Qal — Alluvium and gravels
Includes alluvium, swamp deposits, colluvium, glacial lake deposits, outwash gravels, and damp slope wash.

Qld — Landslide debris and talus
Includes various types of landslide deposits, ordinary talus deposits, and talus with some landslide deposits. Mostly postglacial; some of glacial age.

Qtl — Younger glacial drift
Glacial drift of the most recent (Wisconsin) stage of glaciation. Consists of till, stony loam, sandy loam, and gravel; not deeply incorporated in mantle; does not include outwash and lake gravels.

Ql — Loess
Wind-blown silt derived from the most recent glacial outwash deposits of Wisconsin stage; but older than the latest fill of this stage.

Qtd — Older glacial drift
Glacial drift of older (pre-Wisconsin) stage of glaciation. Consists of till, stony loam, sandy loam, and gravel; weathered glacial till.

Qtg — Early, high-level gravels
Deeply weathered gravel or ancient glacial drift.

Tpr — Pando porphyry
Includes microdiorite porphyry, quartz latite porphyry, alkalic porphyritic felsite in small dikes, probably not all of same age.

Tmr — Eagle River porphyry
Quartz monzonite porphyry. In irregular sills and a few dikes. Includes Mount Powell porphyry, Grizzly Peak porphyry, and Red Cliffs; approximate center of porphyry dikes beneath glacial drift.

Tl — Lincoln porphyry
Quartz monzonite porphyry. Mostly in large irregular sheet-like body, and numerous dikes. Center of Lincoln porphyry (Grizzly Peak) is approximate; probably includes approximate center of porphyry dikes beneath glacial drift.

Ts — Syenophyre
Includes syenite, gabbro, and intermediate rocks, as well as minor amounts of related granitic and mafic rocks. In small dikes, sills, and irregular bodies.

Tr — Sacramento porphyry
Quartz monzonite porphyry. In large domal sills and smaller connecting bodies.

Tmr — Elk Mountain porphyry
Quartz monzonite porphyry. In sills and a few dikes.

Tp — Pando porphyry
Quartz latite porphyry, rhyolite porphyry, and a few dikes. Equivalent to Pando porphyry.

Pm — Minturn formation
Grey, shale, conglomerate, and limestone. Pmc, the base of Jacobs Gulch member; Pmc, Minturn dolomite member; Pmw, Wearyman dolomite member; Pmsc, Scott dolomite bed (of local usage); Pc, dolomite bed; Ps.

Pb — Belden shale
Black shale and limestone.

Mlc/Mg — Leadville dolomite
Dolomite member, Mlc; Gilman sandstone member, Mg.

Dcd — Chaffee formation
Dyer dolomite member, Dcd; Parting quartzite member, Dcq.

Oh — Harding quartzite
Reddish shale and sandstone; present only locally.

Omr — Manitou dolomite
Light-colored dolomite with white chert; wedges out to north.

Ce — Peerless formation
Buff, green, and red sandy dolomite.

Cs — Sawatch quartzite
White and pink quartzite.

Zp — Pegmatite
Several varieties, including alkalic locally; in dikes, pods, and irregular masses.

Zsr — Silver Plume granite
Phase of Mount Princeton quartz monzonite in dikes and irregular bodies.

Hornblendite
Very coarse grained rock, mostly hornblende, with minor amounts of biotite; locally contains a little apatite and plagioclase; in dikes and pods.

Qg — Diorite or gabbro dike, showing dip
Dashed where approximately located; includes several varieties of dark-colored, fine- to coarse-grained dike rocks.

gr — Granite aplite
In dikes and irregular masses; locally grades into injection gneiss.

Tr — Undifferentiated granite
Includes late or three-mica granite, other than Silver Plume granite; in part of precirculation origin.

Ti — Injection gneiss
Schist and gneiss seamed by numerous thin sills of aplite, pegmatite, quartz, or alaskite.

Tbs — Hornblende and calc-silicate gneisses
Dark-green hornblende gneiss, hornblende-biotite gneiss, epidote, diopside, and calcite in various combinations.

Tbg — Biotite schist and gneiss
Quartz-biotite-feldspar schist and gneiss.

Tq — Quartz-sulfide vein showing dip
Outlined in most exposures.

Contact showing dip
Dashed where approximately located.

Indefinite contact
Includes gradational contacts, inferred contacts, and indefinite boundaries of surficial deposits.

Concealed contact

Boundary of altered area
In Lincoln porphyry. Location approximate.

Fault, showing dip
Dashed where approximately located. U, upthrown side; D, downthrown side; arrows show direction of relative horizontal movement.

Doubtful or probable fault
Dashed where approximately located.

Landslide fault
Mostly concealed; location approximate; D, downthrown side.

Shear or sheared zone

Strike and dip of beds

Strike and dip of foliation
Includes both primary and secondary foliation.

Strike of vertical foliation

Strike and dip of foliation and plunge of lineation

Strike and dip of foliation and plunge of double lineation

Strike and dip of foliation, and strike of horizontal lineation

Plunge of minor folds

Shaft

Tunnel

Caved tunnel

Prospect pit

Gravel pit

Holocene (Flandrian) — Pleistocene and Recent — Late Tertiary (?) or early Pleistocene — Early Tertiary — QUATERNARY — TERTIARY — TERTIARY (?) OR QUATERNARY — Leadville Formation — Middle Pennsylvanian — Lower Mississippian — Upper Devonian — Middle Ordovician — Lower Ordovician — Upper Cambrian — PENNSYLVANIAN — CARBONIFEROUS — MISSISSIPPIAN — DEVONIAN — ORDOVICIAN — CAMBRIAN — PRE-CAMBRIAN — PRE-CAMBRIAN

SYMBOLS USED ON SECTIONS ONLY

CM — Cambrian to Mississippian rocks, undifferentiated

pC — Pre-Cambrian rocks, undifferentiated

Relative movement on fault

Given horizon in Minturn formation

GEOLOGIC MAP OF THE TENNESSEE PASS AREA, EAGLE AND LAKE COUNTIES, COLORADO

By Ogden Tweto

INTRODUCTION

The triangular area bounded by the most productive mining districts of central Colorado—Leadville, Climax-Kokomo, and Gilman-Red Cliff—is of economic interest not only because of its mineral deposits but also because it is interesting from a geologic or geographic standpoint. It contains the oldest rocks in the adjoining mining districts and is closely related to them structurally. It shows widespread evidence of fault movement, some of the surface and may contain ore deposits at depth, as the same rocks have been productive in the adjoining mining districts (or beneath a cover of younger rocks in much of the area).

This map of the Tennessee Pass area is the second of a projected series of three large-scale maps to cover this triangular intermontane area. The first map of the series covers the Pando area (Tweto, 1953), in the southeastern part of the Holy Cross quadrangle; and this second map covers the adjoining area on the south. It encompasses an area of about 100 square miles in the Tennessee Pass area, in the Eagle Range, east flank of the Sawatch Range, in Eagle and Lake Counties. The southern edge of the area lies about 7 miles north of Leadville, and the eastern edge adjoins parts of the Kokomo and Climax mining districts.

ROCKS

The bedrock of the Tennessee Pass area comprises pre-Cambrian metamorphic and intrusive rocks, sedimentary rocks of Paleozoic age, and intrusive porphyries of early Tertiary age. These rocks are mantled in places, particularly along the stream valleys, by glacial drift, loess, landslide debris, talus, gravel, and alluvium, all of Quaternary age.

Pre-Cambrian rocks.—Pre-Cambrian rocks are confined to the slopes of the Sawatch Range and the bordering area along the lower western slope of the Gore Range, in the western half of the map area. They are gneisses and schists of the Idaho Springs formation, intruded by Silver Plume granite, and cut by numerous dikes of pegmatite, aplite, diabase, Silver Plume granite, two or three unnamed granites, aplites, and pegmatite.

Paleozoic sedimentary rocks.—The sedimentary rocks include Ordovician, Cambrian, Devonian, Mississippian, and Pennsylvanian age. The pre-Pennsylvanian formations are exposed on the lower western slope of the Gore Range and in patches on the crest of the Sawatch Range, but they are concealed by younger rocks in most of the map area. They are overlain in the eastern half of the area by a thick series of Pennsylvanian clastic rocks made up of a basal thin fine-grained unit called Belden shale and an overlying thick coarse-grained unit called the Minturn formation. Through much of the area no more than the lower 2,000 feet of the Minturn formation is preserved, but in the southeastern part of the area the formation is almost complete and 3,800 feet thick. Farther north, in the Pando area, the Minturn formation is fully preserved and is 5,200 feet thick.

The structural features of the sedimentary rocks are summarized in the adjoining table, and more extended descriptions of them can be found in a report on the stratigraphy of the Pando area (Tweto, 1949). In the western part of the area all the sedimentary formations thin rapidly to the east and northeast (see sections A-A' and B-B'), but farther south the rate of thinning is much lower (see sections C-C' and D-D'). The Leadville dolomite, which is a prominent cliff-forming member of the section, is an unusual over long courses at the surface; the actual distances above the base of the formation are less, owing to slumping—of the basal beds in the east, and see and known precisely.

Early Tertiary igneous rocks.—The early Tertiary igneous rocks form numerous sills and irregular bodies, and a few dikes, in the Minturn formation, the Leadville dolomite, and small irregular bodies. They comprise five varieties of porphyry of quartz-monzonite composition, a group of closely related holocrystalline rocks referred to collectively as syenophyre, and a few dikes of hornblende lamprophyre and porphyrites classed as felsite porphyry. These rocks are described below in order of age.

The Pando porphyry, the oldest of the intrusive rocks, is a fine-grained, light-colored quartz latite porphyry that forms a continuous zone of sills or so zone the base of the Pennsylvanian section from Leadville northward 20 miles almost to Minturn. Work south of the Tennessee Pass area shows that the Pando porphyry is the same as the rock called by Emmons (1886, p. 70) called the Stone Pine porphyry, and this is now in continued by the writer with the White porphyry of Leadville and is merely a less altered facies. The Pando porphyry has a wide range in appearance, depending principally upon the degree of alteration but also upon the original grain size, which differs considerably from place to place. In most of the area it is a porphyry with phenocrysts of plagioclase in a dense felsitic microgranular rock containing minor flakes of biotite or irregular clusters of chlorite, scattered feldspar phenocrysts, and generally a few small grains of quartz; (2) a dense, almost white rock with numerous small phenocrysts of plagioclase and generally a few flakes of biotite but a complete lack of hornblende and (3) a uniform, dense, white rock consisting of a granular mineral grains except occasional flakes of secondary muscovite and a few small round quartz grains—the typical White porphyry of Leadville.

The Elk Mountain porphyry is a quartz monzonite porphyry characterized by abundant phenocrysts of hornblende, generally as inch or more long, and by numerous rounded bipyramidal quartz, typically one-fourth to three-eighths inch in diameter. It contains also numerous small crystals of plagioclase and flakes of biotite are in a dense, gray matrix. The Elk Mountain porphyry is a prominent constituent in the northern part of the area but becomes rare to the south. It forms a large, irregular sheet that crops out on the west slope of Chicago Ridge and Buckeye Peak, and it occurs also in numerous smaller sills and dikes, particularly in the southeastern corner of the area.

The Eagle River porphyry is the latest intrusive rock, except for a few minor dikes of lamprophyre and of hornblende porphyrite. It is a quartz monzonite porphyry (or granite, if common small) but very numerous crystals of feldspar, biotite, and hornblende; quartz is a prominent constituent in the northern part of the area but becomes sparser to the south. The Eagle River porphyry is a prominent constituent in the northern part of the area but becomes sparser to the south. It occurs in numerous sills and irregular bodies, and it is a component of the mass of porphyry bodies making up the north end of Chicago Ridge and the adjoining area along the East Fork of Eagle River. It has not been found south of East Tenmile Creek.

The Lincoln porphyry is a quartz monzonite porphyry characterized by large phenocrysts of orthoclase, generally an inch or more long, and by numerous rounded bipyramidal of quartz, typically one-fourth to three-eighths inch in diameter. It contains also numerous small crystals of plagioclase and flakes of biotite are in a dense, gray matrix. The Lincoln porphyry is a prominent constituent in the northern part of the area but becomes rarer to the south. It forms a large, irregular sheet that crops out on the west slope of Chicago Ridge and Buckeye Peak, and it occurs also in numerous smaller sills and dikes, particularly in the southeastern corner of the area.

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The two felsite porphyry is applied to a few scattered small dikes of fine-grained, light-colored porphyry. Some of these dikes are merely of microcrystalline, but a few are very young, as they cut Eagle River porphyry.

STRUCTURE

The sedimentary rocks of the Tennessee Pass area form an east-northeast-dipping homocline that is extensively faulted and completely intruded. Patches of rocks of early Paleozoic age on the lower slopes of the Sawatch Range, remnants of a cover of sedimentary rocks that once lowed over the top of the ancient Sawatch uplift, dip northeast and east at about 10°. This dip continues across the intervening valleys into the west slope of the Gore Range, where it is 10° to 15° east. The Minturn formation, which crops out in the sections, forming a canopy along a mile wide trending northeastward, they then turn down steeply, dipping 20° to 30° eastward toward the Mosquito fault, which line 7 to 4 miles east of the map area. South of Climax the beds turn up steeply near the Mosquito fault, forming a syncline (Kerchmann and Wells, 1948, p. 69-90), but farther south they again dip eastward at moderate angles.

The homocline is shattered by many faults. Several fault systems can be identified, but most of them are subordinate to two major groups of faults, the Tennessee Pass fault system and the Mosquito fault system, the Tennessee Pass fault system is the oldest, which was probably related to the Mosquito faults.

The Tennessee Pass fault zone extends north-northeast through the central part of the area. At places it is a single fault, and at others it consists of as many as four faults or strands. The faults dip steeply eastward and are upthrown to the east. At Tennessee Pass the fault system consists of three faults, which are 1 to 2 miles apart. The total displacement decreases and probably is not more than 500 feet near the East Fork of Eagle River, where the fault zone is covered by glacial drift and landslide debris. Several faults of northeast and east trend branch from the main fault zone and are doubtless related to movements along the main zone. The Tennessee Pass fault zone has had a long and complex history of movement, intermittent movement along the fault zone and Pando porphyry was intruded, and movement continued at various times until after the Eagle River porphyry was emplaced. As suggested in sections A-A' and B-B', at least a part of the movement occurred before the Minturn formation was deposited, due to emplacement of porphyries of unequal thickness on the two sides of the fault.

The wide belt of closely spaced faults in the southeastern part of the map area apparently marks the intersection of two or three lines of deformation. Most of these faults formed before the Lincoln porphyry was emplaced and have undergone only minor movement since. The Lincoln porphyry is a prominent constituent of the porphyry. Some faults of east-and northeast trend are concentrated in the area between Chicago Ridge and Mosquito Ridge. Some of the faults of northerly trend on the extreme southeast edge of the map area are extensions of faults of the northwestern series that cuts the Leadville district. Most of the faults, however, seem to be related to the Mosquito fault, which is a prominent feature of the structure of the Leadville and Climax districts. The steep eastern inclination faults in the hanging wall of the Mosquito fault, although their exact relations to this fault, and the amount of each fault, are not known, they are in the zone of the grooves and the intervening area is mapped. The displacements on many of the faults are indeterminate because of the lack of marker beds in the lower part of the Minturn formation. The overall displacement across the entire belt shows upthrow to the east, in accord with the movement on the Mosquito fault.

ECONOMIC GEOLOGY

The Tennessee Pass area is characterized by widespread evidence of weak mineralization, but no important mineral deposits have been found in comparison with other areas. The area has been prospected intensively, both because of the proximity to productive districts such as Leadville, Kokomo, and Climax and because of a close similarity of geologic structure and rock types to these districts. Many prospects have discovered some-other deposits of importance; but the area remains of economic interest because of its relation to the nearby productive districts and the possibility that it may contain ore deposits hidden deep beneath porphyry bodies or the Pennsylvanian clastic rocks.

The principal mineral materials and ore deposits of the area are of four general occurrences: (1) veins and mineralized shear zones in the pre-Cambrian rocks; (2) replacement deposits in the dolomites; (3) veins and small stockworks in porphyries and in quantities of the Sawatch and Minturn formations; and (4) gold placers.

Veins in the pre-Cambrian rocks occur in scattered localities throughout the western half of the area. Most of the veins are narrow and contain small amounts of galena and sphalerite and appear to be small. None within the map area is known to have been productive, although most of them have been worked. Just off the southwestern edge of the map area, however, a small amount of silver-lead ore was produced from a vein that was obtained from the initial zone during the early days of mining in the region. The veins in the Homestake deposit occupy overlapping and discontinuous fractures in a fracture zone subparallel to the schistosity and contain silver-bearing sulfide ore in a siderite-barite gangue.

The replacement deposits in the dolomites are few and relatively small, the weak mineralization of these rocks is of interest because of its widespread occurrence and the possibility that it represents the exposed fringe of some heavily mineralized deposits concealed beneath porphyries and the Pennsylvania rocks. The Leadville dolomite is the most consistently mineralized unit. It contains all the known deposits of replacement ore in the area, and it is the host rock for most of the ore in the ore dolomite ("White limestone"), the Dyer dolomite, dolomitic and lime zones in the Belden shale, and dolomite beds in the Minturn formation, are weakly mineralized in places. The Leadville dolomite has been prospected extensively and mines every such shown, and it is known to be mineralized and locally replaced by hydrothermal solutions. In addition, many holes have been drilled, and considerable underground work is in raps and irregular relations accompanied by quartz, and many other openings exposed large masses of limonitic and jasperoid, clayey gossan. Most of the productive deposits are in the east-west part of the area, and they are in the Leadville district and some, such as the Jessie Jane, are essentially former vein deposits in the dolomite.

The two most productive deposits in the area—the El Capitan, on Taylor Hill, and the Jessie Jane group of mines, on East Tenmeer Creek—are of the replacement type. Practically all the ore produced from these and several other mines replacement deposits in the dolomite consisted of galena and sphalerite. The occurrence of galena and sphalerite in the mineralized rocks suggests that the parent sulfide bodies were pyrite-sphalerite deposits. Most of the output was made long ago, and records of production are incomplete or nonexistent.

The El Capitan deposit is at the top of the Leadville dolomite at a place where it is exposed from overlying Eagle River porphyry by a few feet of Belden shale. The ore was a gold-bearing rusty siliceous material forming a lens as much as 75 to 20 feet thick (Emmons, 1886, p. 154-155). This was worked from an incline and two or three levels, and it is said that the workings extended for a distance of 1,000 feet on the vein. The deposit is said to have boomed abruptly, probably at the base of the gold and some but anomalous concentrations of rocks on dumps in the vicinity suggest structural complications, such as low-angle faults, that may account for the ending of the ore.

The Jessie Jane mine is on an east-west-dipping vein in the Leadville dolomite on the south side of East Tenmeer Creek. The vein was discovered in 1916 and produced about $100,000 within a few years after its discovery, since 1918. The mine was last worked in 1950, when it comprised a shaft and two levels at depths of 80 and 150 feet. The vein is a fissure up to 12 inches wide filled with dolomite fragments in a matrix of siliceous material, locally gold bearing. Just south of the Jessie Jane is the Lucy L., which is a vein in the Leadville dolomite that is similar to the Jessie Jane and has some deposits in the dolomite. The Lucy L., as well as the Golden Gate, a similar deposit south of the Jessie Jane, is reported to have been fairly productive, but the records are vague and no records are available.

Veins in the quartzite and porphyry are most numerous in the area of intense faulting in the east-central part of the area, and some of them have been worked in many places, other places in the map area. These are quartz-sulfide veins, outlined as siliceous ferruginous in some exposures, and locally containing a little gold. No more than ounce of gold per ton of ore has been found in any of the veins. The quartz-sulfide veins are locally mineral with iron oxides, and some contain veins or lenses of limonite, suggesting the former presence of pyrite. In addition, the sheared rock between the porphyry and the quartzite is in places a quartz-sulfide-bearing breccia, forming weakly mineralized stockworks. Many of the veins have been prospected in this area have been worked on a small scale, and some probably produced a little gold.

The chief gold placer deposits of the area are in the valley of East Tenmeer Creek; gravelly deposits have been worked in the gulches east of Buckeye Peak, and particularly in the valley of East Tenmeer Creek. Placers have been worked in the valley of East Tenmeer Creek have been worked with power-equipment from the mouth of the valley, south of the Tenmeer Pass area, southeastward for about 2½ miles to the vicinity of the Jessie Jane mine; from there upstream for 2 miles to the head of the valley they have been worked by hand methods. The chief source of the gold was probably the Jessie Jane group of mines, but the occurrence of small amounts of gold in the placer gold spectrum from the Jessie Jane suggests that the numerous small pyritic quartz veins in the Minturn formation and porphyries supplied some of the gold. Veins of this type were also the source of the gold in the small placer deposits in the gulches on the east side of the Gore Range.

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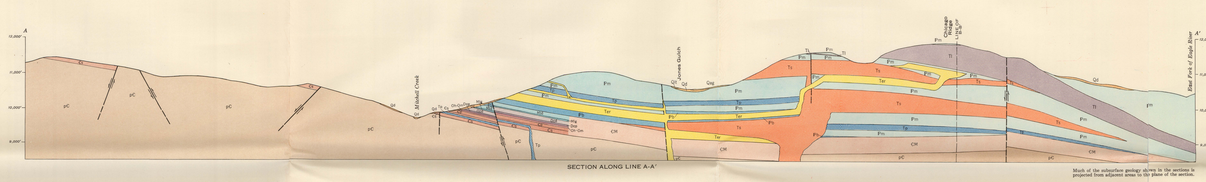
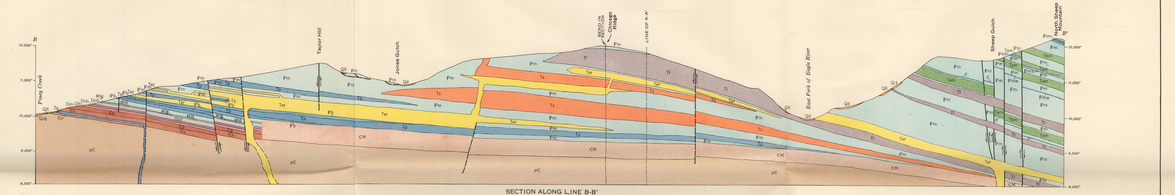


SECTION ALONG LINE A-A'

Much of the subsurface geology shown in the sections is projected from adjacent areas to the plane of the section.



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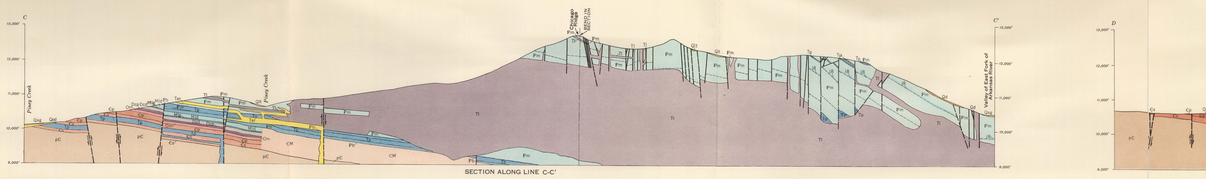

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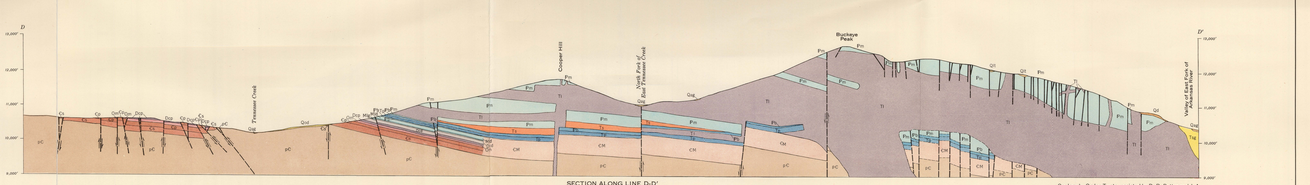

SECTION ALONG LINE D-D'

Geology by Ogden Tweto, assisted by D. B. Potter and J. A. MacKallor, 1950; H. T. Schansberger and D. L. Peck, 1951; and O. W. Weir, R. E. Davis, and J. C. Green, 1952

GEOLOGIC MAP OF THE TENNESSEE PASS AREA, EAGLE AND LAKE COUNTIES, COLORADO

By Ogden Tweto

Scale 1:14 400

1000 0 1000 2000 3000 4000 5000 Feet

Contour interval 50 feet. Datum is mean sea level

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