GEOLOGY OF THE DICKS PEAK AREA, PARK COUNTY, COLORADO

by

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ABSTRACT

The thesis area is located in the central part of the Thirtynine Mile volcanic field in Park County, Colorado.

In the early Tertiary, erosion stripped away most of the continental and marine sedimentary cover that once existed over the area. The entire region now overlain by the volcanic field was eroded to a surface of moderately low relief. Channel sands and arkosic conglomerates were deposited in the major drainages of that time. Volcanic activity began in the late Eocene with the eruption of two trachytic ash flows which formed an extensive sheet; most of this sheet was removed by continuing erosive activity.

In the early Oligocene, fragmental andesitic to basaltic volcanic mudflows with subordinate lava flows and breccias were deposited, associated with small cones randomly scattered throughout the field. Coalescing sheets of mostly laharic breccias increased in thickness as these cones grew.

Several exogenous domes of andesite were intruded through and upon the breccias, possibly after movement along major north-northwest-trending faults adjacent to the area. The configuration of some of these intrusions suggests that they may have been intruded much as ring domes following

subsidence of a proposed caldera to the east.

In the early Oligocene, olivine augite basalt from feeder dikes and central vents covered the area. Projected dips on this unit indicate a large volcano existed to the southeast.

The area overlies the transition zone of opposite-dipping thrusts to the north and south. Tension along this zone may have controlled emplacement of the volcanic rocks.

The area contains no known economic mineralization.

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INTRODUCTION

Purpose and Scope

The purpose of this investigation is to establish the geologic history of the thesis area. To accomplish this, a geologic map with cross sections and a petrographic summary of all volcanic units was prepared.

The area was selected in order to connect and correlate the studies of DeVoto (1961) to the west, DuHamel (1968) to the south, and Buchanan (1967) to the east in the investigation of the Thirtynine Mile volcanic field.

Location and Accessibility

The thesis area occupies 65 square miles in southern Park County, Colorado, and is located in the center of the Thirtynine Mile volcanic field (see figure 1). The volcanic field forms a high plateau covering 1500 square miles separating the Arkansas and South Platte Rivers between the southern Front Range on the east and the Mosquito Range on the west.

Drainage and Climate

Elevations in the area lie between 8,900 and 10,700 feet above sea level. Precipitation averages less than 12

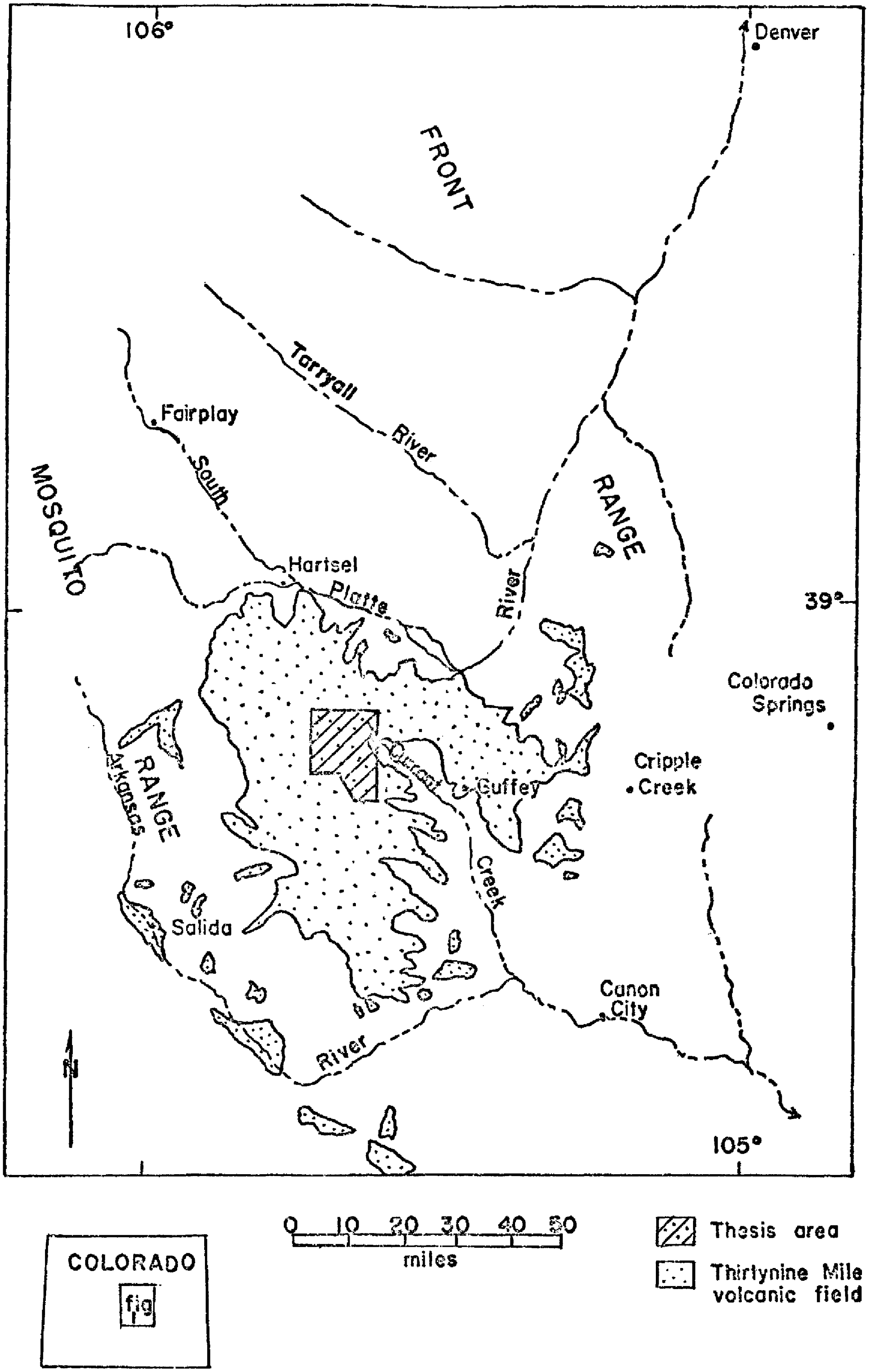

Figure 1- Location of Thirtynine Mile volcanic field and thesis area

inches per year and occurs mostly as daily thunder showers during the summer months. All streams in the area are ephemeral.

Topography and Vegetation

The various rock units in the area display marked differences in topographic expression and vegetation. Areas underlain by the lower member of the lower andesite are irregularly resistant and consequently exhibit irregular topography, locally with drainage adjusting to the most prominent joint directions. Where the veneer of this unit is thin, particularly to the northwest, it forms rolling hills of low relief with an incomplete or absent soil profile and very little vegetation other than grass. The lower andesite, as well as all other rock units in the thesis area, supports pine, spruce, and aspen at higher elevations, especially on north-facing slopes. Extrusive and intrusive andesitic rocks are generally more uniformly resistant than the lower andesite and form rounded topography and constitute the highest elevations (Secs. 26, 27, 34, 35, T. 14 S., R. 74 W.). Radial drainage develops where the intrusive and extrusive andesitic rocks occupy a large area. The Dicks Peak area and those south of Dicks Creek illustrate this very well. The upper member of the lower andesite forms characteristic irregular topography, usually at higher elevations (secs. 20, 21, 28, 29, T. 14 S., R. 74 W.). Isolated intrusives are typically much more resistant than the lower member of the lower andesite. Subsequently, they form subrounded hills several hundred feet higher than the surrounding terrain, which is usually developed on the lower member of the lower andesite (secs. 11, 15, T. 14 S., R. 74 W., sec. 24, T. 15 S., R. 74 W.). Where ash flows 1-2 crop out, vegetation is usually limited to small shrubs and grass.

Previous Investigations

Hayden (1874) and Peale (1874) made the first reference to rocks of the Thirtynine Mile volcanic field while describing the features of South Park, the Park Range, and the upper Arkansas Valley in the Hayden Survey of 1873.

Cross mapped the West Four Mile Creek area a few miles east of the thesis area, and included it as part of Pikes Peak Folio 7 (Cross, 1894). He described "basic breccias and agglomerates" and "augite andesite" which, according to B. Wyckoff (oral communication, 1967) represent the lower and upper members of the lower andesite, respectively.

Burbank (1933) described two principal cycles of volcanism during late Cretaceous to early Tertiary time. The first cycle, from late Cretaceous to early Eocene time, includes Front Range tectonism and the ancestral San Juan uplift. The second cycle was typically more explosive and was centered in the San Juan and Elk Mountains. Debris filled late Eocene basins indicating a late Eocene to early Oligocene age for the volcanism.

Burbank, Lovering, Goddard, and Eckel (1935) compiled the geologic map of Colorado on which the outline of the Thirtynine Mile volcanic field appeared.

Stark, and others (1949) mapped the northern portion of the volcanic field southward to Thirtynine Mile Mountain, just one mile east of the northeast boundary of the thesis area, and westward to the Agate Creek area, west of the thesis area. The thick sequence of andesitic rocks exposed along the south flank of Thirtynine Mile Mountain was named the Thirtynine Mile volcanic series (Stark and others, 1949). The exposures there correspond to the upper member of the lower andesite of Epis and Chapin (1968). Stark and others, (1949) first postulated the occurrence of a volcanic center near Guffey, based on the dips on Thirtynine Mile Mountain and the configuration of nearby dikes. An Early Oligocene age for these rocks, based on stratigraphic relationships, was also postulated.

Bever (1954) mapped and discussed the Precambrian rocks near Guffey. He assigned the gneisses and schists to the Idaho Springs Formation. Granites of the Silver Plume and Boulder Creek types later intruded the gneisses and schists. Bever's study of the volcanic units was incomplete.

DeVoto (1961) mapped the Antero-Agate Creek area immediately west of the thesis area and included a discussion of some of the volcanic rocks common to both thesis areas.

A stratigraphic column was first established as a result of work done in the Tallahassee Creek area by Chapin (1965). Chapin and Epis (1964) summarized most of the relationships of the units in the volcanic field.

Buchanan (1967) mapped the area immediately east of the thesis area, which includes the major volcanic center near Guffey. DuHamel (1968) mapped the area immediately south of the thesis area and postulated three distinct volcanic centers for most of the units in the Thirtynine Mile field.

Wyckoff (in progress) mapped the area immediately east of Buchanan's work. Much of Wyckoff's area involves units and relationships similar to those of immediate concern to the author as both areas flank the proposed volcano at Guffey.

Epis and Chapin (1968) provided a progress report of all field and laboratory investigations prior to this writing.

Method of Investigation

Mapping in the field was completed on aerial photographs at a scale of 1:21,400 and two 15-minute topographic quadrangle maps (Black Mountain, 1959; Guffey, 1959) enlarged to a scale of 1:31,680.

Attitudes of flow structure, joints, bedding, and foliation were measured with a brunton compass.

Thin sections of all volcanic units were prepared for petrographic examination and photomicrographs. Sodium cobaltonitrate staining was used to help determine the composition of the aphanitic groundmass of most units.

All the volcanic rocks were examined microscopically. Precambrian rocks were studied only megascopically. Compositional names are based on phenocryst content, substantiated by groundmass staining. Travis' classification (1955) was followed in naming the rocks. The classification of breccias is that of Fisher (1960), other pyroclastic rocks are classified according to Wentworth and Williams (1932). Plagioclase composition is based on the Fouqué method of determination (Travis, 1956).

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STRATIGRAPHY AND PETROGRAPHY

Introduction

The thesis area covers the northwestern flank of the large composite Guffey volcano centered near Guffey (figs. 2, 3), which is one of three or more active centers from which a large portion of the rocks of the Thirtynine Mile field was extruded (DuHamel, 1968).

The entire volcanic pile rests on an extensive erosion surface of moderately low relief covering 5000 square miles (Epis and Chapin, 1968). This surface extended from the foot of Kenosha Pass southward to the northern Wet Mountains. In an east-west direction it probably extended from Cripple Creek to the upper Arkansas Valley. Local relief of as much as several hundred feet developed on this surface prior to volcanism. The surface was carved into Precambrian granites, gneisses, schists and Paleozoic and Mesozoic sedimentary rocks, leaving only scattered erosional or down-faulted remnants of the sediments, usually confined to prevolcanic valleys.

The oldest volcanic unit, ash flows 1-2 (fig. 4), was probably deposited over much of the field as a thin sheet locally following stream valleys developed in the underlying topography.

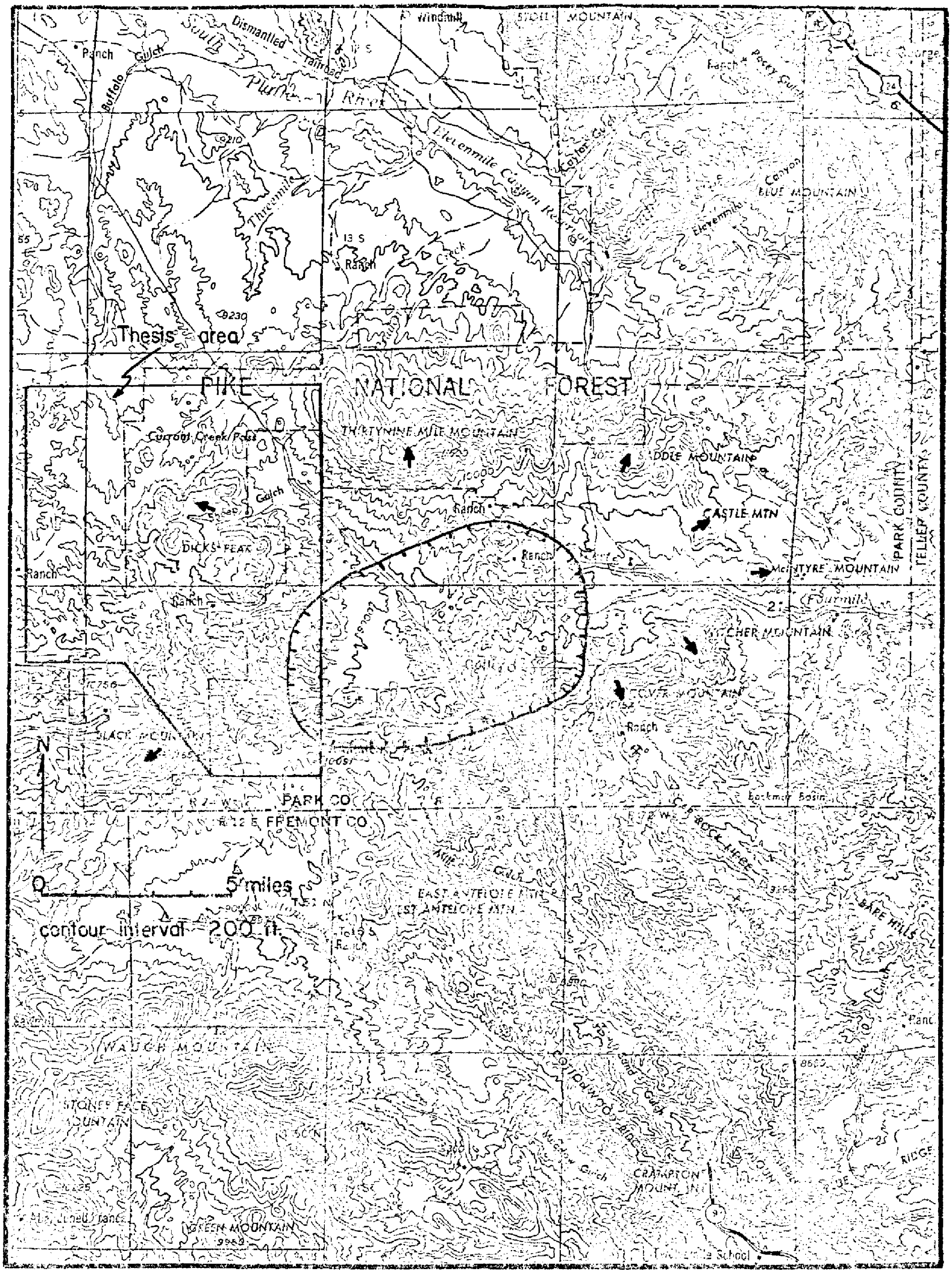

FIGURE 2. Physiographic setting of the thesis area showing spatial relation to the Guffey volcano. Arrows indicate dips of the volcano-building lava flows of the upper member of the lower andesite. Downdropped central portion of the volcano represents caldera ring fault.

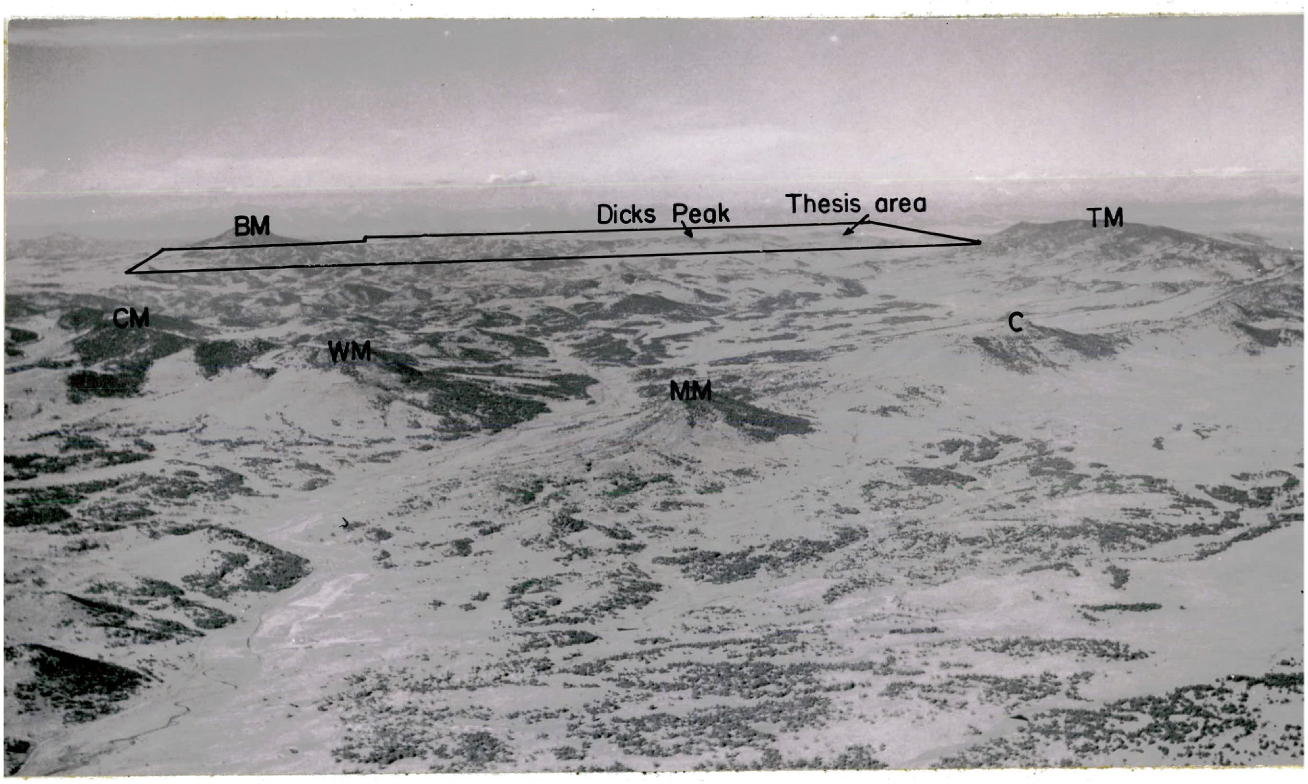

Figure 3. Oblique aerial view looking west-northwest toward elliptical ring of mountains forming erosional remnants of the Guffey volcano. (TM-Thirtynine Mile Mountain, C-Castle Mountain, MM-McIntire Mountain, WM-Witcher Mountain, CM-Cover Mountain, BM-Black Mountain.) Distance between Black Mountain and Castle Mountain is 16 miles. Sawatch Range is in extreme distance. Thesis area occupies dissected northwest flank of volcano. Photo by Epis, 1968.

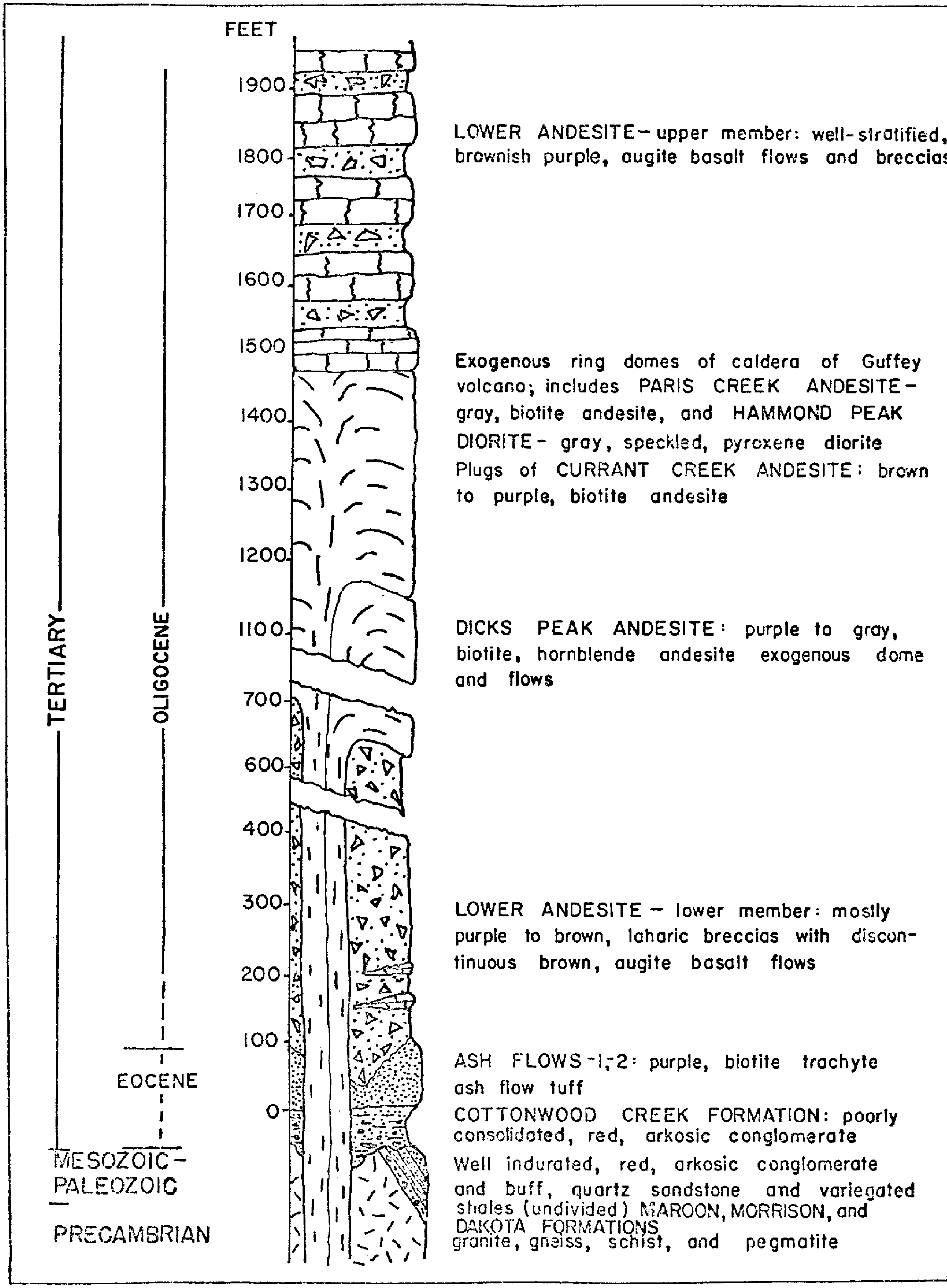

FIGURE 4. Generalized stratigraphic column of rocks in thesis area

The most voluminous unit in the entire field is the lower andesite which has been divided into two members. The lower member consists mostly of laharic breccias which were probably deposited in association with numerous small vents randomly scattered throughout the field (Epis and Chapin, 1968). The upper member, consisting of basaltic lava flows, is the youngest volcanic unit in the area and occurs as erosional remnants of the flanks of the Guffey volcano.

Several exogenous domes of intermediate composition have been assigned informal names for convenient reference only. The domes post-date the lower member of the lower andesite and pre-date the upper member of the lower andesite.

Precambrian

Precambrian coarse- to fine-grained biotite granite, quartz monzonite, gneiss, and schist are exposed in 3-4 square miles of the thesis area (secs. 22, 25, 26, 27, 36, T. 14 S., R. 74 W.; sec. 35, T. 14 S., R. 75 W.; secs. 1, 13, T. 15 S., R. 74 W.; sec. 13, T. 15 S., R. 75 W.). Discordant pegmatite and aplite bodies, probably Precambrian, locally intrude these rocks, particularly in the eastern part of the area. In the western part of the area, the Precambrian rocks are typically coarse-grained granites whereas to the east the basement rocks are strongly foliated gneisses and schists. Bever (1954) assigned these rocks to the Idaho Springs Formation. Quartz, orthoclase, plagioclase, biotite, and locally, muscovite are the major constituents of the granite, gneiss, and schist. The pegmatites consist of quartz, orthoclase, biotite, or muscovite and occasionally garnet or tourmaline. Where developed, foliation strikes east to northwest and dips steeply to the north, and may have provided a weakness plane influencing predominant northwest-trending faulting in basement rocks (pl. 1, sec. 36, T. 14 S., R. 74 W.). Joints are generally parallel or perpendicular to the foliation.

Pennsylvanian-Permian

Maroon Formation

Small, scattered inliers of well indurated, red, arkosic conglomerate of the Maroon Formation crop out along Thirty-one Mile Creek in the southern part of the area (pl. 1, secs. 23, 24, T. 15 S., R. 74 W.). Here, this unit lies with depositional contact on Precambrian rocks. Buchanan (1967) described a large inlier of the Maroon Formation just one mile east of the area with a minimum thickness of 140 feet.

The Maroon Formation consists mostly of clay- to boulder-size, subrounded to subangular fragments of Precambrian granite and biotite gneiss. The maximum fragment size is about 3 feet in diameter. Both the fragments and the silica-clay cement are stained with hematite imparting a distinctive red color to the unit. Where outcrops are lacking, red soils develop over the subcrop. Lack of sufficient outcrop in the area precludes a discussion of the bedding characteristics, although to the east, Buchanan noted graded bedding, locally. He also noticed that the arkosic conglomerates are interbedded with silty shales, micaceous siltstones, and discontinuous sandstones. Massive bedding generally predominates.

Considerable relief was created on the underlying Precambrian rocks along Thirtyone Mile Creek. This paleovalley narrows to the west and the Precambrian valley floor slopes gently to the east, suggesting eastward direction of transport of Maroon sediments. Maximum thickness of the Maroon Formation along Thirtyone Mile Creek is less than 10 feet. The overall lack of sorting and large size of individual fragments within this unit combined with the valley configuration suggest a nearby source to the west during deposition.

In the northern part of the area (pl. 1, sec. 10, T. 14 S., R. 74 W.) silicified rocks of the Maroon Formation dip 70° east on the downthrown side of the northern extension of the Mill Gulch fault (fig. 5). Here, exposed by a bulldozer cut, the total thickness of the Maroon Formation is less than 5 feet and it is overlain by 5 feet of fine grained, well sorted, well rounded quartz sandstone which may be the Garo Formation. The sandstone is exposed only here and is unmappable because of its limited extent.

Jurassic

Morrison Formation

Larger exposures of down-faulted Mesozoic inliers elsewhere in the volcanic field have been identified as portions of the Morrison Formation and the Dakota Sandstone. Because the lithology and nature of occurrence of pre-Tertiary sediments in the thesis area are similar to other larger exposures, the small outcrops within the thesis area probably represent portions of these same formations.

The only outcrop of the Morrison Formation in the thesis area is along the downthrown side of the Mill Gulch fault in central sec. 10, T. 14 S., R. 74 W. Here, buff to gray silicified shales and siltstones dip 70° east in a bulldozer exposure with Garo? and Maroon rocks. The total exposed thickness of all these units is less than 20 feet

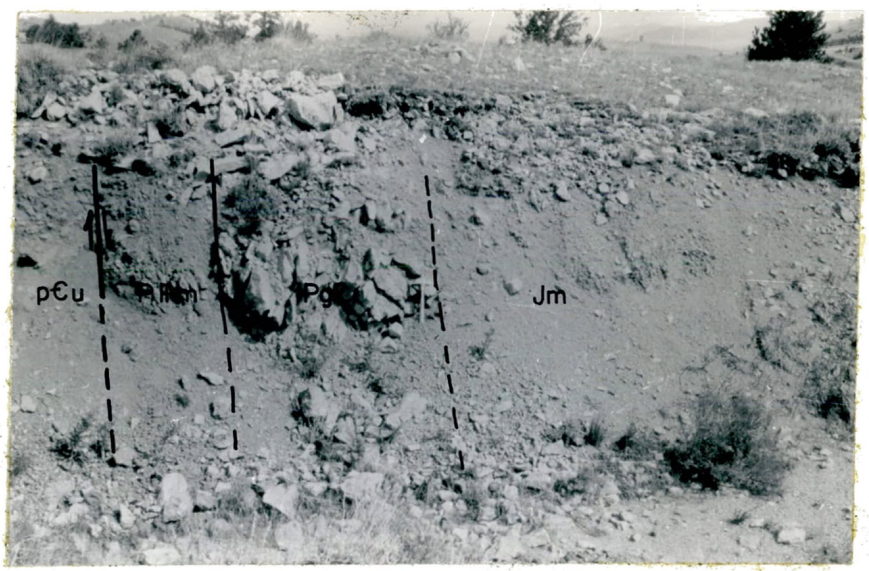

Figure 5. Outcrop of silicified Maroon (PPm), Garo? (Pg?), and Morrison (Jm) rocks dipping steeply toward the east in bulldozer cut along Mill Gulch fault (sec. 10, T. 14 S., R. 74 W.). Precambrian granite (PCu) is upthrown at left.

(see fig. 5).

Cretaceous

Dakota Sandstone

The only outcrops of what may be the Dakota Formation are exposed in three prospect pits along Thirtyone Mile Creek. Here, the unit is a highly silicified, buff-colored, fine- to medium-grained, well-sorted, well-rounded, quartz sandstone. In west-central section 23, T. 15 S., R. 74 W., this unit contains abundant worm casts and carbonized wood fragments. Where exposed, the Dakota Formation always appears to be in fault contact with Precambrian rocks. Bedding is typically massive. Total thickness of the Dakota Sandstone is at least 5 feet.

Tertiary

Cottonwood Creek Formation

The youngest prevolcanic unit in the area is the Cottonwood Creek Formation of DuHamel (1968), formerly the Arkosic Conglomerate of Chapin and Epis (1964). This unit is exposed along gully banks in Thirtyone Mile Creek (fig. 6) and in west-central section 10, T. 14 S., R. 74 W.

The Cottonwood Creek Formation consists of unconsolidated,

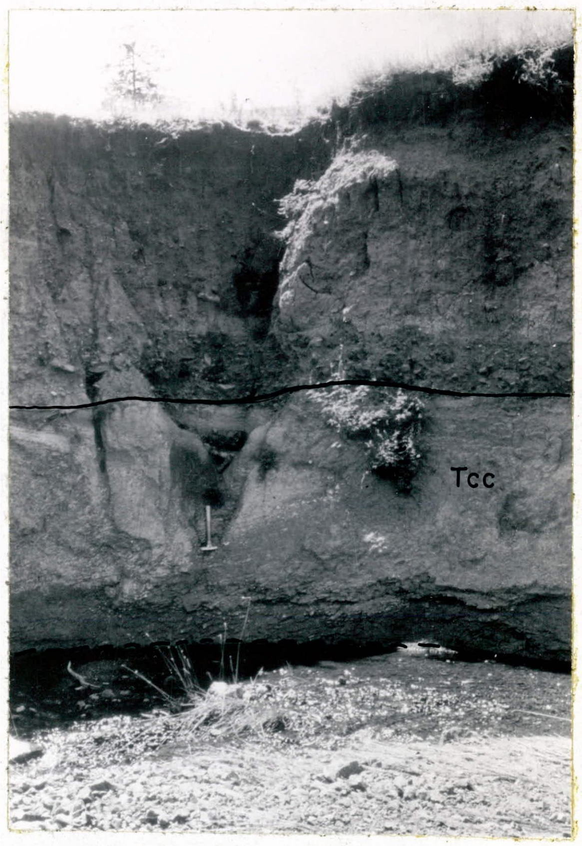

Figure 6. Cottonwood Creek Formation (Tcc) exposed along Thirtyone Mile Creek (south-central sec. 15, T. 15 S., R. 74 W.). Bedding is horizontal.

red, arkosic gravels, sands, and red to green silts. The deposits are unsorted, containing coarse detritus ranging from sand size up to subrounded boulders 20 feet in diameter embedded in a friable silty clay matrix. Iron oxide is present in the fine matrix. Bedding is irregular and can be traced only a few feet. The thickness of the Cottonwood Creek Formation in the area is less than 10 feet.

The Cottonwood Creek Formation closely resembles both underlying weathered Precambrian terrain and Maroon Formation. DuHamel (1968) outlined characteristics by which the Cottonwood Creek Formation could be identified. He noted that the Cottonwood Creek Formation possesses greenish-gray and red mudstone lenses and contains a greater variety of Precambrian rock types than does an area directly underlain by Precambrian bedrock. Buchanan (1967) outlined differences between the Maroon and Cottonwood Creek Formations. Maroon rocks are much more consolidated and contain boulders no larger than 3 feet in diameter whereas the Cottonwood Creek Formation contains boulders up to 20 feet in diameter.

The deposit occupies a straight, steep-walled valley farther south in the vicinity of Cottonwood Creek (DuHamel, 1968) and is probably fault-controlled in part (Epis and Chapin, 1968). This valley-fill deposit has been traced 20 miles from the northern side of the Arkansas River at Devils Hole north-northwestward to Chumway Park just east of the area. The deposits in the northern part of the area lie on the projected trend of the paleovalley one mile northwest of Currant Creek Pass. Overlap by early volcanic units obscure most relationships northward. The valley (see fig. 7) probably served as a major drainage system of South Park (Epis and Chapin, 1968).

The age of the Cottonwood Creek Formation is probably middle or late Eocene. Stark and others (1949) and Sawatzky (1967) have shown that the prevolcanic surface truncates principal Laramide structures in South Park where Precambrian and Mesozoic rocks of the western Front Range are thrust over folded beds of the Denver Formation along the Elkhorn Fault. Whole-rock potassium-argon age determinations (Sawatzky, 1967) and paleontologic data by J. H. Johnson (1937a,b) and Brown (1962) indicate an age of latest Paleocene or earliest Eocene for the basal beds of the Denver Formation. The prevolcanic surface developed later since it beveled the thrust and cut deeply into the Precambrian rocks of the upper thrust plate (Epis and Chapin, 1968). Ash flows 1-2, the earliest volcanic units of the area, were erupted during latest Eocene and directly overlie the Cottonwood Creek Formation. Chapin (1965) obtained a potassium-argon age determination of 40.0 (±1.2) million years on these ash flows.

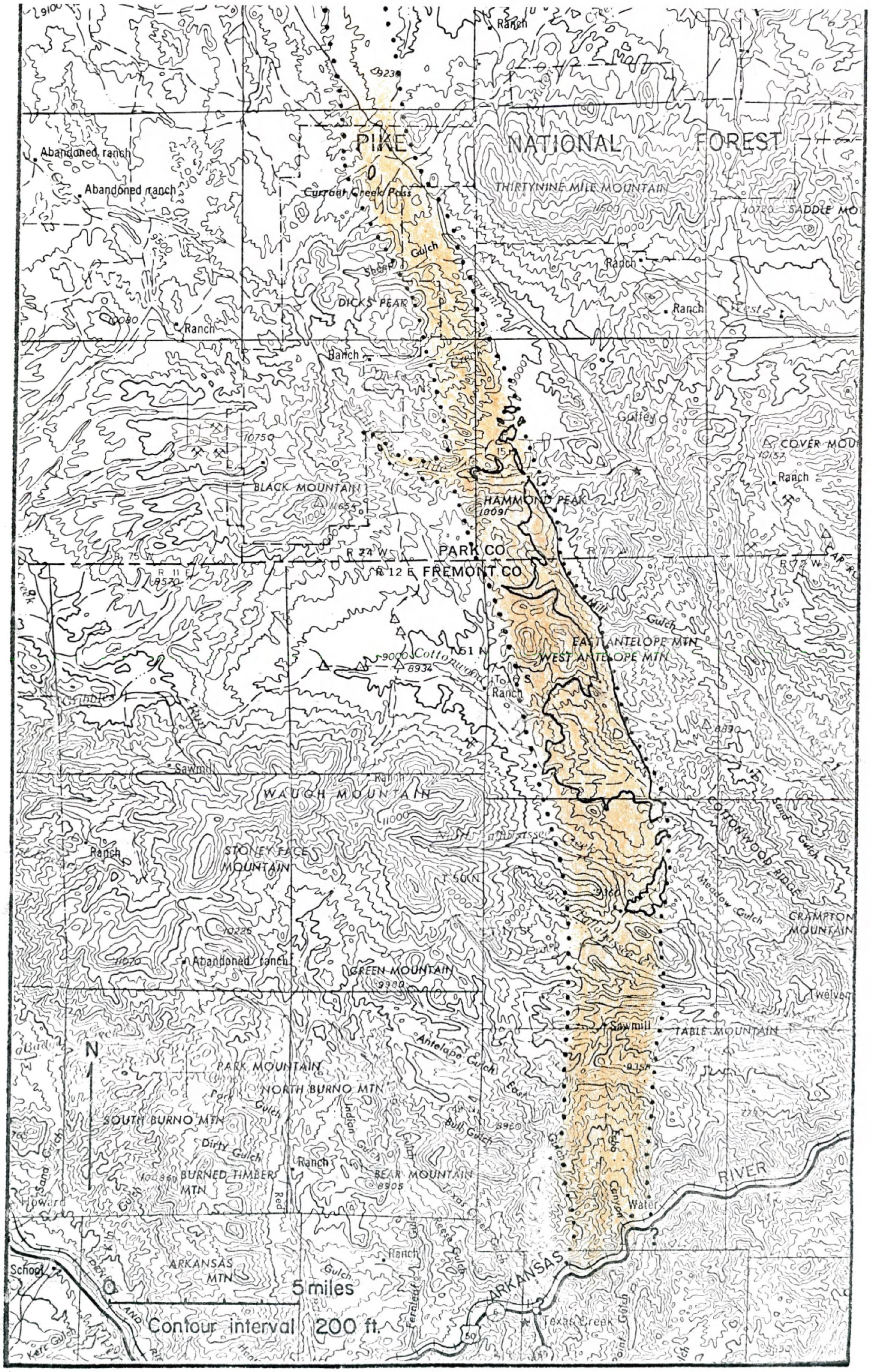

FIGURE 7. Proposed configuration of prevolcanic Tertiary arkose channel which probably drained South Park. Solid lines within channel represent known outcrops of the arkose. The course of the channel south of the Arkansas has yet to be investigated. Data from Chapin, 1965; Sawatzky, 1967; Buchanan, 1967; DuHamel, 1968; Morris, 1969

Ash Flows -1 and -2

The oldest volcanic unit in the thesis area and in the entire Thirtynine Mile volcanic field consists of a multiple-flow, single cooling unit, ash-flow sheet originally named Ash Flows -1 and -2 by Chapin and Epis (1964). The unit is actually made up of two megascopically similar ash flows which extend throughout much of the volcanic field and are distinguishable only on the basis of 2V variation of sanidine crystals (Chapin and Epis, 1964).

The unit crops out in the area as small erosional remnants which are usually confined to valley floors (Dicks Creek and Thirtyone Mile Creek). During emplacement, these ash flows often followed small stream valleys carved into the prevolcanic erosion surface (Epis and Chapin, 1968). Although to the south the unit is as thick as 90 feet, in the thesis area it is less than 50 feet thick. Exposures of ash flows -1 and -2 weather to brownish-purple and display well-developed eutaxitic foliation imparted by flattened and stretched pumice lapilli.

The unit is a lithic, crystal, vitric, biotite, sanidine, trachyte, lapilli tuff. It is composed of 60 to 70 percent ash-size glass shards and elongate pumice lapilli, and 30 to 40 percent broken lapilli-size crystal fragments. Lithic fragments are usually absent. The rock is poorly sorted.

The vitroclastic matrix is moderately welded and nearly completely devitrified (fig. 8). It is stained uniformly brown from

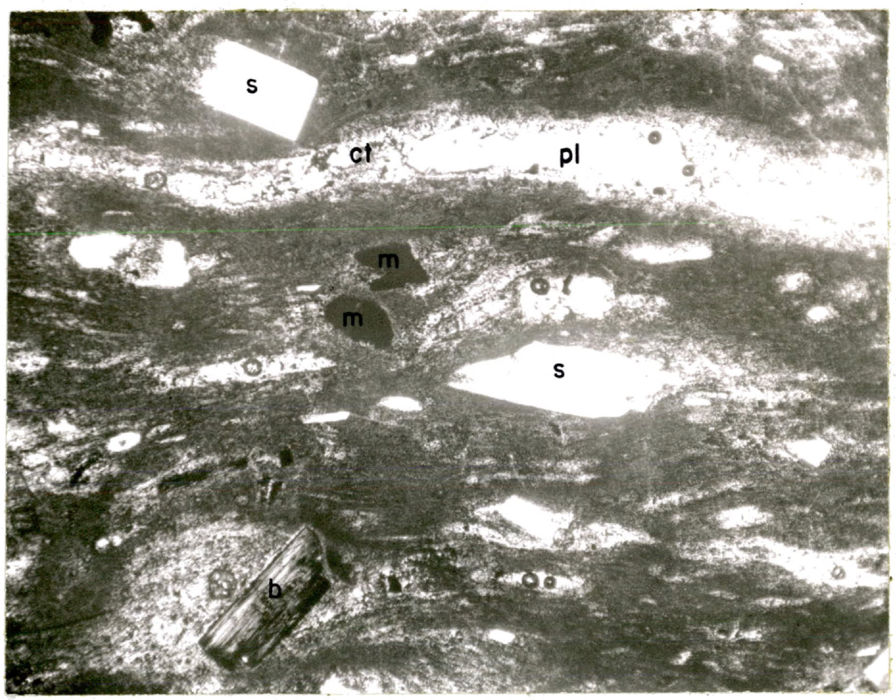

Figure 8. PRC-53-2, 27x, ordinary light. Photomicrograph of ash flows -1 and -2. Vitroclastic matrix is moderately welded, iron-stained, and nearly completely devitrified. Eutaxitic foliation is imparted by large, elongate, flattened and stretched pumice lapilli (pl., upper third of photo). Light-colored grains are sanidine (s); biotite crystal is at lower left (b); opaque grains are magnetite (m); cristobalite and tridymite (ct) rim pumice lapilli.

iron oxide. The pumice lapilli are less affected by iron oxide and are white. Vapor phase activity consists of cristobalite/tridymite and potash feldspar growth in the pumice lapilli and the vitroclastic matrix.

Clear, glassy anhedral to subhedral sanidine is the most abundant phenocrystic mineral. Some of the grains have been fractured and rounded. Most of the fragments are 2 to 3 millimeters in diameter, although they range from 1 to 5 millimeters. Some of the sanidine fragments are zoned. Alkali feldspar is present in a 10:1 ratio to plagioclase. The composition of the plagioclase is An 16. Most plagioclase fragments are kaolinized. Euhedral bronze-colored biotite and subhedral magnetite make up 2 to 3 percent of the phenocrysts. The rims of the biotite grains are oxidized.

Ash flows -1 and -2 were extruded from an unknown source during latest Eocene time. Potassium-argon dating indicates an age of 40 (±1.2) million years (Chapin, 1965).

Lower Andesite, Lower Member

The lower andesite of Chapin and Epis (1964) forms the most extensive unit in the thesis area. It has been divided into a lower member of mostly laharic breccias, subordinate flow breccias and discontinuous lava flows, and an upper member of well-stratified flows and breccia zones. Because the lower and upper members are separated stratigraphically by other volcanic units in the thesis area, they will be discussed separately.

The lower member crops out over 50 square miles in the thesis area and consists of a variety of rock types attaining a maximum thickness of 600 feet. To the south, DuHamel (1968) reports a maximum thickness of 1200 feet in the vicinity of Waugh Mountain. Basaltic to andesitic fragmental material of the lower member was distributed laterally largely by lahars since this breccia type predominates. The matrix is light-colored, tuffaceous, and distinctly clastic. Bedding is chaotic and cannot be traced for more than a few feet (fig. 9). Usually more than one rock type makes up the gray to purple fragments. Fragments range from angular to subrounded. Locally, elongate fragments are oriented with their longest and shortest diameters in the bedding plane. Where the breccia fragments are of one rock type, the lahar tends to be much more indurated and the matrix darker.

Discontinuous gray to black basalt flows occur throughout the lower member, but seem to be concentrated in the lower portion (fig. 10). Breccia zones commonly separate the flows (fig. 11). The flows are generally porphyritic-aphanitic, intergranular subophitic or pilotaxitic.

Figure 9. Heterolithic, poorly-indurated laharic breccia of the lower member of the lower andesite in NE¼, sec. 24, T. 14 S., R. 74 W. False impression of bedding appears to right of billfold.

Figure 10. Erosional remnant of a basaltic lava flow within the lower member of the lower andesite (Tlal). View is to north in north-central sec. 24, T. 14 S., R. 74 W. Rocks exposed in gully in foreground are laharic breccias of Figure 9 .

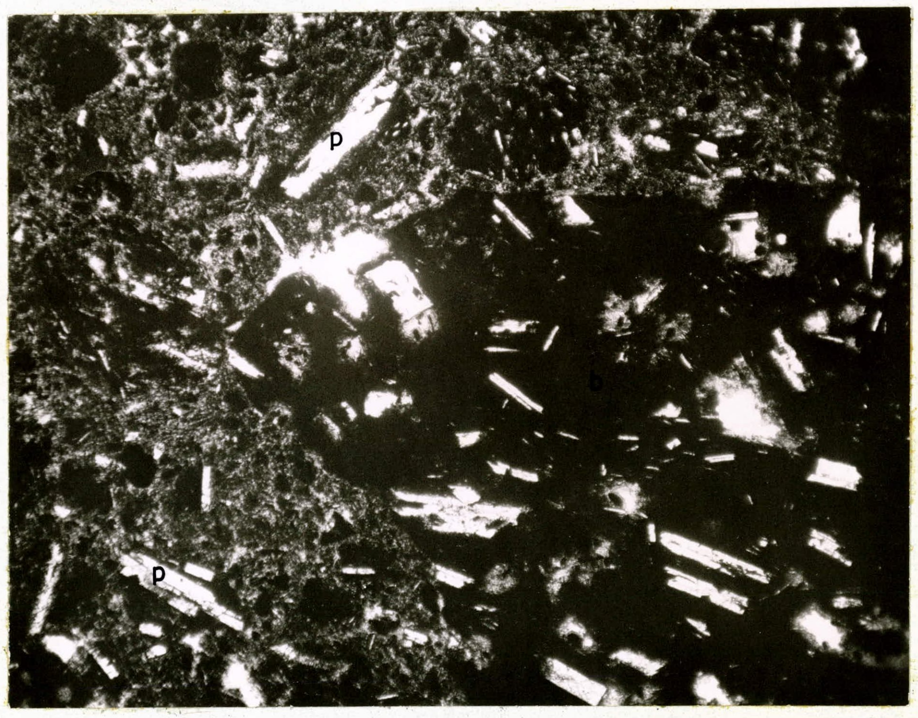

Figure 11. PRC-53-9, 27x, ordinary light. Photomicrograph of a flow breccia within the lower member of the lower andesite. Breccia fragment (b, right) is set in a magmatic matrix (note plagioclase (p) (An 54) growth within matrix). Rock is monolithic.

Interstitial, microcrystalline, diopsidic augite and magnetite fill void spaces between plagioclase microlites (An 58 to An 70). Euhedral olivine, diopside-augite, plagioclase, and hornblende are the most common phenocrystic minerals, making up 40-55 percent of the rock (figs. 12-14). The phenocrysts range in size from .3 to 4 millimeters. The groundmass in the flows is made up generally of subparallel microlites of plagioclase, occasionally in glass, or is intergranular with interstitial micro-pyroxene and magnetite. Magnetite varies from 5 to 10 percent of some flows. Partial seriticization of the groundmass plagioclase is common. Iron-oxide staining and local calcification and zeolite growth in voids of the groundmass is also common.

Several light-colored tuffaceous lenses were observed in the field within the lower member. These probably represent local streams developed on the changing topography during formation of the extensive sheet of laharic breccias.

Several small vents randomly scattered throughout the field probably erupted the fragmental rock of the laharic breccias. Epis and Chapin (1968) noted several breccia cones as large as a half mile in diameter and 500 feet high. Exposed cross-sections of these cones reveal throat fillings of autoclastic breccia within a pile of stratified heterolithic and monolithic laharic and flow breccias. Inward

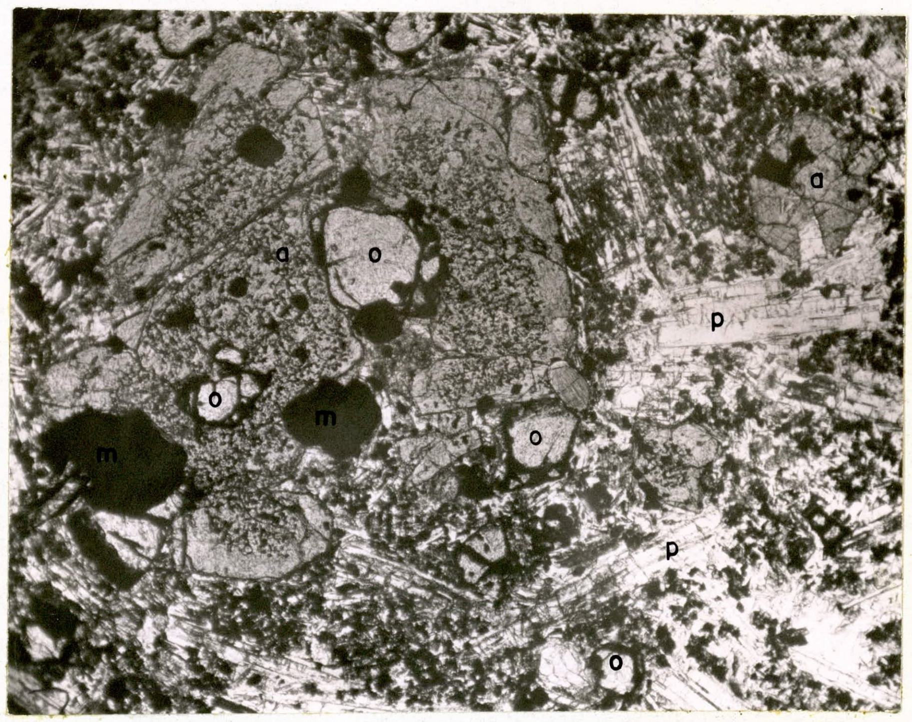

Figure 12. PRC-53-4, 27x, ordinary light. Photomicrograph of an augite, olivine basalt flow within the lower portion of the lower member of the lower andesite. Rock is porphyritic-aphanitic with subophitic to pilotaxitic groundmass. Subhedral olivine (o) and magnetite (m) are poikilitic in large augite grain (a) set in groundmass of plagioclase (p) (An 68) with interstitial microcrystalline augite and magnetite.

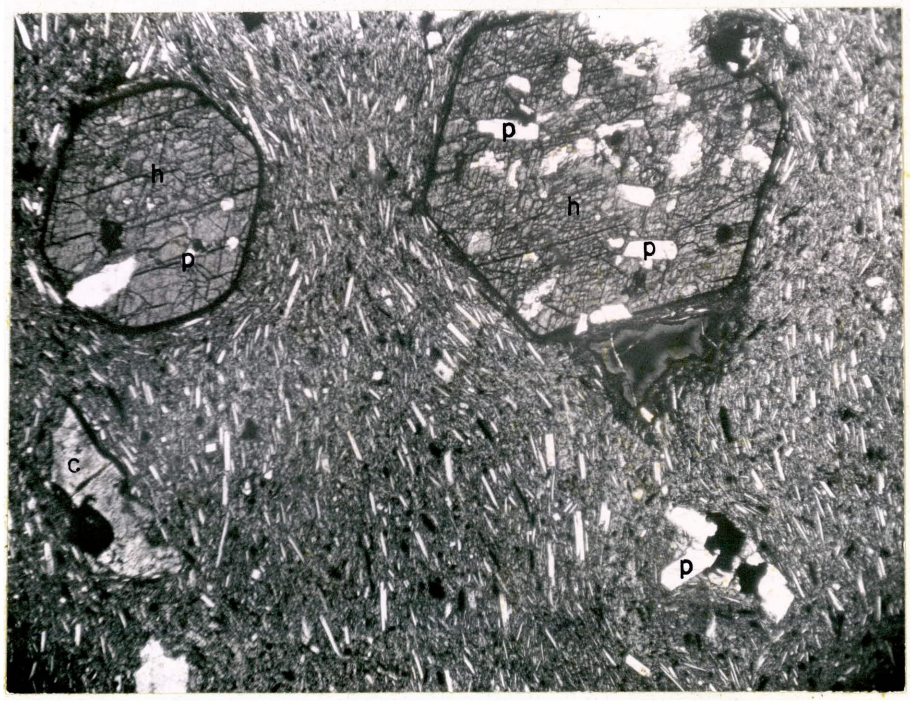

Figure 13. PRC-53-5, 27x, ordinary light. Photomicrograph of hornblende basalt flow in the lower member of the lower andesite. Euhedral, partially resorbed hornblende (h) grains are set in an aphanitic pilotaxitic groundmass of plagioclase (An 58) microlites in partially devitrified volcanic glass. Plagioclase (p) is poikilitic in both hornblende grains. Secondary calcite (c) appears at lower left.

Figure 14. PRC-53-6, 27x, ordinary light. Photomicrograph of an augite olivine basalt of the lower member of the lower andesite, somewhat similar to figure 13. Here, euhedral olivine crystals (o) with iddingsite in fractures, together with large euhedral augite grains (a, upper right and left) comprise most of the phenocrysts. Plagioclase (p) occurs only in the groundmass (An 56) and is randomly oriented.

dipping laharic breccias were also recorded.

In the thesis area no such large scale vents were observed, although in several areas small, well-indurated, autoclastic, monolithic plug-like bodies 10 to 50 feet high stand above surrounding heterolithic laharic breccias. A remnant of one such possible vent crops out along Agate Creek (sec. 25, T. 14 S., R. 75 W.; fig. 15). Here, angular blocks of andesite up to 15 inches in diameter occur in a clastic matrix.

The lower member rests on ash flows -1 and -2 where the ash flows were not completely eroded away; elsewhere in the area it is underlain by prevolcanic sediments or Precambrian rocks.

Dicks Peak Andesite

A grayish-purple to brown, porphyritic, biotite-hornblende andesite, here termed the Dicks Peak andesite, crops out over 6 square miles in the east-central part of the thesis area (secs. 26, 27, 34, 35, T. 14 S., R. 74 W.). Detached flows and intrusions southward to Thirtyone Mile Creek have been included in this unit as they are similar to the Dicks Peak andesite mineralogically and span the same stratigraphic interval. Included in this unit is the Dicks Creek andesite of Buchanan (1967). The exogeneous domes in

Figure 15. Monolithic, autoclastic breccia within the lower member of the lower andesite along Agate Creek (north-central sec. 25, T. 14 S., R. 75 W.). This breccia may be the throat-filling of one of several small vents from which the lower member was erupted.

the vicinity of Dicks Peak represent the main centers of intrusion.

The Dicks Peak andesite is porphyritic-aphanitic, pilotaxitic to felted and locally glomeroporphyritic (figs. 16 and 17). Phenocrysts make up an average of 25-30 percent of the rock, are mostly euhedral, and range in size from .5 to 3 millimeters. Plagioclase (An 50 - An 64) is the most abundant phenocrystic mineral, and is commonly zoned. Equal parts of oxidized, opaque hornblende and biotite make up the rest of the phenocrysts. The groundmass is composed of microlites of plagioclase, usually uniformly seriticized and argillized, with interstitial microcrystalline magnetite sometimes making up to 15 percent of the groundmass.

There is some lateral variation, texturally and mineralogically, within the Dicks Peak andesite. Flows become more aphanitic and less porphyritic in all directions laterally away from the intrusive center at Dicks Peak. The biotite: hornblende ratio is slightly less at Dicks Peak than along the periphery of the flows. Locally, spherulitic secondary zeolite or cristobalite/tridymite occurs in the groundmass as does patchy calcite. Iron-oxide haloes around mafic grains become more prevalent away from the intrusive center. Resorbed biotite and hornblende are common throughout.

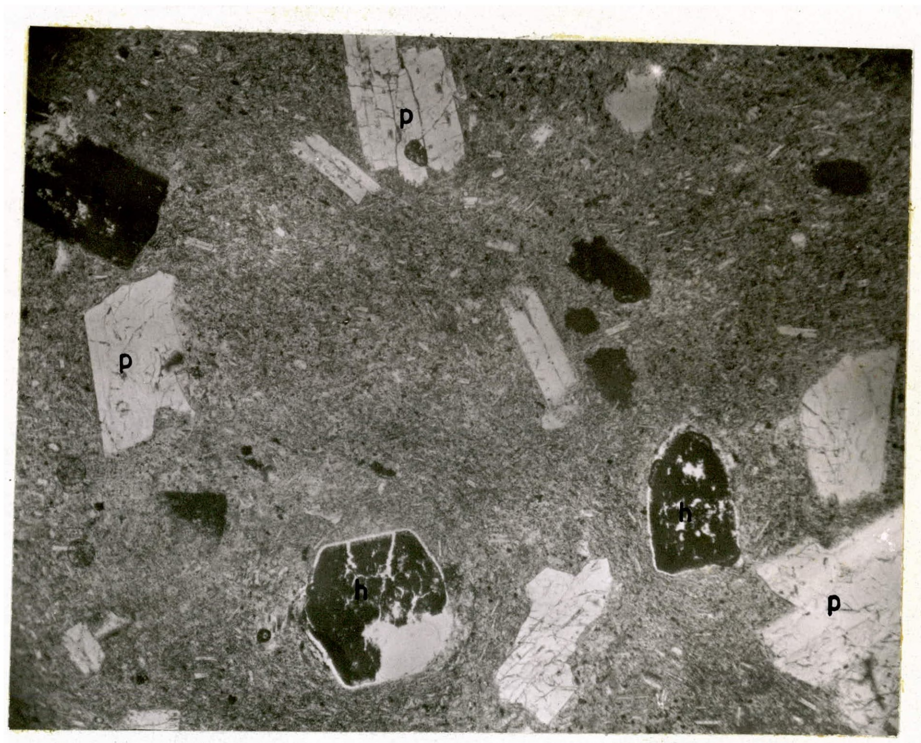

Figure 16. PRC-53-17, 27x, ordinary light. Photomicrograph of the Dicks Peak andesite. Rock is porphyritic-aphanitic subpilotaxitic. Dark subhedral grains are oxidized, nearly opaque biotite (b) and hornblende (h). Light, euhedral grains are plagioclase (p) (An 50). Groundmass is uniformly sericitized and argillized.

Figure 17. PRC-53-18, 27x, crossed nicols. Photomicrograph of Dicks Peak andesite. Large, euhedral, oscillatory-zoned plagioclase crystal (core An 73, rim An 47) is partially kaolinized. Felted microlites of plagioclase occupy groundmass.

The region immediately surrounding Dicks Peak constitutes the highest ground in the area. Where the lower member of the lower andesite was not deposited or was eroded prior to emplacement of the Dicks Peak andesite, the later unit directly overlies Precambrian rocks at elevations up to 10,000 feet above sea level. The maximum thickness of the Dicks Peak andesite is 700 feet.

Cliffs northwest and west of the intrusive center of the Dicks Peak andesite are breached flows dipping away from the main center (see pl. 1, secs. 27, 34, T. 14 S., R. 74 W., and figures 18, 19, and 20). The flows exhibit contorted sheeting, usually parallel to mineral alignment, which is especially well-developed near the top (see figure 20).

The Dicks Peak andesite was emplaced during deposition of the lower member of the lower andesite. Early Oligocene dikes feeding flows of the upper member of the lower andesite cut the Dicks Peak andesite.

<u>Hammond Peak Diorite</u>

Several small, exogenous domes crop out in the eastern part of the area. Hammond Peak is one such intrusion (fig. 21). Because each dome is surrounded by the lower member of the lower andesite, the relative ages of the domes are enigmatic. The domes, therefore, appear in the explanation of the geologic map (pl. 1) in staggered fashion. It can only

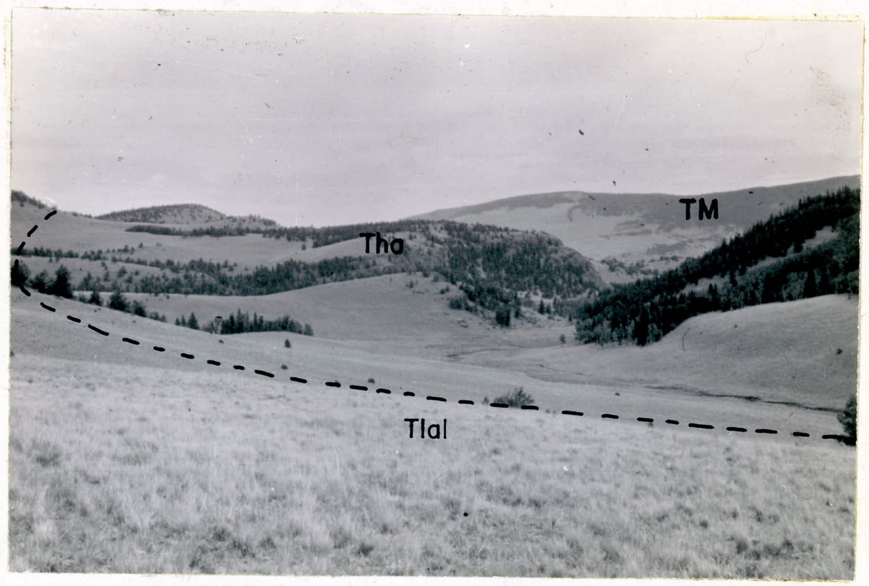

Figure 18. Grass-covered dip slopes (middle distance) of Dicks Peak extrusive andesitic rocks (Tha) dipping to the northwest away from Dicks Peak (to right of picture) along Sheep Gulch (sec. 27, T. 14 S., R. 74 W.). Thirtynine Mile Mountain (Tm) is in distance. Tlal is lower member of lower andesite.

Figure 19. Looking east at remnants of extrusive Dicks Peak andesite (Tha), (middle distance) dipping west off peak one mile west of Dicks Peak (NW¼, sec. 34, T. 14 S., R. 74 W.).

Figure 20. Close-up of contorted sheeting of Dicks Peak extrusive rocks along Sheep Gulch (north-central sec. 27, T. 14 S., R. 74 W.).

Figure 21. View to east from top of Black Mountain. Thirtyone Mile Mountain (TM) is at extreme right in middle distance. Hammond Peak (Td) is forested mountain slightly to left of Thirtyone Mile Mountain. Paris Creek intrusion (Tba) is at left.

be shown that the domes are younger than the lower member of the lower andesite. The Paris Creek andesite and the Currant Creek andesite also have the same age relationships.

The Hammond Peak intrusion of Buchanan (pl. 1, sec. 25, T. 15 S., R. 74 W.; sec. 30, T. 15 S., R. 73 W.) is a gray, speckled, medium- to fine-grained phaneritic, subophitic, intergranular, augite diorite (fig. 22). Approximately 55-60 percent of this rock is subhedral plagioclase (An 58), mostly 1 to 2 millimeters long. Anhedral to subhedral augite contributes 20 percent. Partially oxidized subhedral biotite makes up 8 to 10 percent, and magnetite contributes 10 percent. Traces of interstitial quartz were noted. The rock is partially seriticized and oxidized.

The isolated Hammond Peak diorite is younger than the lower member of the lower andesite, as shown by intrusive relationships.

Paris Creek Andesite

The Paris Creek andesite is equivalent to Buchanan's Paris Creek Intrusion (secs. 13, 24, T. 15 S., R. 74 W.). This unit is a grayish-purple, biotite andesite. The intrusive is an exogenous dome and has been deeply dissected (see cross-sections, pl. 1 and fig. 23). Flow structure dips steeply both inward and outward. Well-developed

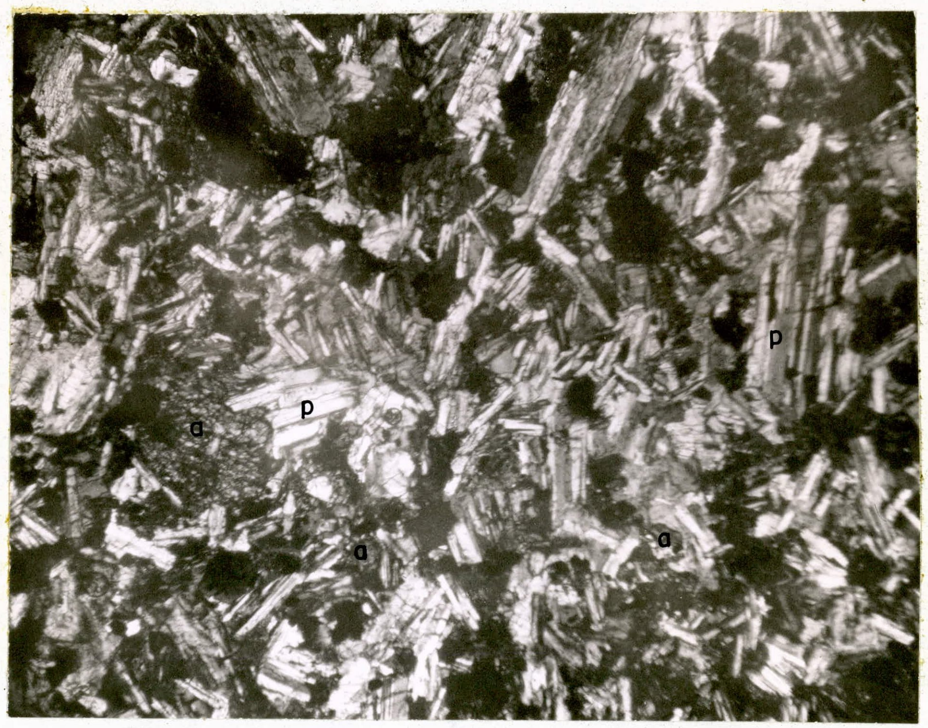

Figure 22. PRC-53-19, 27x, crossed nicols. Photomicrograph of Hammond Peak diorite. Note intergranular subhedral augite (a, left-central and lower third) and plagioclase (p) (An 58). Opaque areas are magnetite.

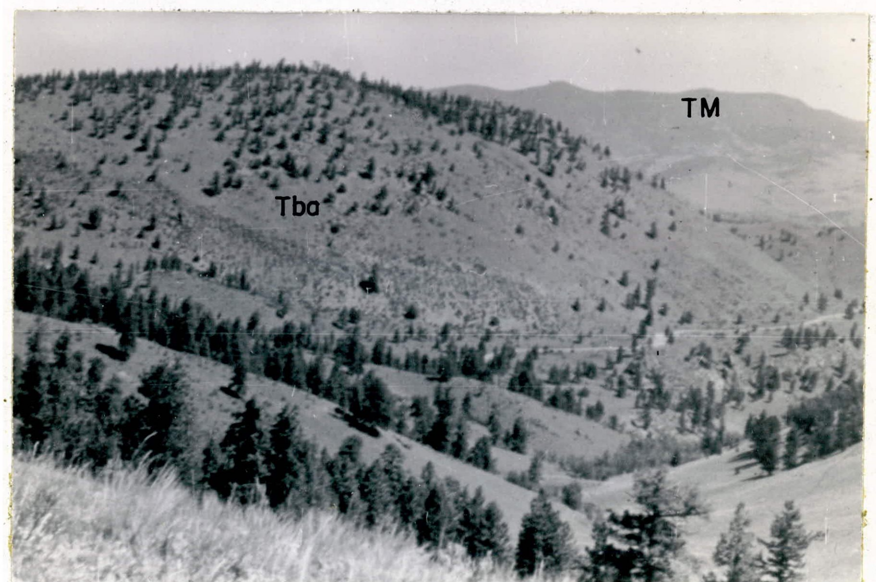

Figure 23. Looking northeast at Paris Creek intrusion (Tba) along Thirtyone Mile Creek (NW¼, sec. 24, T. 15 S., R. 74 W.). Mountain in distance is Thirtynine Mile Mountain (TM).

sheeting parallels the flow structure as in the Dicks Peak andesite.

Precambrian rocks and especially ash flows -1 and -2 have been strongly altered adjacent to the intrusion. The ash flows are overturned along the southwest boundary. Several dikes trend away from the intrusive and are probably associated with it.

The rock is porphyritic-aphanitic, felted, and locally glomeroporphyritic (fig. 24). Subhedral to euhedral phenocrysts, 1 to 3 millimeters long, make up 20 percent of the rock. Most phenocrysts are plagioclase (An 60) with normal zoning (see figure 25). Oxidized, resorbed opaque biotite makes up the remainder of the phenocrysts. The groundmass consists of interwoven plagioclase microlites with interstitial microcrystalline magnetite. Calcite and sericite have replaced parts of the groundmass.

The Paris Creek andesite is younger than the Dicks Peak andesite. Paris Creek andesite dikes (fig. 25) trend radially away from the Paris Creek intrusive and cut Dicks Peak andesite extrusive rocks to the north (sec. 12, T. 15 S., R. 74 W.).

<u>Currant Creek Andesite</u>

In the northeastern part of the area (secs. 11, 15, T. 14 S., R. 74 W.) several isolated intrusive bodies

Figure 24. PRC-53-20, 27x, crossed nicols. Photomicrograph of the Paris Creek andesite. Two large euhedral crystals of plagioclase (p) averaging overall An 60 show normal zoning and combined carlsbad-albite twins. Opaque grains are oxidized subhedral biotite crystals. Groundmass plagioclase is felted to pilotaxitic.

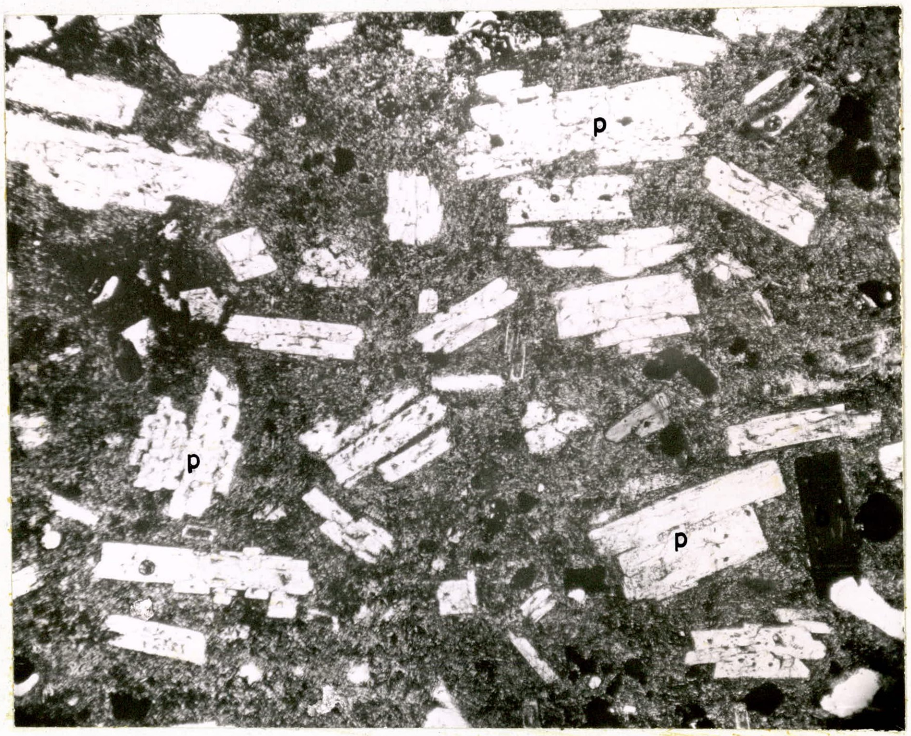

Figure 25. PRC-53-21, 27x, ordinary light. Photomicrograph of porphyritic-aphanitic biotite andesite dike-rock probably associated with Paris Creek intrusion. Light, euhedral grains are plagioclase (p) (An 60) crystals. Darker grains are oxidized biotite (b). Groundmass plagioclase is randomly oriented and iron stained. Sub-parallel orientation of phenocrysts parallels trend of dike.

intrude the lower member of the lower andesite. These rocks are mineralogically similar and appear to be spatially and genetically related. Therefore, they will be discussed together.

All these intrusions are gray to brown, biotite andesites. They are merocrystalline to porphyritic-aphanitic rocks displaying hyalopilitic to pilotaxitic textures. They are locally flow-layered (fig. 26). Autoclastic monolithic breccias along the lower slopes of these intrusions grade upward into massive sheeted rocks of the same composition with good flow structure. Phenocrysts, 1 to 2 millimeters in diameter, make up 50 percent of the rock and are mostly rounded and fragmented plagioclase grains averaging An 54. About 2 to 3 percent euhedral augite and 5 percent biotite with oxidized rims makes up the rest of the phenocrysts. The groundmass is locally vuggy and consists of microlites of plagioclase and biotite arranged in subparallel fashion in volcanic glass. Flow bands are prominent (see figure 26). The groundmass is mostly devitrified and strongly stained with iron. Zeolites are not uncommon in some vugs.

All these intrusions are topographically high and display steep foliation and sheeting. The intrusion in the southeast quadrant of section 11, T. 14 S., R. 74 W., contains a black vitrophyre zone 10 feet wide which appears to

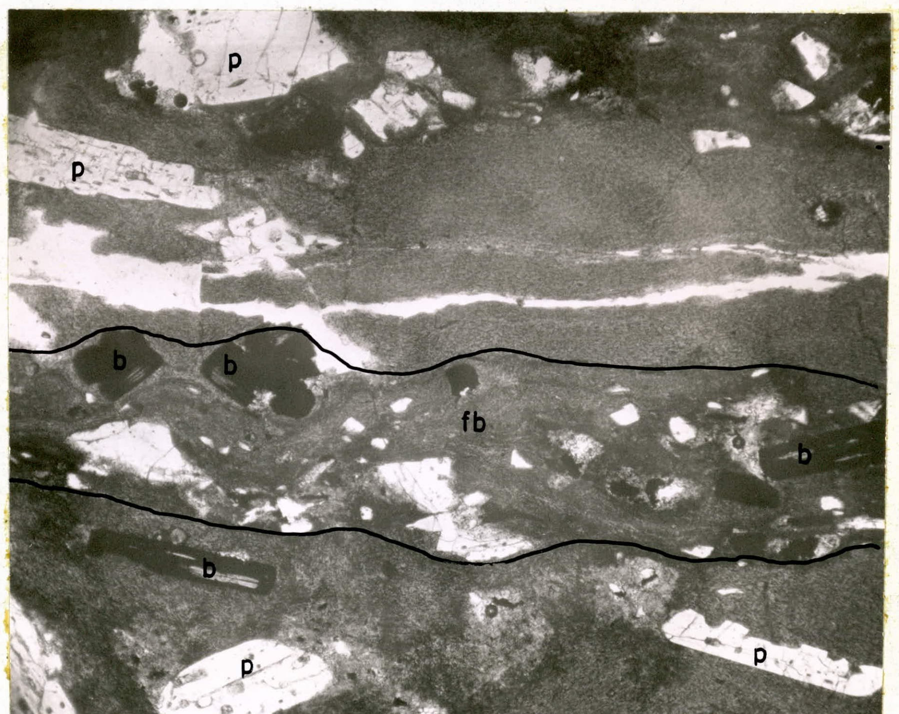

Figure 26. PRC-53-23, 27x, ordinary light. Photomicrograph of the Currant Creek andesite. Fragmented and rounded plagioclase phenocrysts (p) (An 54) are arranged in subparallel fashion in a glassy groundmass. Note smaller fragmented plagioclase grains in flow banded zone (fb) traversing middle third of photo. Darker grains are biotite crystals (b) with oxidized rims.

be locally derived.

The elongate intrusion in east-central section 15, T. 14 S., R. 74 W. is dike-like and projects northward toward the outcrop of prevolcanic sediments exposed along the down-thrown side of the projected Mill Gulch fault of Buchanan (1967). It was probably emplaced during movement along this fault.

The Currant Creek andesites are younger than the lower member of the lower andesite, but were probably later buried by the upper member of the lower andesite.

Lower Andesite, Upper Member

The youngest volcanic unit of the area (but not of the field) consists of the well-stratified basalt flows and associated breccias of the upper member of the lower andesite. This unit attains a maximum thickness of 400 feet west of Dicks Peak (pl. 1, sec. 28, T. 14 S., R. 74 W.). Here, and in adjacent outcrops of this unit, basic flows dip westerly from 5 to 7 degrees. These flows and their associated breccias represent erosional remnants of the flanks of a large composite volcano (the Guffey volcano) which was constructed on the top of the laharic breccia sheet of the lower member of the lower andesite (Epis and Chapin, 1968).

The upper member consists of alternating well-stratified gray to black basalt flows and breccias. The rock is porphyritic-aphanitic, intergranular to pilotaxitic (figs. 27-30). One half of the phenocrysts are subhedral plagioclase (An 70). The rest of the phenocrysts are subhedral to euhedral augite and olivine, olivine usually being less abundant. Phenocrysts range in size from .2 to 4 millimeters and make up 15 to 30 percent of the rock. A trace of biotite is present.

The groundmass is composed of microlites of plagioclase enclosing microcrystalline augite and magnetite. Magnetite is present in amounts up to 10 percent of the rock. Sericitization of plagioclase both in the groundmass and in phenocrysts is common. Spherulitic secondary minerals, probably cristobalite/tridymite and zeolites have formed locally in the groundmass.

The exogenous intrusives of the thesis area (the Dicks Peak andesite, the Hammond Peak diorite and the Paris Creek and Currant Creek andesites) are all probably older than the upper member of the lower andesite since they have all intruded an incomplete veneer of the lower member of the lower andesite. If this is the case, they were most likely completely buried by the upper member. Projected dips of the upper member justify this, depending on differential erosion of these proposed buried intrusives. Chapin (1965) recorded a potassium-argon age determination of 34.1 (±1.1) million years from a flow of the upper member of the lower andesite on Thirtynine Mile Mountain. Therefore these

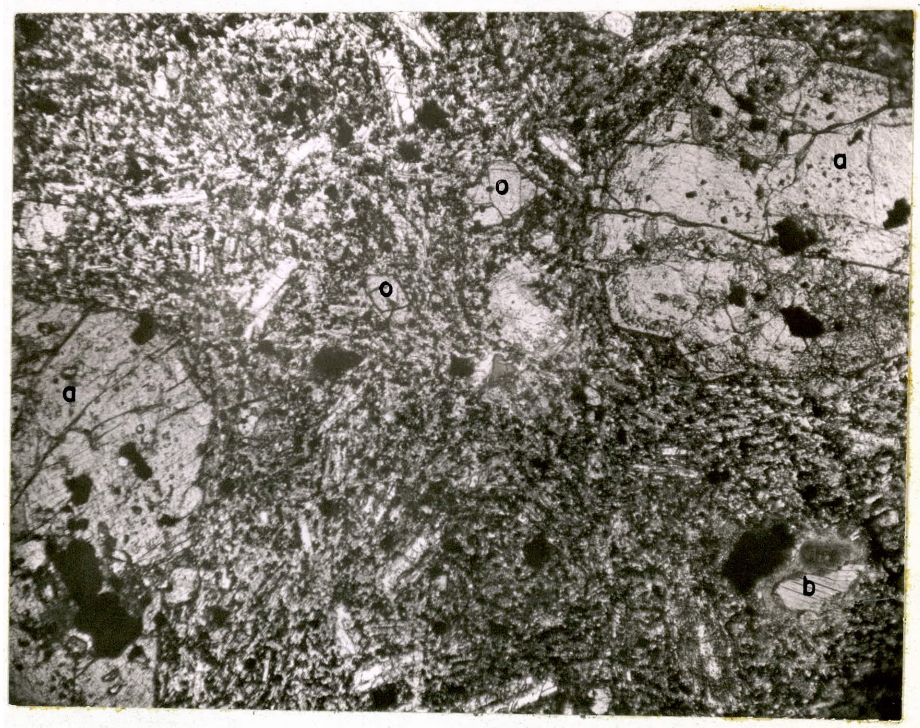

Figure 27. PRC-53-24, 27x, ordinary light. Photomicrograph of olivine augite basalt of the upper member of the lower andesite. Large zoned euhedral augite grains (a) and smaller subhedral olivine crystals (o) are set in an intergranular to subophitic groundmass of plagioclase and pyroxene. Opaque grains are magnetite. Biotite fragment (b) appears in lower right-hand corner.

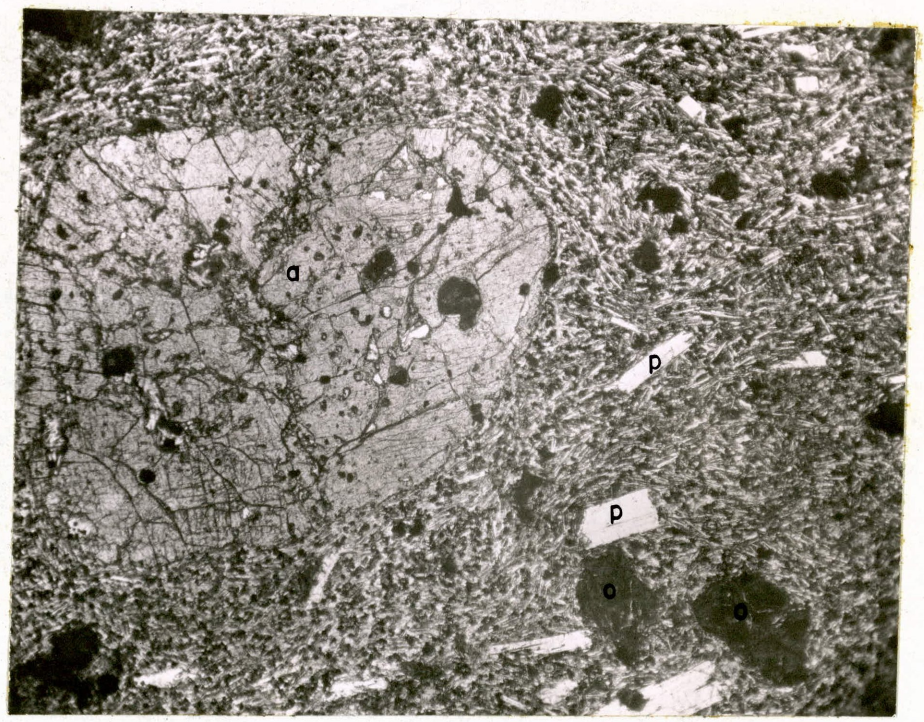

Figure 28. PRC-53-25, 27x, ordinary light. Photomicrograph of olivine augite basalt flow within the upper member of the lower andesite. Large augite crystal (a) with poikilitic magnetite and olivine is set in a pilotaxitic groundmass of plagioclase (p) (An 70) with interstitial augite and magnetite specks. Dark grains in lower right-hand corner are serpentinized euhedral olivine crystals (o).

Figure 29. PRC-53-24, 27x, ordinary light. Photomicrograph of same olivine augite basalt flow as figure 27. Note large olivine grains (o) set in seriticized groundmass.

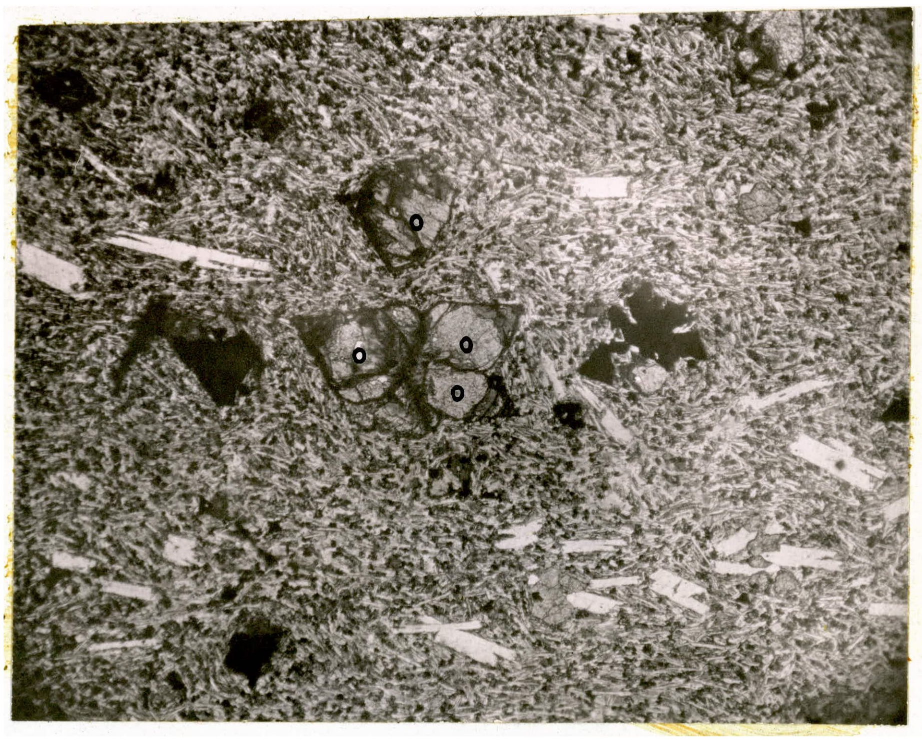

Figure 30. PRC-53-25, 27x, ordinary light. Photomicrograph of same olivine augite basalt flow as figure 28. Note serpentinized euhedral olivine grains (o). Small equant grains between plagioclase microlites in groundmass are augite.

intrusives are probably of early Oligocene age.

Quaternary

Stream-deposited, loosely consolidated, alluvial sediments are confined to modern drainages and represent the youngest unit mapped in the area. The alluvium consists of poorly sorted silt, sand, and gravel containing fragments of all rock types in the area.

STRUCTURAL GEOLOGY

Regional Structure

Much of the following description of the regional structural setting of the Thirtynine Mile volcanic field has been documented in earlier efforts by Epis and Chapin (1964, 1968).

The Thirtynine Mile volcanic field lies within a regional belt of north-northwest-trending intermontane structural basins extending from North Park to the Raton basin (Epis and Chapin, 1968). These basins were part of a major trough which formed between the Front Range - Wet Mountains on the east, and the Mosquito - Sawatch Ranges on the west. The structural features along this trough formed during Precambrian, late Paleozoic, and Laramide time (Burbank, 1933). Laramide tectonics formed a series of open folds within this trough. With increasing compression, thrust and reverse faults developed. To the north, the Williams Range Thrust and the Elkhorn Thrust developed along with several other minor faults (fig. 31). To the south the major thrusts include the Wet Mountain and Parkdale Thrusts. The thrusts to the north dip easterly, while those to the south dip westerly. Within the volcanic field most faults are near vertical (DuHamel, 1968).

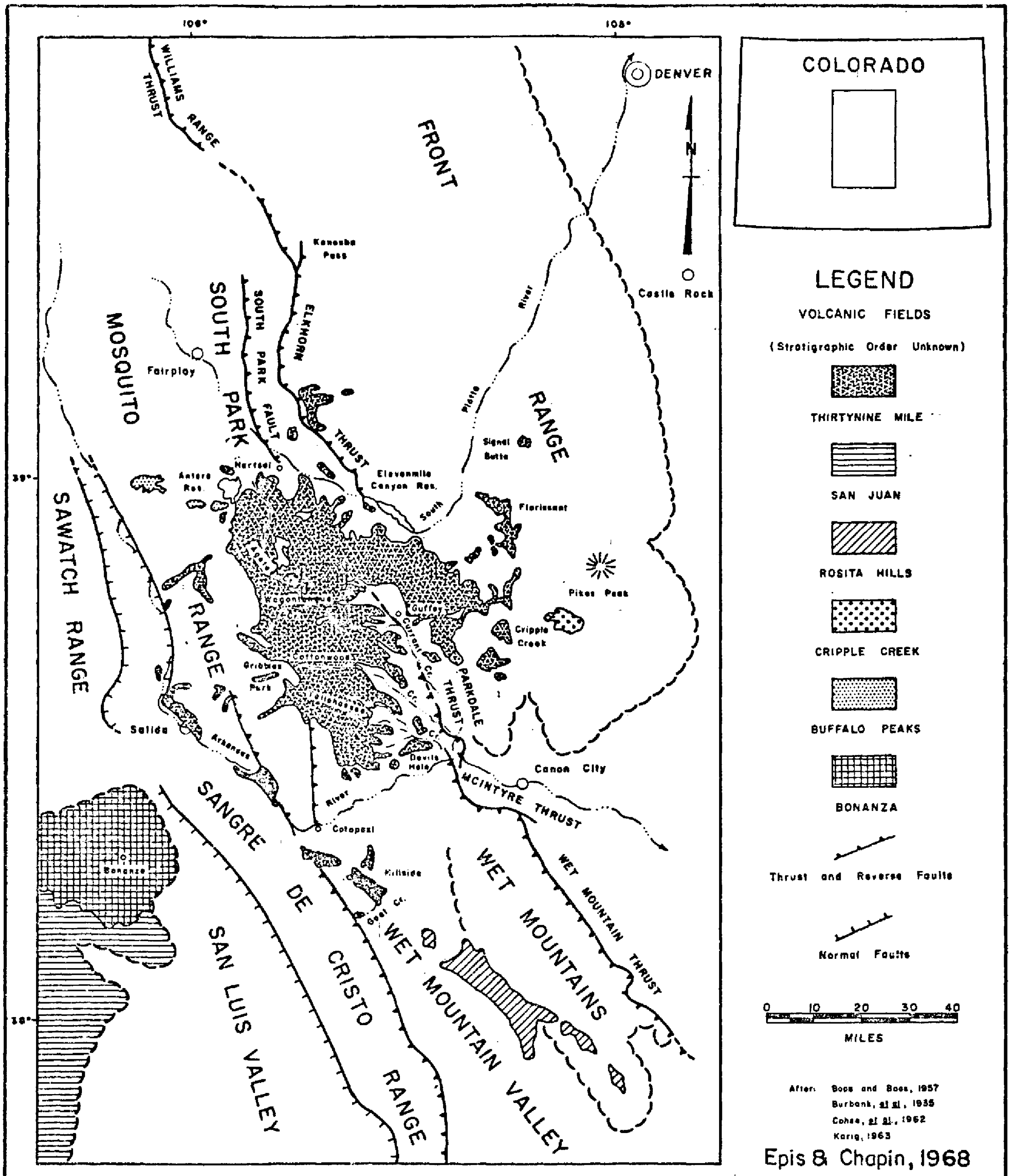

Figure 31, REGIONAL SETTING OF THE THIRTYNINE MILE VOLCANIC FIELD

The Thirtynine Mile volcanic field thus occupies a positive hinge area between oppositely dipping thrusts. Crustal tension would develop in such a region. Conditions of tension are extremely favorable for the generation and rise of magma.

Local Structure

Faults

The Mill Gulch Fault and the Ring Fault of the caldera of the Guffey volcano are the only recognizable faults in the thesis area. Faults elsewhere in the area are difficult to trace through the chaotic bedding in the breccias of the lower member of the lower andesite. Inliers of Paleozoic and Mesozoic rocks are preserved along the downthrown side of the Mill Gulch Fault in section 10, T. 14 S., R. 74 W., and along minor faults where the Dakota Sandstone is in contact with Precambrian rocks along Thirtyone Mile Creek. The ring fault of the caldera of the Guffey volcano is, for the most part, covered by later ring domes (Paris Creek andesite and Hammond Peak diorite) which were intruded during or slightly after movement along the fault.

Mill Gulch Fault

Buchanan (1967) mapped the north-northwest trend of this fault a few miles east of the thesis area. DuHamel

(1968) mapped the southern extension of this same fault. In the thesis area, Buchanan originally projected the fault trace northward along the boundary between the lower andesite and Precambrian rocks. The trace north of Sheep Gulch remains obscure as it is covered by the lower member of the lower andesite. Continued northward, however, the trace follows the trend of the elongate Currant Creek andesite intrusion (sec. 15, T. 14 S., R. 74 W.). The fault is exposed in sec. 10, T. 14 S., R. 74 W. Here, silicified Pennsylvanian, Permian, and Jurassic sediments are downdropped and dip steeply toward the east off upthrown Precambrian rocks (fig. 5). The fault trace north of here is covered by the lower andesite.

The fault exhibits pre-volcanic and post-volcanic displacements; differential movement probably has taken place several times since the Precambrian.

Ring Fault of the Guffey Caldera

Buchanan (1967) mapped part of the proposed ring fault zone of the Guffey caldera through the Paris Creek and Dicks Creek intrusions and associated flows. The existence of a caldera seems certain (see Epis and Chapin, 1968); however, the exact location of the proposed ring fault is difficult to ascertain because the volcanics have been so deeply dissected. The amount of demonstrable subsidence is small and the caldera might better be classified, according to

Williams (1941), as an erosion caldera (Epis and Chapin, 1968), (see figure 4).

Because the domal intrusives through which the proposed ring fault passes are spatially situated much like ring domes (Epis and Chapin, 1968), the configuration of Buchanan's ring fault has been retained on the geologic map. It appears that the domes were intruded along the ring fault during or shortly after movement. The amount of demonstrable displacement of ash flows -1 and -2 in the thesis area is in excess of 200 feet.

MINERALIZATION AND ALTERATION

No rocks in the area appear to be mineralized significantly. Several small prospect pits were encountered but apparently possessed nothing of economic potential. No record of any mines in the thesis area exists.

Channel sands of the Cottonwood Creek Formation host both oxidized and unoxidized uranium ore in the Tallahassee Creek area to the south (Chapin, 1965).

Only in the volcanic rocks was alteration observed, and this is mostly of magmatic or deuteric origin. Intrusive and extrusive andesitic rocks exhibit partial to complete oxidation of virtually all mafic minerals. Resorption of biotite and hornblende phenocrysts is also common in these rocks. Zeolite growth in the more mafic rocks has taken place to a minor degree. Plagioclase crystals in almost all units are at least partially seriticized and/or kaolinized.

Local silicified zones border Precambrian-sediment contacts. Chalcedony has formed in small localized pockets in both members of the lower andesite.

GEOLOGIC HISTORY

The geologic history of the thesis area reflects only part of the history of the volcanic field as a whole, since only a portion of the column of Thirtynine Mile volcanic rocks are present.

The pre-volcanic history of the area involves continental and marine sedimentation during the Pennsylvanian, Permian, Jurassic and Cretaceous alternating with erosion. Early influence of the north-northwest-trending structural elements has recurred intermittently from the Precambrian through the Laramide.

During and after the uplift of the Laramide orogeny, great thicknesses of sediments were stripped away from the area. Only isolated inliers, usually fault bounded, attest to their earlier existence (sec. 10, T. 14 S., R. 74 W., and along Thirtyone Mile Creek).

Precambrian rocks were planed to a moderately low-relief erosion surface extending from the foot of Kenosha Pass southward to the Wet Mountain Valley (Epis and Chapin, 1968). The surface sloped gently to the south. Arkosic channel deposits of the Cottonwood Creek Formation filled local valleys which drained the erosion surface. Inliers of this unit occur along Thirtyone Mile Creek and on the upthrown block of the Mill Gulch Fault.

Volcanic rocks were first deposited in the thesis area during late Eocene. They include ash flows -1 and -2, which spread out laterally over much of the erosion surface, locally filling valleys. Erosive activity stripped away most of the ash flow unit, leaving only irregular, isolated patches usually confined to stream valleys.

Eruptions, probably from small, randomly scattered vents and fissures throughout the area, began to deposit fragmental andesitic to basaltic laharic and flow breccias and small discontinuous basalt flows of the lower member of the lower andesite. As these vents grew, a thick sheet of breccia, predominantly volcanic mudflows, coalesced and spread out over the entire area. Deposition of the breccias must have taken place for a considerable length of time.

The Dicks Peak andesite was intruded in the central part of the area during deposition of the lower member of the lower andesite and may have contributed some breccia to it.

Following the intrusion of the Dicks Peak andesite during the early Oligocene, several biotite andesites and coarser rocks intruded into and extruded onto the southeastern and northeastern parts of the area. Associated dikes cut Dicks Peak rocks. They may have been emplaced during or after movement along the Mill Gulch fault as the western block was upthrown. Included in this suite of ring-dome-like and other intrusions are the Paris Creek, Hammond Peak, and Currant Creek rocks. They may have been intruded during and immediately following subsidence of the Guffey caldera to the southeast.

The Guffey volcano was built up during early Oligocene, probably by large dike and vent feeders, and the resulting well-stratified, basaltic and andesitic flows and breccias of the upper member of the lower andesite probably covered all other rocks of the area. Dips on this unit project upward toward the southeast.

During late Tertiary and Quaternary time, the rocks of the area have been deeply dissected, especially along pre-existing north-northwest trending faults. Post-volcanic sedimentary rocks may have been deposited in the thesis area, but erosive activity has removed all evidence of their earlier existence.

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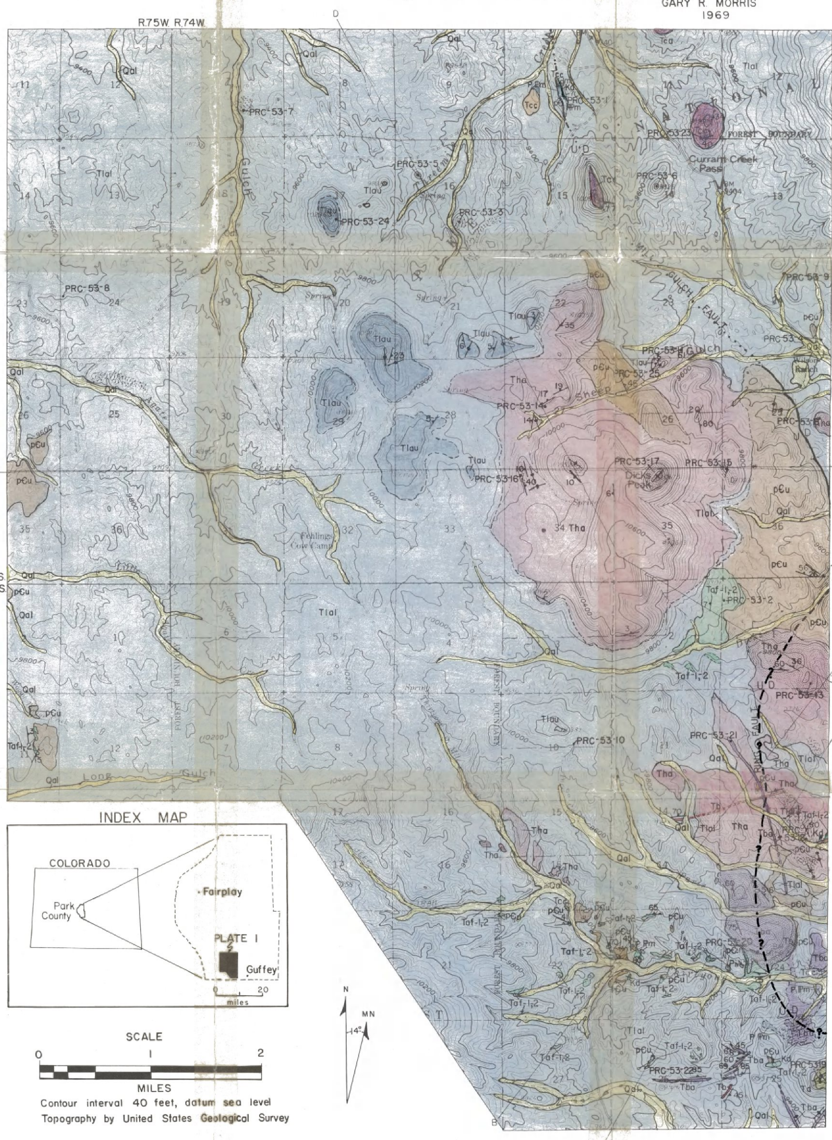
PLATE I

T1231

GEOLOGIC MAP AND CROSS SECTIONS, DICKS PEAK AREA, PARK COUNTY, COLORADO

GARY R. MORRIS
1969



SCALE

0 1 2

MILES

Contour interval 40 feet, datum sea level

Topography by United States Geological Survey

EXPLANATION

QUARTERNARY

- Qal — ALLUVIUM: poorly sorted, stream deposited, sand, silt, and gravel

TERTIARY (OLIGOCENE – EOCENE)

- Tlau — LOWER ANDESITE (upper member): reddish brown to purple, flow breccias and basalt flows and dikes (Tb)
- Tca — CURRANT CREEK ANDESITE: purple to brown, biotite andesite plugs
- Tba — PARIS CREEK ANDESITE: gray, biotite andesite flows and exogenous dome
- Td — HAMMOND PEAK DIORITE: gray to buff, pyroxene diorite plug
- Tha — DICKS PEAK ANDESITE: gray to purple, biotite, hornblende andesite flows and exogenous domes
- Tlal — LOWER ANDESITE (lower member): chaotically stratified, purple to brown, laharic and flow breccias and discontinuous basalt flows
- Taf-1,2 — ASH FLOWS-1,2: reddish brown to purple, moderately welded, biotite trachyte ash flow tuff
- Tcc — COTTONWOOD CREEK FORMATION: poorly consolidated, brownish red conglomerates, siltstones, and mudstones

CRETACEOUS

- Kd — DAKOTA FORMATION: buff, quartz sandstone

JURASSIC

- Jm — MORRISON FORMATION: buff, quartz sandstones and variegated shales

PERMIAN–PENNSYLVANIAN

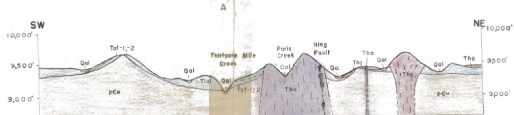
- P Pm — MAROON FORMATION: consolidated arkosic conglomerate

PRECAMBRIAN

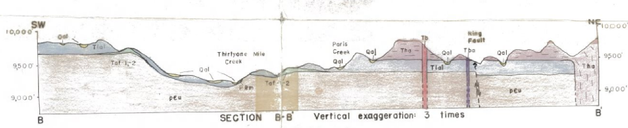
- pCu — PRECAMBRIAN ROCKS (undivided): granite, gneiss, schist, and quartzite

SYMBOLS

- Geologic contacts, dashed where approximately located, dotted where covered
- U/D High angle fault, dashed where approximately located, dotted where covered
- ·PRC-53-12 Sample location - permanent rock collection
- Flow structure (volcanics)
- Foliation (Precambrian rocks)
- Bedding
- Joints
- Intrusive center
- Alteration zone
- Unconformity



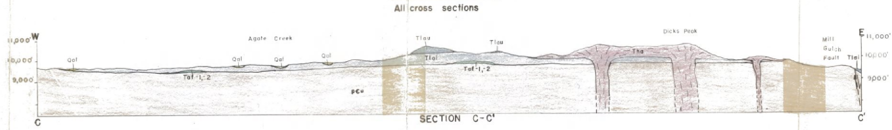
SECTION A-A' Vertical exaggeration: 3 times



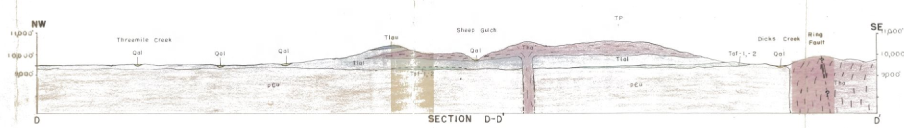
SECTION B-B' Vertical exaggeration: 3 times

Horizontal scale 0 1 mile

All cross sections



SECTION C-C'



SECTION D-D'