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GEOLOGY OF THE SARGENTS AREA, GUNNISON AND SAGUACHE COUNTIES, COLORADO

By

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ABSTRACT

The Sargents area is on the western flank of the southern-most part of the Sawatch Range in Colorado. Rocks of the area consist of quartz monzonite which intricately intrudes a Precambrian metamorphic complex. Jurassic and Cretaceous sedimentary rocks and Tertiary volcanic and sedimentary rocks unconformably overlie these Precambrian rocks. The Mesozoic rocks consist of the Morrison Formation, the Dakota Group, and the Mancos Shale, which are in part overturned or near vertical. Where exposed, these sedimentary rocks mostly are in fault contact with the Precambrian rocks. Tertiary rocks consist of lava flows, tuffs, and boulder beds filling a paleodrainage system.

Faulting is the most significant structural element. The oldest faulting is a pre-Laramide, east-west vertical fault system which appears to cross the Sawatch Range. The Crookton Fault on the western edge of the area is a high-angle reverse fault of Laramide age. The youngest faulting in the area is a north-south system of normal faults that formed a zone of weakness in which a paleodrainage system developed. This north-south fault system was active before the volcanic rocks entered the area and movement on these faults continued up to Holocene time.

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INTRODUCTION

The structural features and stratigraphy of about 31 square miles in the northern part of the Sargents quadrangle and the eastern part of the Doyleville quadrangle were studied to gain a better understanding of the geology of the northern part of the Bonanza volcanic field. The utility of color and color infrared photography in studying the geology of a heavily forested area was also evaluated.

The area is on the western slope of the Sawatch Range, north of Sargents, Colorado. The area (fig. 1) is reached by an unpaved road that leads north from U. S. Highway 50, and which connects with an east-west unpaved road crossing the northern end of the area. Access is generally poor.

Elevation in the area ranges from 8,200 feet to 10,845 feet, with relief of 2,645 feet. This elevation range is within the Montane vegetation life zone. Local precipitation is 15 inches per year, and the mean annual temperature is 30^{o}F. Due to the local weather and altitude, the area is heavily forested. Thick soils have developed, resulting in poor bedrock exposure. The amount of exposed bedrock is estimated at 15 percent; south-facing slopes have the best exposures.

The area was mapped previously at reconnaissance scale (Stose, 1935). Adjacent areas were mapped in detail at a

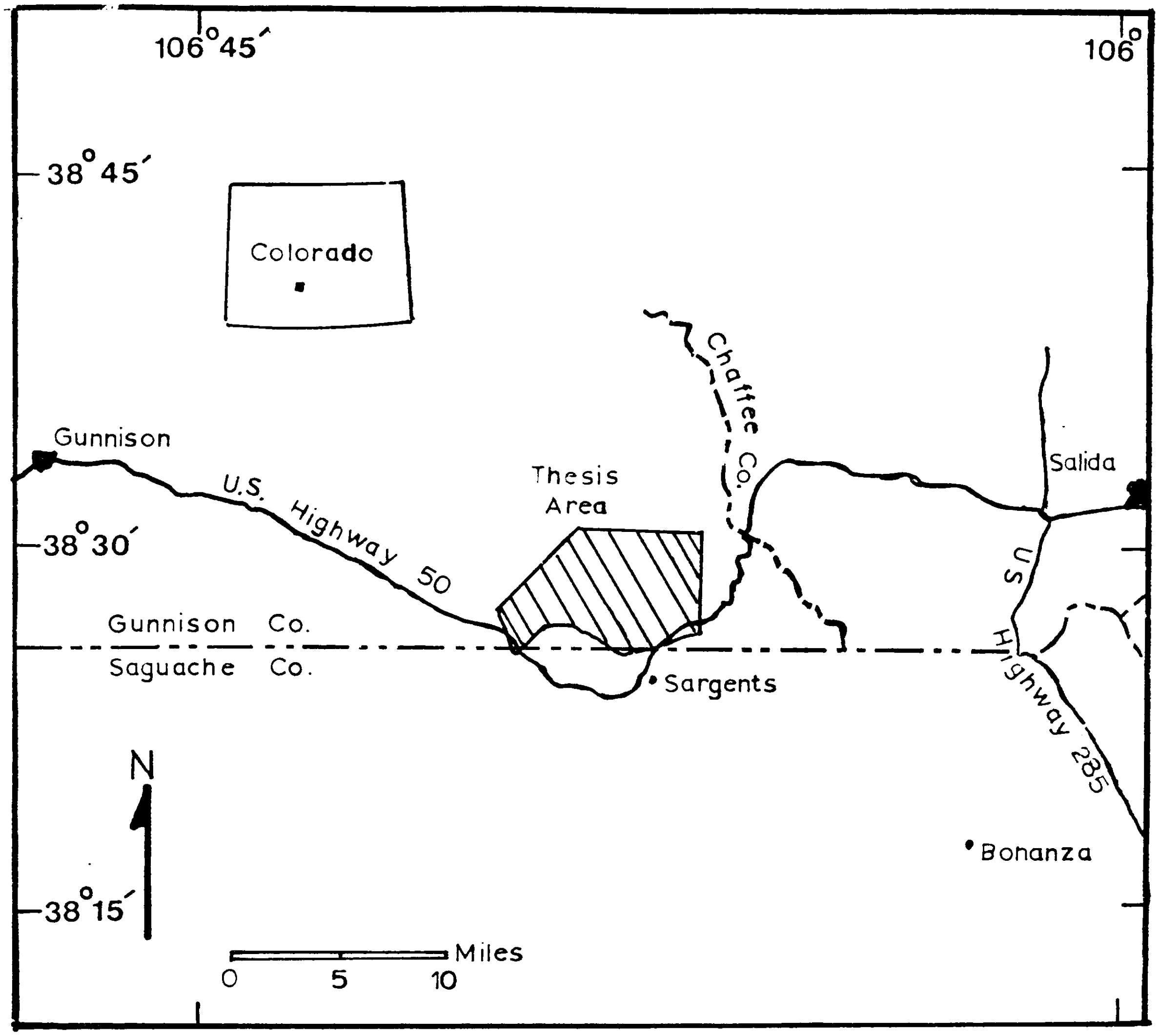


Figure 1: Index map. Cross-hatched area is the subject of this report.

scale of 1:78,125 (Stark and Behre, 1936) and a scale of 1:31,680 (Dings and Robinson, 1957). These workers investigated the Precambrian granitic and metamorphic rocks and the Jurassic and Cretaceous sedimentary rocks, but did not study the volcanic rocks. Other work not specifically cited in this report is listed in Appendix A.

The assistance and interest of the members of my committee, Drs. R. G. Reeves, R. J. Weimer, L. T. Grose, R. C. Epis, and K. Lee and the personnel of the Bonanza Project are gratefully acknowledged. I was supported while doing this research by a Bonanza Project Research Assistantship (NASA Grant NGL-06-001-015). I also would like to thank my wife for her patient assistance and the George Means family of the Sargents area, who provided assistance and information about mining and accessibility in the area.

DESCRIPTIVE GEOLOGY

The rocks of the Sargents area are Precambrian metamorphic and igneous rocks, Mesozoic sedimentary rocks, Tertiary volcanic and sedimentary rocks, Tertiary-Quaternary (?) sedimentary rocks and Quaternary alluvium.

Precambrian Rocks

The Precambrian basement complex of the Sargents area consists of two lithologic units: metamorphic rocks and quartz monzonite.

Metamorphic Rocks--The metamorphic rocks are the oldest rocks in the Sargents area. They were complexly folded prior to and during intrusion by the quartz monzonite. The best exposures of these rocks are in road cuts along U. S. Highway 50, just south of the mapped area (fig. 2). Where the metamorphic rocks predominate, but the intrusive rocks are complexly interfingering, these metamorphic and intrusive rocks are mapped as Precambrian undivided. These rocks were not differentiated due to the lack of exposures and time limitations; the primary objective was to study the volcanic rocks.

The metamorphic rocks are predominately quartz-biotite gneiss. However, garnetiferous metaquartzites and marble were also observed within the Precambrian complex. Intense deformation associated with metamorphism and intrusion

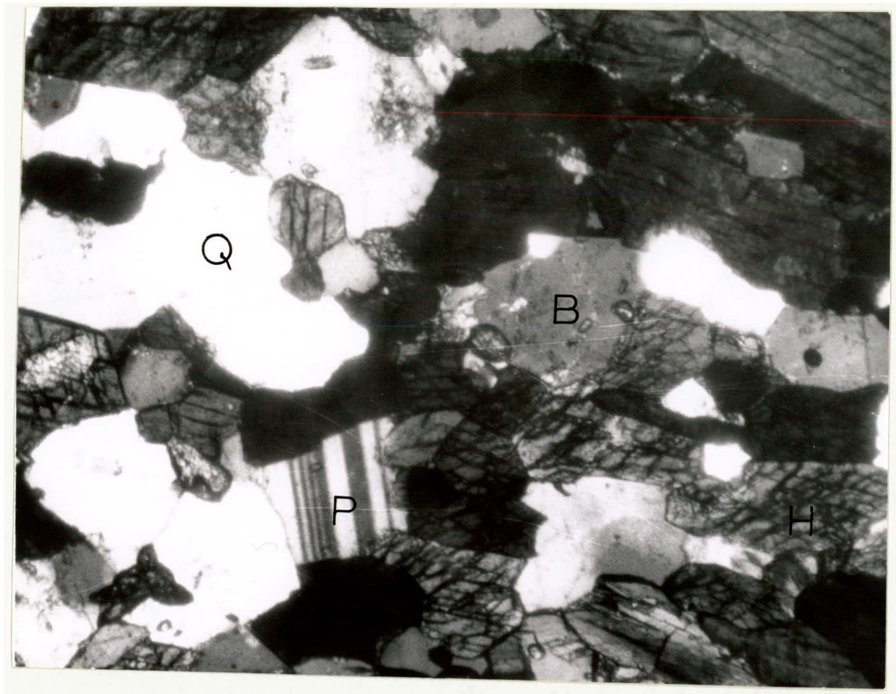
Figure 2: Outcrop of the quartz-biotite gneiss in sec. 23, T.48N., R.4E., showing the typical gneissic banding.

produced complex relationships and gradations between the various metamorphic rocks and between metamorphic rocks and quartz monzonite. Iron and lead were introduced into the contact areas between gneiss and quartz monzonite and into marble in the form of disseminated sulfides.

Quartz-biotite gneiss also occurs as large, irregular inclusions in the quartz monzonite. Only the largest mass of gniess has been mapped; however, masses too small to map occur throughout the area. The best exposure of a gneiss inclusion occurs on the Quakey Mountain Trail near Black Sage Pass in sec. 30, T.49N., R.5E. Adjacent to the gneiss, the quartz monzonite is generally pegmatitic and extensively and intricately intrudes the gneiss.

In hand specimen the quartz-biotite gneiss has a salt-and-pepper appearance, is moderately foliated, and sometimes contains quartz and microcline seams concordant with foliation. The rock is fine-grained and equigranular. The major constituents consist of biotite (50 percent), quartz (45 percent), plagioclase (5 percent), orthoclase (trace), and variable amounts of hornblende (fig. 3). When the hornblende content increases the biotite content decreases. This composition suggests a sedimentary origin for the gneiss.

<u>Quartz Monzonite</u>--The quartz monzonite underlies nearly 75 percent of the total area. The quartz monzonite has been called Silver Plume (?) granite by Dings and Robinson (1957) and was dated 1,650 m. y. ± 35 m. y. by Wetherill and Bickford (1965). The quartz monzonite in the Sargents



0.3 mm

Figure 3: Photomicrograph of the quartz-biotite gneiss. The minerals are quartz (Q), plagioclase (P), biotite (B), and hornblende (H).

area consists of four distinct facies. These facies are a biotite quartz monzonite facies, which is the most widespread; an alkali feldspar porphyry facies; a foliated biotite, alkali feldspar facies; and a biotite granodiorite facies. The best exposures of these facies occur on Black Sage Pass where the biotite quartz monzonite facies is exposed and on Old Monarch Pass Road where all of the facies are exposed.

The biotite quartz monzonite facies (fig. 4) is a highly jointed, medium-grained, pink rock which has a granitic texture. This facies generally is extensively weathered and jointed so that grus is very common. On weathered surfaces the rock is light tan and feldspars stand out in relief. Xenoliths of quartz-biotite gneiss are locally abundant and are as large as 30 feet in diameter. Thin section examination shows the rock to contain 50 percent microcline, 35 percent plagioclase (oligoclase), 10-15 percent quartz, and a variable amount of biotite up to 5 percent (fig. 5). A few opaque grains, probably magnetite, were observed.

The granitic rocks in the Sargents quadrangle are characterized by rapid textural changes, from fine- to coarse-grained. The alkali feldspar porphyry and fine-grained, light-gray, biotite granodiorite facies occur throughout the mapped area. These two facies generally are intruded extensively by the biotite quartz monzonite facies;

Figure 4: Typical outcrop of the quartz monzonite located in sec. 21, T.49N., R.5E.

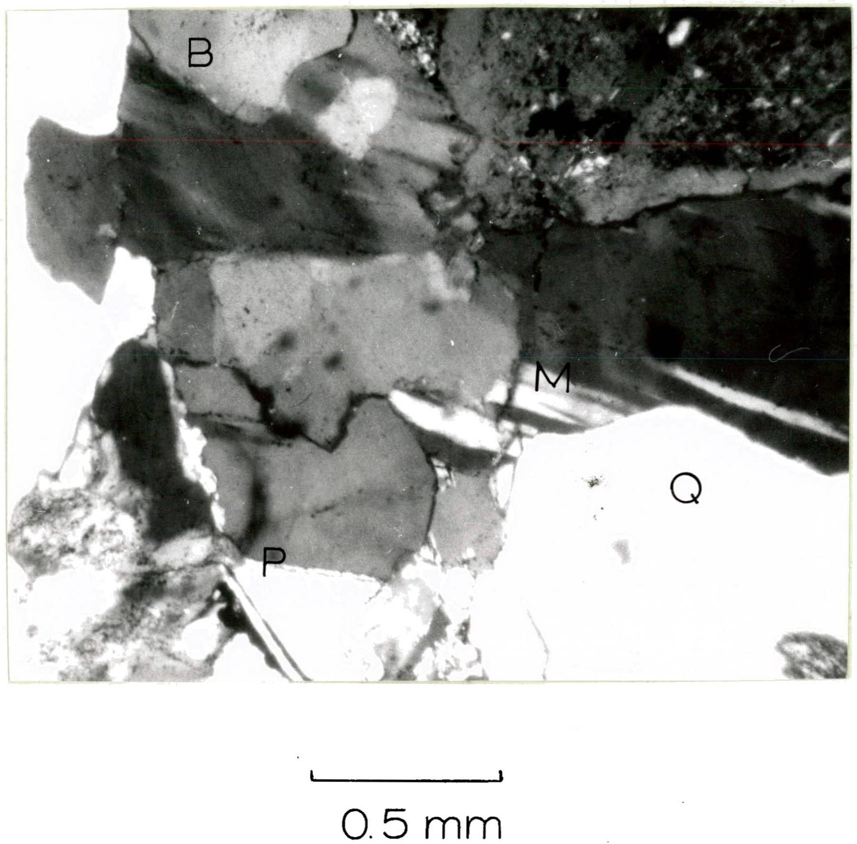


Figure 5: Photomicrograph of the quartz monzonite. The minerals are quartz (Q), plagioclase (P), microcline (M), and biotite (B).

they also appear to grade into the biotite quartz monzonite. The amount of biotite varies from a few percent to 50 percent. When the biotite content of the alkali feldspar porphyry facies is high, a distinct foliation occurs.

There are many similarities between the quartz monzonite of the Sargents area and the St. Kevin Granite of Tweto and Pearson (1964); the St. Kevin Granite originally was called Silver Plume (?) granite by Stark (1935) and later Behre (1953).

The St. Kevin Granite occurs in the northern part of the Sawatch Range, in the vicinity of the St. Kevin mining district northwest of Leadville (fig. 6). Tweto and Pearson (1964) made the following statements and conclusions about the batholithic mass of St. Kevin Granite:

> Where it has been mapped in detail, the batholith is characterized by extremely intricate borders...The only part of the batholith relatively free of "islands" and projecting fingers of gneiss is an area 3 or 5 miles in diameter near its center. ...Although many of the bodies of gneiss within the batholith are clearly xenoliths,...contacts between the granite and the metasedimentary gneisses are predominately concordant but in detail are discordant in many places...typically the contacts are gradational...the transition from granite to gneiss takes place in a broad pegmatitic zone.
>
> The St. Kevin Granite comprises many textural and compositional varieties of granite rocks. Four main facies (1) trachytoid hybrid, (2) normal, (3) granodioritic, and (4) fine grained...A fifth major facies is called Hell Gate Porphyry...
>
> ...contact relations and gradations between the various facies of the St. Kevin Granite suggest that all the facies are of the same general age...
>
> ...the batholith is a product of local melting, the granite is a unit genetically distinct from the Silver Plume Granite and its cognates in the Front Range, even though it is probably of the same general age.

EXPLANATION

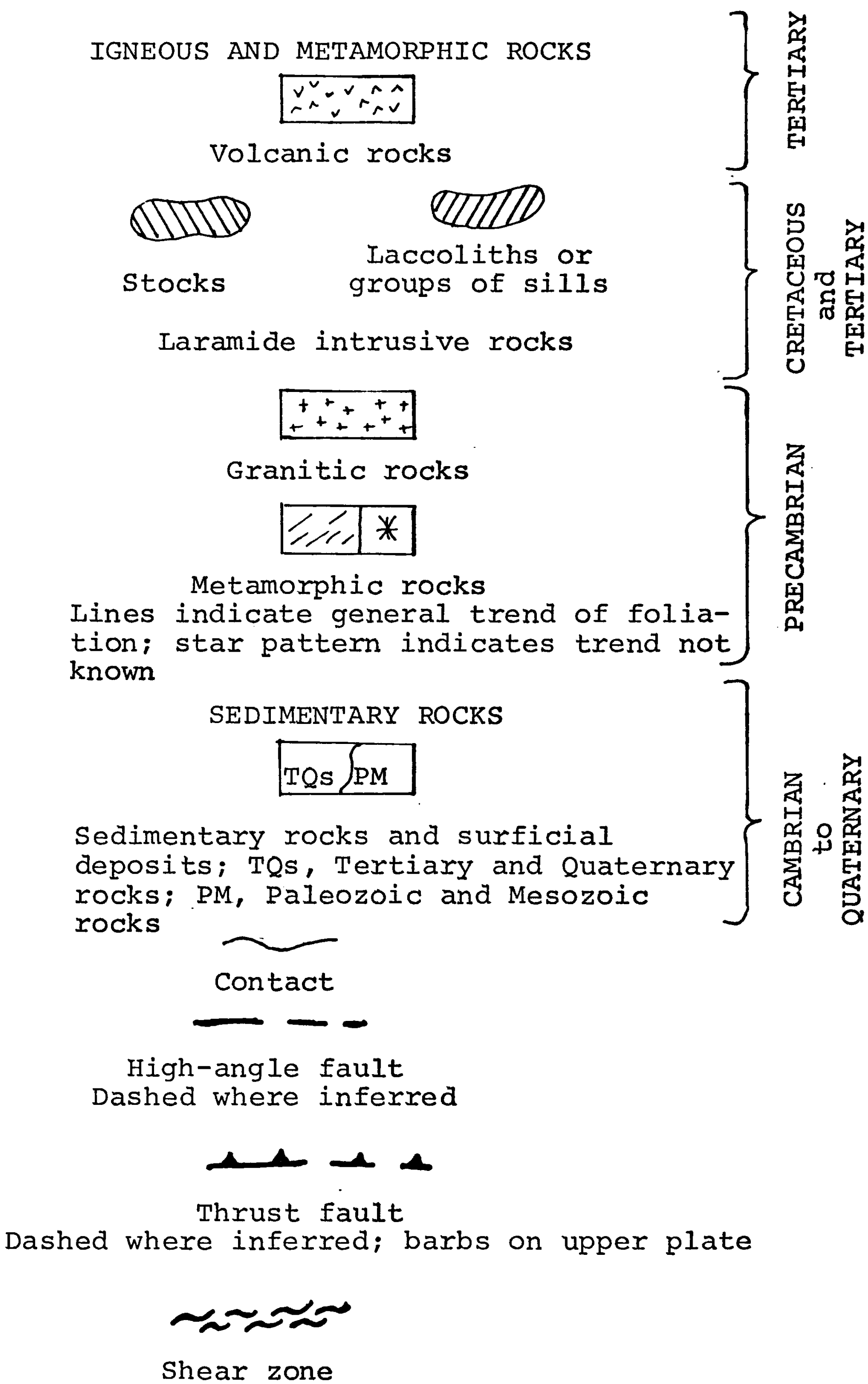


Figure 6a: Explanation of Figure 6b, showing geologic setting and the orientation of the Laramide faulting on the western flank of the Sawatch Range. After Stose (1935), Tweto and Sims (1963), Van Alstine (1968), and Raines.

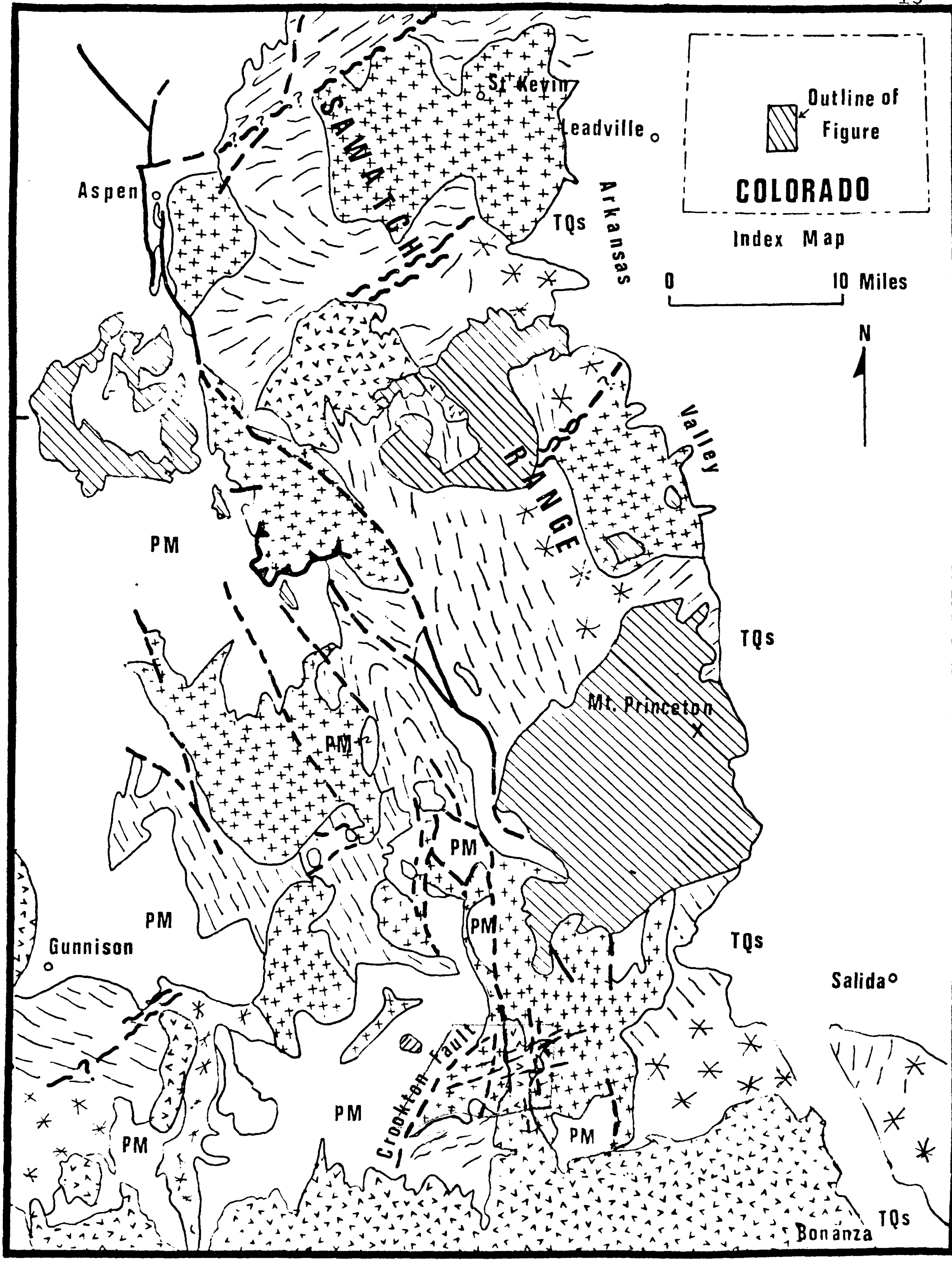


Figure 6b: Geologic sketch map of the Sawatch Range. Sargents area outlined in red.

Relationships and facies described above are similar to those of the Sargents area. These similarities, coupled with major spacial problems involved in relating the Silver Plume (?) granite of Dings and Robinson (1957) (the quartz monzonite of this paper) to the Silver Plume Granite of the Front Range, suggest that the quartz monzonite of the Sargents area may have an origin similar to that of the St. Kevin Granite. If this correlation with the St. Kevin Granite is correct, the quartz monzonite of the Sargents area is a product of local melting and is genetically distinct from the Silver Plume Granite of the Front Range. However, more work is needed to establish this suggested correlation.

Mesozoic Rocks

The Mesozoic rocks of the Sargents area include the Morrison Formation, the Dakota Group, and the Mancos Shale. The best exposures are at the southern end of Cat Rocks, sec. 2, T.48N., R.4E., where the Morrison and the Dakota are exposed, and in an old road cut north of the Double Heart Ranch, sec. 15, T.48N., R.4E., where the upper Dakota and lower Mancos are exposed. See Figure 7 for a photograph of this Mesozoic section.

Morrison Formation--The Morrison Formation of late Jurassic age is the oldest unmetamorphosed sedimentary rock in the area (Dings and Robinson, 1957). In most of the area, the Morrison Formation is overturned or vertical and

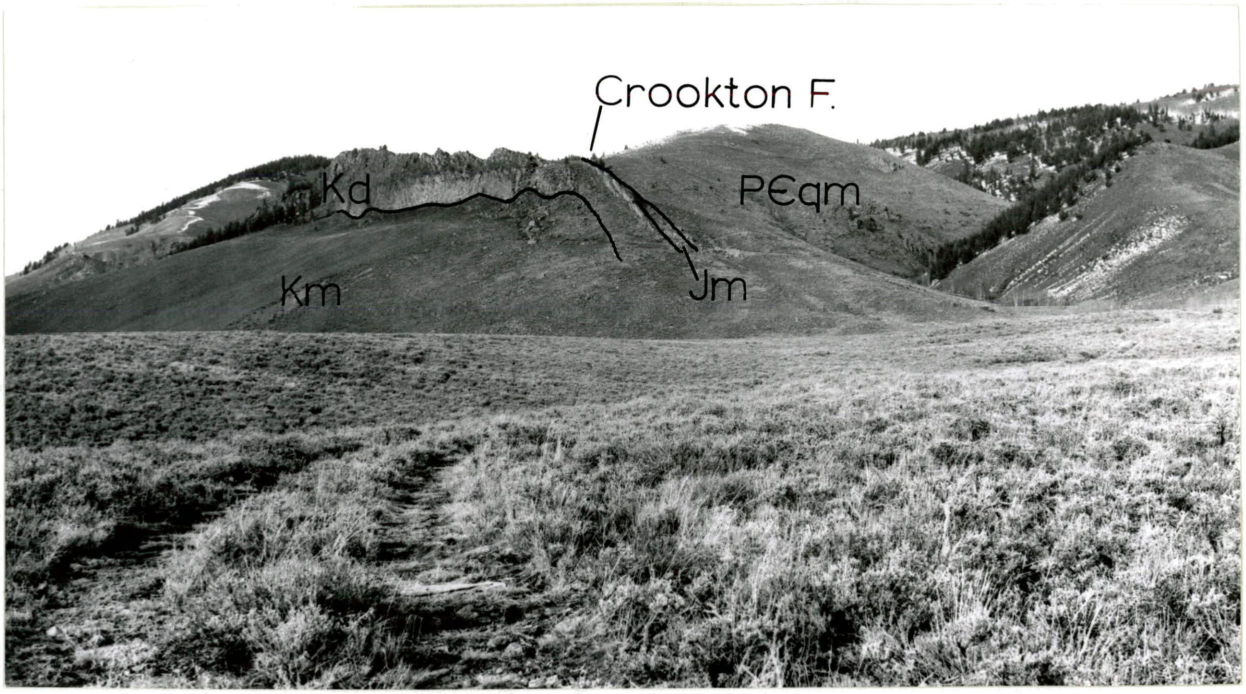


Figure 7: Outcrop of the Mesozoic section at Cat Rocks (sec. 2, T.48N., R.4E.). View to the northeast. The high-angle reverse Crookton Fault brings Mesozoic rocks on the left (west) against Precambrian rocks on the right (east). The units are quartz monzonite (PЄqm), Morrison Formation (Jm), Dakota Group (Kd), and Mancos Shale (Km).

in fault contact with the Precambrian; however, in the northwest part of the area it has a low westerly dip and is in nonconformable contact with the Precambrian. The maximum thickness is 400 feet with only the upper 135 feet exposed at the south end of Cat Rocks, sec. 2, T.48N., R.4E.

The Morrison Formation consists of purple, green, or brown calcareous shales. In the lowest part exposed, there are a few knobby thin-bedded limey mudstones. See Figure 8 for the details of the section.

Dakota Group--The Dakota Group of Cretaceous age conformably overlies the Morrison Formation (Dings and Robinson, 1957). The exposed Dakota is overturned or near vertical, except in the northwest part of the area where it has a low westerly dip, and at Cat Rocks where it conformably overlies the Morrison Formation. The maximum exposed thickness of about 150 feet occurs at Cat Rocks.

The Dakota Group was not subdivided during this mapping, although three lithologic units were observed. The sequence is a basal sandstone, a middle shale, and an upper sandstone. The sandstones are predominately tan, medium- to thick-bedded, well-sorted, fine- to medium-grained quartz sandstone. The quartz grains are subrounded. Cross-stratification and numerous trace fossils occur in the upper sandstone. The lower part of the basal sandstone of the Dakota Group is conglomeratic and conformable with the underlying Morrison Formation. The upper and lower sandstone are separated by

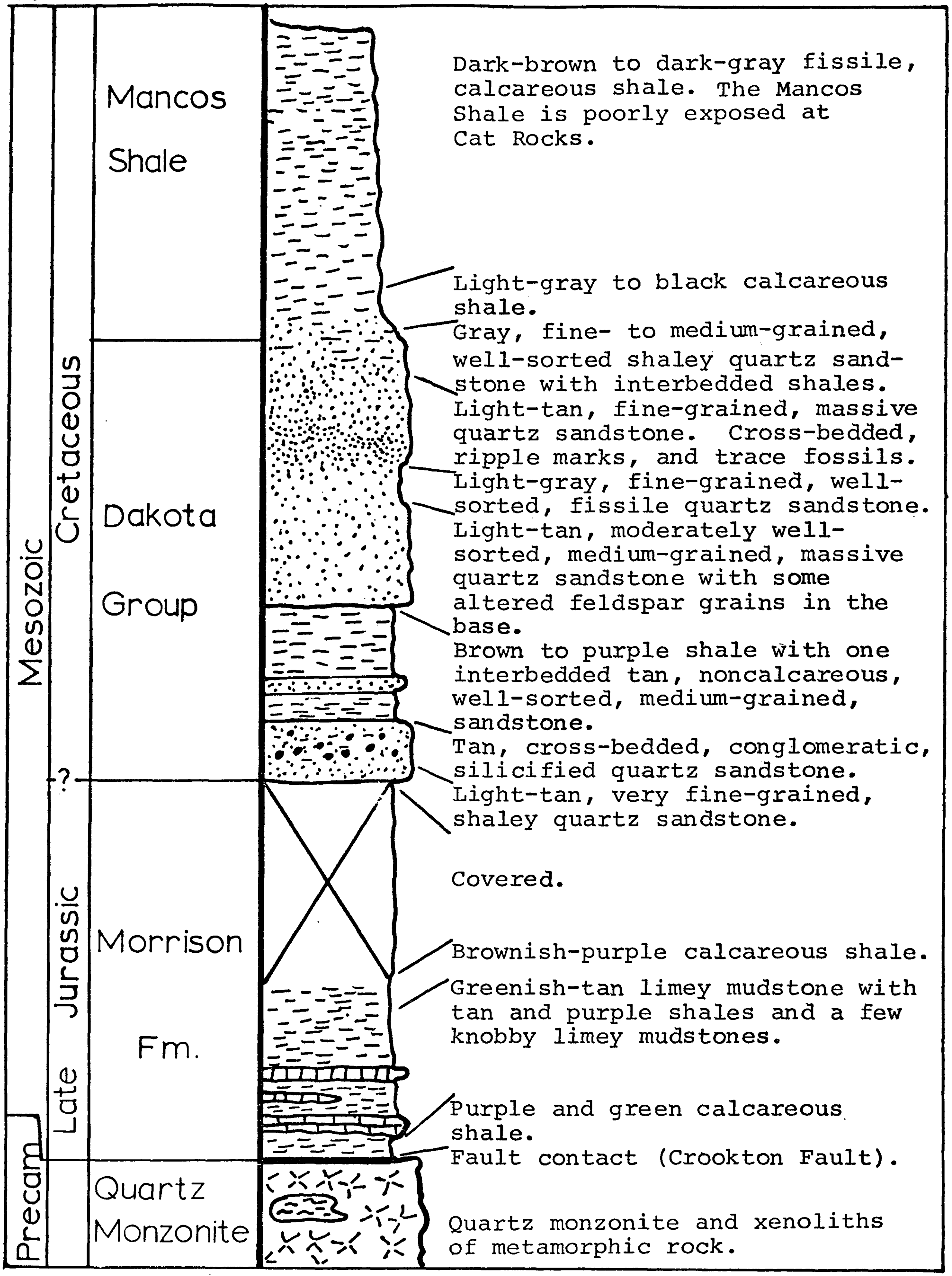


Figure 8: Mesozoic section measured at the south end of Cat Rocks (sec. 2, T.48N., R.4E.). Scale: one inch to fifty feet.

35 feet of brown to purple shale. The Dakota Group grades upward into the overlying Mancos Shale. See Figure 8 for details of the section.

Mancos Shale--The Mancos Shale of late Cretaceous age conformably and gradationally overlies the Dakota Group (Dings and Robinson, 1957). The Mancos Shale is at least 2,500 feet thick around Tomichi Dome (Stark and Behre, 1936). The top does not occur in the mapped area. The Mancos Shale has a low regional southeasterly dip that is reversed (dipping west) to overturned (dipping east) along the Crookton Fault.

The Mancos Shale is very poorly exposed in the mapped area. It is heavily covered with sagebrush, slumps are common, and soils are moderately well developed (fig. 7). The best exposures within the mapped area are at Cat Rocks (sec. 2, T.48N., R.4E.) and in an old road cut north of the Double Heart Ranch (sec. 15, T.48N., R.5E.). The base of the Mancos in these exposures is a light-gray to black, moderately well-consolidated, laminated, calcareous shale. It is overlain by a buff, poorly-consolidated, calcareous shale with lenses of more resistant shale and some gypsum flakes. This is overlain by a dark-brown to dark-gray fissile, calcareous shale which has cone-in-cone structures and contains interbedded layers of more resistant tan shale that are a few inches thick (fig. 8). An outcrop of a thin, dark-gray limestone with a sulfurous odor when broken was found in this latter part (sec. 19, T.49N., R.5E.). Stark and Behre (1936) reported finding small _Baculites_, _Inoceramus deformis_, and _Ostrea lugubris_ in the Sargents area.

Tertiary Rocks

Three lithologic units of probable Tertiary age are delineated. These units are, from oldest to youngest, Porphyry Creek Rhyolite, andesite lava flow, and water-laid tuff. The Porphyry Creek Rhyolite and the andesite lava flow are probably of early to mid-Tertiary age, but evidence in the Sargents area can only give a post-Mancos to late Tertiary age for them. Outliers of the Morrison Formation (sec. 20, T.49N., R.5E. and sec. 4, T.48N., R.5E.) adjacent to the volcanic rocks and the thick Mesozoic section west of the Crookton Fault suggest that Jurassic and Cretaceous rocks once covered the area and were later eroded. Thus, the volcanic rocks are younger than the Mancos Shale (late Cretaceous), but they are older than the water-laid tuffs (late Tertiary)which lie on them unconformably. Also in this part of Colorado the volcanic rocks are of Tertiary age (Knepper and Marrs, 1971); so this suggests that the Porphyry Creek Rhyolite and the andesite lava flow are late Cretaceous to mid-Tertiary in age, probably early to mid-Tertiary. The stratigraphic ordering of these units was difficult to determine because the units generally are preserved only in depressions eroded into the Precambrian quartz monzonite by streams. The depressions are part of a paleodrainage system in which the volcanic units could accumulate in great enough thickness to be preserved today. See Figure 9 for a diagrammatic columnar section of the Cenozoic rocks.

Porphyry Creek Rhyolite--The Porphyry Creek Rhyolite rests on a surface of erosion on the quartz monzonite. The best exposures occur on the north side of Porphyry Creek in sec. 30, T.49N., R.5E. (fig. 10), hence the informal name Porphyry Creek Rhyolite. It is also exposed in Tomichi Creek valley north of Porphyry Creek and at the east foot of Dawson Ridge just south of Black Sage Pass road. The unit may be as thick as 500 feet, but poor exposures preclude determination of its actual thickness.

The rock is a white, highly fractured biotite rhyolite porphyry. It contains euhedral bipyramidal quartz crystals that are as large as 0.15 inches in diamter. The groundmass is aphanitic and has a very uniform appearance in hand specimen. Phenocrysts and xenocrysts in addition to quartz are biotite, microcline, and altered plagioclase. The percentage of the phenocrysts and xenocrysts has a very rapid lateral and vertical variation, ranging from a few to 50 percent of the whole rock. On the basis of phenocryst and xenocryst composition, a hand specimen would be given a field classification of rhyolite to quartz latite. The variation in

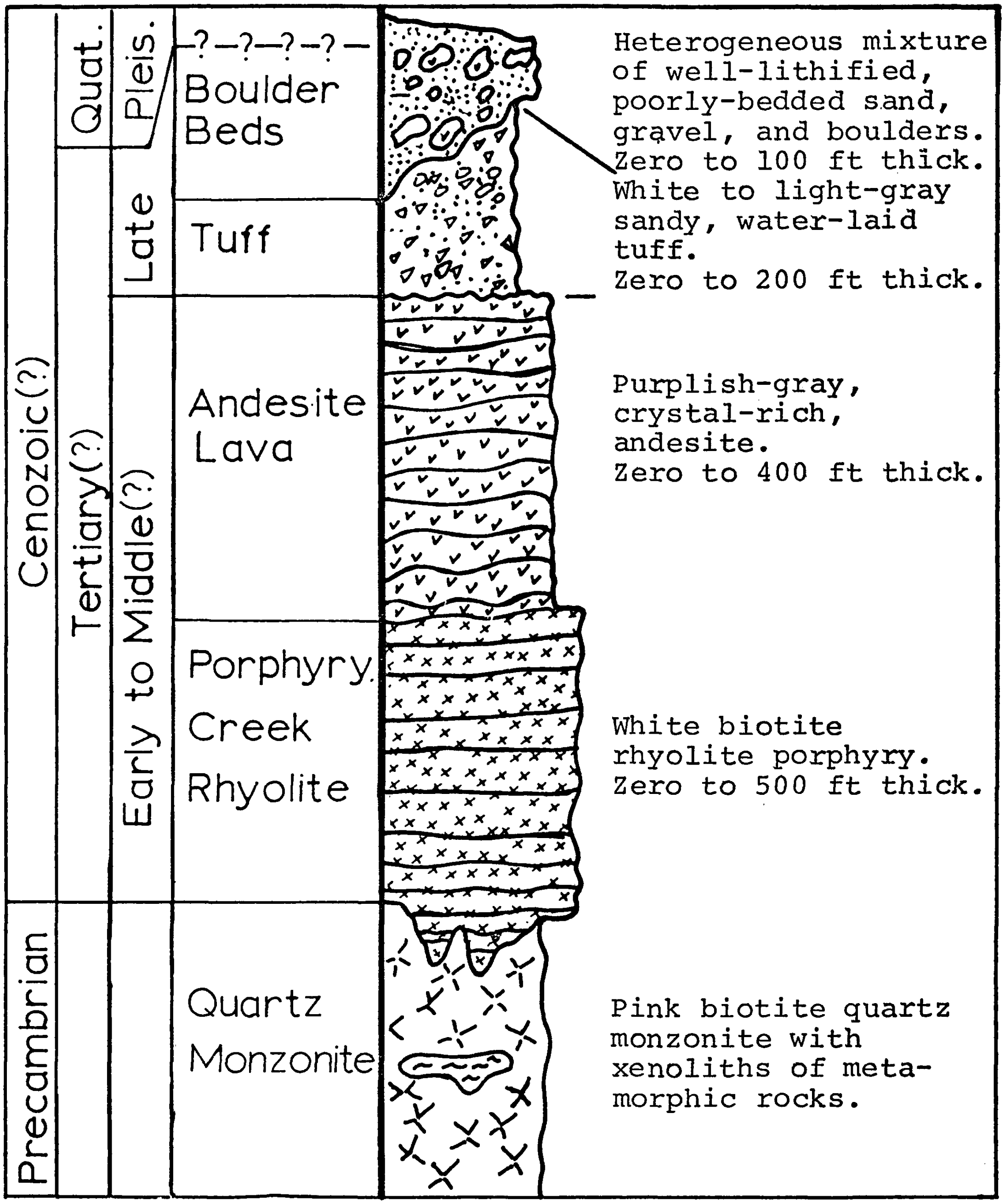


Figure 9: Diagrammatic columnar section of the Cenozoic rocks. Vertical scale two inches to 400 feet.

Figure 10: Outcrop of the Porphyry Creek Rhyolite (sec. 27, T.49N., R.5E.). Note the well-developed jointing and the tabular nature of the debris.

mineralogy and percentage of phenocrysts and xenocrysts is due to multiple flows, which can be seen in a few places in sec. 27, T.49N., R.5E.

Examination of thin sections shows that the Porphyry Creek Rhyolite has an equigranular aphanitic groundmass of 85 percent sanidine and 15 percent quartz. Phenocrysts and xenocrysts consist of microcline (50 percent), plagioclase (35 percent), quartz (15 percent), and biotite (a trace to 5 percent), all of which are euhedral and fractured. A zone of much finer-grained groundmass surrounds the quartz phenocrysts (fig. 11). The composition of phenocrysts and xenocrysts and the occurrence of microcline and plagioclase as lithic fragments suggest that the xenocrysts were derived from country rock.

The Porphyry Creek Rhyolite is concluded to be a lava flow and not an intrusive. This is based on the occurrence of the same lithology farther south along Marshall Creek, and, more significantly, on the evidence presented to show that the Porphyry Creek Rhyolite fills a paleodrainage system (see discussion of the paleodrainage system).

Andesite Lava Flow--An andesite flow appears to rest on the quartz monzonite and overlap the Porphyry Creek Rhyolite. A period of erosion between the extrusion of the Porphyry Creek Rhyolite and the andesite is indicated by the development of drainage across the Porphyry Creek Rhyolite

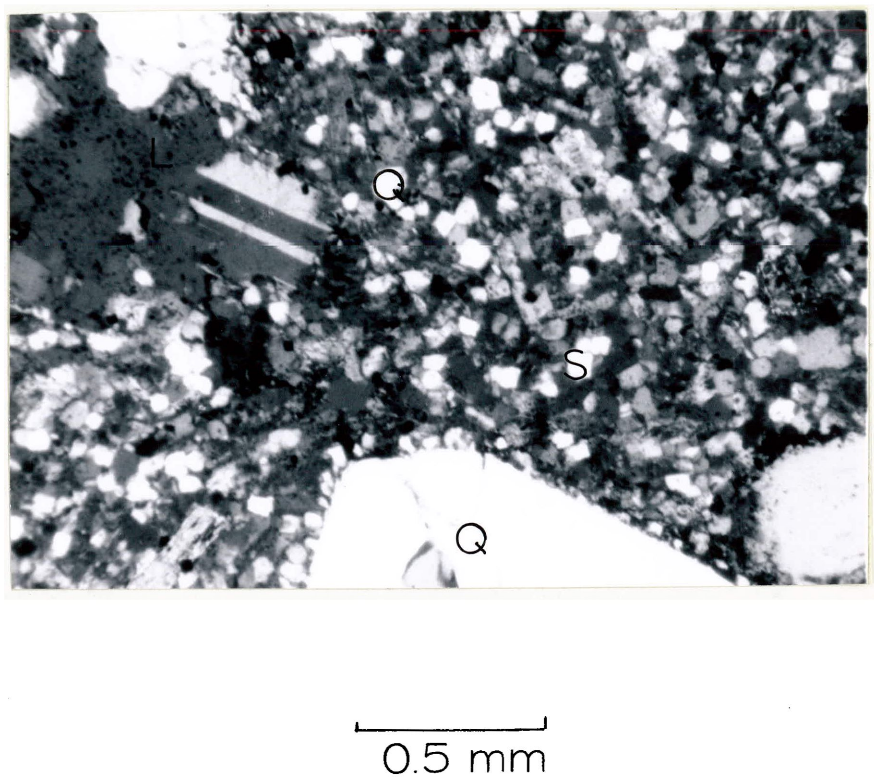


Figure 11: Photomicrograph of the Porphyry Creek Rhyolite. Note the large quartz crystal in the bottom of the photo and the finer-grained groundmass adjacent to the quartz crystal. The minerals are quartz (Q) and sanidine (S), with a granitic lithic fragment (L).

which was buried by the andesite (sec. 34, T.49N., R.5E.). The andesite averages 200 feet thick, but locally may be 400 feet thick.

The flow is a purplish-gray, crystal-rich biotite andesite with a basal vitrophyre and lithic fragments in the lower part. The lack of glass shards in thin section indicates that this unit is a lava flow and not an ash flow.

Individual crystals are highly fractured. On a weathered surface the rock is generally pinkish-brown. Outcrops have a well-developed jointing that parallels a moderately-developed foliation; this jointing gives the outcrops a characteristic tabular appearance (fig. 12).

Preservation of the andesite is due to accumulation in a drainage system. This interpretation is supported by the attitudes of the foliation and the geometry of the basal contact. A complete explanation of this geometry is given in the section on the paleodrainage system. Individual lava flows are not seen. Locally, small areas of a vitrophyre are exposed at the base (secs. 33 and 34, T.49N., R.5E.).

In thin section, the andesite lava flow has a dark cryptocrystalline groundmass that contains abundant highly fractured phenocrysts (fig. 13). The phenocrysts are 75 percent sodic plagioclase, 15 percent biotite, 5 percent quartz, and traces of a pyroxene (probably augite) and sanidine. Most of the plagioclase crystals are well-zoned. Phenocrysts constitute about 80 percent of the rock.

Figure 12: Outcrop of the andesite lava flow in sec. 33, T.49N., R.5E. Note the well-developed jointing that produced a tabular weathering habit.

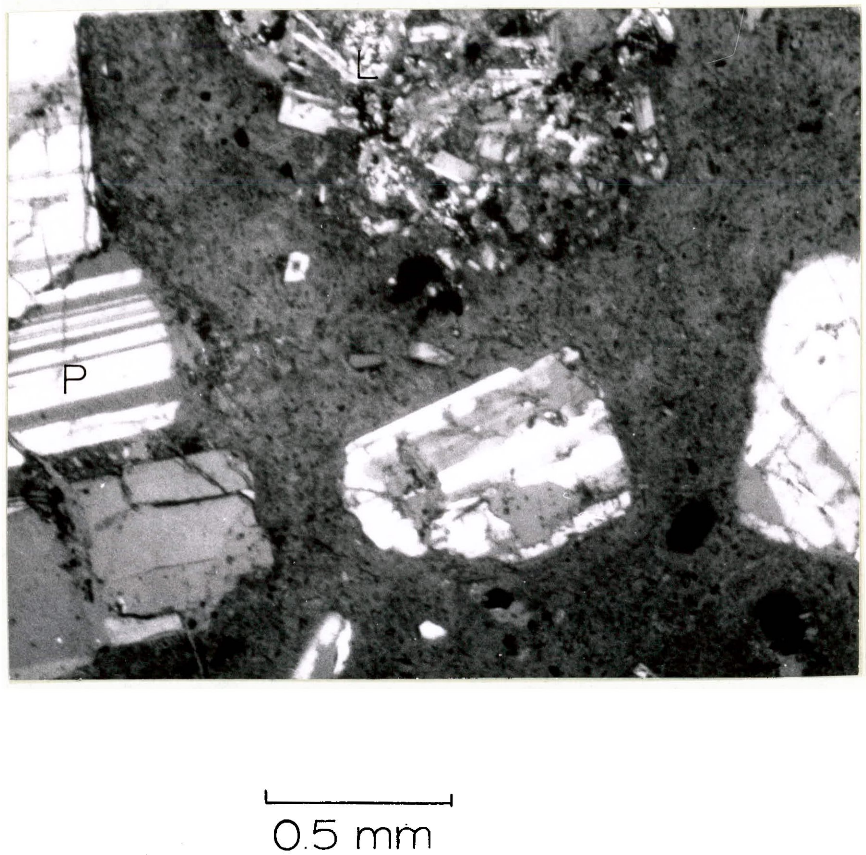


Figure 13: Photomicrograph of the andesite lava flow. Note the lithic fragment (L) at the top of the photograph and the fractured nature of the crystals. Plagioclase (P).

Water-laid Tuff--Water-laid tuff is the youngest volcanic unit in the area. It unconformably overlies the quartz monzonite, the Porphyry Creek Rhyolite and the andesite flow. Its upper contact is mostly concealed; however, in a new road cut (sec. 4, T.48N., R.5E.), tuff is interbedded with sandy gravel in the overlying boulder beds (fig. 14). Exposures high on the Old Monarch Pass Road and a water well penetrating 70 feet of tuff in the valley bottom suggest that the tuff may have been 200 feet thick.

The tuff is white to light gray. It is composed of glass shards, minor amounts of fresh black biotite, and granitic- and volcanic-derived sand. Graded bedding and cross-bedding are present. Locally the tuff is conglomeratic, containing rounded to sub-rounded boulders as large as two feet in diameter. Most of the sand and boulders is of volcanic material; however, some is granitic material. The volcanic boulders consist of Porphyry Creek Rhyolite, andesite lava flow, and other foreign andesites. The tuff generally dips at a low angle toward the center of the modern valley of Tomichi Creek.

Gastropods were found in this tuff in a prospect pit at the north end of the valley of Tomichi Creek (sec. 16, T.49N., R.5E.). Gastropods from the same prospect pit were dated as late Tertiary (probably Pliocene) by Dings and Robinson (1957), and were believed to represent a freshwater environment.

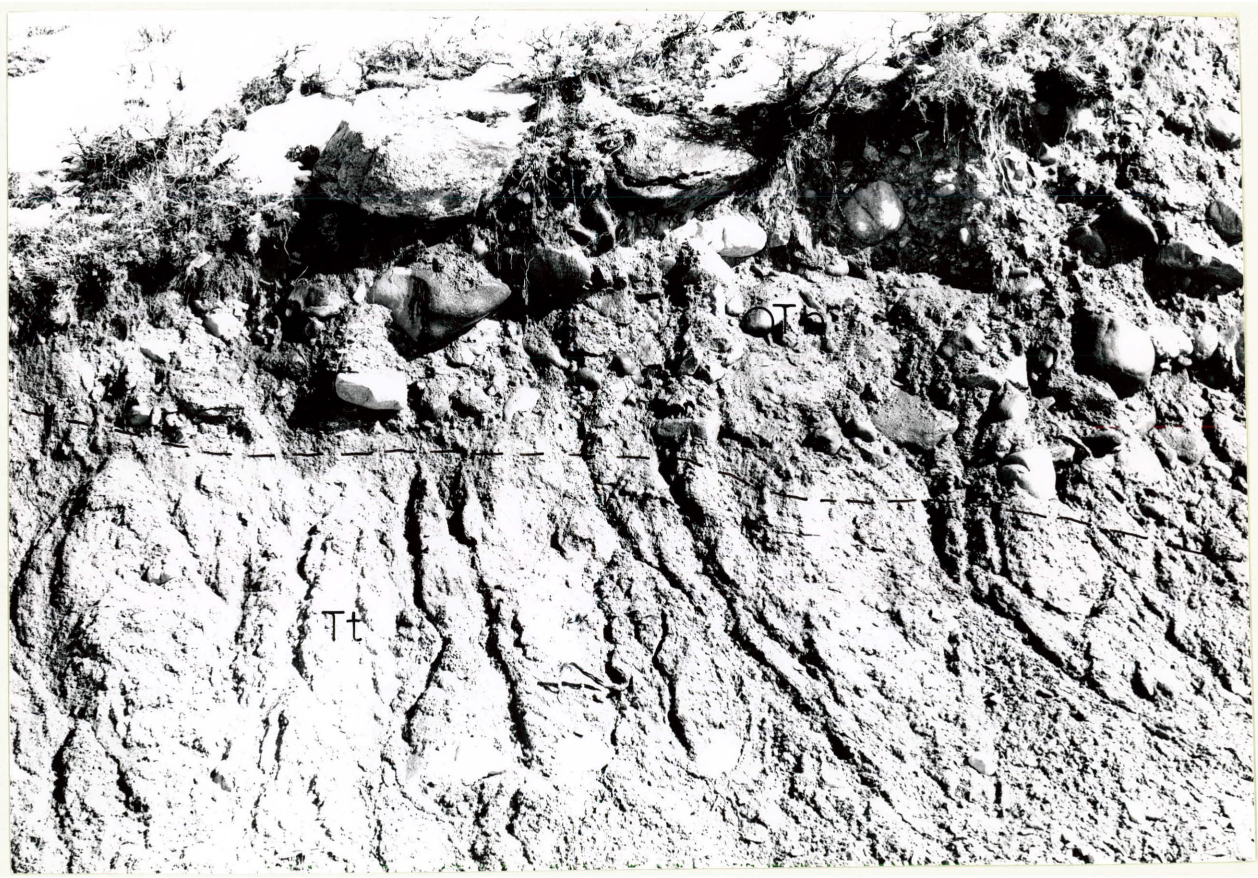


Figure 14: Outcrop of the water-laid tuff showing the overlying boulder beds. Located in sec. 4, T.48N., R.5E. Note the crude bedding in the water-laid tuff (Tt) and boulder beds (QTb).

It is concluded that the tuff was washed into a depression, probably forming alluvial fans at the mouths of mountain streams, resulting in a thick accumulation. This same tuff is also found at Agate Creek Campground (sec. 2, T.48N., R.5E.) and farther south along Marshall Creek.

Tertiary-Quaternary (?) Rocks

Boulder beds of probable Tertiary-Quaternary age are preserved in the area.

Boulder Beds--The boulder beds overlie the other lithologic units delineated. The best exposure is in the new road cut in sec. 4, T.48N., R.5E. (fig. 15). The basal contact is generally concealed; however, where observable, the boulder beds mostly lie either on the quartz monzonite or on the Tertiary (?) volcanic rocks or in places are interbedded with the upper part of the late Tertiary water-laid tuff. The upper part of the boulder beds contains unweathered boulders and is not lithified, whereas the lower part contains highly weathered boulders and is well-lithified. The upper part may have been reworked by water and some new material was added.

The boulder beds are composed of a very poorly-sorted, crudely-bedded, heterogeneous mixture of sand, gravel, and boulders. The crude bedding is best exposed in road cuts along U. S. Highway 50 (sec. 10, T.48N., R.5E.). Boulders

Figure 15: Road cut in the boulder beds in sec. 4, T.48N., R.5E. Note the heterogeneity, the crude bedding and the rounded to sub-rounded nature of most of the boulders.

as large as six feet in diameter are observed, but most are less than two feet in diameter. Most of the boulders exposed at the modern surface of this unit were derived from the andesite flow; some granitic boulders are also included; however, in fresh road cuts many completely weathered granitic boulders are mixed with the boulders of volcanic rocks. In deep new road cuts the boulder beds contain sub-angular boulders in a very well-lithified matrix of gravel and minor amounts of sand. The gravel consists of a heterogeneous mixture of local and foreign rock types. Shown below is the result of a pebble count made in sec. 4, T.48N., R.5E. of fine to very coarse pebble gravels. The count is the average of three separate counts of approximately 50 pebbles each, selected from randomly chosen 2-foot square areas within areas of fine to very coarse pebble gravel. These areas were selected since it was believed that this grain-size fraction would give more representative figures for the composition of the boulder beds. Most of the pebbles could be locally derived; however, some of the pebbles of volcanic rock are not of local origin and possibly came from the Sawatch Range.

Rock type or formation	Pebbles counted, percent
Quartz monzonite	43
Porphyry Creek Rhyolite	10
Quartzite	9
Tan, fine-grained, silty sandstone (Morrison Formation (?))	9
Purple, crystal-poor andesite	8
Quartz-biotite gneiss	5
Andesite lava flow	5
Water-laid tuff	5
Jasper	4
Miscellaneous fine-grained, dark volcanic rocks	2

Summary of Tertiary and Tertiary-Quaternary (?) Rocks

The Sargents area traditionally has been included in the Bonanza volcanic field. Regional reconnaissance and the State geologic map (Stose, 1935) indicate that volcanic rocks extend south from the Sargents area to the volcanic field around Bonanza. The Porphyry Creek Rhyolite is a mineralogically distinct rock; it is somewhat similar to the Porphyry Peak Rhyolite of the Bonanza area (Burbank, 1932), but it is not considered to be the same (Harry Perry, 1970, oral communication). The andesite lava flow is not very distinctive; andesites are common in most of the volcanic fields of Colorado; and thus the andesites in the Sargents area cannot be correlated with certainty with those in the Bonanza area. The water-laid tuff and boulder beds are similar to tuffs and boulder beds along Marshall Creek south of the Sargents area. My interpretation of the paleodrainage system (see section of paleodrainage system) suggests that the drainage in which the volcanic rocks are preserved flowed to the south and that as much as 1,200 feet of relief (cross-section E--E', Plate 1) existed in the Sargents area when the volcanic rocks were formed.

The source of these volcanic rocks is difficult to conclude without reservation; however, it appears that the volcanic flows in the Sargents area most likely came from somewhere to the north or northeast of Sargents.

Quaternary Rocks

Two lithologic units of Quaternary age were mapped in the area: valley-fill alluvium and fans. Both are composed of local detritus. The fans are developed where mountain streams enter the valley of Tomichi Creek.

STRUCTURE

The post-Precambrian structures in the Sargents area are not complex. The main post-Precambrian elements are the pre-Crookton faults, the Crookton Fault and the associated syncline, and the north-south faults.

Faulting

The three mapped east-west faults that approximately parallel Porphyry Creek (secs. 26, 27, 28, 34, and 35, T.49N., R.5E.) are the oldest in the area. These three faults are very poorly exposed. They apparently are a set of vertical or near vertical faults with undetermined offset.

The evidence for these lineaments is geomorphic. On 1:100,000 color infrared photography, the lineaments can be traced to the east over the Continental Divide for more than 15 miles. One of the most significant expressions of this faulting is Porphyry Creek, which has developed along this extremely straight zone of weakness. Minor depressions and very straight segments of streams are also observed along these lineaments. The central fault of the three abruptly stops at the Crookton Fault. This east-west fault system provided a zone of weakness along which the paleodrainage system and the modern Porphyry Creek developed and in which the Tertiary (?) volcanic rocks are now preserved. This evidence suggests that the east-west faulting began before the Crookton Fault formed, possibly with minor movement after the volcanic rocks were deposited.

The Crookton Fault (Stark and Behre, 1936) is near the western margin of the area. It is a high-angle reverse fault (dipping at greater than 45°E.) that has brought Precambrian rocks over the Mesozoic sedimentary rocks. These sedimentary rocks have a regional low southeasterly dip (Stark and Behre, 1936) into the Crookton Fault where they are dragged into a syncline. In the southern part of the area the syncline's eastern limb has overturned attitudes dipping at 55°SE. to 90° (cross-section C--C', Plate 1). In the northern part of the area the drag was not as pronounced, and the eastern limb of the syncline dips at 20° to 30°W. The axis of this syncline is only very approximately located on the map. Local evidence to exactly locate the axis is not found due to the slumping and vegetative cover that is characteristic of the Mancos Shale.

The trace of the Crookton Fault is well exposed in the southern and extreme northern parts of the area. A zone of highly fractured quartz monzonite and (or) silicification of Mesozoic sedimentary rocks occurs along the trace of the fault. At Cat Rocks (sec. 2, T.48N., R.4E.) the fault is offset by a set of left-separation faults trending N.45W., with horizontal separation of approximately 3/4 of a mile.

Only the two most significant faults of this set are mapped due to lack of exposure and marker beds. In the extreme northern part of the area the Crookton Fault is displaced by several right-separation faults trending about N.45W. and a vertical fault trending north-south.

The age of the Crookton Fault is difficult to establish in this area. The youngest rock affected by the Crookton faulting is the Mancos Shale which is folded by drag on the Crookton Fault and faulted by the cross-cutting faults. Thus, the most recent movement of the fault is post-Mancos. However, the Crookton Fault is of the same style of faulting as Laramide faults of the Sawatch Range and occupies a position in line with Laramide faulting on the western flank of the Sawatch Range (see fig. 6 and Stark, 1934). Therefore, the Crookton Fault probably was active during the Laramide orogeny.

The cross-cutting faults trending N.45W. (at Cat Rocks and the northwestern-most part of the area) are tear faults along the Crookton Fault. Since these faults are only found along the Crookton Fault and have a symmetrical arrangement along it, it is suggested that they are contemporaneous with Crookton faulting.

The north-south faults along the flanks of the valley of Tomichi Creek are the youngest recognized in the area. These are vertical faults with their Tomichi valley sides down. On the basis of offset boulder beds (sec. 22, T.49N., R.5E.), one of these faults has moved vertically as much as 200 feet, but generally the separation of the boulder beds is too small to be seen at map scale. These faults have resulted in the local reversal of dips of water-laid tuff (sec. 33, T.49N., R.5E.), offsetting of boulder beds (sec. 22, T.49N., R.5E.), bringing the boulder beds into fault contact with the quartz monzonite (sec. 3, T.48N., R.5E.), silicification and minor alteration, intense fracturing, and the localization of springs. The north-trending part of the paleodrainage system parallels these faults (see discussion of the paleodrainage system). The offset of the volcanic and sedimentary rocks suggests that these faults controlled the development of the paleodrainage system, and thus must predate the system. Movement continued along these faults after deposition of the boulder beds, offsetting the boulder beds. On the basis of fossil evidence (Dings and Robinson, 1957) which dates the offset water-laid tuff stratigraphically below the boulder beds, the latest activity of the faults is post-late Tertiary (probably post-Pliocene).

These north-south faults are easily observed on 1:100,000 and 1:16,000 color and color infrared photography. (See section on Photo Interpretation for a more complete discussion.) The 1:16,000 color photography was especially useful because the color enhanced subtle geomorphic detail. The 1:100,000 photography was useful to observe regional features which were not observed initially on large-scale photography.

PALEODRAINAGE SYSTEM

The paleodrainage system is believed to have developed in the Sargents area owing to the east-west and north-south faulting, which provided zones of weakness along which drainage systems could easily develop. In detail, a major axis of the system trends northeast across secs. 23, 26, 27, 33, and 34, T.49N., R.5E. The geometry of the system is shown in cross-sections D--D' and E--E' (Plate 1) and on Figure 16 as contours on the contact between the Tertiary (?) volcanic rocks and the quartz monzonite. The rest of the system trends north-south along the modern valley of Tomichi Creek, through secs. 16, 21, 28, and 33, T.49N., R.5E., and secs. 3, 4, 9, and 10, T.48N., R.5E. The paleodrainage system has been preserved owing to filling by Tertiary volcanic rocks. This interpretation is based on 1) the geometry of the modern topography and the contact between the Cenozoic rocks and the quartz monzonite, 2) the orientation of the foliation in the andesite lava flow, 3) the orientation of a fracturing that is characteristic of the Porphyry Creek Rhyolite, and 4) the southwesterly inclination of the axis of the paleovalley system. This interpretation suggests that downstream was to the south; however, the possibility that regional tilting has reversed this direction cannot be ruled out completely.

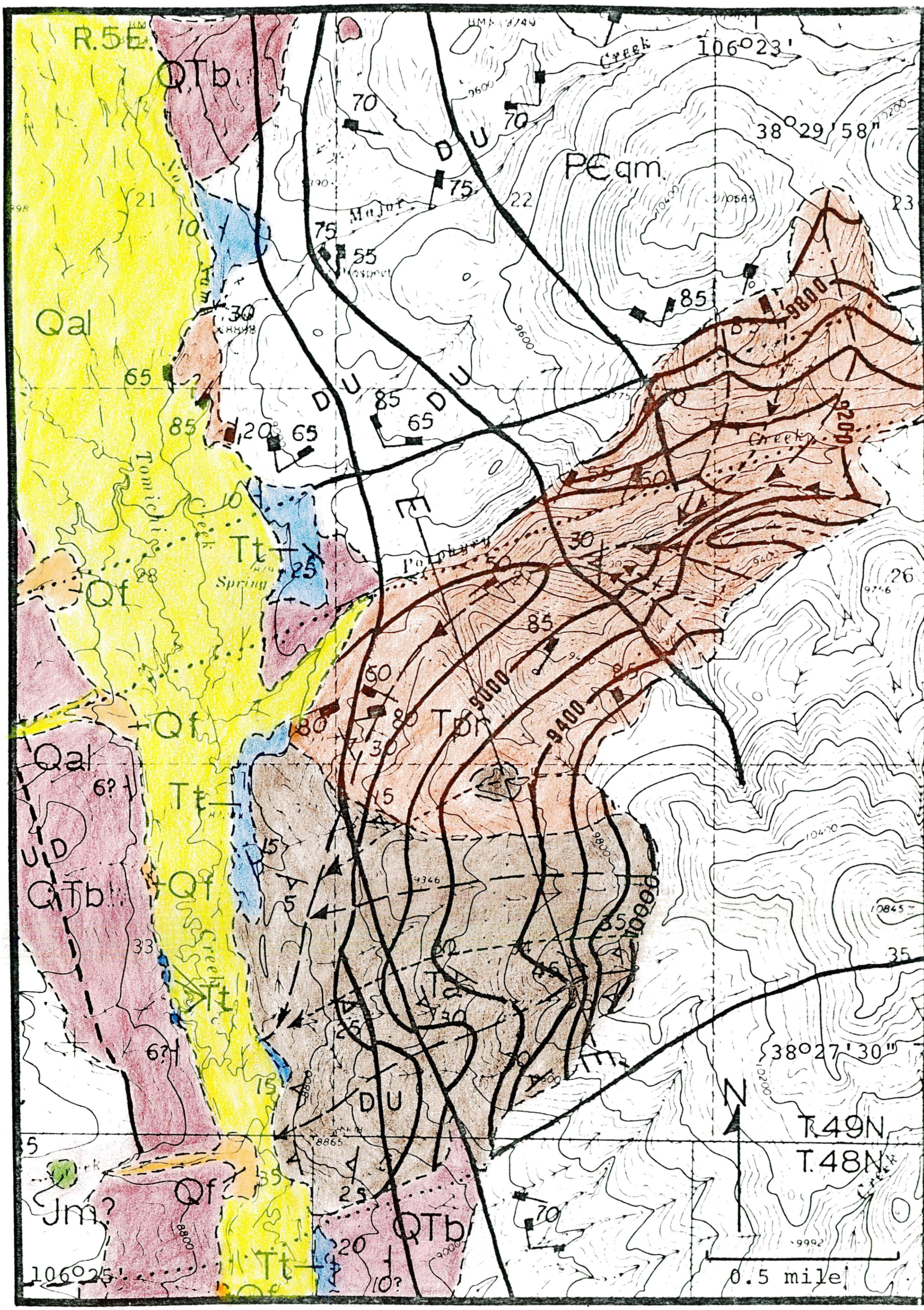


Figure 16a: Contours on the contact between Tertiary (?) volcanic rocks and the quartz monzonite. Contour interval 200 feet.

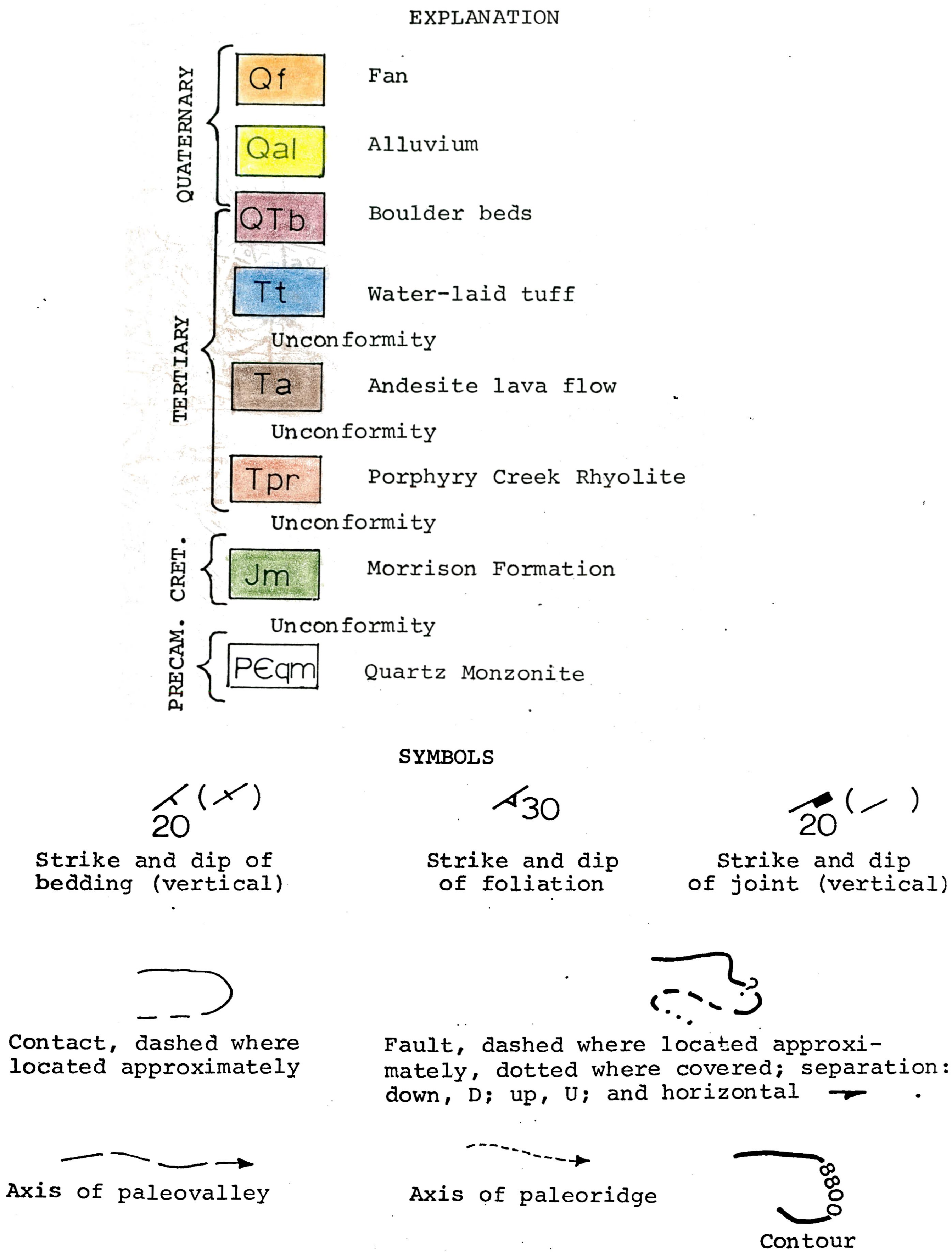


Figure 16b: Explanation of Figure 16a.

The paleodrainage system appears to have been affected by regional tilting, and offset by faults. This is suggested by the attitude of the axis of the system in the volcanic rocks and the dip of the Porphyry Creek Rhyolite. The inclination of the axis is as high as 30 degrees, which suggests significant uplift of the Sawatch Range since the emplacement of the Tertiary volcanic units.

Thus, the paleodrainage system appears to have been a southeasterly- to southerly-flowing drainage system cut into the quartz monzonite with at least 1,200 feet of local relief.

GEOLOGIC HISTORY

The oldest exposed rocks in the Sargents area are the metamorphic rocks in the southern part of the area. These rocks were deeply buried and highly deformed. High temperature and pressure associated with deep burial probably were responsible for generation and emplacement of the quartz monzonite.

Although evidence from within the Sargents quadrangle is lacking, local and regional studies suggest that the area was covered by a sequence of Paleozoic and Mesozoic sedimentary rocks (Dings and Robinson, 1957). Regional studies indicate that this area was on the flank of the ancestral Uncompaghre Uplift, and erosion of the pre-Morrison units is attributed to this uplift (Oriel and Craig, 1960; Mallory, 1960).

The late Jurassic Morrison Formation was deposited on the then exposed Precambrian rocks. Regional studies in central Colorado indicate that in the early Cretaceous the Dakota Group records a transgressive-regressive-transgressive sequence (Weimer, 1970) followed by the deeper-water deposition of the Mancos Shale. The Dakota section at Cat Rocks (fig. 8) is indicative of this sequence.

This sedimentation was followed in the area by uplift, Laramide and post-Laramide tectonism, and the subsequent development of the paleodrainage system. According to my interpretation this system was filled by the Porphyry Creek Rhyolite. Following a period of erosion, the andesite flow entered the area, followed by another period of erosion.

Sometime during this last period of erosion, a long narrow depression apparently formed in the Sargents area. This depression was filled with the water-laid tuff and the boulder beds. Tuff apparently was deposited in numerous alluvial fans at the mouths of mountain streams emptying into the depression, during the late Tertiary (Pliocene). This conclusion is supported by the thickness of tuff occurring here; the attitude of the tuff, which generally is dipping into the modern valley center; and because the tuff is sandy and often cross-bedded.

After deposition of at least a hundred feet of tuff, the boulder bed material began to be deposited with continued deposition of tuff. These boulder beds may suggest the beginning of significant tectonic activity in this part of the Sawatch Range probably late in the Tertiary, and possibly continuing into the Pleistocene.

The north-south faulting continued after deposition of the boulder beds; silicification and minor local alteration occurred along these faults. This tectonic activity and erosion resulted in deformation and partial reworking of the boulder beds, and the addition of new material to them.

PHOTO INTERPRETATION

Color and color infrared photography of the Sargents area, obtained from NASA as part of the Colorado School of Mines Bonanza Remote Sensing Project, was used and evaluated in the course of this thesis research. Color and color infrared stereo photography at scales of 1:100,000 and 1:16,000 was obtained by NASA on Missions 101 and 105 with an RC-8 metric aerial camera, which has a 6-inch focal length and produces 9x9 inch square photos.

> Mission 101 was flown about 50,000 feet above mean terrain (a.m.t.) using Kodak 2448 film; Mission 105 was about 8,000 feet a.m.t. and used SO-397 film.
>
> Color infrared photography was taken on Mission 101 and 105. On Mission 101, SO-117 film was used in...an RC-8...camera giving...[a scale] of 1:100,000...A Wratten 15 filter was used with the RC-8...Quality of...[the] photography is good.
>
> Color IR photos from Mission 105 have a scale of about 1:16,000, taken with an RC-8. Film used was Type SO-117, with three filters--a Wratten 12, CC20M, and 4600. Quality of this photography is poor; the film is underexposed, vignetting is apparent, and portions of each frame are out of focus. (Bonanza Remote Sensing Project, 1970).

In the Sargents area, color and color infrared photographs from both Missions 101 and 105 have been exceedingly useful in establishing two fault orientations, the east-west faulting (A--A' on figs. 17 and 18) and the north-south faulting (B--B' on figs. 17 and 18). Also the large scale Mission 105 photography has provided much information about the Precambrian rocks and consequently has served to verify the interpreted faulting. This faulting is extremely

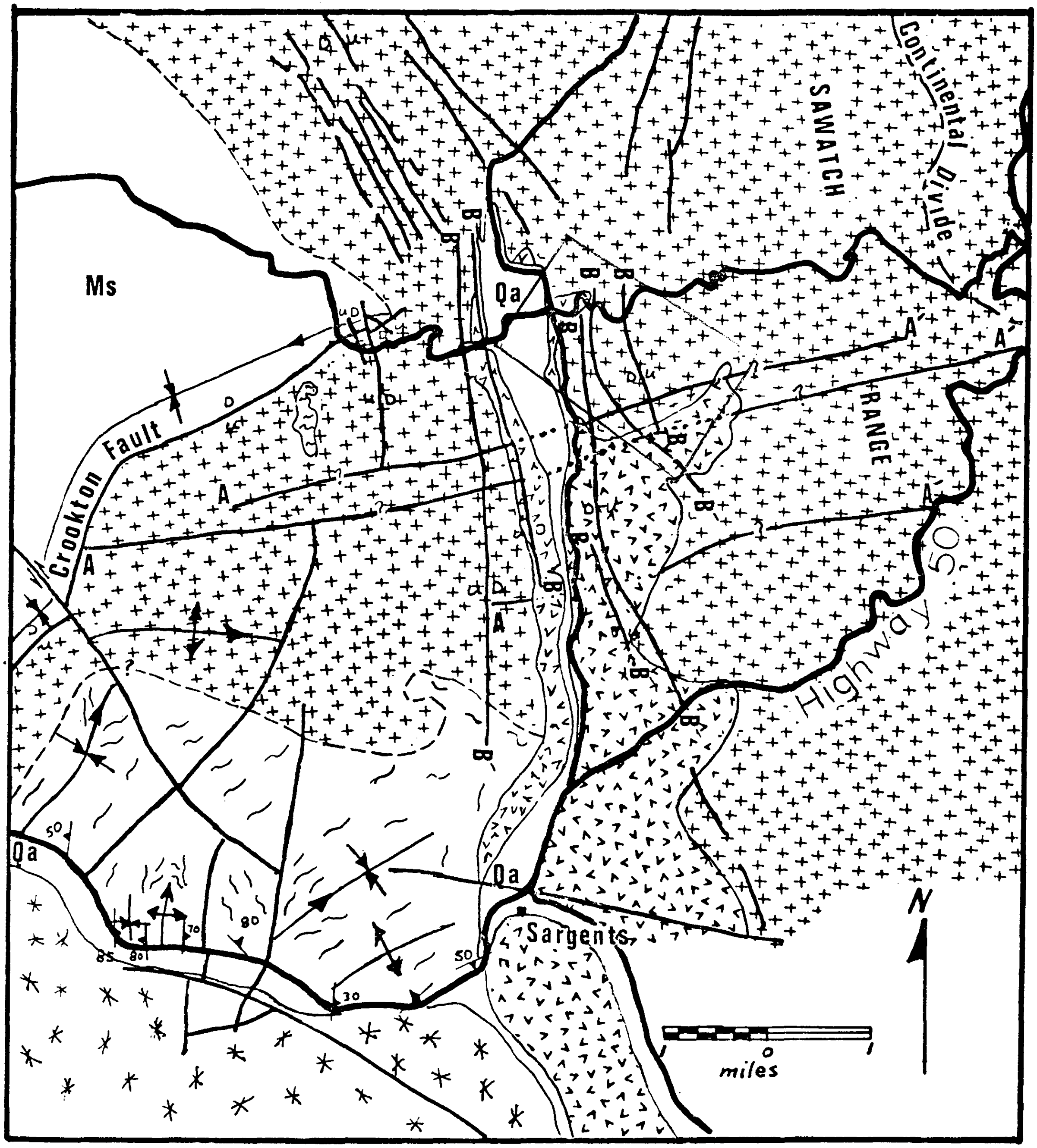
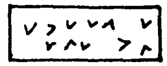


Figure 17a: Regional photogeologic map of the Sargents area. A--A', east-west fault system; B--B', north-south fault system.

EXPLANATION

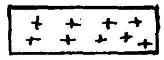
CENOZOIC

Igneous and Metamorphic Rocks



Volcanic rocks and volcanic-derived sedimentary rocks

PRECAMBRIAN



Granitic Rocks

Metamorphic Rocks
Lines indicate general trend of foliation
Star pattern indicates trend not determined

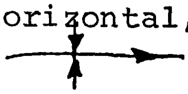
MESOZOIC and CENOZOIC

Sedimentary Rocks

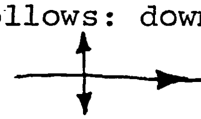
Sedimentary Rocks and Surficial Rocks
Ms -- Mesozoic sedimentary rocks
Qa -- Quaternary alluvium

Contact, dashed where inferred

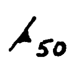
Fault, dashed where inferred, symbols used on faults that have been field checked, separation as follows: down, D; up, U; and horizontal,



Plunging synform



Plunging antiform



Foliation measured in the field

Road

Figure 17b: Explanation of Figure 17a.

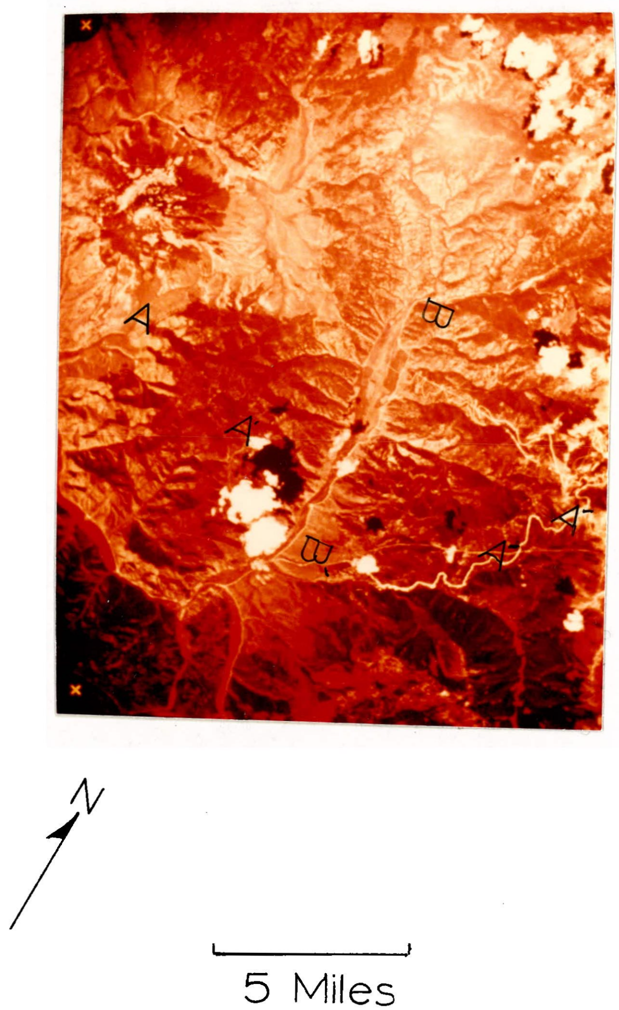


Figure 18: Photo of a color infrared 1:100,000 scale original. A--A', east-west faults; B--B', north-south faults. Same area as Figure 17a.

difficult to recognize on conventional black and white aerial photography. Three factors make Mission 101 and 105 photography better than conventional photography for geologic mapping: (1) the small scale of Mission 101 photography, which is excellent for regional and some local work, (2) the high resolution, which is excellent for showing detail, and (3) color, and especially color infrared, which definitely ehances subtle lithologic differences.

Southwest of the mapped area (figs. 17 and 18), color differences in Mission 105 color photography are most probably due to different lithologies with different colors in the highly metamorphosed Precambrian rocks, the Precambrian undivided of this report. Tightly folded antiforms and synforms have been delineated through photo interpretation, and good evidence has been established for several major faults. These features are much more easily delineated on color and color infrared photography than on conventional photography; the human eye can distinguish more colors than shades of gray.

The east-west faulting (A--A', figs. 17 and 18) was first discovered on the 1:100,000 scale color infrared photography. On large scale photography this east-west faulting went unobserved because minor irregularities in topography obscured the linearity of the fault traces. However, on small scale photography, the confusing and masking detail is essentially eliminated by the synoptic view, making it easy to delineate the east-west faulting.

Similarly, the north-south faulting (B--B', figs. 17, 18 and 19) was first discovered on the 1:100,000 color infrared photography and then mapped in detail with the aid of the 1:16,000 color photography (fig. 19). Anomalous vegetation concentrations, probably associated with damming of ground water and springs along faults, were enhanced on the 1:16,000 color photography. Features such as these vegetation and ground water anomalies and enhancement of geomorphologic features that might and probably would have gone undetected on conventional photography are readily observable by experienced photo interpreters on color and color infrared photography.

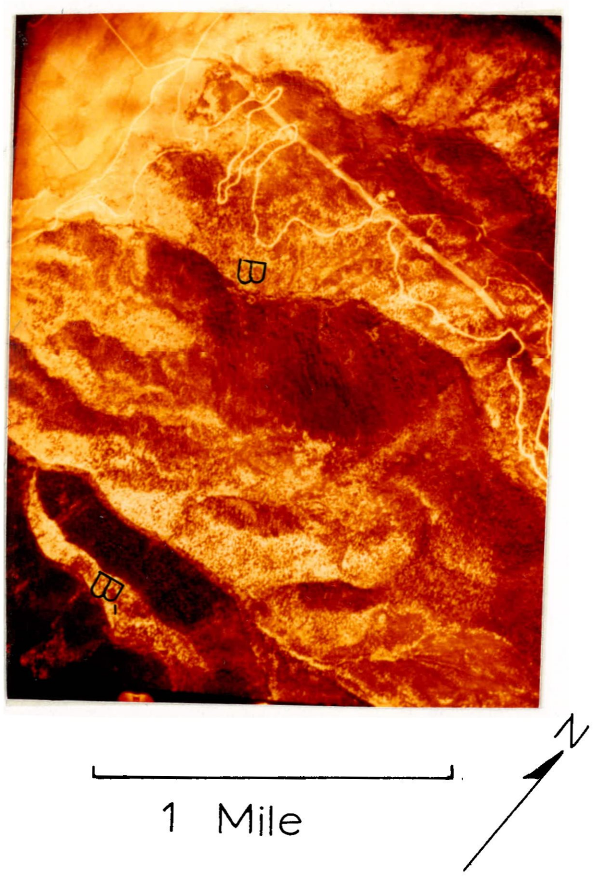


Figure 19: Photo of a color 1:16,000 scale original. B--B', north-south faults. The color of this example is distorted due to the reproduction processes necessary to obtain this copy. Area indexed in red on Figure 17a.

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APPENDIX A

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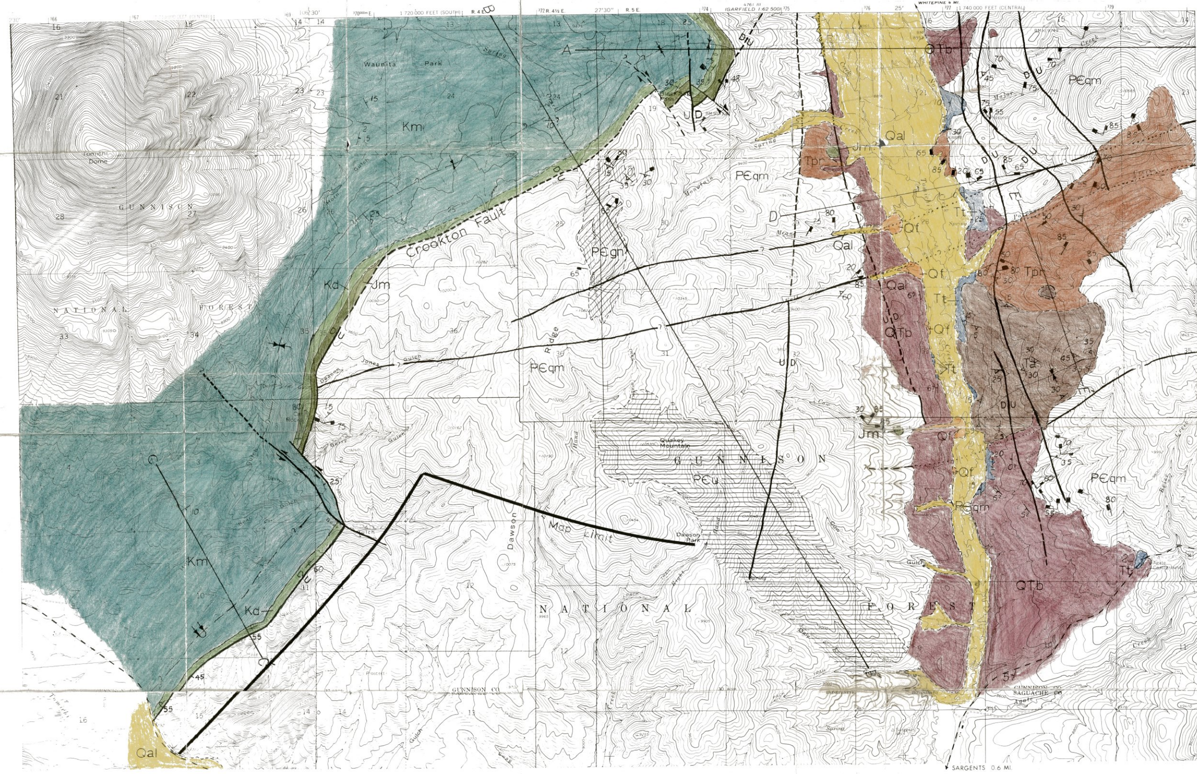
COLORADO SCHOOL OF MINES
THESIS NO. 1378

DEPARTMENT OF GEOLOGY

PLATE 1



Topography from U.S. Geological Survey Doyleville (1962) and Sargents (1964) quadrangles.

Geology by Gary Raines, 1969-1970

EXPLANATION

Quaternary
- Fan — Qf
- Alluvium — Qal

Quaternary Tertiary
- Boulder beds — QTb

Tertiary
- Water-laid tuff — Tt
- Unconformity
- Andesite lava — Ta
- Unconformity
- Porphyry Creek Rhyolite — Tpr
- Unconformity

Cret.
- Mancos Shale — Km
- Dakota Group — Kd

Jur.
- Morrison Fm. — Jm
- Unconformity

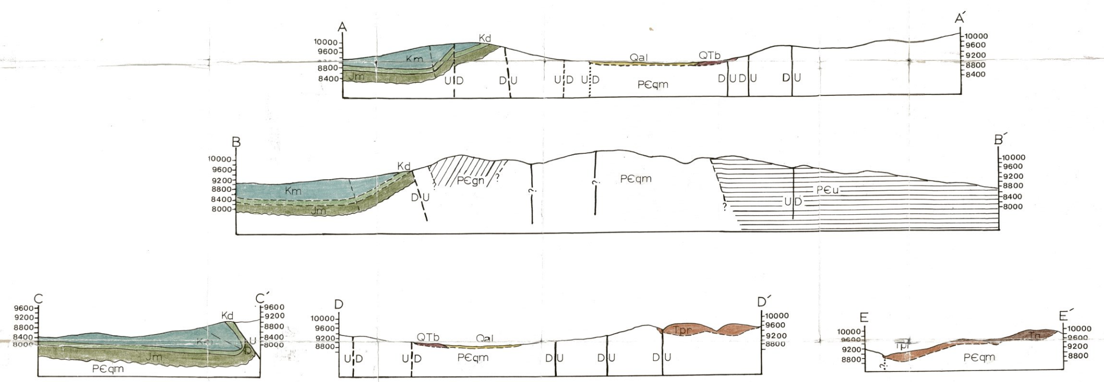
Precambrian
- Undivided — PЄu
- Quartz Monzonite — PЄqm
- Quartz biotite gneiss — PЄgn

SYMBOLS

- Strike and dip (vertical, overturned) of stratification
- Strike and dip of foliation
- Strike and dip of joint (vertical)
- Contact, dashed where located approximately
- Fault, dashed where located approximately, dotted where covered, "?" where inferred, separation down, D, up, U, horizontal,
- Syncline, dashed where located approximately.
- Overturned syncline

SCALE 1:24000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL



GEOLOGIC MAP AND SECTIONS OF THE SARGENTS AREA,
GUNNISON AND SAGUACHE COUNTIES, COLORADO