THE GEOLOGY OF THE SCHOOLHOUSE MOUNTAIN QUADRANGLE, GRANT COUNTY, NEW MEXICO

by

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ABSTRACT

The Schoolhouse Mountain quadrangle is bounded by Lat. 32° 45'--32° 52' 30" N; Long. 108° 30'--108° 37' 30" W, and is located in northern Grant County, New Mexico, approximately 20 miles west of Silver City.

Volcanic pyroclastics and flows crop out in the northern part of the area. These rocks have been divided into nine formations containing 24 members. The lowermost units are andesites. The andesites are overlain by a thick series of pyroclastics and flows of rhyolitic composition. The rhyolites are overlain by a thin basalt flow. Precambrian granite and amphibolite overlain by Cretaceous sediments crop out in the southern part of the quadrangle.

Two major faults are found in the area; the north-south trending Schoolhouse fault and the east-west trending Wild Horse fault. A broad, complex arch trending in a north-northwest direction crosses the quadrangle.

A study of: (1) magnetic susceptibilities, (2) chemical compositions and (3) refractive index of fused rock reveals a means of distinguishing between some of the volcanic units that appear identical in the field. Closely spaced sampling and adequate geologic control are important to a successful application of these three correlation methods.

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PART I —— GEOLOGY

INTRODUCTION

Location and Description

The Schoolhouse Mountain quadrangle* is located in northern Grant County, New Mexico and is bounded by Lat. 32° 45'--32° 52' 30" N; Long. 108° 30'--108° 37' 30" W. A total of 63 square miles is included within the quadrangle (See Fig. 1).

Access to the quadrangle from the town of Silver City, approximately 20 miles to the east, is provided by U. S. Highway 260. Within the quadrangle, gravel roads lead along the Gila River to the vicinity of the McCauley ranch in sec. 12, T. 17 S., R. 17 W. Some of the larger

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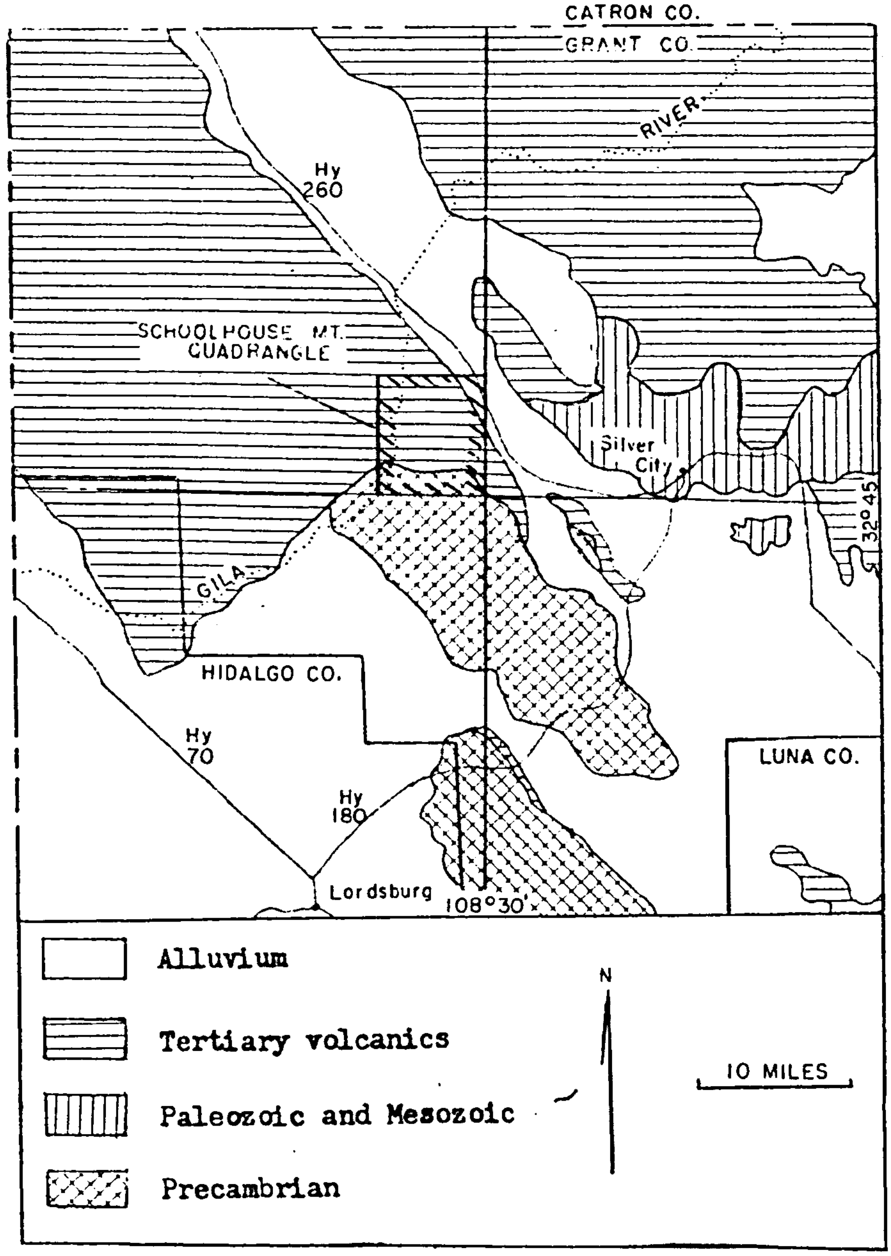
*No official quadrangle name has been assigned to this area by the U. S. Geological Survey (J. M. Lawson, U. S. Geol. Survey Regional Engineer, Pers. Comm., 1956). The U. S. Forest Service refers to this general area as the "Schoolhouse Mountain area." Because of this priority, the name "Schoolhouse Mountain quadrangle" will be used here, with the understanding that future U. S. Geological Survey work may render the name obsolete.



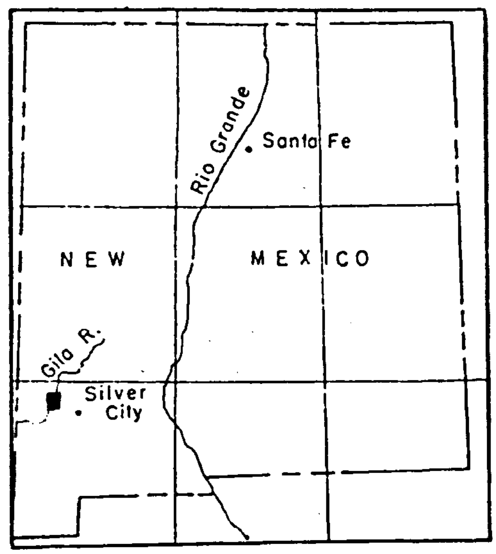


Fig. 1 Index maps of the Schoolhouse Mt. Quadrangle, Grant Co., New Mexico.

tributaries to the Gila River can be negotiated with a 4-wheel drive vehicle.

The topography ranges from moderate to rugged, with approximately 2100 feet of relief within the area. The highest point is Schoolhouse Mountain, which lies in the center of the quadrangle and reaches an elevation of 6305 feet. Along the western side of the quadrangle, the southward flowing Gila River carves a narrow canyon in the volcanic rocks and Precambrian granite. Major tributaries to the Gila River include Mangas Creek, which has its head in the Mangas Valley along the east side of the quadrangle. In the vicinity of the Foster ranch, the creek turns abruptly westward and carves a rugged canyon through the volcanic rocks, joining the Gila River in sec. 3, T. 17 S., R. 17 W. In the same section, the confluence of Schoolhouse Creek and Mangas Creek is to be found. A number of lesser intermittent streams flow down from the higher country in the center of the quadrangle including Ira Creek, Wildhorse Creek and Bear Creek. Davis Creek, Cherokee Creek and Road Creek are typical of the smaller tributaries which have their head in the mountainous country west of the quadrangle under discussion.

Most of the quadrangle lies within the confines of the Gila National Forest. Private ranches are located along the Gila River where the valley floor is carpeted with flat lying gravels and soil, and along the Mangas Valley on the east side of the quadrangle.

The name "Mangas" is spelled locally as "Mangus," and various maps carry both versions. Calvin (1946, p. 52) states that the stream is called the Rio Mangas. The stream was probably named after Mangas Coloradas ("Red Sleeve"), an Apache chieftan circa 1846. The spelling "Mangas" is apparently preferred and is used in this report. The present Mangas Creek is dry most of the year in its upper reaches. Its channel is, in some places, an impressive gash in the valley floor some 50-200 feet across and bordered by 15-foot high sheer vertical walls cut in the soil mantle of the valley —— mute testimony to the ravages of running water in an area of flagrant overgrazing.

Previous Geologic Work

The Geologic map of New Mexico (Darton, 1928) shows that the Schoolhouse Mountain quadrangle is covered largely by alluvium —— a point in which the map is decidedly in error. The geologic map shows none of the structures present in the area and omits a prong of volcanics that follows along the west bank of the Mangas Valley. More recent mapping has been done by Elston (1955) in connection with the work on a new geologic map of New Mexico. Elston states (Pers. Comm., 1956) that he "covered the geology of the Virden quadrangle (Lat. 32° 30'--33° 00' N; Long. 108° 30'--Arizona border) in brief reconnaissance fashion in the summer of 1955. His 1 inch = 2 mile map will be a part of the new geologic map of New Mexico on a reduced scale. The map and a brief preliminary report are on file with the New Mexico

Bureau of Mines, in Socorro." Elston (1956, p. 1553) has also commented briefly on the Virden quadrangle in general, but not specifically on the area under consideration in this report.

In the southern part of the quadrangle, some work has been done by Hewitt (1956), who concentrated on the Precambrian rocks found there. Hewitt states (Pers. Comm., 1956) that "the northern limit of my (sic) area is approximately the southern edge of the volcanics. Because of time limitations and because my problem was primarily with the Precambrian rocks, I mapped the Cretaceous sediments and younger volcanics in the areas northwest and northeast of Wild Horse Mesa in a reconnaissance manner only to delineate the Precambrian exposure." Hewitt mapped on aerial photographs, on a scale of 2 inches = 1 mile. Since Hewitt has undertaken to concentrate attention on the Precambrian rocks in the southern part of the quadrangle, less emphasis will be given those rocks than was originally intended.

Gillerman (1951, p. 286-287) briefly describes the Cloverleaf and Purple Heart fluorite deposits in the southern part of the quadrangle. Gillerman notes that the Purple Heart prospect is located in sec. 3, T. 18 S., R. 17 W., about 1-1/2 miles southeast of the confluence of Wild Horse Creek and the Gila River. The Clover Leaf prospect is located about 1/2 mile southwest of the Purple Heart. Both prospects are on northwest striking fluorite veins in granite.

The Black Hawk district is located approximately two miles south of the southeast corner of the quadrangle. Gillerman and Whitebread (1956) have described a series of intrusive and metamorphic rocks and associated uranium-nickel-cobalt-silver mineralization. At the time of this writing (spring, 1957) some attempt to re-open the mines in the Black Hawk district was being made.

The writer (Wargo, 1958) has also commented briefly on the structure and volcanic stratigraphy of the region.

Reference Maps and Photographs

No detailed topographic maps of the Schoolhouse Mountain quadrangle are available. Aerial photographs of the area are available from the Soil Conservation Service (USDA), as are semi-controlled mosaics and ozalid prints of stream patterns. Newer, high altitude photographs have been flown by the U. S. Forest Service. The photographs and maps pertinent to the area are listed in Table 1.

Field Methods

Field mapping was undertaken in the usual manner, using aerial photography as a base, in the absence of topographic sheets. In order to overcome the problems of distortion and scale change inherent in aerial contact prints, the mapping was done on an enlarged portion of the mosaic New Mexico 386. The mosaic was enlarged from a scale of 1 inch = 1 mile to a scale of 4 inches = 1 mile without significant loss of

Table 1

List of maps and photographs pertaining to the Schoolhouse Mountain quadrangle, Grant County, New Mexico.

Aerial Photographs

Agency--Soil Conservation Service (USDA)
Scale--2 inches = 1 mile (Approx.)
Name--Gila Indian Reservation, New Mexico (Grant Co.)
Number -- 4340--4346 incl., 4307--4302 incl.
Remarks--Flown in 1935(?)

Agency--U. S. Forest Service
Scale--1:40,000 (Approx.)
Number--DRA-7-139
Remarks--High altitude photographs

Aerial Mosaics

Agency--Soil Conservation Service (USDA)
Scale--1 inch = 1 mile
Control--Semi-controlled
Number--New Mexico 386

Base Maps

Agency--Soil Conservation Service (USDA)
Scale--1 inch = 1 mile
Name--Cliff Quadrangle (Gila No. 44)
Remarks--Shows land lines. Drainage traced from mosaic New Mexico 386

Agency--New Mexico Highway Dept.
Scale--1 inch = 2 miles
Name--Virden Quadrangle (SW9C)
Remarks--Shows some roads, most drainage, land lines

Agency--U. S. Forest Service
Scale--1 inch = 1 mile
Name--Gila National Forest (1948)
Remarks--Shows drainage, roads and land lines

clarity or detail. Contact prints were used stereoscopically to pinpoint locations on the enlarged mosaic.

The enlarged portion of the mosaic was cut into 8" x 9" rectangles and covered with acetate overlays, on which the actual mapping was done. Note locations were pricked through the photograph and acetate and the number recorded on the back. Only the note number, strike and dip data and specimen numbers (in red) were recorded on the back of the photograph. Each day's work was carefully inked and transferred onto a master sheet in the office, at the end of the day.

Approximately 200 days were spent in the field gathering the information shown on Plate 1 and in collecting various samples and checking correlation methods.

Climate and Vegetation

The climate in the Schoolhouse Mountain area is typical of that found in the higher mesas of southern New Mexico. Summer days, even at the altitudes encountered, tend to be excessively warm and less suited to field work than the cooler days during autumn, winter and early spring. Precipitation is negligible, amounting to less than 4 inches during the winter. The rainy season occurs during the late summer months. Vegetation includes several varieties of pinion, cedar, cottonwood and willow, along with numerous grasses ans shrubs and a few cacti. Yucca are abundant in the valleys. Except for small areas on the higher hills, the vegetation creates no particular problem in field mapping.

Acknowledgments

The writer gratefully acknowledges the assistance received from the Bear Creek Mining Company for subsidization of the field work and for chemical analyses and other laboratory work. Special thanks are due Ray E. Gilbert and the staff of the Rocky Mountain District, for their advice and encouragement. The writer also profited materially from discussions with Professors R. L. DuBois, J. W. Anthony, W. C. Lacy and E. B. Mayo of the University of Arizona, concerning various phases of the field and laboratory work. The completion of the thesis was aided by a grant from the Kennecott Copper Company.

REGIONAL GEOLOGIC SETTING

The Rocks —— A Regional Picture

Rocks of every major era are represented in the mining districts surrounding the Schoolhouse Mountain quadrangle. Within the Central District, Cretaceous sediments (Colorado formation) predominate at the surface, but are underlain by carbonates and clastics of Paleozoic age. Precambrian rocks appear in the Silver City quadrangle along the eroded tops of northwest trending monoclines. Mineralization in the Central district occurs either in the intrusive monzonites, as at Santa Rita, or in the folded carbonates, as in the vicinity of Fierro and Hanover. Mineralization is not well developed in the Cretaceous shales.

The largest mass of Precambrian rocks near the Schoolhouse Mountain quadrangle occurs in the Burro Mountains, and a portion of this complex crops out in the southern part of the quadrangle (See Plate 1). The rocks consist largely of granite, and are known as the Burro Mountains batholith. Associated with the batholith is a complex series of high grade metamorphic rocks, including hornfels, amphibolite and various kinds of gneiss, as well as migmatites and similar rocks of unknown origin (Hewitt, 1956). Monzonite stocks of Cretaceous(?) age invade the Burro Mountains rocks in at least three places, the largest being in the vicinity of Tyrone (Paige, 1922).

Intrusive rocks of possible Tertiary age are found in the southeast corner of the Schoolhouse Mountain quadrangle. No sedimentary rocks older than Cretaceous are known to occur anywhere within or upon the Burro Mountains complex. Sandstones and shales tentatively correlated with the Beartooth and Colorado formations crop out in the quadrangle and in a few places to the west.

For scores of miles to the west and north of the quadrangle, the surficial rocks consist of volcanics of Tertiary(?) age. These rocks may be a continuation of the Datil volcanics in west central New Mexico, or they may be a part of an even larger field that extends southward into central Mexico. The study of a small part of these volcanic rocks is the main theme of this paper.

The Tectonic Pattern — A Regional Picture

Two dominant features emerge in the analysis of the tectonic patterns in and around the Schoolhouse Mountain quadrangle, namely: (1) the trend of highlands and major outcrop masses and (2) the trend of major fracture patterns. The first of these, the trend of highlands and major outcrop masses may be a reflection of uplifts that have occurred in this region at intervals throughout geologic time. A glance at the Tectonic Map of the United States reveals that outcrop trends in this region are dominantly northwest. This is perhaps best illustrated by the long, narrow Burro Mountains uplift, which begins in the southeastern part of Grant County and continues northwestward until it disappears beneath the volcanics of the Schoolhouse Mountain quadrangle. Within the quadrangle, the volcanic rocks reflect the influence of this uplift by fault patterns and by complex flexures that impose a northwest strike on most of the effusive rocks. The trend of the Burro Mountains is accentuated by the presence of major drainage lines on both sides; the Mangas Valley on the northeast and the upper Lordsburg and Virden Valley on the southwest. Other examples of northwest to north-south trending outcrops, mostly of volcanic rocks, can be found along the Arizona border and in the vicinity of Silver City.

Two sets of fractures dominate in the area surrounding the Schoolhouse Mountain quadrangle. One set, trending in a northwesterly direction often serves to outline the highlands and probably represents major lines of weakness along which the vertical uplifts occurred. Examples of such fractures are to be found along the northwest side of the Mangas Valley, along the southwest side of the Burro Mountains, along broken monoclinal uplifts in the little Burro Mountains and in the Silver City Range. In the Little Burro Mountains at least, the movement along the faults has been relatively recent, as indicated by faulting of the later Tertiary gravels in that area (Paige, 1922).

Northwest-trending faults appear in the metamorphic and intrusive rocks near the southwest corner of the Schoolhouse Mountain quadrangle.

Hewitt (1956, Pl. 1) shows at least four major faults in the Clark's Peak area, some six miles northeast of Redrock. The faults either disappear into or beneath the volcanic rocks in that area. The most important feature of the faulting here, and in the southern part of the quadrangle is the fact that remanents of the Cretaceous Colorado(?) and Beartooth(?) formations are often preserved on the upthrown sides, permitting study of these units which, very likely, once covered a large part of this region.

The other set of fractures dominating the region around the Schoolhouse Mountain quadrangle trends northeast. In general, these faults tend to be more numerous and shorter, especially in the Silver City quadrangle. In the Silver City Range, a group of northeast-trending faults slice the Silver City monocline into blocks. Paige (1916) suggests that the faults occurred as a result of tension release, causing a stepping down of the section to the northwest. In the Central district, northeast-trending faults are of considerable economic importance. The Groundhog Fault, for example, is the site of extensive zinc mineralization in the Groundhog mine. The Barringer Fault, another major northeast-trending fracture in the district parallels the northwest side of the Bayard Arch and effectively forms a northwest limit to mineralization in the district. Northeast-trending faults are not prominent in the Schoolhouse Mountain quadrangle.

Intersections of the two fracture sets in this region could be of practical interest. The importance of structural intersections has been elaborated upon by Billingsley and Locke (1941) among others. Certainly the two main structural directions (northeast and northwest) which predominate here, extend far beyond Grant County, and even New Mexico. The northwest trend of fold axes, outcrop patterns and fracturing is present in the Sierra Madre Occidental, extends into southern New Mexico and is dominant along the southwest side of the Colorado Plateau in Arizona. The northeast trend is less well defined regionally but often appears as trends of foliation and fold axes in the Precambrian rocks of southern Arizona and New Mexico. Conceivably, this northeast line of weakness may have been re-activated in post Precambrian times, accounting for the fracturing in the overlying rocks. Hence, on a regional scale, intersections do occur in the vicinity of the Schoolhouse Mountain quadrangle, but whether these intersections constitute a significant factor in the mineralization of the area remains problematical. In passing, it might be mentioned that Leroy (1954, p. 743) states, concerning the Santa Rita deposit "the localization of the Santa Rita deposit at the intersection of two main structural zones has not been proven and possibly does not exist."

The Ore Deposits —— A Regional Picture

The Schoolhouse Mountain quadrangle lies in a geologically complex area and is nearly surrounded by major base metal ore deposits.

To the east lies the Central mining district, an area characterized by intricate fault patterns, rather mild folding and intrusive bodies of Cretaceous and Tertiary age. Southeastward from the Schoolhouse Mountain quadrangle lies the Tyrone mining district, where the major geologic feature is a large, nearly circular body of Cretaceous(?) monzonite porphyry which has invaded the Precambrian Burro Mountains complex. Directly westward from the quadrangle is the Steeple Rock district, an area of minor mineralization along fractures in the volcanic rocks, while to the northwest lies the large copper deposits at Clifton and Morenci. The Mogollon district lies about 25 miles to the north of the quadrangle.

The above observations make it obvious that the Schoolhouse Mountain quadrangle is surrounded on three sides at least by mineralized areas of major importance, namely Central, Tyrone and Morenci. In a larger sense, these three districts and the Schoolhouse Mountain quadrangle lie somewhere along the southern border of the Colorado Plateau, whose influence in the localization of ore deposits has been pointed out by Butler (1933, p. 219) and others.

Thus, from the point of view of economic geology, the justification for further exploration in this region seems established. Furthermore, the fact that most of the area between these three major deposits is covered by Tertiary(?) volcanic rocks brings forth the omnipresent question as to the nature of the geology underlying these rocks and speculation as to the occurrence of ore deposits that may underlie these younger volcanics.

Paleogeography

Viewing the southern part of New Mexico and Arizona as a whole, the Schoolhouse Mountain quadrangle can be seen to lie on the border of the Sonoran Geosyncline. Further, the quadrangle also lies within or near an east-northeast trending belt of strike deflections, intrusions and structural dislocations prominent in south central New Mexico. The relationship of the quadrangle to the Sonoran Geosyncline and the belt of tectonic activity is shown in Figure 2.

McKee's (1951, p. 451-505) maps indicate that the Silver City-Schoolhouse Mountain-Morenci area has been a borderland adjoining a moderately active geosyncline throughout a large part of geologic time. The geosynclinal phase in southwestern New Mexico was probably best developed during the Cretaceous period. In the Big Hatchet Mountains of southern Hidalgo County, Zeller (1953, p. 142-143) recognized three unnamed Lower Cretaceous formations — a red bed formation at the base, a medial limestone formation and an upper sandstone and shale formation. The units total about 7000 feet in thickness. These three units Zeller tentatively correlates with the Bisbee group in southern Arizona. Zeller believes that the 12000-24000 feet of Lower Cretaceous rocks reported by Lasky (1936, p. 1) in the Little Hatchet Mountains

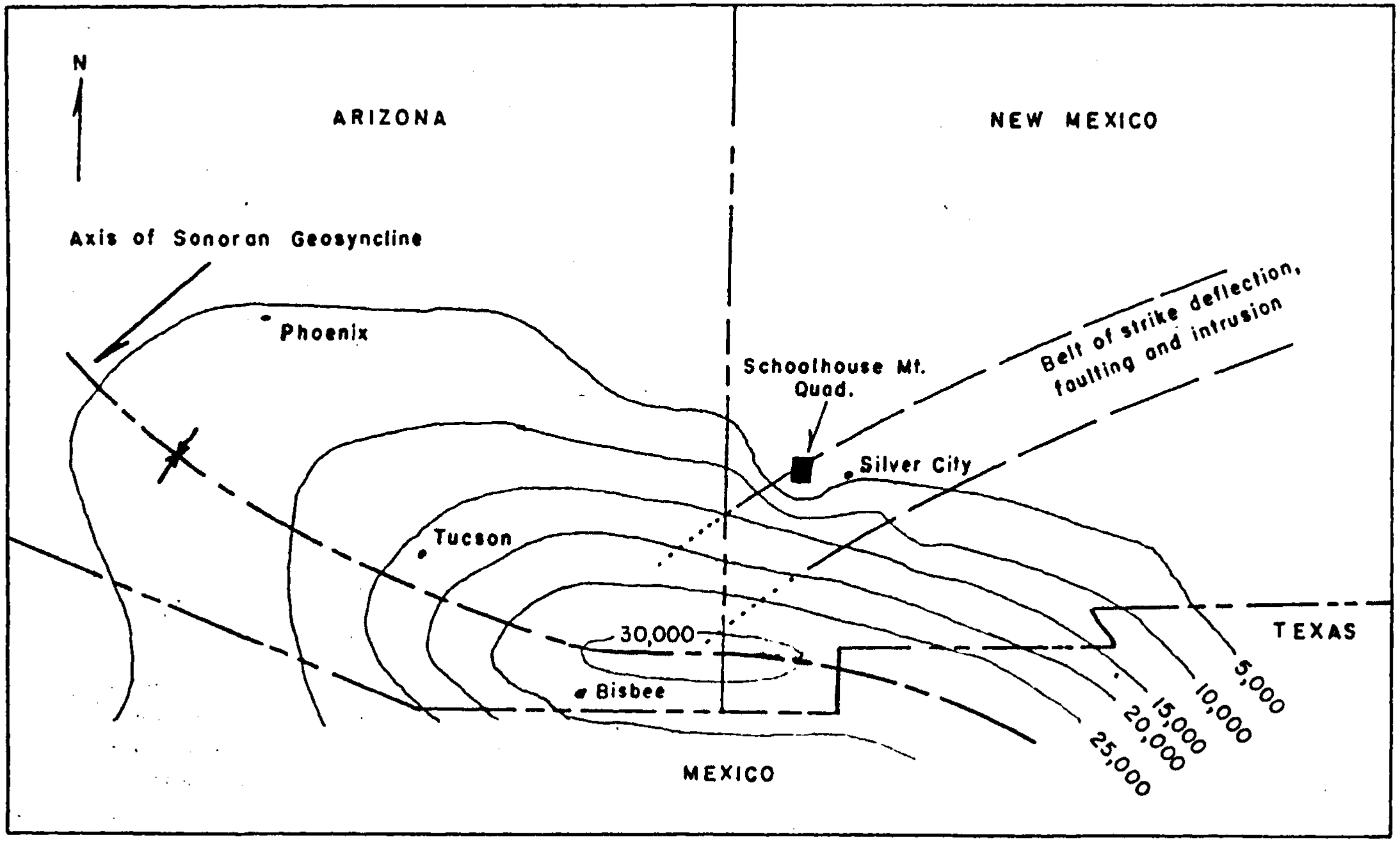


Fig. 2 Index map showing location of Schoolhouse Mt. quadrangle, belt of tectonic activity and Sonoran geosyncline. After Hernon, Jones and Moore (1953); Isopach data for combined Paleozoic and Mesozoic after McKee (1951).

nearby may contain at least one duplication.

In contradistinction to the relatively thick series of rocks that appear near the center of the Sonoran Geosyncline, the rocks in the Silver City-Schoolhouse Mountain quadrangles are relatively thin. Lower Cretaceous rocks are not represented in the Silver City area, and Upper Cretaceous Beartooth quartzite and Colorado shale total about 1140 feet (Lasky and Hoagland, 1948). In the southern part of the Schoolhouse Mountain quadrangle, the writer has measured 695 feet of Upper Cretaceous(?) shales and quartzites, although obviously some has been removed by erosion.

SEDIMENTARY ROCKS

Beartooth(?) quartzite

The lowest sedimentary formation in the stratigraphic column is the Beartooth(?) quartzite. This formation crops out in sec. 2 and 11, T. 18 S., R. 17 W., in sec. 6 and 7, T. 18 S., R. 16 W., and in various places along the Wild Horse Fault. The most extensive outcrop forms the rim of the structural and topographic basin found on top of Wild Horse Mesa.

The Beartooth(?) quartzite almost everywhere in the Schoolhouse Mountain quadrangle consists of hard, buff or brown quartzite. Quartzite conglomerate lenses occur in places in the section (See Plate 2, Fig. 1) and a shaly phase crops out along Wild Horse Creek, but neither of these is very extensive.

Usually the quartzite rests on a weathered granite surface (See Plate 2, Fig. 2). The lowermost 6-24 inches of the formation consists of a coarse grained quartzite which contains subrounded quartz fragments and argillaceous material evidently derived from the underlying weathered granite. Above this zone, the quartzite is finer grained and usually very pure. Although the granite is deeply weathered — in places up to 20 or 30 feet — the pre-Beartooth(?) topography appears to be rather smooth and rolling, rather than having the steep slopes and sharp ridges present now.

The total Beartooth(?) outcrop area was probably much greater prior to the formation of the Wild Horse Fault, and subsequent erosion of the upthrown block. This is suggested by the fact that the quartzite forms small isolated outcrops along the fault, and that portions of a rhyolite sill which once invaded the quartzite are now found unroofed along the fault.

The fact that everywhere it is exposed in the southern part of the quadrangle the Beartooth(?) quartzite rests on Precambrian rocks is significant, in that it shows that the rocks making up the interval between Precambrian and Upper Cretaceous had been stripped away prior to the deposition of the quartzite — if indeed these rocks had ever been deposited at all. Further speculation on the pre-volcanic rocks in the northern part of the quadrangle is presented elsewhere in this report (See "Structure").

In some places a rhyolite sill invades the lower part of the Beartooth(?) quartzite (See Fig. 3). The sill is up to 75 feet thick, and invades the Colorado formation as well.

No fossils have been found in the Beartooth(?) quartzite, and correlation can only be based on comparison with similar rocks in the Silver City quadrangle to the east. A brief summary of these arguments is presented in the discussion of the Colorado(?) shale.

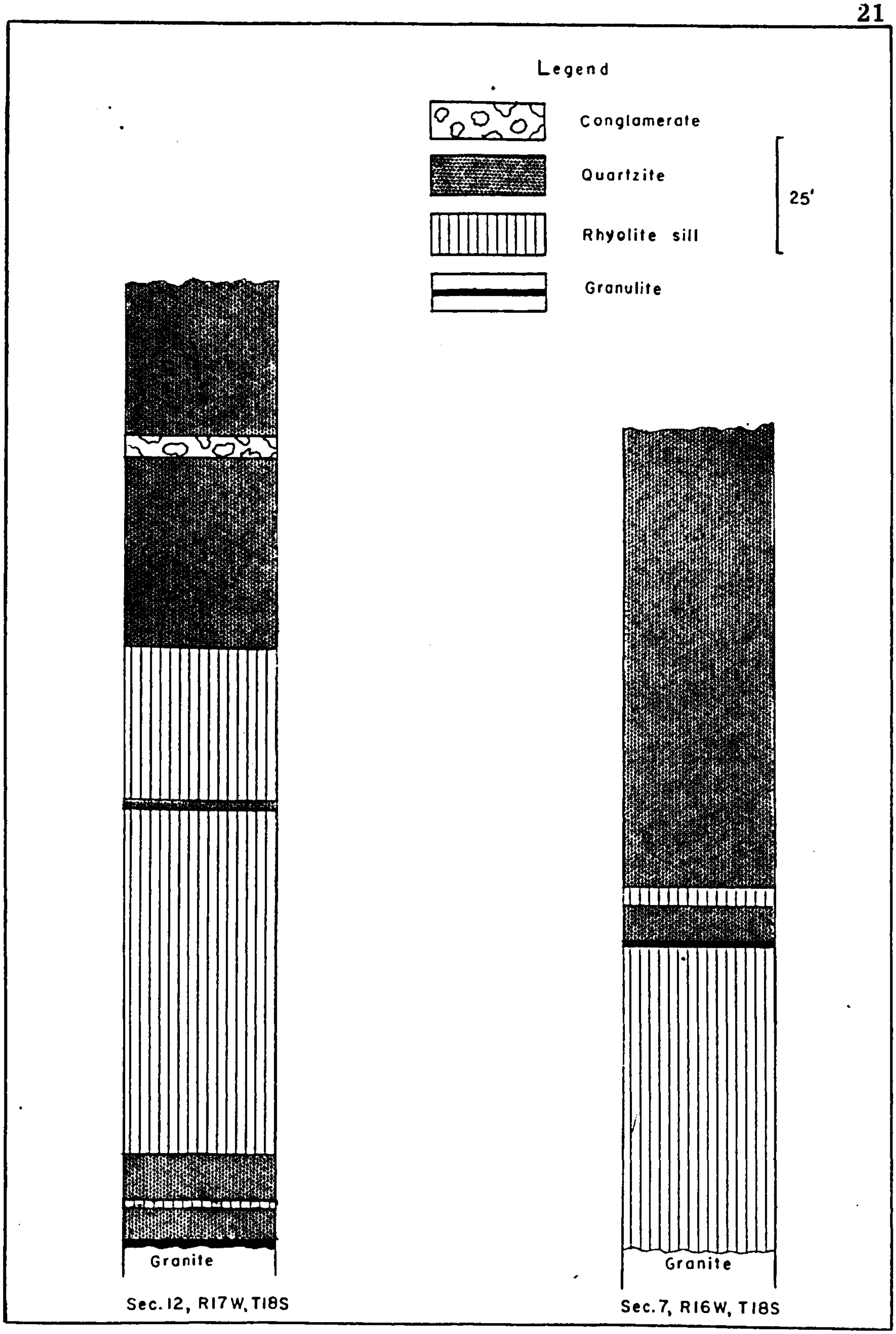


Fig. 3 Comparison of two sections involving the Beartooth quartzite and a rhyolite sill, in the southern part of the Schoolhouse Mt. quadrangle.

Petrographic description of the Beartooth(?) quartzite---The Beartooth(?) quartzite consists almost entirely of quartz. A thin section of a slightly conglomeratic phase shows that the majority of the quartz grains are sub-rounded and approximately of the same size. Conglomerate fragments consist of a fine grained, nearly aphanitic rock which may be jasperoid or chert. A secondary overgrowth of quartz is indicated by the following: (1) some of the quartz grains have shadowy outlines of quartz which are optically continuous with the grain, and separated by a line of tiny, dust-like inclusions, and (2) one of the conglomerate fragments is cut by a tiny quartz veinlet which appears to continue past the boundaries of the fragments into the surrounding quartz matrix. Most of the quartz grains are filled with dust-like inclusions, the nature of which could not be determined.

Colorado(?) formation

A sequence of shales and sandstones cropping out in the southern part of the quadrangle has tentatively been correlated with the Colorado formation present in the Silver City area, 20 miles to the east.

The main outcrops occur in sec. 36, T. 17 S., R. 17 W., in the vicinity of the Wild Horse Fault, in sec. 2 and 11, T. 18 S., R. 17 W., and in sec. 1 and 12, T. 18 S., R. 17 W. In most places it appears that the Colorado(?) formation occurs on the upthrown side of the faults which often bound the outcrops on one or more sides. On Wild Horse

Mesa, the Colorado(?) shales occupy the floor of a faulted, shallow structural and topographic basin (See Plate 1, Cross section BB'). A maximum of 560 feet of shale and sandstone has been found in the Schoolhouse Mountain quadrangle.

The formation consists of alternating beds of olive green to dark brown sandstone and fissle black or dark green shale (See Plate 3, Fig. 1). Occasionally buff colored sandstone beds are found in the section. Limy beds are rare, but one such bed of impure, dark limy shale cropping out along the upper reaches of Wildhorse Creek, in the SW 1/4 of sec. 31, T. 17 S., R. 16 W., yielded some poorly preserved fossils of what appear to be molluscs.

Deformation of the shale has been slight, except in the vicinity of faults, where the rock is apt to be highly contorted and crushed. Elsewhere, gently dipping beds, with occasional weak folds such as is shown in Plate 3, Figure 2 are the rule. Intrusion along bedding planes by rhyolite sills occurs in sec. 31, T. 16 S., R. 16 W., and sec. 35, T. 17 S., R. 17 W. Metamorphism caused by these intrusions is mild, and is usually manifest in a slight hardening and baking of the shale and formation of a hornfels-like rock along the rhyolite-shale contact.

The correlation of the formation is tentative and awaits the discovery of identifiable Upper Cretaceous fossils. A comparison of the stratigraphic sequence in the sediments located in the southern part of the Schoolhouse Mountain quadrangle with the sequence found in certain places in the Silver City quadrangle reveals a marked similarity. In the Silver City area, Paige (1916), Lasky (1936) and others note that the Colorado shale consists of dark colored shales and sandstones which rest in places on dense, hard quartzite (Beartooth). Since the sedimentary section in the Schoolhouse Mountains quadrangle is much the same in lithology and sequence, it seems logical to correlate these rocks with the Upper Cretaceous rocks in the Silver City area.

Gravels

Introduction---Within the Schoolhouse Mountain quadrangle, three different stages of gravels have been recognized and mapped on Plate 1. The three stages are readily differentiated on the basis of rock type, degree of consolidation and stratigraphic position.

For the most part, the alluvial cover and talus gravels in the higher mountains have not been mapped, owing to the limitations of the scale employed. In general, the effusive rocks are lightly covered with debris derived from their own erosion, but in most places enough outcrop remains to make accurate mapping possible. In the Precambrian rocks at the south end of the quadrangle, the weathering of the granitic rocks has provided a substantial mantle of soil, making outcrops scarce except on hilltops and canyon bottoms. As a consequence, many of the more detailed structural features of the rocks may have been overlooked.

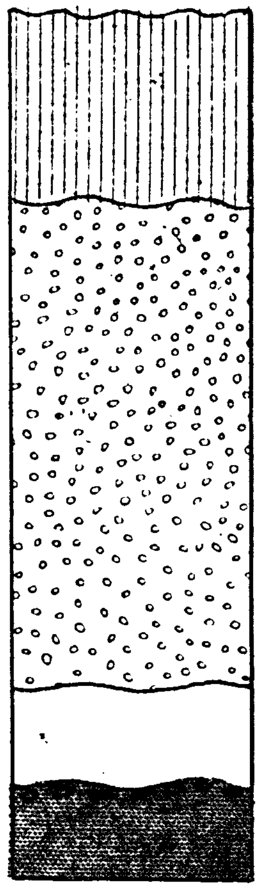
The gravels mapped in the Schoolhouse Mountain quadrangle are called in this study simply "Stage One, Stage Two or Stage Three gravels" as the case may be. The Stage One gravels are here named the youngest and the Stage Three gravels the oldest.

The term "Gila Conglomerate" is probably justified in the case of the Stage Three gravels, but will not be used in the absence of any specific criteria for correlation of this unit with similar gravels in the intermontane valleys of southern Arizona and New Mexico. In passing, it might be noted that the term "Gila Conglomerate" has been confined to the consolidated or semi-consolidated gravels of Pliocene-Pleistocene age, which crop out along the Gila River and its tributaries in New Mexico and Arizona. Knechtel (1936, p. 81-92) points out that three stratigraphically equivalent facies comprise the Gila Conglomerate, namely: (1) lake beds, stream gravels and bolson deposits, in the center of the basin, (2) fanglomerates along the edge of the basin and (3) a transition zone between (1) and (2) (cf. Heindl, 1952, p. 113-116).

Stage Three gravels---The largest outcrop of gravels in the northwest part of the quadrangle is designated the Stage Three gravels. These gravels crop out in sec. 32, 33, 34 and 35, T. 16 S., R. 17 W., and sec. 1, 2, 3, 4, 5, and 10, T. 17 S., R. 17 W. and in parts of adjoining sections. A small outcrop of gravels of possible Stage Three age is located in sec. 17, T. 16 S., R. 16 W., in the eastern part of the quadrangle.

The stratigraphic position of the Stage Three gravels is best revealed along Davis Creek, in sec. 32, T. 16 S., R. 17 W., along the western edge of the quadrangle. Here, the Stage Three gravels clearly overlie the Moonstone Tuff formation, and a little farther west are overlain by basalt flows. The Moonstone Tuff which overlies the Cherokee Creek formation (See Plate 4, Fig. 1) thins and disappears to the east, and in most of the Davis Creek drainage, the Stage Three gravels rest directly on the Red Rhyolite member of the Cherokee Creek formation. The contact between the Stage Three gravels and the Moonstone Tuff is smooth and almost horizontal (See Plate 4, Fig. 2) and the contact with the overlying basalt also seems devoid of major irregularities (See Plate 5, Fig. 1). A partial section in sec. 32, T. 16 S., R. 17 W. shows the position of the gravels with respect to the other formations in the area (See Fig. 4).

The Stage Three gravels consist of angular fragments of rock, cemented by silica to form a compact, solid mass. Crude bedding is present almost everywhere. The most abundant rock type in the Stage Three gravels is a dense gray rhyolite and rhyolitic welded tuff bearing narrow, streaky vesicles which are lined with tiny quartz crystals. In places where the gravels do not crop out, their presence beneath the soil cover is indicated by this gray rhyolite float. Most of the fragments have one or two flat surfaces and sharp corners, and have a low



Basalt; dark, dense, scoriaceous; 0-100 feet.

Stage 3 gravels; good bedding, well cemented, many fragments of grey rhyolite member, McCauley formation; 100-275 feet.

Moonstone tuff; grey, adularia bearing crystal vitric tuff; 0-100 feet.

Cherokee Creek formation (Red rhyolite member)

Fig. 4 Composite section in Sec. 32, R17W, T16S, Schoolhouse Mt. quadrangle.

order of sphericity. The flat surfaces are due to the original jointing of the rocks, rather than to abrasion. Other rocks recognized in the gravels include brown rhyolite tuff breccia, red rhyolite tuff breccia and a few blocks of sanadine (Moonstone) tuff.

The gray rhyolites mentioned above are identical with those of the McCauley formation, both in the hand specimen and in thin section. The slabby character of the gravel fragments coincides with the observation that closely spaced jointing is common in the McCauley formation, especially in sec. 31, T. 16 S., R. 16 W. and sec. 22, T. 17 S., R. 17 W. The rather large areal extent of the Stage Three gravels in the northwest corner of the quadrangle and in the region farther north suggests that considerably more of the McCauley formation cropped out in this region in the past, than crops out now.

A study of the structure and contacts of the Stage Three gravels reveals that no major angular unconformity exists between this unit and the underlying Cherokee Creek formation or Moonstone Tuff. Dips of the gravels on the east side of the Gila River range from 15 to 30 degrees to the northeast. Similar readings are to be found in the Cherokee Creek formation immediately underlying the gravels, although dip readings in the volcanics are apt to be less reliable than those in the bedded gravels. On the west side of the Gila River, the gravels and the Cherokee Creek rocks dip to the northwest and southwest. Again, the gravels appear to be largely conformable with the Cherokee Creek formation and the

Moonstone Tuff. Faulting is present in the Stage Three gravels, but not to a marked degree. The largest fault noted on Plate 1, which cuts both gravels and underlying rocks is located in sec. 4, T. 17 S., R. 17 W. The fault appears to be a steep normal fault, striking slightly west of north and dropping the gravels against the red rhyolites of the Cherokee Creek formation.

The fact that the gravels are conformable with the underlying volcanics, participate in the arching in the northwest part of the quadrangle, and have been faulted suggests that the gravels were deposited near the end of the period of uplift which tilted the volcanic rocks in this region.

Stage Two gravels---The gravels of Stage Two are younger than those of Stage Three. The Stage Two gravels occur as higher terraces and as subdued hills, especially in the Mangas Valley along the east side of the quadrangle. These gravels are, at the present time, being actively eroded by Mangas Creek and its tributaries and probably supply most of the debris for the younger gravels to be discussed below. In the northeast part of the quadrangle, the gravels have been eroded into rounded, subdued hills generally less than 100 feet high (See Plate 5, Fig. 2). The tops of these hills in the quadrangle to the east present a remarkable flat surface. Along the Gila River, the Stage Two gravels are thinner — less than 50 feet — and occupy the higher banks next to the river. Bedding is usually well developed in the Stage Two gravels (See Plate 6, Fig. 1). Consolidation is not far advanced and most of the gravels are loose and friable, hence easily eroded.

The source of the Stage Two gravels in the Mangas Valley appears to have been from the west — that is, from the volcanic rocks now exposed in the center of the quadrangle. This is shown by the fact that the beds in the Stage Two gravels which border the volcanics consist almost entirely of tuff breccias and brown tuffs and their comminuted equivalents. In sec. 21, T. 17 S., R. 16 W., the gravels overlap and dip gently away from the higher outcrops of volcanic rocks. The source of the Stage Two gravels in the Gila River area is less evident. The presence of granitic and basaltic boulders suggests that some of the debris may have been supplied from the basalt highlands several miles to the northwest and from undiscovered Precambrian outcrops farther upstream.

Although igneous rocks are abundant in the Stage Two gravels, sedimentary rocks, save for a few quartzite boulders, are missing. No carbonate rocks were seen among the gravels. The significance of such a situation cannot be fully understood from the study of such a small area, but it may point up the possibility that the Paleozoic formations, in which carbonates are abundant, are not present, or at least have never been exposed in the upper drainage basin of the Gila River, north of the Schoolhouse Mountain quadrangle. Quartzites, on the other hand, are common in the Cretaceous system and hence may have been exposed upstream in some past erosion interval. Although beyond the scope of this paper, it would be interesting to determine the provenance of the various gravels along the Gila. In doing so, it might be possible to cast some light on the kind of rocks that existed in the highlands to the north. The answer to the question as to whether a Paleozoic section such as is found near Silver City is present under the volcanic rocks between Silver City and Morenci may provide further impetus to the exploration for ore deposits beneath these volcanics.

Stage One gravels---The gravels of Stage One are the youngest gravels in the area, and are now in the process of being deposited by the intermittent streams and by the Gila River. These gravels always occupy the lowermost portions of the stream or river bed and often exhibit evidence of having been re-worked a number of times. The Stage One gravels are most abundant along the Gila River from D. McCauley's ranch to the north boundary of the quadrangle and beyond. Numerous changes have been made in the channel of the Gila River, causing reworking and re-deposition of the Stage One gravels. A good example of such channel shifting can be seen in sec. 27 and 28, T. 17 S., R. 17 W., where the river has moved from one side of the flood plain to the other —— a distance of some 300 feet —— in the interval between 1935 and the present. Stage One gravels in the Mangas Valley have been deposited by Mangas Creek. For the most part, these gravels are interbedded with finer grained sand and silt, and a well developed soil profile is present in places.

The gravels of Stage One have been won from the accumulations of Stage Two and Three gravels which generally occupy a slightly higher elevation along the river. Hence, owing to their continued re-working, the Stage One gravels are usually well rounded and possess a high degree of sphericity. Rock types are varied, including flows and pyroclastics of many colors, basalt boulders and occasional cobbles of granite and peridotite. Bedding is usually poorly developed and cementation is negligible.

Age of the gravels---The absence of fossil remains in the gravels precludes the possibility of dating these rocks on that basis. For the reasons mentioned above, the Stage Three gravels appear to be equivalent to the Gila Conglomerate which elsewhere is considered to be of Pliocene-Pleistocene age. In the Schoolhouse Mountain quadrangle, the Stage Three gravels are overlain by basalt flows, which in some parts of southern New Mexico are considered to be of Quaternary age (Jicha, 1954, Pl. 1). Callaghan (1953, p. 143-144) notes that basaltic lavas of several different ages represent the latest stage of igneous activity in southwestern New Mexico. Stage One and Two gravels, being younger, are then considered to be of Pleistocene-Recent age.

Inter- and Intra-formational sediments

Scattered throughout the northern three fourths of the Schoolhouse Mountain quadrangle are numerous, small outcrops of sedimentary rocks interbedded with the volcanics. Some of the larger outcrops are shown on Plate 1. For the most part, these sediments consist of sandstone, shale and conglomerate that were deposited during lulls in the volcanic activity in that area. The source of the sediments was undoubtedly from the nearby volcanic outcrops, as is shown by the preponderance of volcanic fragments in the sediment. The angularity of the fragments suggests that the particles had not travelled very far from their source. Crude cross lamination, pebble lenses and silt beds attest to the work of running water. Limy sediments were not seen.

METAMORPHIC AND INTRUSIVE IGNEOUS ROCKS

Granite and Related Rocks

Coarse grained rocks of granitic composition crop out in the Schoolhouse Mountain quadrangle, south of the Wild Horse Fault. These rocks consist of: (a) coarse grained pink or greenish granite with varying amounts of biotite, (b) amphibolite, biotite gneiss and biotite schist and (c) sillimanite schists and migmatites.

In sec. 12, T. 18 S., R. 17 W., a small mass of hornblende gneiss and amphibolite having a north-south elongation crops out. The foliation within the mass is parallel to the elongation of the mass as a whole. The contact between the amphibolite and the granite is sharp (See Plate 6, Fig. 2). Within the amphibolite mass, numerous stringers of coarse grained, hornblende-bearing granite are found. Judging from the outward appearance, the granite magma appears to have invaded the amphibolite, in part inserting itself along fracture planes and in part reacting with the amphibolite to produce diffuse masses of a rock intermediate between granite and gneissic hornblende granite.

The rock in the southwestern part of the quadrangle includes numerous small masses of biotite schist, aplite, sillimanite schist and migmatite. In places the normally homogeneous granites give way to migmatites and rocks with large (up to 1-1/2 inch) porphyroblasts of orthoclase. In many of these rocks tiny bright grains of pyrite are visible, although other forms of alteration are to be seen only along fracture zones. The origin of the pyrite in a dominantly fresh rock remains an enigma, although conceivably it may have been formed by the sulfidization of iron originally present in the rock, in a manner suggested by Sales and Meyer (1948, p. 9-33).

The origin of the granite in the southern part of the quadrangle has not been definitely established. Classically, Hewitt (1956, Pl. 1) suggests that the granite is part of the Burro Mountain batholith, which has invaded a metamorphic terrane —— an interpretation often rendered in such a complex of granitic and metamorphic rocks. An extensive analysis of the origin of the granites in the Schoolhouse Mountain quadrangle is beyond the scope of this report, and indeed would probably be of little value, since the granitic rocks are only a small part of a much larger mass to the south.

Petrographic description of the amphibolite---The amphibolites consist largely of hornblende and plagioclase distributed in rather poorly defined layers. The hornblende is dark green to blue in color, and often has a well developed seive structure with abundant quartz inclusions. The plagioclase is andesine. Some secondary development of sericite along the borders of feldspar crystals is present.

Petrographic description of the granite---The rock is made up largely of orthoclase porphyroblasts and quartz. Lesser amounts of biotite which has been altered to pale green chlorite are present. The orthoclase porphyroblasts tend to be nearly euhedral, but along the more irregular edges, the effect of crystal growth and subsequent envelopment of the bordering mineral grains can be seen. Sericitic alteration products are common along cleavage cracks in the orthoclase.

Dikes and Sills in the Volcanics

Dikes and sills have not been recognized in abundance in the volcanic rocks of the Schoolhouse Mountain quadrangle. Possibly one reason stems from the fact that they seldom weather out to form topographic highs, and hence are likely to be covered by talus and consequently overlooked.

The two largest dikes which cut the volcanic rocks have an intermediate composition. In sec. 20, T. 17 S., R. 17 W., a 50 to 75 foot thick, vertically dipping dike cuts through the gray rhyolite member of the McCauley formation. The dike weathers into a conspicuous northwest-trending ridge, and is easily recognized. In the outcrop, the dike appears as a fine grained, slightly porphyritic andesite or basalt, ranging in color from a light gray to a very dark gray. The darker phases of the dike are found near the contact. Planar structures in the form of oriented streams of mafic minerals are present along the contacts of the dike. The planar structures always parallel the contact with the rhyolite. In some places the fine grained, banded rock looks much like some of the banded sandstones seen elsewhere in the quadrangle.

A second dike, consisting of porphyritic andesite or latite cuts the white tuffs and brown tuff breccia of the Mangas Creek formation in the northeastern part of the quadrangle. Outcrops are sparse, and the trend of the dike is not well defined, although along most of its exposure it appears to cut across the strike of the Mangas Creek rocks at an acute angle. In sec. 6, T. 17 S., R. 16 W., along Mangas Creek, an irregular intrusive of similar aspect is thought to be a part of the same dike.

Other dikes cut the volcanic rocks in sec. 30, T. 17 S., R. 16 W. and sec. 6, T. 18 S., R. 16 W., to name two of the most prominent. None of these dikes can be followed for more than 1/2 mile, and seldom are they over 40 feet wide. Compositions are variable. Those in sec. 30 and 6, mentioned above, are andesite porphyry, while others are rhyolite.

The strikes of the various dikes in the volcanic rocks, when plotted on a diagram such as is shown in Plate 24, Figure 2 suggests that most of the dikes were intruded along northwest-trending planes of weakness. When the strikes of the faults and joints in the volcanics are compared with the strikes of the dikes, it becomes evident that many of the dikes were probably injected along fault planes which had been formed earlier in the tectonic history of the area.

Petrographic description of the acid dikes---The rock consists of orthoclase phenocrysts set in a matrix of brownish, dusty material which is probably mostly glass. An occasional glomeroporphyritic aggregate of quartz and feldspar is found in the section. Biotite occurs as small (1 mm) curved flakes which often have been somewhat altered to magnetite. The feldspars are, in part, altered to sericite.

The rock resembles the more acidic volcanic members, especially those which make up the Mangas Creek formation. Although the amount of quartz observed as phenocrysts is small, the rocks, by virtue of their lighter color and resemblance to the surrounding volcanic rocks are mapped as acidic intrusives.

Petrographic description of the basic dikes---The rock consists almost entirely of an intergrowth of feldspar laths and a dark, aphanitic material, possibly glass. One or two larger feldspar phenocrysts and an occasional flake of biotite are found in thin section.

The basic composition of the rock cannot be proven, in the absence of a chemical analysis. However, the rock can be distinguished from the more acidic dikes which contain glass and fragments similar to those found in acidic volcanic rocks. In addition, the basic dikes tend to have a darker color than the acidic dikes.

Rhyolite Dikes and Sills in Older Rocks

Intrusive igneous rocks of rhyolitic composition are found in the southeastern part of the Schoolhouse Mountain quadrangle. In sec. 7, T. 18 S., R. 16 W., the nature of the intrusive may be seen. Here, the rhyolite invades the lowermost beds of the Beartooth(?) quartzite, forming a thick sill. The sill-like nature of the intrusive is further shown in sec. 1, T. 18 S., R. 17 W., where the rhyolite invades the sandstones and shales of the Cretaceous Colorado(?) formation. The sill has inserted itself just beneath a rather prominent buff colored sandstone bed in the shales. Along the Wild Horse Fault, in sec. 6, T. 18 S., R. 16 W., the rhyolite rests on the Precambrian granite, and is now exposed because the overlying quartzites have been stripped away. In sec. 12, T. 18 S., R. 16 W., the rhyolite appears as thin, flat lying dikes cutting the granite.

The rhyolite sill in the southeastern part of the quadrangle is generally light gray to buff in color. Phenocrysts are usually absent, but a few grains of quartz and feldspar are visible. The rock has been moderately altered almost everywhere. Neither bedding nor breccia fragments were observed in the sill, although a crude columnar jointing is at times visible. The sill is often tightly welded to the rocks it invades, and has caused minor metamorphism in the shales. Small stringers of the intrusive in places cross the bedding in the quartzite.

In sec. 7, the contacts between the sill and the quartzite are well exposed.

The relative age of the rhyolite can be determined with some degree of accuracy. Since the rhyolite invades both the Beartooth(?) and Colorado(?) formations, it must be at least post-Colorado in age. In sec. 31, T. 17 S., R. 16 W. the rhyolite rests on the blue andesite units, and appears to be an unroofed sill. The age of this andesite unit also is unknown, but by analogy with the andesitic rocks occupying a similar stratigraphic position elsewhere in New Mexico, it appears that an Upper Cretaceous-Lower Tertiary age assignment of the andesite is not amiss. Hence, the rhyolite is regarded as being post-Cretaceous in age. To pinpoint it more closely is difficult, but judging from the large amount of acidic rock of probable Middle Tertiary-Late Tertiary age elsewhere in the quadrangle, it would seem reasonable to assume that the sill is of the same age.

Petrographic description of the rhyolite sill---The rock consists of an interlocking mosaic of quartz and orthoclase(?) grains, clouded by alteration minerals. The quartz and orthoclase(?) are equigranular for the most part, and the outlines of larger plagioclase and orthoclase phenocrysts are observed in places. Elongate slivers of altered hornblende(?) are present in one slide. The alteration products consist of tiny, irregularly shaped aggregates of a dark, usually opaque mineral.

Larger flakes have a faint brown color, suggesting that the mineral is an iron oxide. Other alteration products include clay minerals and sericite.

VOLCANIC ROCKS

Introduction

Nine volcanic formations including 23 members have been recognized in the Schoolhouse Mountain quadrangle. Cognizant of the difficulties to be encountered in the correlation of volcanic units from region to region, the writer has attempted to include in the various formations named a suite of rocks that is distinctive enough to make their correlation elsewhere possible. Rather than to name each rock type encountered as a separate formation, it was thought prudent to name them as members, lumping together a number of members to make a formation. The gathering together of the various members was not done indiscriminately; but rather only those members which showed some stratigraphic relationship to one another were grouped and given a formational name. In some instances the stratigraphic relationships between formations is not distinct; for example those between the Mangas Creek formation and the Kerr Canyon formation. In the descriptions of these formations an attempt is made to present some justification for dividing the units in the manner shown on Plates 1 and 22.

The names of the formations are based, whenever possible, on geographic or local names. In the instance of the Gamma and Delta formations and the members in the latter formation, no suitable names were available and it was necessary to resort to some other system of naming. On the following pages the volcanic rocks are discussed in order of decreasing age.

Nomenclature of Pyroclastic Rocks

The nomenclature used to refer to the various varieties of pyroclastic rocks in this paper is largely adapted from discussions of the problem by Anderson (1933), Wentworth and Williams (1932) and Williams, Turner and Gilbert (1955).

A general study of pyroclastic rock terminology has been made by Anderson (1933, p. 220-222) who considers at length the contributions made previously in that field. In this study, Anderson finds that although the term "agglomerate" is widely used, there is little agreement as to what it means. As a consequence, he discards the term, and it will not be used in this paper. The term "breccia" has been defined by Williams (1926) as "a more or less indurated pyroclastic rock, consisting chiefly of angular ejecta 32 mm or more in diameter." That definition is somewhat modified in this paper, but the stress on the angular aspect of the lithic and crystal fragments is retained.

Norton (1917, p. 160-194) suggests the term "tuff breccia" for fragmental products of explosive eruptions, where the matrix consists of the finer materials of eruption. Wentworth and Williams (1932, p. 19-53), in an attempt to standardize the classification of pyroclastics also use the term "tuff breccia." The following sizes and names for the fragments making up pyroclastic rocks are proposed by Wentworth and Williams (1932):

> Blocks--Chiefly angular fragments, larger than 32 mm.
> Lapilli--Essential, accessory and accidental ejecta 32 to 4 mm.
> Lapilli tuff--An indurated deposit of lapilli in a fine tuff matrix.
> Tuff--Indurated pyroclastics finer than 4 mm.
> Volcanic gravel and volcanic sand--Unconsolidated sediments containing an admixture of volcanic debris.
> Volcanic conglomerate--Sedimentary, containing coarse pyroclastic material and an abundance of large, rounded, water-worn fragments.

The term "tuff" as a rock name, is subject to further classification based on the constituents involved. Thus, Williams, Turner and Gilbert (1955) distinguish vitric tuff, made up largely of glassy fragments, crystal tuff, made up chiefly of crystals, and lithic tuff made up chiefly of accidental rock fragments. Obviously further combinations such as crystal vitric tuff or crystal lithic tuff can be coined.

Confusion often arises because the terms "tuff" and "breccia" are used both as rock names and as size of particle names. The term "tuff breccia" is usually used as a rock name. In this paper the terms "tuff," "breccia" and "tuff breccia" will be used as rock names.

A tuff is defined as an indurated pyroclastic rock made up of crystal, lithic and/or vitric fragments less than 4 mm in diameter. A tuff is analagous to a fine grained, equigranular rock. A breccia is defined as a pyroclastic rock made up of crystal, lithic and/or vitric fragments greater than 4 mm in diameter. A breccia is analagous to a coarse grained, equigranular rock. The writer is aware that the term "breccia" may also have sedimentary and structural implications. A tuff breccia consists of a rock whose crystal, lithic and/or vitric constituents have a great range in size, including material which is less than 4 mm in diameter, and material which is greater. A tuff breccia is analagous to an inequigranular rock with a porphyritic or seriate texture. The term "megabreccia" is used in this report, but is not separately included in the classification. The term refers to breccias whose lithic fragments are several tens of feet in diameter.

A classification of pyroclastic rocks should be compact enough to be used for field mapping and inclusive enough to cover most of the types of pyroclastic rock encountered. The classification proposed here uses terms generally accepted and refers to the indurated pyroclastics, rather than to their unconsolidated equivalents.

Three variables readily recognized in pyroclastic rocks are (1) the amount of glass, especially as shards, (2) the amount of crystal mega-phenocrysts and (3) the amount of lithic fragments, either of the same composition as the matrix, or of a different composition. One convenient way of representing these variables is by the use of a triangular diagram, with the variables at the apices of the triangle. In the preparation of "pigeonholes" in these diagrams, there is much room for ingenuity of design —— each particular design having its favorable and unfavorable features. The design proposed in Figure 5 is one possible type of classification. Another design is presented by Heinrich (1956) in a somewhat similar classification of pyroclastic rocks, but Heinrich does not use the rock names proposed here.

The determination of the percentage of crystal, lithic and vitric fragments can be rather exact, however, some arbitrary limits must be set in determining whether the rock is a tuff, breccia or tuff breccia. For the purposes of this paper, if over 90% of the fragments are less than 4 mm in diameter, the rock shall be called a tuff; if 90% are more than 4 mm, the rock is a breccia. All other rocks will be termed a tuff breccia.

Table 2 is a list of abbreviations which may be used in connection with the classification chart shown in Figure 5.

Saddle Rock Canyon formation

Andesite Porphyry member (TKp)---The oldest volcanic unit present in the Schoolhouse Mountain quadrangle is the andesite porphyry member of the Saddle Rock Canyon formation (See Plate 9, Fig. 2). The andesite porphyry is a dense, greenish flow rock, with little indication

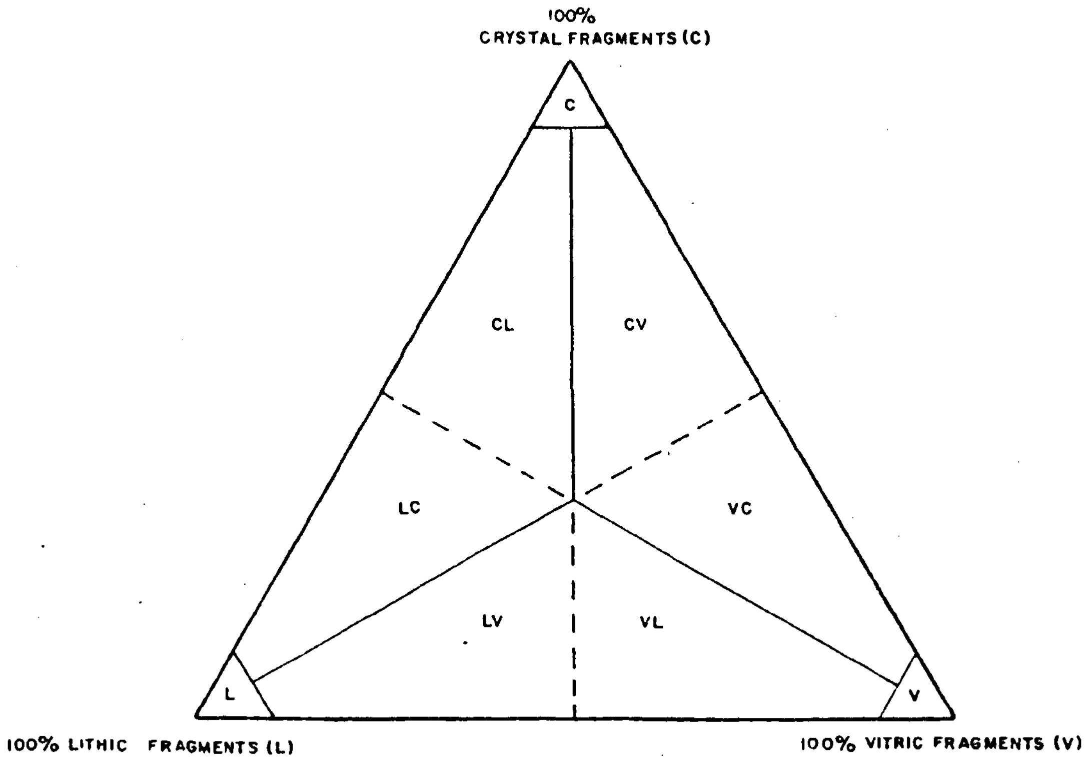


Fig. 5 Classification chart for pyroclastic rocks showing crystal-lithic-vitric fields. See text for explanation.

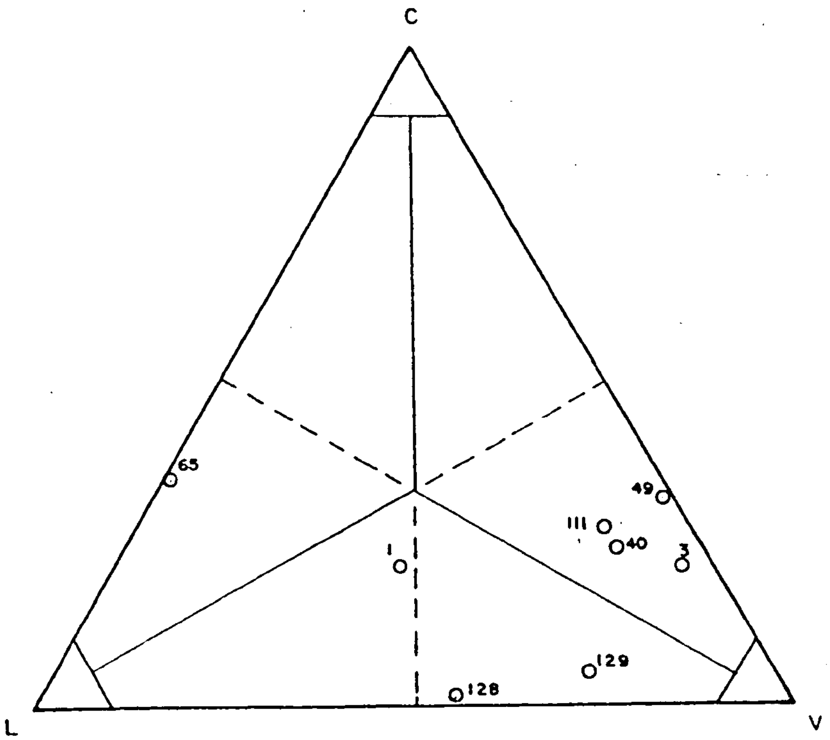


Fig. 6 Crystal-lithic-vitric plots of some pyroclastic rocks from the Schoolhouse Mountain quadrangle. See text for explanation.

Table 2

List of abbreviations used in the classification of pyroclastic rocks.

Field	Basic Abbr.	Rock Name
Vitric	V	VT (Vitric tuff) VB (Vitric breccia) VTB (Vitric tuff breccia)
Crystal	C	CT (Crystal tuff) CB (Crystal breccia) CTB (Crystal tuff breccia)
Lithic	L	LT (Lithic tuff) LB (Lithic breccia) LTB (Lithic tuff breccia)
Lithic-Vitric	*LV	LVT (Lithic-vitric tuff) LVB (Lithic-vitric breccia) LVTB (Lithic-vitric tuff breccia)
Crystal-Lithic	*CL	CLT (Crystal-lithic tuff) CLB (Crystal-lithic breccia) CLTB (Crystal-lithic tuff breccia)
Crystal-Vitric	*CV	CVT (Crystal-vitric tuff) CVB (Crystal-vitric breccia) CVTB (Crystal-vitric tuff breccia)

*Letter sequence may be reversed, depending on which constituent is the most abundant.

of flow structures. Inclusions of lithic fragments are not common. Some evidence that the unit is a flow rather than an intrusive mass can be seen in sec. 8, T. 18 S., R. 16 W., where both streaky vesicles and aligned breccia fragments are found just north of the exposure of stage two gravels shown on Plate 1. In the hand specimen, the andesite porphyry member has a dark green color, with a few recognizable hornblende needles. The rock alters to an aggregate of greenish brown chlorite.

The base of the unit is exposed in the southern part of sec. 8, T. 18 S., R. 16 W., where the andesites rest in part on the Cretaceous Beartooth(?) quartzite and in part on Precambrian granite (See Plate 7, Fig. 1). The andesite dips uniformly to the east and, in sec. 5, T. 18 S., R. 16 W., it is overlain by the next oldest unit, the blue andesite member.

Outcrops of the andesite porphyry member in sec. 11 and 12, T. 18 S., R. 17 W. rest on Cretaceous sediments and on Precambrian granite. There is some indication that the andesite here represents an unroofed sill in the Cretaceous rocks, however the evidence is inconclusive. The andesite occurs as intrusive dikes just south of the quadrangle, where an east-west trending dike swarm cuts through the Precambrian granite. Conceivably the origin of the andesites in the southern part of the quadrangle could have been from these fissures, although no direct evidence has been found.

Petrographic description of the andesite porphyry member---The andesite porphyry member of the Saddle Rock Canyon formation appears highly altered in thin section. For the most part, the alteration products are magnetite and other iron oxides, calcite, sericite and chlorite. Feldspar phenocrysts are replaced by an aggregate of dust-like minerals, probably clays and sericite, and by calcite. The presence of calcite in one section suggests that initially the plagioclase was rather basic. One plagioclase crystal, showing faint twinning, was determined to be at least as basic as labradorite. The close association of the calcite with the feldspar indicates that the calcite is an alteration product, rather than being an introduced secondary mineral.

Hornblende has been largely converted to magnetite, but rhombic cross sections and needle-like prisms remain. Magnetite also occurs as discrete crystals in the groundmass. Some of the magnetite shows a reddish color, indicating replacement by hematite.

The groundmass of the rock is essentially microcrystalline and is clouded by numerous dust particles. In one section, some quartz was recognized in the groundmass, although the mineral is not commonly seen in the hand specimen. A Rosiwal analysis of the andesite is given in Table 5, specimen no. 147.

Blue andesite member (TKa)---The blue andesite member rests conformably on the porphyritic andesite unit in sec. 5, T. 18 S., R. 16 W. The blue andesite member consists of a dense blue andesitic rock, with tiny needles of what appears to be hornblende scattered throughout. Coarse grained phases were not observed. In some places reddish andesites of a similar texture and composition were noted.

The blue andesite member is in fault contact with the Colorado shale in sec. 36, T. 17 S., R. 17 W. and sec. 5, T. 18 S., R. 16 W. (See Plate 7, Fig. 2). Farther east, the fault appears to die out, and in sec. 31, T. 17 S., R. 16 W., the andesite rests directly on deeply weathered red shales of the Colorado(?) formation. In sec. 5, T. 18 S., R. 16 W. the white tuff breccia member of the Kerr Canyon formation overlaps the blue andesite (See Plate 8, Fig. 1).

Petrographic description of the blue andesite member---The rock is composed of hornblende and magnetite crystals set in a felted hornblende and plagioclase matrix. Hornblende phenocrysts have been altered almost entirely to magnetite. The hornblende needles appear to have a preferred orientation, with all the C axes pointing in one direction. The groundmass consists of a mass of tiny, needle-like crystals of hornblende and plagioclase, having a pilotaxitic texture. In places, the groundmass appears to swirl around the phenocrysts, as if the phenocrysts had rotated while the groundmass constituents were still well lubricated with uncrystallized lava (See Plate 8, Fig. 2).

Kerr Canyon formation

Introduction---The Kerr Canyon formation crops out in the east central part of the Schoolhouse Mountain quadrangle, and occupies most of sec. 29, 30, 31 and 32, T. 17 S., R. 16 W., as well as parts of adjacent sections. The formation is named after Barney Kerr Canyon, in whose walls the formation is well exposed. The northern contact of the formation, as well as its exact position in the stratigraphic column is not distinct. The contact has arbitrarily been drawn in such a manner as to include all of the reddish and brownish tuff breccias in sec. 19 and 20, T. 17 S., R. 16 W. in the Kerr Canyon formation. Rather poor exposures in sec. 19 indicate that an actual contact exists, and that the white tuffs of the Mangas Creek formation overlie the Kerr Canyon rocks. Considering the fact that the great majority of the dips in the southeast part of the quadrangle are toward the northeast or southeast, and that the white tuffs of the Mangas Creek formation extend along the east side of the quadrangle, it seems reasonable to assume that the Kerr Canyon formation is stratigraphically lower than the Mangas Creek formation. The relationships between the Delta formation and the Kerr Canyon formation are not known, because these two units are nowhere in contact. The lower contact of the Kerr Canyon formation is well exposed in the high cliffs south of Schoolhouse Mountain, where the formation clearly rests on the blue andesite member of the Saddle Rock Canyon formation.

White tuff member (Txw)---The white tuff member is the lowermost unit of the Kerr Canyon formation. The member crops out in parts of sec. 5, 8 and 9, T. 18 S., R. 16 W., in the southeast part of the quadrangle. In sec. 5, the white tuff member overlies the dense blue andesite member of the Saddle Rock Canyon formation (See Plate 8, Fig. 1). The northern extension of the unit is questionable. Some white tuffaceous rocks are found in the steep cliffs on the south side of Schoolhouse Mountain in sec. 31, T. 17 S., R. 16 W., but since these rocks could not be directly correlated with the white tuff member, they were mapped with the brown breccia member. Exposures in Saddle Canyon show that the pink rhyolite and breccia member overlies the white tuff member (See Plate 9, Fig. 1).

Judging from exposures in sec. 5, T. 18 S., R. 16 W., in the area shown in Plate 8, Figure 1, it seems that a rather irregular erosion surface had been developed on the Saddle Rock Canyon formation prior to the deposition of the Kerr Canyon rocks. Here, one hill of andesite projects about 150 feet above the highest outcrop of the white tuff member. This observation tends to support the suggestion that the Saddle Rock Canyon andesites are considerably older than the overlying acid volcanic sequence, as has been mentioned in the chapter on the age of the volcanic rocks.

The white tuff member consists largely of soft, white or cream colored crystal vitric tuff, much like the tuffs of the Mangas Creek formation.

Rhyolite and breccia member (Txr)---The rhyolite and breccia member of the Kerr Canyon formation crops out in sec. 4 and 9, T. 18 S., R. 16 W., in the southeastern corner of the quadrangle. The upper part of the ridge between Saddle Rock Canyon and Black Hawk Canyon is composed largely of this member.

The rhyolitic phase is confined to Saddle Rock, a prominent saddle shaped hill at the confluence of Saddle Rock and Black Hawk Canyons. The rock is a pink rhyolite porphyry with conspicuous small phenocrysts of feldspar and some quartz set in a dense groundmass. Flow structures and pronounced jointing are present in places.

The breccia phase makes up most of the outcrop in sec. 4, T. 18 S., R. 16 W., and consists of light brown, pink and buff colored breccias and tuff breccias. The absence of an overall brown color serves to distinguish the rock from the brown tuff breccia member.

Petrographic description of the rhyolite and breccia member---The rock consists of a few euhedral to subhedral crystals of sanadine and plagioclase embedded in a fine grained groundmass. Quartz is not common as a phenocryst mineral, but is found in discrete, tiny grains in the groundmass, along with streaky brown glass and tiny feldspar(?) crystallites. Biotite is rare, and when found, occurs as small, elongate brown flakes which may be slightly altered to magnetite. The feldspars consist of sanadine and plagioclase. The sanadine is generally euhedral, with a very small 2V, so that it appears almost uniaxial. The sanadine grains are clear of inclusions, but often contain tiny bubbles. Plagioclase is the most abundant and noticeable phenocryst. The plagioclase varies in composition from high albite to high oligoclase, and an Ab_{80} An_{20} composition probably represents an average. The plagioclase is seldom zoned, in contrast to many of the other plagioclases observed in various rocks collected from the quadrangle. Alteration of the plagioclase is slight, and is confined to small fractures which are lined with a highly birefringent mineral, probably sericite.

The groundmass, which comprises about 83% of the rock consists of fine grained to cryptocrystalline minerals and brown streaky glass. There is no evidence to indicate that the groundmass has been mashed or squeezed, and the conclusion is drawn that the unit is a flow, rather than a welded tuff. A Rosiwal analysis of the rhyolitic rock is given in Table 5, specimen no. 132.

Brown tuff breccia member (Txb)---The brown tuff breccia member is the most extensive unit in the Kerr Canyon formation. Excellent exposures of the member are present in the walls of Kerr Canyon, and in the higher country in sec. 32, T. 17 S., R. 16 W. The most common rock type is a brown tuff breccia, having numerous brown, angular lithic fragments up to three inches in diameter, cemented in a tuffaceous matrix. Darker red flows are sometimes interbedded with the tuff breccia. Columnar jointing is well developed in both the flows and the pyroclastic rocks. The unit is, in part, a welded tuff breccia, as is indicated in some of the exposures seen in the tributaries to Kerr Canyon. The upper part of the tuff breccia is virtually structureless and quite soft, showing no evidence of welding. As one proceeds down section the unit becomes progressively harder, and a few flattened vesicles appear. Near the bottom of the canyon, the unit is hard and tightly welded. The tuffaceous matrix is partially wrapped around the lithic fragments. This condition of increased tenacity and density toward the bottom of a welded tuff unit is considered to be rather common by Gilbert (1938) and Enlows (1955), among others.

In sec. 29, T. 17 S., R. 16 W., thin sills invade the brown tuff breccia (See Plate 10, Fig. 1). The sills are seldom more than two feet thick and often terminate abruptly. In the vicinity of Schoolhouse Mountain the brown tuff breccia contains numerous fragments of a dense, banded rock which has not been recognized elsewhere in the quadrangle.

Petrographic description of the brown tuff breccia member---The rock consists mainly of sub-angular to sub-rounded lithic fragments embedded in a glassy brown matrix. Thin sections of the rock show very few phenocrysts, and none can be seen in the hand specimen. The phenocrysts, when present, consist of small rounded fragments of quartz or broken pieces of feldspar.

The lithic fragments can be divided into two types: (a) a coarser grained equigranular quartz-feldspar rock and (b) a fine grained to aphanitic rock with a fine felted texture made up of tiny, elongate crystallites. Type "b" is the most abundant, and is similar to lithic fragments found in the breccia member (Txx).

The matrix of the brown tuff breccia member consists of dusty brown glass shards, with a vitroclastic texture. The brown coloring agent is probably limonite, although the individual grains are too small to be resolved under the microscope. The glass shards are, in places, broken and crushed between the lithic fragments indicating some welding. This welding, although common locally, is not common throughout the unit as a whole.

Crystal-lithic-vitric percentages of the brown tuff breccia member are given in Table 4, specimen no. 129. The position of the rock in the classification triangle is given in Figure 6. Chemical data are presented in Table 7. The rock is a vitric-lithic tuff breccia (VLTB).

Breccia member (Txx)---A small outcrop of a hard, dense breccia is located in sec. 33, T. 17 S., R. 16 W., at the eastern edge of the quadrangle. This unit, called the breccia member, lies on the brown tuff breccia member of the Kerr Canyon formation. The breccia member appears to range in thickness from a few feet to about 40 feet.

The member is characterized by a hard, brown matrix in which are set angular fragments of gray quartzite. The breccia is hard and tightly cemented, in contrast to the rocks of the brown tuff breccia member, which tend to be much softer. Similar, hard, compact breccias are found in sec. 30, T. 17 S., R. 16 W., and are mapped with this member, although no direct correlation exists between these rocks and those farther southeast.

Petrographic description of the breccia member---The rock consists of sub-angular lithic fragments cemented by a brown, glassy matrix. The fragments are composed of a fine grained rock with an interlocking matrix of quartz and lath-like feldspar(?). Magnetite is scattered throughout the thin section, but appears to be somewhat more abundant in the lithic fragments. The matrix is largely brown, dusty glass which in places is cut by slivers of a darker brown material, also probably glass. A crystal-lithic-vitric plot of a typical specimen is given in Figure 6. The crystal-lithic-vitric percentages are given in Table 4. The rock is a vitric-lithic breccia (VLB).

Delta formation

Beta member (Tdb)---The Beta member of the Delta formation crops out in sec. 1 and 12, T. 17 S., R. 17 W., and in parts of the adjoining sections to the west and south. North of Mangas Creek, the nature of the original rock, its boundaries and its textural features, are obscured by extensive argillic alteration and iron oxide staining. In the vicinity of Schoolhouse Creek, the rock is a dense, porphyritic latite or rhyolite with an aphanitic groundmass and a few dark lithic fragments. South of Schoolhouse Creek the rocks of the Beta member lie along the top of a minor fold. The position of the Beta unit at the top of this anticline suggests that the unit is older than, and underlies the Mangas Creek formation.

Petrographic description of the Beta member---A thin section made from an altered specimen shows several highly embayed quartz phenocrysts. Orthoclase(?) phenocrysts are almost completely altered to sericite. The groundmass consists largely of fine grained, very irregular quartz blebs and shards, and an aphanitic, somewhat devitrified glass. Hydrothermal effects can be seen along fractures where the amount of sericite increases. The sericite evidently formed at the expense of the devitrifying glass, as did the quartz blebs. The presence of quartz and orthoclase suggests that the rock in the thin section was a rhyolite (See also "Alteration in the volcanic rocks" below).

Alpha member (Tda)---The Alpha member crops out in parts of sec. 35 and 36, T. 16 S., R. 17 W. and in the northern part of sec. 1, T. 17 S., R. 17 W. The Alpha member is more variable in composition, both laterally and vertically, than the overlying units. The upper portion of the Alpha member consists of fine to medium grained gray, red and pink equigranular rhyolite and latite, with few lithic inclusions. About 50 to 75 feet below the top of the member, purple latites and pink, equigranular rhyolites appear. Closely spaced jointing is common in many of these beds. Variations continue to the bottom of the unit, where it likes in fault contact with the underlying Beta member. In general, this contact is covered with talus, thus its location on the geologic map is only approximate. The contact is placed where the surface debris begins to show moderate amounts of the altered rhyolite characteristic of the underlying Beta member.

Petrographic description of the Alpha member---The rock consists mostly of broken orthoclase crystals in a brown, dusty matrix. The orthoclase crystals are generally angular and are clouded by inclusions of brown dust and by alteration minerals. Fragments of broken and twisted biotite are found occasionally. Magnetite occurs in quantities of less than 1%. The groundmass consists of almost opaque, dark brown glass.

<u>Mangas Creek formation</u>

Introduction---The Mangas Creek formation has the largest outcrop area of any of the formations in the Schoolhouse Mountain quadrangle. The name is taken from Mangas Creek, which carves a deep canyon across this formation in the northern part of the quadrangle. The thickness of the formation is variable, but may average about 4500 feet.

The formation has been divided into six members: (1) the brown tuff breccia member, (2) the brown breccia member, (3) the white tuff member, (4) the gray andesite member, (5) the andesite breccia member and (6) the pink rhyolite member. Some of these units are interbedded with one another, as is the case with the brown tuff breccia and the white tuff members. These two units also make up most of the outcrop area of the Mangas Creek formation.

Brown tuff breccia member (Tmb)---The brown tuff breccia member has the largest outcrop area of any of the members of the Mangas Creek formation. The unit is particularly well exposed along Mangas Creek where, in sec. 6, T. 17 S., R. 16 W. and parts of adjoining sections, the brown rocks are interbedded with white tuffs.

In the hand specimen, the rocks have an overall brown color. Lithic fragments are common, and sometimes make up 50% of the rock. The fragments usually consist of brownish, aphanitic rocks, but fragments of porphyritic grayish rhyolite and latite and an occasional andesite fragment are sometimes found. In one place in sec. 7, T. 17 S., R. 16 W., an equigranular intrusive rock of monzonitic composition was observed as an inclusion in the tuff breccia. No monzonite intrusives are known in the quadrangle. The tuffaceous phases of the rock, dominant in places, cause the unit to be soft and easily broken. The tuffaceous rocks are apt to exfoliate as flat, shingle-like slabs and form low, rounded, dome-like topographic features. Almost everywhere the rock is somewhat porphyritic, showing small (1 mm) rectangular phenocrysts of feldspar, and an occasional biotite flake and/or quartz crystal. Quartz is rarely seen in the hand specimen.

The rock can be distinguished from the somewhat similar red rhyolite member of the Cherokee Creek formation by the brown color and the absence of streaky vesicles. While vesicles are often found in the brown tuff breccia, they are commonly only slightly flattened, and seldom are filled with secondary minerals.

In sec. 6, T. 17 S., R. 16 W. the nature of the interbedding with the white tuff member is revealed. For convenience, the beds have been lettered from A through J. In general, the contact between the white tuffs and the brown tuff breccias is sharp and well defined. However, the tendency of the white tuffs to contain occasional brownish phases leads to the possibility of some error in determining contacts in some places. Because the contacts between beds E, F, G and H were especially well defined (See Plate 12, Fig. 1), these beds have been chosen for further study on methods of correlation. The results of this study are presented in Part II of this report. The various beds tend to become less distinctive south of Mangas Creek and some of them (for example tuff beds B and D) pinch out and disappear. Nowhere else in the quadrangle is there such a clear-cut sequence of interbedded volcanics as in sec. 6.

The upper and lower contacts of the Mangas Creek formation are fairly well defined north of Mangas Creek. The upper contact with the McCauley formation is largely along the J tuff bed, while the lower contact with the Delta formation is at the base of the A tuff breccia unit. Both upper and lower contacts are marked by lenses of sediment. The lower contact with the Delta formation is of some interest. Here, the sediment lens at the contact consists of sandstones and sandy shales which were evidently deposited sometime after Delta time, but before the Mangas Creek rocks. One 1 inch bed in this sandy lens contains casts and molds of what may be raindrop impressions. The indentations were probably made by a few drops of rain falling on the soft, unconsolidated sediment, which was later covered by more sand. The orientation of the casts and molds provides conclusive evidence that the beds have been tilted up to about 50 degrees from the horizontal, and shows which side of the bed is toward the top.

Jointing in the brown tuff breccia member is usually irregular and not as common as in some of the other units in the quadrangle. In the B bed, some jointing and minor faulting tend to confuse the interpretation of the way the bed is dipping, but on closer inspection, it was found that the lower contact of the bed and the attitude of vesicles were a better indicator of bed orientation than any interpretation derived from the study of jointing.

In the southwestern part of the volcanic area the relationships between the brown tuff breccia member and the interbedded white tuffs are less well defined, and gradational contacts are common. On the west side of the Gila River, the brown tuff breccia is in part overlain by the McCauley formation (See Plate 10, Fig. 2), and in part in fault contact with that formation.

Petrographic description of the brown tuff breccia member--- The unit, being rather thick, varies somewhat in texture and composition from place to place. Everywhere, however, the rock is characterized by brown, rather fine grained angular to sub-angular lithic fragments set in a brown, glassy matrix. The lithic fragments are of two kinds: (a) broken pieces of volcanic rock and (b) broken pieces of crystals.

The ratio between the amount of groundmass and the amount of lithic fragments is variable. This variation is reflected in the color and the hardness of the rock. With increasing amounts of glass in the groundmass, the rock becomes more tuffaceous and assumes a lighter color. A complete gradation between a hard, well cemented tuff breccia and a soft, friable vitric tuff seems to exist. Welding is more conspicuous in some of the harder units particularly the thin units interbedded with tuff in sec. 6, T. 17 N., R. 16 S. An example of welding is shown in Plate 11, Figure 1.

The feldspar in the rock consist mostly of orthoclase, with lesser amounts of plagioclase and sanadine. Alteration of the feldspars to clay minerals and sericite appears in every section. The alteration is not intense, in that the outline and general optical characteristics of the feldspar are still discernible.

Mafic minerals are less conspicuous. An occasional sliver of a birefringent pyroxene, as well as a flake or two of biotite are to be seen, but in general are quite rare. Seldom can mafic minerals be distinguished in the hand specimen.

A comparison between an average mineral composition and an average chemical composition for the unit reveals an anomaly in the case of quartz. A Rosiwal analysis shows granular quartz present in amounts of less than 1%, whereas the analyzed SiO_2 content is 72.68%. The reason evidently lies in the fact that the glassy groundmass consists largely of a silica-rich glass. This phenomenon is to be seen in other members of this formation, as well as in the other formations in the quadrangle.

One consequence of the discrepancy between the SiO_2 content shown by a Rosiwal analysis and that shown by chemical analysis is that a thin section examination is apt to be misleading, in the matter of naming an acid volcanic rock from the quadrangle. However, with information on the SiO_2 content of the rock, a much more reasonable determination of the rock type becomes possible. Further discussion of the SiO_2 content and the content of other oxides in these rocks is found in Part II of this paper.

A crystal-lithic-vitric plot for an average specimen from the brown tuff breccia member is given in Figure 6, specimen no. 1. The percentage of crystal, lithic and vitric constituents is presented in Table 4, specimen no. 1. The rock is a vitric-lithic tuff breccia (VLTB). A composite sample made by combining numerous samples from various parts of the member was analyzed chemically, and the results are reported in Table 7.

Brown breccia member (Tmx)---A rock consisting of small, brown, sharply angular lithic fragments cemented by a quartz and tuff matrix crops out in a few places in the quadrangle. The unit, called the brown breccia member, is interbedded with the white tuffs and brown tuff breccias of the Mangas Creek formation. The largest continuous outcrop of the brown breccia member is found in sec. 22 and 27, T. 17 S., R. 17 W. Smaller outcrops are found in sec. 8, 17 and 20, T. 17 S., R. 16 W. The breccia beds in the latter mentioned sections are usually less than 40 feet thick, and are usually discontinuous along strike.

Petrographic description of the brown breccia member---The rock consists of fine grained, dark brown, glassy, angular lithic fragments cemented by an aggregate of chalcedony and orthoclase (See Plate 11, Fig. 2). The lithic fragments contain large (up to 4 mm) phenocrysts of plagioclase. The material filling the fractures between the lithic fragments consists of fine grained chalcedony, small orthoclase crystals and broken fragments of plagioclase and glass. Plagioclase crystals are usually somewhat altered to sericite.

The fact that the plagioclase phenocrysts are embedded in the glassy lithic fragments, and that the plagioclases are occasionally broken along the border of the fragment indicates that the initial step in the formation of the rock involved the deposition of the glassy material in which the plagioclase crystals were included. After the glassy rock had solidified, it was slightly fractured, and the fractures were subsequently healed with quartz and orthoclase. The movement along fracture planes has not been large, and as a result, a mosaic type breccia was formed.

A listing of the crystal, lithic and vitric percentages is given in Table 4, specimen no. 65, and the position of the rock in the classification triangle is shown in Figure 6. The rock is a lithic crystal breccia (LCB).

White tuff member (Tmt)---The white tuff member has the second largest outcrop area of any of the units in the Mangas Creek formation. Bed J in sec. 6, T. 17 S., R. 16 W. extends southeastward and, along most of its length, is in contact with the lower members of the McCauley formation. Contacts between the white tuff member and the Kerr Canyon formation and between the white tuff member and the brown tuff breccia member of the Mangas Creek formation become indistinct in the central part of the quadrangle, owing to the fact that all the rocks are the same shade of brown. Distinction of the formations in this area depends largely on a study of the type and amount of lithic fragments —— a criterion which is not dependable.

The white tuff member generally has a white, cream, buff or light brown color. The rock is soft and friable, and contains a few phenocrysts of feldspar, set in a tuffaceous, glassy matrix. Inclusions of greenish masses of chlorite(?) and black manganese oxides are not uncommon. Fragments of brown tuff breccia are also present, and small, irregular intrusives are occasionally found. Bed H in sec. 6 contains a few hard, fine grained well rounded nodules or pisolites. Williams, Turner and Gilbert (1955) believe that such spheroidal pellets are formed when fine vitric ash falls with rain.

Petrographic description of the white tuff member---Thin sections show that the white tuff member is variable in composition and texture. Probably the most common type of rock contains clear sanadine phenocrysts set in a matrix of light brown glass and dust. A few phenocrysts of orthoclase and quartz are also present.

All of the crystals tend to be broken. Lithic fragments, when they are found, consist of glassy, microcrystalline rock, with a subrounded shape. In general, lithic fragments are rare and scarcely recognizable without the aid of a microscope. None of the sections show any signs of flattening or welding in the rock.

A crystal-lithic-vitric plot of an average specimen is given in Figure 6, specimen no. 3. The crystal, lithic, and vitric percentages are given in Table 4. The rock is a vitric crystal tuff (VCT).

Gray andesite member (Tmg)---The gray andesite member crops out in sec. 17, T. 17 N., R. 16 W., along one of the tributaries to Mangas Creek. The rock has a dark gray color, and is mottled with specks of a yellowish mineral, possibly an iron silicate (Hisingerite?). Plagioclase phenocrysts are visible in the hand specimen. The rock appears to be a porphyritic flow.

Petrographic description of the gray andesite member ---The rock consists of a fine grained to glassy matrix in which is set phenocrysts of plagioclase and orthoclase, and aggregates of opaque minerals. The hisingerite(?) appears as deep yellow crystals bordered by an opaque mineral (magnetite?). The groundmass is heavily clouded with dark minerals, and is nearly opaque, but lath-like crystals of plagioclase are visible. Small, irregular vesicles are lined with quartz(?) crystals.

Andesite breccia member (Tma)---Fine grained, dark red rocks identified as andesite crop out in sec. 17, T. 17 N., R. 17 W. The fine grained reddish groundmass of the rock encloses small, somewhat altered grains of plagioclase. The presence of angular fragments of a darker rock in the reddish matrix serves to distinguish the rock as a breccia.

Petrographic description of the andesite breccia member---The groundmass of the rock consists of dark reddish brown glass and dust, with numerous crystallites of plagioclase. Euhedral plagioclase crystals are found as phenocrysts. Slivers of biotite and clumps of magnetite are present in minor amounts. Small spherulites were observed in one place.

Pink rhyolite member (Tmp)---A pink rhyolite member representing the final volcanic outburst during Mangas Creek time is found in sec. 22 and 23, T. 17 S., R. 17 W. The unit consists of pinkish, glassy rocks not unlike some of those seen in the McCauley formation, which succeeds it in the section. A thin black vitrophyre bed lies at the base of the pink rhyolite member. In the hand specimen, the rock is hard and dense, containing a few flattened vesicles. Lithic fragments are rare.

Petrographic description of the pink rhyolite member---The rock consists largely of a fine grained to glassy groundmass in which is embedded a few phenocrysts of orthoclase. Quartz lined vugs are present, but rare. The groundmass appears to contain a substantial amount of quartz crystals, although most are so small as to preclude resolution by a microscope. The rock resembles the gray rhyolite member of the McCauley formation. The unit is here mapped as a separate member of the Mangas Creek formation, on structural grounds.

McCauley formation

Introduction---The name McCauley formation is given to a sequence of rocks consisting of rhyolite, vitrophyre and assorted breccias and shaly sandstones which crop out in three different places in the Schoolhouse Mountain quadrangle. The largest outcrops occur along the Gila River, in the Ira Creek and Road Creek drainage basins. The second largest outcrops are found in the northeast part of the quadrangle, just west of Highway 260, and a third small block is found along the Schoolhouse Fault in sec. 11 and 13, T. 17 S., R. 17 W. The total outcrop area amounts to approximately six square miles. The name of the unit is taken from the McCauley ranches located beside the Gila River.

Four members have been recognized and mapped on Plate 1. They are, in order of decreasing age: (1) sandstone and breccia member, (2) vitrophyre member, (3) pink rhyolite member and (4) gray rhyolite member. Of these, the gray rhyolite member is by far the most extensive, making up most of the outcrop in the three areas mentioned above.

The stratigraphic position of the McCauley formation with respect to the Mangas Creek formation and the Cherokee Creek formation can be determined from exposures in sec. 15, T. 17 S., R. 17 W. and along the northeast side of the quadrangle. In sec. 15, the red rhyolite member of the Cherokee Creek formation overlies the McCauley formation, although occasionally the two are in fault contact. In the northeastern part of the quadrangle, all the rocks dip to the northeast and the lower shale and breccia member of the McCauley formation clearly rests on the tuff and brown tuff breccias of the Mangas Creek formation. Thus, of the three formations, the Cherokee Creek formation is the youngest, the McCauley formation is the next oldest and the Mangas Creek formation the oldest.

Sandstone and breccia member (Tmcs)---The lowermost member of the McCauley formation is a sandstone and breccia unit which is well exposed in sec. 8, T. 16 S., R. 16 W., in the northeast part of the quadrangle. This member has not been recognized in either of the other two areas where the McCauley formation crops out.

In sec. 31, T. 16 S., R. 16 W., the sandy unit, which underlies the breccia, rests directly on a brown tuff breccia unit in the Mangas Creek formation. Here the sandstone is 10 to 20 feet thick, and appears to have been deposited by running water. In most places the sandstone is slabby and thin bedded, and occasionally grades into a fine grained fissle shale. The sandy unit becomes progressively thicker toward the southeast until, in sec. 8 and 17, T. 17 S., R. 16 W., it averages about 100 feet in thickness. In sec. 8, the sand has a light gray color, becomes coarser grained, and is best described as a slabby, thin-bedded sandstone.

The breccia unit consists of angular fragments of rhyolite cemented with a red, tuffaceous material. This unit overlies the sandstone in sec. 8, but disappears to the southeast. The total thickness of the sandstone and breccia unit is variable, ranging from 0 to about 100 feet.

The presence of the sandstone unit is strongly suggestive of a period of erosion which must have occurred after the deposition of the Mangas Creek formation. Much of the sandstone has a light color, and thin sections reveal that the more resistant particles of the Mangas Creek formation are incorporated into the sandstone. The angular character of the grains indicates that they had not been transported very far (See Plate 12, Fig. 2). The increase in thickness of the sandstone in sec. 8 is suggestive of a depositional basin in that area.

Petrographic description of the sandstone and breccia member---The rock consists of sub-angular quartz and feldspar fragments in a matrix of brown, dusty glass. Mineral grains of the same size tend to be concentrated in the same layer, and the individual beds show signs of graded bedding. Occasionally a sub-rounded fragment of a brown volcanic rock is found. The arrangement into layers, the sub-angular shape of the grains and the presence of various sedimentary structures suggests that the rock is a volcanic sandstone of the type alluded to by Williams, Turner and Gilbert (1955).

Vitrophyre member (Tmcv)---The vitrophyre member of the McCauley formation crops out in several places in the quadrangle. In all outcrops, the vitrophyric rocks of the McCauley formation underlie pinkish rhyolite. In sec. 22, T. 17 S., R. 17 W., the underlying shales in the McCauley formation are missing, and the vitrophyres rest directly on tuffs of the Mangas Creek formation. Although the member is thin (less than 50 feet), it is remarkably consistent over the whole length of its outcrop. In contrast to the vitrophyre members of the Cherokee Creek formation, the McCauley vitrophyres do not have a well defined transition zone at the base, and in most places the contact between the vitrophyre and the underlying rocks is quite distinct and sharp.

In the hand specimen, the vitrophyres are typically black in color and possess a distinct vitreous luster on their broken surfaces. Lithic inclusions are not common, but when they do occur, they usually consist of brown, tuffaceous fragments. The only mineral visible to the unaided eye is feldspar, which occurs as small (1 mm) grayish phenocrysts set in a glassy groundmass.

Petrographic description of the vitrophyre member---In thin section the rock reveals its glassy nature (See Plate 13, Fig. 1). The glass is either clear and colorless, or varying shades of brown. Swirls and streaks of dark brown glass are intermixed with the clear glass. Under crossed polaroids, tiny pinpoints of light are seen in the darker streaks, indicating incipient de-vitrification. The glass always has a swirled, contorted appearance. Perlitic cracks are common. The refractive index of the glass is 1.497.

The predominant phenocryst mineral is sanadine. Crystals tend to be smooth, clear and somewhat rounded. In one section the sanadine crystals contain magnetite inclusions, suggesting that the magnetite grains formed a nucleous around which the sanadine grew. Other minerals include plagioclase, green, euhedral hornblende and grains of magnetite. The plagioclase crystals tend to show complex twinning and are in some places embayed by the glassy matrix. Overgrowths of sanadine on plagioclase are seen occasionally. Lithic fragments are rare.

A Rosiwal analysis of a typical specimen is given in Table 5, specimen no. 103.

Pink rhyolite member (Tmcl)---The pink rhyolite member overlies the vitrophyre member of the McCauley formation. The unit differs from the overlying gray rhyolite member in its color, the amount of quartz present, and the peculiar type of fracture it possesses. The pink rhyolite often breaks with an uneven fracture, having a rough, blocky surface. The member is predominantly pink in color, although various shades of gray are present in places. The contact with the overlying gray rhyolite is probably gradational over a few feet.

Petrographic description of the pink rhyolite member---In thin section the rock looks almost exactly like the gray rhyolite member of this formation. The rock consists of a streaky grayish or pinkish groundmass of fine grained quartz crystals in which is embedded a few crystals of sanadine and plagioclase. Mafic minerals are absent. Small cavities in the groundmass are lined with quartz crystals.

Gray rhyolite member (Tmcr)---The gray rhyolite member of the McCauley formation is by far the most abundant unit in that formation. The gray rhyolite crops out in the northeastern part of the quadrangle, where it rests on the pink rhyolite member, and is overlapped by Stage Two gravels in the Mangas Valley. Other areas where the gray rhyolite is exposed include the west central part of the quadrangle, on both sides of the Gila River, and a small fault-bounded block in sec. 11 and 13, T. 17 S., R. 17 W.

The gray rhyolite member is characteristically light colored, usually some shade of gray. Toward the base of the unit, streaky, flattened vesicles are common. In the upper portions of the unit, these vesicles are absent and the rock is a dense rhyolite with a few feldspar phenocrysts. Quartz is seldom recognizable in the hand specimen, owing to the small size of the crystals. Lithic inclusions are very rare. Jointing is a common feature in the gray rhyolite member as a whole. In the outcrops along the northeastern side of the quadrangle, examples of closely spaced jointing can be found in sec. 31, T. 16 S., R. 16 W., where an east-west trending fault hinges in the gray rhyolite member. Here the rhyolite is broken along myriads of joint planes, some of which are less than one inch apart. Two sets dominate; one trending about N. 70° E., paralleling the strike of the fault in that area, the other trending north-south to N. 20° W. The net result of the closely spaced joints is to break the rock into irregular flat slabs which cover the hillsides and fill the stream beds. The attitude of the vesicles appears to have no influence on the jointing. The flattened vesicles dip about 35° to the northeast, whereas the joints cut indiscriminately across the plane of dip and themselves have dips ranging from 70° to 90°. A similar condition exists in another place where a fault hinges in the gray rhyolite, in sec. 22, T. 17 S., R. 17 W. Only one set of joints is present here, crossing the hinge axis at right angles. Jointing in the gray rhyolite member tends to be slabby rather than columnar.

The small block of the gray rhyolite member in sec. 11, T. 17 S., R. 17 W. is bounded by faults on at least three sides, and probably on all four. The block represents a part of the gray rhyolite member which had been torn loose during faulting, at the time of formation of the Schoolhouse Fault, and lifted to its present position. Judging from the erratic dips and the presence of complex joint patterns, the block is probably even more broken by faulting than is shown on Plate 1. Smaller slivers of the same unit extend down into sec. 13, T. 17 S., R. 17 W., along the Schoolhouse Fault.

Petrographic description of the gray rhyolite member---The rock consists mostly of sanadine and orthoclase phenocrysts embedded in a gray, streaky, vuggy microcrystalline groundmass (See Plate 13, Fig. 2 and Plate 14, Fig. 1). The sanadine usually contains tiny bubble inclusions and is apt to be somewhat embayed along the boundaries of the crystal. The embayments are made by tiny quartz veinlets. Plagioclase is rare. Biotite flakes are also rare, as are magnetite grains. All the phenocryst minerals appear unaltered, except for the quartz embayments mentioned above.

The groundmass consists of a streaky aggregate of microcrystalline grains, which are probably mostly quartz. Quartz lined vugs which are elongate parallel to the banding in the groundmass are common in most sections. In places the quartz has completely filled the vug, forming a bleb of quartz crystals in the rock. Occasionally the streaky groundmass is not evident, and the rock contains a little brown glass. Lithic fragments are rare.

In general, the streaky flow(?) lines wrap around the phenocrysts, but there is no sign of crushing. The fact that the vugs are lined with quartz crystals which have not been broken suggests that the quartz was deposited after the rock was essentially solid.

A Rosiwal analysis of a specimen from this member is given in Table 5, specimen no. 11. A chemical analysis of a composite specimen made by combining several specimens from this member is given in Table 7.

Cherokee Creek formation

Introduction---The name Cherokee Creek formation is given to a wide assortment of red rhyolite tuffs, welded tuffs and glassy rocks which crop out in the northwestern part of the Schoolhouse Mountain quadrangle. The name is taken from a minor tributary to the Gila River called Cherokee Creek, which is located in sec. 4 and 5, T. 17 S., R. 17 W., and along whose canyon the formation is found exposed with some degree of clarity.

The Cherokee Creek formation is bounded on the east by the Schoolhouse Fault and on the south, in part, by the Ira Creek Fault. The Cherokee Creek formation overlies the McCauley formation in sec. 15, T. 17 S., R. 17 W., but its relationship to the Mangas Creek formation is not so evident. Consideration of the dislocation along the Ira Creek Fault shows that the Cherokee Creek formation must be younger than the Mangas Creek formation, and hence lies on the downthrown side of the Schoolhouse Fault. The details of this interpretation are considered further in the paragraphs under "Structure."

The Cherokee Creek formation has been subdivided into six different members, mainly on the basis of rock type. Of these units, the red rhyolite member is by far the most widespread and distinctive. The various flows and welded tuff beds in this member recur a number of times and therefore both overlie and underlie the other members of the Cherokee Creek formation herein described. The vitrophyre member of the formation covers the smallest outcrop area, but is a quite distinctive marker unit, and hence more fully described than its size warrants. Since the vitrophyres are rather thin (less than 40 feet) the flows were subject to the vagaries of the topography on which they were deposited and thus tend to lens out both parallel and perpendicular to the strike. The tuff member embraces a number of rock types, mostly crystal vitric tuff, tuff breccia and pumice which are intercalated with the red rhyolite member. The breccia member is found in only one place in the Cherokee Creek formation and its position with regard to the other members is unknown. Breccia units occur sporadically throughout the Cherokee Creek formation. For the most part, these breccia units are a part of the red rhyolite member, which has been broken and recemented by a tuffaceous cement. The porphyry member consists of minor porphyritic rocks, and probably lies near the base of the Cherokee Creek formation.

Porphyry member (Tcp)---The porphyry member crops out in sec. 2, T. 17 S., R. 17 W., along Mangas Creek. The outcrop is small, less than 1/3 square mile, and is bordered on the east by the Schoolhouse Fault. On the north side of Mangas Creek the rock is altered and resembles an altered equivalent of the red rhyolite member of the Cherokee Creek formation. The true nature of the porphyry member is seen on the south side of Mangas Creek, where the rock is gray in color and contains conspicuous (5 mm) feldspar phenocrysts. Flow structures are present in one place, and consist of streaky gray glass lenses intercalated with the gray porphyry. Lithic fragments were not seen in this member.

Petrographic description of the porphyry member---The rock consists of a fine grained groundmass in which are set phenocrysts of plagioclase and sanadine. The groundmass appears to be made up of innumerable tiny rod-like crystallites which interlock to form a fine felted texture. Some brownish material in the groundmass may be glass. Phenocrysts consist of plagioclase and sanadine, usually found in glomeroporphyritic aggregates. Most of the phenocrysts are either rimmed by a glass charged border or contain glassy inclusions throughout. Fragments of biotite are found occasionally, along with diamond shaped aggregates of biotite and magnetite which represent pseudomorphs after hornblende. One or two rounded and embayed fragments of quartz were seen. The predominance of plagioclase and the presence of biotite, along with the low percentage of visible quartz suggests that the rock may be an andesite. It has been noted, however, that these lighter colored rocks often contain rather high silica percentages. Assuming that this rock does contain more silica than is visible as silicate minerals, it may be more desirable to call the rock a dacite porphyry or latite porphyry.

Red rhyolite member (Tcl)---The red rhyolite member is the most widespread unit in the Cherokee Creek formation. The member crops out mostly in sec. 2, 4, 8, 9, 10 and 14, T. 17 S., R. 17 W., as well as in parts of adjoining sections. These rocks enclose all the other members of the Cherokee Creek formation except the porphyry member.

The red rhyolite member is characterized by a prevailing brick red color and a streaky texture. On this basis they can be differentiated from the brownish red rhyolite tuff breccias of the Mangas Creek formation. In some places the red rhyolites contain lithic fragments, but on the whole, less than the Mangas Creek formation. Welded tuff units are common, and are characterized by well developed columnar or slabby jointing, as in sec. 4 and 10, T. 17 S., R. 17 W. (See Plate 14, Fig. 2). The joint planes may break the rock into flat slabs or polygonal columns. In the latter case, the joints provide a moderately good clue as to the orientation of the beds, inasmuch as the columns usually intersect the bedding at right angles, in the manner shown in Figure 7. The streaky lenses present in most of the red rhyolite member are present in the welded tuffs as well, and usually are due either to slight variations in the color of the glassy shards, or to flattened vesicles which are lined with tiny quartz crystals. In parts of the red rhyolite member along Schoolhouse Creek and in sec. 9 and 10, T. 17 S., R. 17 W. the rocks contain a conspicuous copper-hued micaceous mineral.

Gravel lenses appear at intervals throughout the member, especially in Cherokee Creek, near the west side of the quadrangle. Here, in sec. 5, a bed of gravels is composed almost entirely of red rhyolite boulders and is bounded above and below by red rhyolite flows. The gravels probably represent an intra-flow stream valley which was later covered by more Cherokee Creek rocks. That some faulting has occurred after the deposition of the red rhyolite member, but prior to the extravasation of the Moonstone Tuff is indicated by the fact that faults cut the gravels, but do not pass into the overlying Moonstone Tuffs (See Plate 15, Fig. 1). In Plate 15, Figure 1, the overlying white rocks are part of a tuff member in the Cherokee Creek formation. The nature and extent of these faults is discussed further under "Structure."

The thickness of the red rhyolite member is not known, and

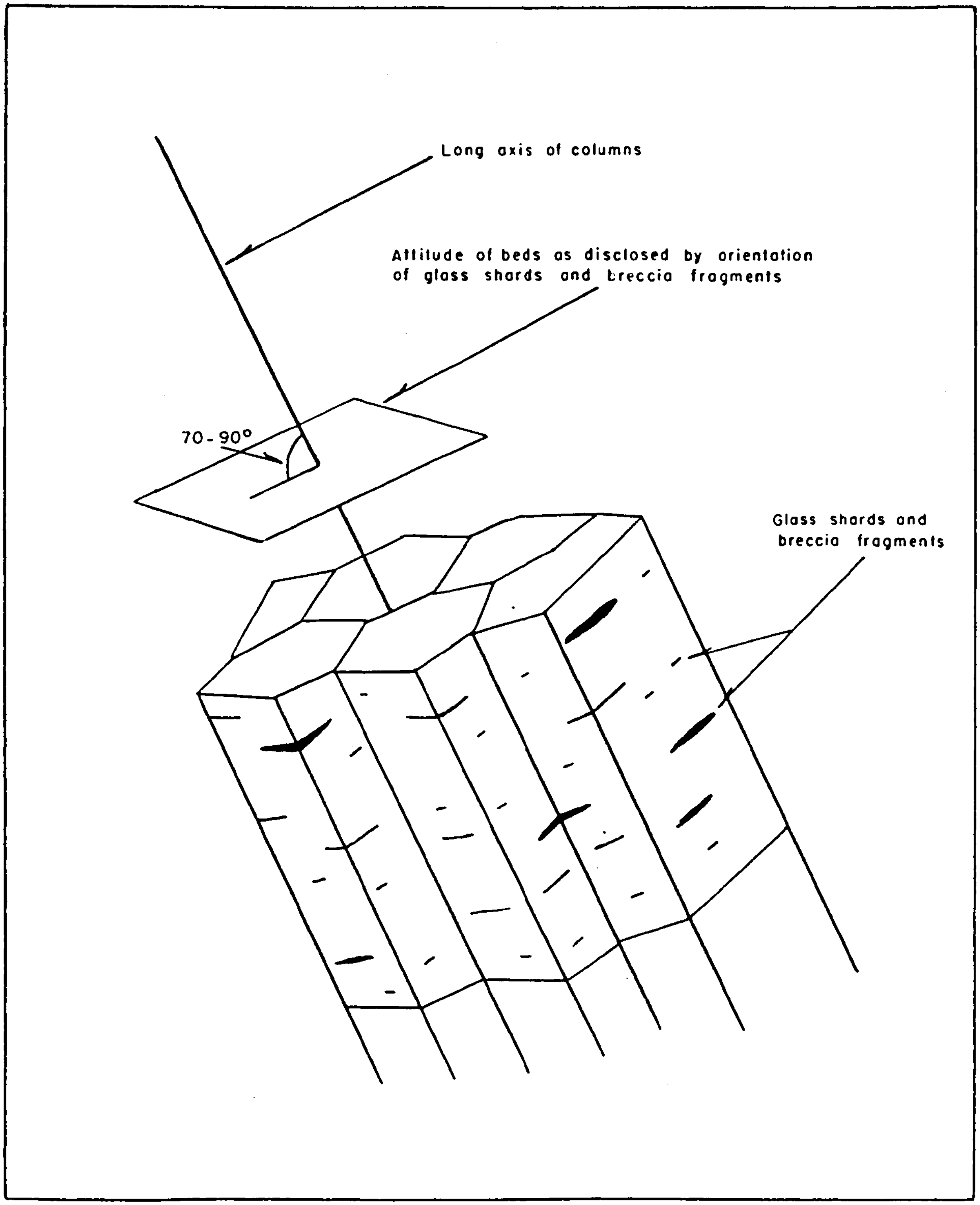


Fig. 7 Diagram showing relationship between long axes of columnar joints and bedding in welded tuffs, Schoolhouse Mt. quadrangle.

indeed appears to vary considerably from place to place. In sec. 15, T. 17 S., R. 17 W., where the base of the formation is exposed, at least 200 feet of red rhyolites are known, but the unit is probably much thicker west of the Gila River. An estimate based on cross sections drawn in this area shows a minimum of 1200 feet of red rhyolite, not counting minor interbedded tuffs, gravels and vitrophyres.

The lower contact of the Cherokee Creek formation is not well exposed, but in sec. 15, T. 17 S., R. 17 W., the red rhyolite at the base of the formation appears to rest conformably on the gray rhyolite of the McCauley formation. In sec. 9, T. 17 S., R. 17 W., however, the McCauley formation stands up as a hill around which the red rhyolites were deposited, hence it is concluded that some relief was present before Cherokee Creek time. The top of the formation is exposed in Davis Creek in sec. 32, T. 17 S., R. 17 W., where the Moonstone Tuff clearly rests on rubble derived from the weathering of the Cherokee Creek formation (See Plate 4, Fig. 1). Some of the red rocks are incorporated into the bottom of the Moonstone Tuff formation.

Petrographic description of the red rhyolite member---The rock consists of plagioclase and sanadine phenocrysts embedded in a groundmass of streaky brownish glass. The groundmass is made up of glass shards, pumice fragments and brownish dust. All of the groundmass constituents have been crushed and deformed by the phenocrysts grains and lithic fragments in the rock (See Plate 15, Fig. 2). Small crystal filled cavities are found occasionally.

Phenocryst minerals include clear, slightly fractured sanadine, glomeroporphyritic aggregates of plagioclase and an occasional grain of magnetite and quartz. Lithic fragments are not common. A crystal - lithic-vitric plot of an average specimen is shown in Figure 6, and the percentage values are given in Table 4, specimen no. 111. The results of a chemical analysis made from a composite sample taken from the red rhyolite member are given in Table 7. The presence of welding throughout the unit dictates that it be called a welded vitric-crystal tuff.

Megabreccia member (Tcm)---Rubble breccias occur in various places in the Cherokee Creek formation. For the most part, the outcrops are small and the total outcrop area does not exceed 1/8 square mile. Megabreccia is found in sec. 2 and 5, T. 17 S., R. 17 W.

In sec. 2, the rubble breccias form local highs in the topography, owing to the fact that they are more resistant to erosion than the surrounding red rhyolite. This resistance is due largely to the presence of quartz and chalcedony cementing agents in the breccia. The blocks forming the unit are largely red rhyolite and tuff breccia, with an occasional fragment of pitchstone. The fragments usually range in diameter from a few inches to two feet. Blocks up to 30 feet in diameter have been seen in some places. Small seams and geodes lined with chalcedony are not uncommon.

The origin of the megabreccia is not clear. Evidently they are the result of localized volcanic explosions and may represent a renewal of volcanic activity, during which time the debris frozen in the vents was cleared away. In sec. 5, T. 17 S., R. 17 W. this is especially evident, and a whole sequence of volcanic activity can be developed from the volcanic section found there (See paragraphs on "Vitrophyre and Tuff members").

The coarseness of the megabreccia precludes any attempt at making a representative thin section of these rocks. Descriptions of the various rocks involved are found in the sections on "Red rhyolite member" and "Mangas Creek formation."

Breccia member (Tcb)---Rocks identified as breccias crop out in sec. 10 and 11, T. 17 S., R. 17 W. These rocks have a total outcrop area of approximately 1/3 square mile and have not been recognized elsewhere in the Schoolhouse Mountain quadrangle.

Some of the breccias consist of a light brown rock having a somewhat mottled appearance due to the presence of glassy streaks. Some quartz is visible in the hand specimen. A white tuff breccia unit included in this member is not well defined. In some places it appears to be much like the breccias in the Kerr Canyon formation. In hand specimen the rock is white to dull gray in color, with numerous angular, light colored lithic fragments.

Faulting and associated hydrothermal alteration are conspicuous in some of these rocks. Northwest-trending faults cut through the breccias, but in one place the rocks clearly rest on the red rhyolite member of the Cherokee Creek formation.

Petrographic description of the breccia member---The rock consists of clear, angular plagioclase and sanadine crystals set in a matrix of brownish red glass. The feldspar crystals are often broken along cleavages, so that the slide is littered with small angular fragments of the mineral. Biotite and hornblende are present in quantities less than three percent. Spherulites formed by radiating quartz fibers are occasionally found. The groundmass consists of brownish red glass heavily charged with opaque, dust-like particles. Larger glass fragments and pumice shards, as well as larger lithic fragments are found occasionally and the rock is termed a breccia on this account. A crystal-lithic-vitric plot of a finer grained portion of the member is given in Figure 6, and the percentages of the crystal, lithic and vitric constituents are given in Table 4, specimen no. 86.

Vitrophyre and tuff members (Tcv) (Tct)---The intimate association of the tuff and vitrophyre members in the Cherokee Creek formation dictates that the two units be discussed together.

The tuff units are more abundant, volume-wise, than the vitrophyre. For the most part the tuffs crop out in sec. 4, 5, and 8, T. 17 S., R.

17 W., and cover a total area of about 1/2 square mile. In places the lower part of the tuff member grades into a soft, brown, highly vesicular pumice. The tuff member, which ordinarily underlies the vitrophyre member is seldom well cemented and can easily be broken with a hammer. The tuff is generally white to buff in color and contains both crystal and vitric constituents, rendering the prefix "crystal-vitric" applicable. In places the tuff gives way to tuff breccia in which angular fragments of red rhyolite are found.

The thickness of the tuff units is variable. Along Cherokee Creek, pumice and tuff outcrops 75 to 100 feet thick are present, but appear to wedge out rapidly, only to re-appear a little higher in the section. It is likely that at least two and possible three different tuff eruptions occurred during Cherokee Creek time. In sec. 5, T. 17 S., R. 17 W., the tuffs and tuff breccias in part overlie gravels in the red rhyolite member and in turn are overlain by a thin (30 feet thick) flow of glassy red rhyolite.

The vitrophyres, while occupying much less outcrop area than the tuffs, are so distinctive as to make excellent marker beds within the formation. The average thickness of the vitrophyre members amounts to about 25 feet. As a consequence, the continuity of the bed is often disturbed by irregularities in the topography upon which it was deposited.

In hand specimen, the vitrophyres are characterized by a dark gray to black, rarely red, color. The rock is brittle and hard, with a conchoidal to sub-conchoidal fracture and a distinctive, shiny, vitreous luster on the freshly broken surface. Rocks much like the vitrophyres in appearance, but with a greasy to resinous luster are sometimes found and are mapped with the vitrophyre. Similar resinous lustered rocks have been called pitchstones by Travis (1955) and Williams, Turner and Gilbert (1955).

In most places in the Cherokee Creek formation the vitrophyres are intimately related to, and often overlie the tuffaceous rocks in the volcanic section. A relationship similar to that shown in the diagram in Figure 8 is present in at least a half dozen places.

The transition zone shown in Figure 8 gives the most enlightening insight into the relationship between the hard, dark, glassy vitrophyres and the soft, light tuffs below. At the base of the transition zone, the vitrophyre is present in the tuff as small, black blebs. The amount of vitrophyre increases rapidly proceeding upward, until little or no fragmental material is present. The transition zone is seldom more than 25 feet thick, and is always welded. Vitrophyre blebs are flattened to a disc shape ranging in size from a dinner plate to a silver dollar, and show evidence of having been squeezed by the weight of the overlying rock. No lineation is visible in the plane of foliation —— a factor which tends to discount flowage at this stage of formation (See Plate 16, Fig. 1). Many of the vitrophyre blebs are rimmed by a thin

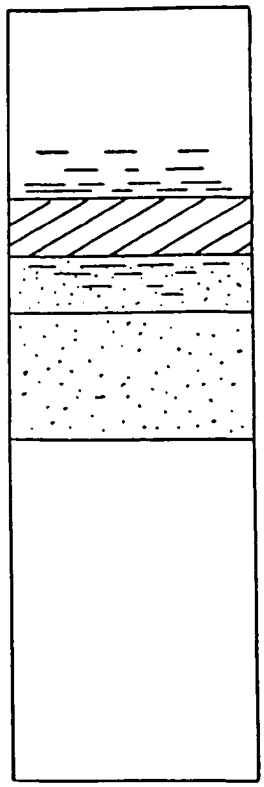


Fig. 8 Typical section involving vitrophyre, tuff and rhyolite members in the Cherokee Creek formation, Schoolhouse Mountain quadrangle.

(1/4 inch) skin of a darker glass, which is interpreted as being a chilled contact. A photograph of a cross section through some of these blebs is shown in Plate 16, Fig. 2.

The conclusion that can be drawn from such a feature as shown in Plate 16, Fig. 2, is that the vitrophyre was still in a plastic state as it was deposited with the tuff, and did not begin to solidify until after it had been flattened to a disc shape, e.g., after the "welding" process had been largely carried to completion.

In one place in sec. 5, T. 17 S., R. 17 W., along Cherokee Creek, the sequence of volcanic activity is particularly well revealed. A section through the area is shown in Figure 9. The initial outburst probably occurred in the form of a major explosion of the Pelean type, avalanching great blocks of broken rock over the countryside. These blocks are present in the section as a megabreccia zone, which contains fragments up to 30 feet in diameter. This megabreccia is cemented by finer grained tuff of rhyolitic composition. A layer of fine tuff and tuff breccia lies above the rubble, indicating an advanced stage in the volcanic activity. After 50 to 200 feet of this tuff had been deposited, the volcano began giving off incandescent debris which settled down and became compacted, forming the welded tuff unit. Succeeding blasts contained more and more glassy vitrophyre bombs which fell with the incandescent tuffs, and were subsequently flattened and cooled. The final stages of the eruption consisted largely of vitrophyre flows, which

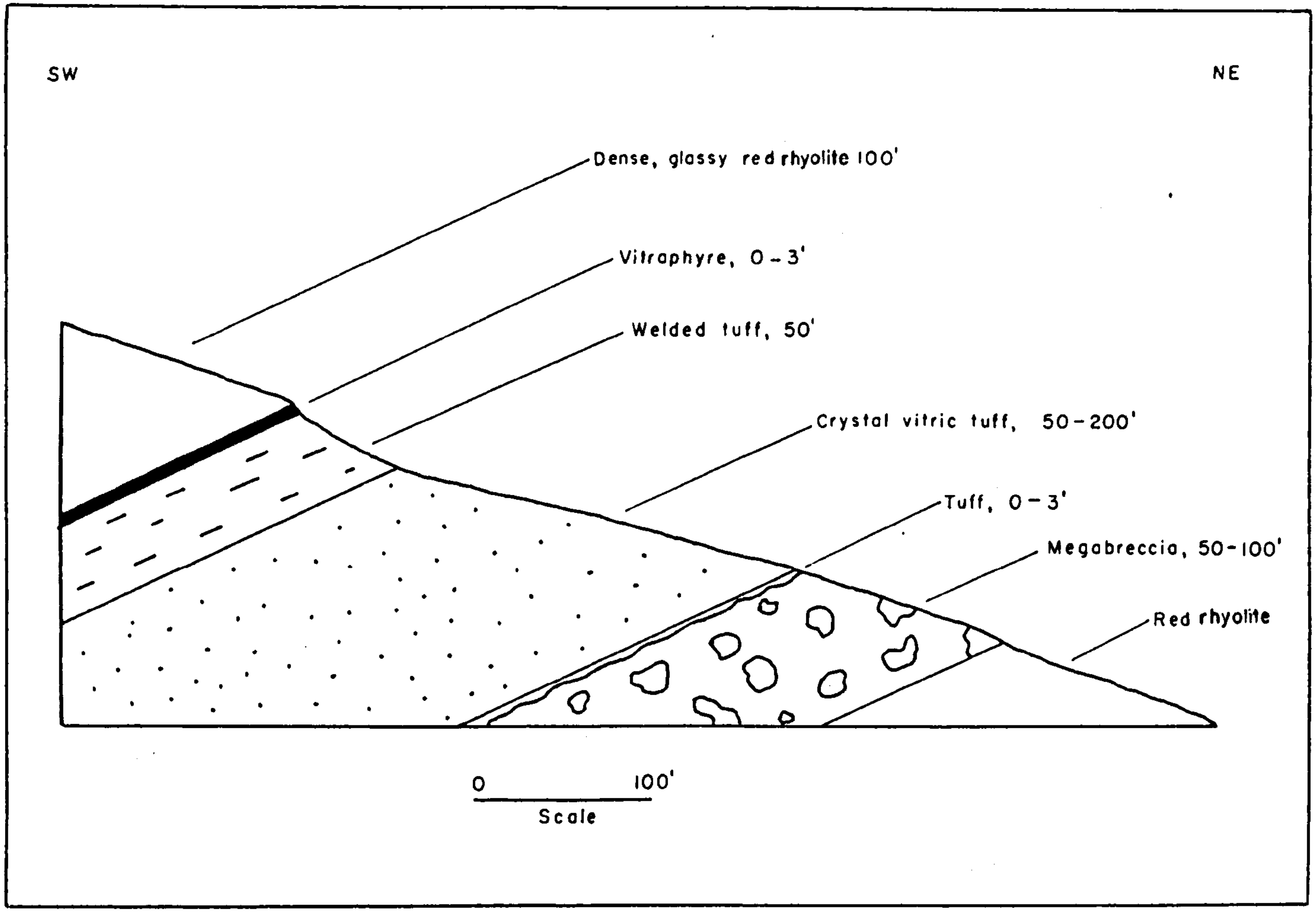


Fig. 9 Cross section showing rhyolite, vitrophyre and tuff units in Cherokee Creek, Schoolhouse Mt. quadrangle.

graded into a glassy red rhyolite and some welded material which makes up the top of the section in this area.

Petrographic description of the vitrophyre member---The Cherokee Creek vitrophyres differ from those found in the McCauley formation by their general lack of clear glass and the unique mineral assemblages.

The groundmass of the Cherokee Creek vitrophyre member consists of brownish to colorless glass, with varying amounts of minute, dust-like particles distributed throughout. De-vitrification is not far advanced. Some sections made from the stratigraphically lower part of the member contain numerous glass shards and some lithic fragments, reflecting the transition from tuff to vitrophyre mentioned above.

Characteristic of all the Cherokee Creek vitrophyres examined are glass charged phenocrysts of plagioclase (See Plate 17, Figs. 1 and 2). The phenocrysts are of two kinds: (a) completely charged with glass, or (b) clear, twinned crystals with glass charged borders. Sanadine and orthoclase are rare. Other phenocrysts include brown hornblende, faintly pleochroic hypersthene, biotite and magnetite. The hypersthene occurs as clear, faint green, stubby crystals, or in glomeroporphyritic aggregates of hypersthene and hornblende. Alteration of hypersthene to hornblende and magnetite is common. Biotite flakes are present in some sections.

Gamma formation (Tg)

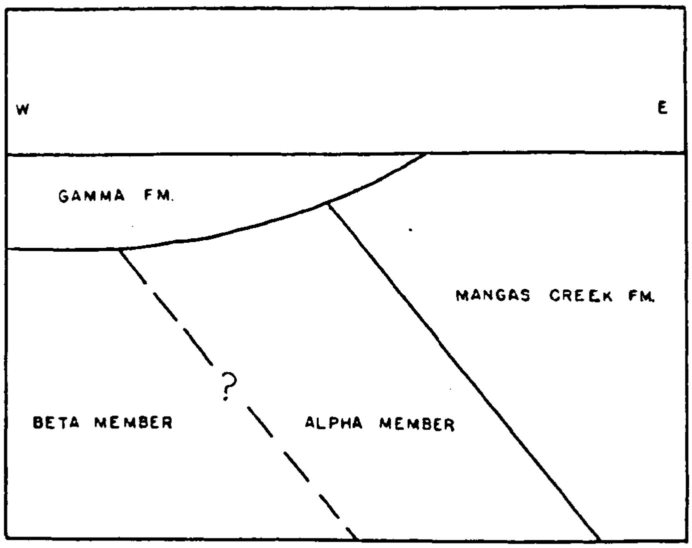
The name "Gamma formation" is given to a small outcrop of breccias and tuff breccias that are found in sec. 35, T. 16 S., R. 17 W. The unit appears to overlie portions of the Mangas Creek, and Delta formations in that area. The relationships between the Gamma and Mangas Creek formations are not clear. In places the Gamma formation overlies the brown rocks of the Mangas Creek formation. Elsewhere, the units appear to grade into one another. An interpretation of the possible relationships is given in Figure 10.

The rocks of the Gamma formation consist of purplish and brownish tuff breccia. Some of the lithic fragments are as much as one foot in diameter, and are cemented by a purplish, tuffaceous matrix.

The most prominent topographic feature in sec. 35, T. 16 S., R. 17 W. is three well defined domes of knobs of tuff breccia similar to that described immediately above. The outward appearance of the small hills is that of an eroded dome or volcanic neck. A number of items support the hypothesis that the hills actually are the remenants of a small volcano that existed there:

1. Vesicles are larger and more numerous in the hills than in the surrounding rocks. The vesicles range in size from 1/8 inch to 1 foot in diameter. In contrast to most of the vesicles in the Mangas Creek formation, the vesicles here do not have any recognizable orientation. Such a condition might be

A



B

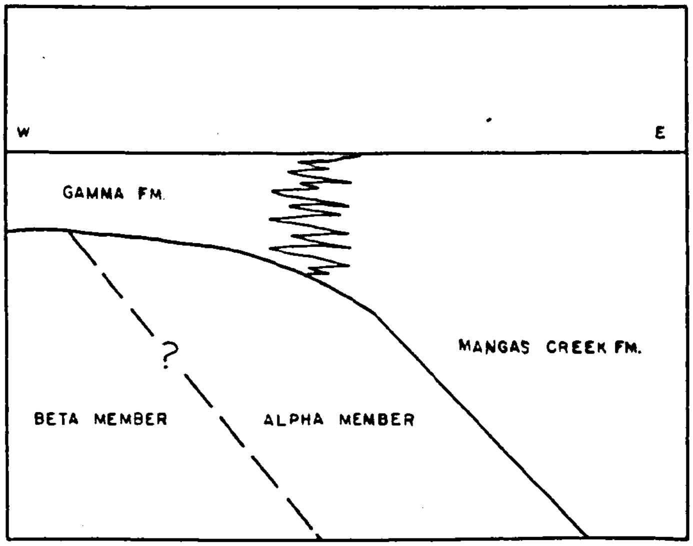


Fig. 10 Possible relationships between Gamma formation and Mangas Creek formation. A—Gamma formation younger than Mangas Creek formation; B—Gamma formation interfingers with and is contemporaneous with Mangas Creek formation. (Cross section, topography omitted, not to scale)

expected in a vent, or near the top of a dome where the churning action in a viscous lava facilitated the escape of gases, with the subsequent formation of voids.

2. The percentage of breccia fragments ranges from 50 to 75%. A number of different rock types are to be found, including angular pieces of rhyolite of various colors, sandy, banded shales and dark basaltic and andesitic rocks. On the whole, the lithic fragments in the hills are larger and more varied in number and type than any of those noted in other formations.

3. The matrix in which the lithic fragments are embedded is a dark purple, tuffaceous or porphyritic rhyolite. The same rock, along with some cream colored tuffs is found on all sides of the hills. The unit appears to become thinner as one proceeds away from the area. In places the purplish rhyolite contains numerous lithic fragments similar to those seen in the small hills.

4. The topographic shape of the small hills suggests an eroded dome or neck.

5. The northward projection of the Schoolhouse Fault and of the fault that separates the Delta formation from the Mangas Creek formation suggests an intersection in the vicinity of the small hills. Thus, the structural setting for the formation of volcanic vents appears to be favorable.

Petrographic description of the Gamma formation---The rock consists of angular orthoclase phenocrysts set in a streaky brown glassy groundmass. The orthoclase phenocrysts have, for the most part, been slightly altered to sericite and clay(?) minerals. The groundmass consists of dark brown and light brown streaky glass which is often squeezed between the phenocrysts, indicating some welding.

The areal extent of the formation is not large, and it is probable that the whole unit was formed as a result of a single eruption from the small volcanic domes postulated above.

A crystal-lithic-vitric plot is given in Figure 6 and the percentages of the crystal, lithic and vitric constituents is given in Table 4, specimen no. 40.

Moonstone Tuff (Tm)

A formation designated the Moonstone Tuff crops out along the western side of the Schoolhouse Mountain quadrangle in the vicinity of Davis and Cherokee Creeks. The areal extent of the formation is not large, probably less than 1/2 square mile, but the unit is sufficiently distinctive to warrant separate description. The unit thins and disappears to the east, but thickens and appears to be more prominent in the mountains west of the quadrangle.

The Moonstone Tuff consists of a light gray, fine grained to porphyritic sanadine bearing vitric-crystal tuff, with very few lithic inclusions. The name of the unit stems from the presence in the rock of euhedral sanadine (moonstone) phenocrysts, up to 5 mm in diameter. In many of the phenocrysts an iridescent blue color can be seen when a cleavage face is rotated in strong sunlight. The moonstones are a distinguishing characteristic of the formation.

The stratigraphic position of the Moonstone Tuff is readily observed in sec. 5, T. 17 S., R. 17 W. and in sec. 32, T. 16 S., R. 17 W. In sec. 32, the Moonstone Tuff rests directly on rubble derived from the red rhyolite member of the Cherokee Creek formation (See Plate 4, Fig. 1). Some of the red rhyolites are incorporated into the basal part of the Moonstone Tuff. Similar relationships are to be seen in sec. 5. A few hundred feet west of the quadrangle boundary, along Davis Creek, Stage Three gravels rest directly on the Moonstone Tuff (See Plate 4, Fig. 2). A composite section measured in this area reveals a maximum of 100 feet of Moonstone Tuff (See Fig. 4).

The Moonstone Tuff is tilted uniformly to the southwest, within the confines of the quadrangle. In sec. 5, the dip of the unit is less than 25 degrees and thus appears to be conformable with the underlying Cherokee Creek formation. Pre-Moonstone Tuff faulting is present in Cherokee Creek, but no faults were found cutting the Moonstone Tuff itself. The irregular shape of the outcrops in sec. 5 and 8, T. 17 S., R. 17 W., is a consequence of erosion of moderately inclined beds.

The fact that the Moonstone tuff unit appears to be conformable with the underlying rocks, is tilted to the southwest, and is overlain by gravels which have been faulted and tilted suggests that the tuff was deposited prior to the uplift of the area in the central part of the quadrangle.

Petrographic description of the Moonstone Tuff---The rock consists of sanadine phenocrysts set in a vitroclastic, glassy groundmass.

A high power lens reveals that the groundmass contains small crystallites of orthoclase(?) as well as glass shards and gray-brown dust. Phenocryst minerals are clear and unaltered, although commonly broken along cleavage planes. The iridescence usually seen in the hand specimen is difficult to see in section, owing to the thinness of the rock slice.

A crystal-vitric-lithic plot of the rock is given in Figure 6, and the percentages are listed in Table 4, specimen no. 49.

Basalt (Tb)

Basalt crops out in a few places in the northwestern part of the quadrangle. These scattered outcrops represent the eastern edge of an extensive basalt sheet that covers a wide area northwest of the quadrangle. With one exception, the basalts rest on Stage Three gravels with a slight angular unconformity. The exception is found in sec. 25, T. 17 S., R. 17 W., where the basalt rests on an andesite unit in the Mangas Creek formation. The basalts are dark in color, usually fine grained and often tend to be scoreaceous.

Petrographic description of the basalt---The rock consists of lath-like plagioclase, pyroxene and olivine. A sub-ophitic texture is common. Alteration of the pyroxene and olivine forms dark brown aggregates of iron oxide which cloud the slide.

Summary of Petrographic Features

A consideration of the petrography of the units in the Schoolhouse Mountain quadrangle bears out the distinctions noted in the field.

The lower andesite units are characteristically dark colored and usually show phenocrysts of hornblende and feldspar. Alteration of the hornblende to magnetite and replacement of the cores of zoned plagioclase crystals by calcite is a common feature observed in thin section. No olivine or pyroxene were seen. Some quartz is found in one of the sections. Flow structures are uncommon, with the possible exception of some lineation noted in the blue andesite member of the Saddle Rock Canyon formation. Lithic inclusions and glass are rarely found.

The lower andesites are interpreted as having been extruded from nearby vents or fissures. Since andesite dikes are found just to the south of the quadrangle, it seems feasible to assume that they were the fissures from which the andesitic lavas issued.

The sequence of rocks overlying the Saddle Rock Canyon andesite is characterized by: (1) its general alkali rhyolite composition, (2) the preponderance of pyroclastic rocks and (3) its thickness. Mafic minerals (i.e., biotite, hornblende pyroxene, and magnetite) are rare. Quartz seldom appears as a phenocryst mineral, but is abundant in the groundmass. Most of the rocks contain over 70% SiO_2.

Interbedded with the pyroclastics are flows of rhyolite and vitrophyre. Clastic beds in the column attest to periods of erosion and re-deposition of volcanic debris.

A comparison of $CaO/Na_2O + K_2O$ ratios of some chemical analyses of the major units with figures given by Nockolds (1954, p. 1012-1013) shows that the average rhyolitic rock in the quadrangle is an alkali rhyolite. The $CaO/Na_2O + K_2O$ ratio for the Schoolhouse Mountain rhyolite is somewhat less than that given for normal calc-alkaline rhyolite, and the $Al_2O_3/Na_2O + K_2O$ ratio is greater than that required for classification as a peralkaline rhyolite (cf. Shand, 1947, p. 229). The Niggli values for three analyzed specimens are given in Table 3. The analyses themselves are given in Table 7.

Table 3

Niggli values for selected specimens from the Schoolhouse Mountain quadrangle.

	si	al	fm	ca	alk	k	mg	ti	p
*Tmcr (gray rhy. mem. McCauley fm.)	492	46	7	2	44	.45	.36	-	0
*Tmb (Brwn. tuff bx. mem. Mangas Cr. fm.)	422	49	10	3	38	.49	.28	1	.35
*Tcl (Red rhy. mem. Cherokee Cr. fm.)	394	45	11	7	37	.43	.27	1	.3

*All specimens are composites

At variance with the general alkali rhyolite composition of the thick section of pyroclastics are two andesite units containing olivine and pyroxene. These thin units (Tmg and Tma) are interbedded with the pyroclastics of the Mangas Creek formation.

The source of the pyroclastics remains an enigma. One possible source for the Gamma formation rocks is from some low, dome-like hills in sec. 35, T. 16 S., R. 17 W., which have been interpreted as volcanic domes or necks. Whether or not other units in this series of pyroclastics also originated from this source is unknown. A sequence of events deciphered in Cherokee Creek and described under the heading "Cherokee Creek formation, Tuff and Vitrophyre members" indicates that explosive activity producing tuffaceous material intermixed with lava bombs and lithic fragments was a not uncommon occurrence. The general pyroclastic aspect of the acid sequence, along with the presence of numerous welded tuff units indicates that much of the volcanism was of the violently explosive (Pelean) type, resulting in the formation of avalanche deposits which covered the countryside with volcanic debris.

The rocks overlying the acid pyroclastics are basalts, which are found in only a few places in the northwest part of the quadrangle, but are quite extensive in the area to the west and northwest. The rocks contain olivine and pyroxene, and are considered to be normal olivine basalts.

Table 4

Crystal-Lithic-Vitric percentages for some pyroclastic rocks from the Schoolhouse Mountains quadrangle.

*Specimen no.	1	3	40	49	65	111	128	129
% Crystal	21	21	24	36	34	27	1	5
% Lithic	38	4	11	1	65	11	44	24
% Vitric	41	75	65	63	1	62	55	71

*

1 Brown tuff breccia member, Mangas Creek formation, Unit "E," (Tmb). Location: sec. 6, T. 17 S., R. 16 W.

3 White tuff member, Mangas Creek formation, Unit "J," (Tmt). Location: sec. 5, T. 17 S., R. 16 W.

40 Gamma formation (Tg). Location: sec. 35, T. 16 S., R. 17 W.

49 Moonstone Tuff (Tm). Location: sec. 32, T. 16 S., R. 17 W.

65 Brown breccia member, Mangas Creek formation (Tmx). Location: sec. 17, T. 17 S., R. 16 W.

111 Red rhyolite member, Cherokee Creek formation (Tcl). Location: sec. 23, T. 17 S., R. 17 W.

128 Breccia member, Kerr Canyon formation (Txx). Location: sec. 33, T. 17 S., R. 16 W.

129 Brown tuff breccia member, Kerr Canyon formation (Txb). Location: sec. 28, T. 17 S., R. 16 W.

Table 5

Rosiwal analyses of some rocks from the Schoolhouse Mountain quadrangle.

*Specimen no.	11	89	103	132	147
Quartz	15			2	
Sanadine			14		
Orthoclase and Sanadine	10				
Hornblende		4	1		
Pyroxene		2			
Biotite and Magnetite	3	2		Tr	10
Calcite					20
Plagioclase			1	15	12
Orthoclase and Plagioclase		21			
Groundmass (mostly glass and micro-crystals)	72	71	84	83	58

*

11 Gray rhyolite member, McCauley formation (Tmcr). Location: sec. 31, T. 16 S., R. 16 W.

89 Vitrophyre member, Cherokee Creek formation (Tcv). Location: sec. 4, T. 17 S., R. 17 W.

103 Vitrophyre member, McCauley formation (Tmcv). Location: sec. 17, T. 17 S., R. 16 W.

132 Rhyolite and breccia member, Kerr Canyon formation (Txr). Location: sec. 9, T. 18 S., R. 16 W.

Table 5, continued

147 Andesite porphyry member, Saddle Rock Canyon formation (Tkp).
Location: sec. 8, T. 18 S., R. 16 W.

Origin of Volcanic Breccias and Associated Pyroclastic Rocks

The origin of breccias has been considered by Anderson (1933). Following LaCroix (1906, p. 635), he divides the origin of breccias in the following manner:

I Volcanic breccias not transported by water

- A. Crumbling of a dome
- B. Intrusion
- C. Friction
- D. Crumbling of an advancing flow
- E. Eruptions
    1. Vulcanian
    2. Pelean
    3. Ultra-vulcanian
- F. Dry avalanche

II Volcanic breccias transported by water

- A. Eruptions
    1. Through a crater lake
    2. Melting of snow and ice
    3. Accompanied by heavy rains
    4. Followed by heavy rains
- B. Not related to eruptions
    1. Collapse of the dam of a crater lake
    2. Heavy rains on unconsolidated ejecta
    3. Rapid melting of snow and ice.

Although Anderson suggests that A, B, C, and D under I above may not be considered as true breccias by some, it seems a rather fine point to belabor. In "A" and "C" the breccia fragments are associated with the disintigration of a Pelean spine, while in "B" the breccias are formed by intrusion of a magma into wet sediments. Examples of the crumbling of the crust on an advancing flow are numerous in the basaltic flows of Hawaii, and have been described by McDonald (1953). Breccias associated with volcanic eruptions are probably most widespread. The Pelean type eruptions, consisting of a glowing cloud of expanding gases, blocks of rock and shreds of lava have been responsible for the deposition of immense quantities of breccias, tuffs and welded tuffs in the Valley of Ten Thousand Smokes (Fenner, 1923), Monte Pelee, and elsewhere. Recent work by Enlows (1955) points out the presence of Pelean avalanches (nuees ardentes) in Arizona. It is the writers observation that further study of the more acidic units in the volcanic fields of New Mexico and Arizona will reveal more examples of these avalanche deposits.

Dry avalanches are more local in character, and consist of unstable piles of gas charged ejecta which slide down the side of a cone, when dislodged by a tremor. The propelling force is gravity, and the situation is analagous to a snowslide or a landslide.

Of the volcanic breccias transported by water, most are associated in some way with mud flows or lahars, which form when pyroclastic material is intimately mixed with water.

Curtis (1954) suggests that the breccia of the Mehrton formation in California was formed by slow movement of a nearly solidified lava mass. The movement allowed explosive release of entrapped gases which shattered the rock along fracture planes. Further movement caused more brecciation, and the mass can be said to have been autobrecciated.

The mode of origin of the pyroclastic units in the Schoolhouse Mountain quadrangle has not been exactly determined. The presence of welding in many of the units suggests that some of the material was blasted out from a vent, probably during a Pelean-type explosion, and subsequently settled and became consolidated. In one place (See Fig. 9) a sequence of explosions and flows can be determined. The intimate mixing of the constituents of the pyroclastic units and the lack of sorting or bedding further suggests a catastrophic type of deposition. Autobrecciation in the manner suggested by Curtis (1954) is not evident, nor is there any evidence to support brecciation at the face of an advancing flow.

An overall view of the volcanic activity suggests that it was characterized by explosive outbursts which avalanched the debris over the countryside, thus accounting for the pyroclastics and welded tuff units now recognized. Interspersed with the periods of violent explosive activity were times of relative quiescence during which lava flows covered the area, forming the flow units in the various formations.

Age of the Igneous Rocks

A Precambrian age has been assigned to the granites and metamorphic rocks in the southern part of the quadrangle. Although no direct evidence for such an age has been found in the quadrangle, similar granitic rocks in the Central mining district have been called Precambrian by Paige (1916). Granitic and metamorphic rocks in the Burro Mountains have been called Precambrian by Paige (1922) and more recently by Hewitt (1956). Hewitt subdivides the Precambrian complex of the northern Burro Mountains into a lower Bullard Peak series and an upper Ash Creek series which consist of hornfels, migmatite and other high grade metamorphic rocks. These two series, according to Hewitt, have been invaded by the Burro Mountains batholith made up of granites similar to those found in the southern part of the quadrangle. Since no period of orogeny in post Precambrian times has produced such profound metamorphism and intrusion, the rocks are assumed to be of Precambrian age, as indeed are most rocks of similar aspect in the southwestern United States.

The absence of floral or faunal remains in the volcanics and related intrusives precludes the possibility of dating those rocks on that basis. No physio-chemical dates are available. J. L. Kulp (Pers. Comm., 1956) states that the potassium-argon method is not particularly accurate in Tertiary volcanics, owing to the lack of data on retention of argon by those rocks.

Elsewhere in southwestern New Mexico and southeastern Arizona the volcanic rocks have been regarded as having ages ranging from Cretaceous to Recent. It may be possible to assign a relative age to the volcanic rocks in the Schoolhouse Mountain quadrangle by comparing the column there with the volcanic columns found elsewhere in this region.

It has been stated by Graton (Lindgren, Graton and Gordon, 1910) and Callaghan (1953), among others, that the volcanic column in southwestern New Mexico is dominated by a unique succession of rocks, consisting of the following elements: (1) a basal series of andesites, with minor rhyolites, (2) a middle series of rhyolite, latite and dacite and (3) an upper series of basalts. In general, the andesites are considered to be of Upper Cretaceous-Lower Tertiary age, the acidic series of Middle or Upper Tertiary age and the basalts of Upper Tertiary-Quaternary age. Examination of the literature concerning the volcanic columns at Mogollon (Ferguson, 1921), the Lake Valley quadrangle (Jicha, 1954), Peloncillo Mountains (Quaide, 1953), Aravaipa-Stanley (Ross, 1925), Little Hatchet Mountains (Lasky, 1947) and Santa Rita (Hernon, Jones and Moore, 1953) bears out the generalities stated above. Reconnaissance studies by the writer of most of the ranges in southwestern New Mexico reveals that this sequence is widespread. The middle acidic unit is particularly impressive, and a perusal of the literature describing volcanic columns in the southeastern part of Arizona indicates that the sequence is continuous over a wide area.

Recent work on the re-mapping of the Santa Rita quadrangle has prompted Jones, et. al. (1955) to assign a Miocene(?) age to the intermediate group of volcanics there, while Lasky (1947) and Ross (1925) note that the andesitic rocks at the base of the volcanic column are probably of Upper Cretaceous age in the areas where they have been studied. The presence of basalt flows on, and interbedded with gravels of Gila and Santa Fe age suggests an Upper Tertiary-Quaternary age for these basic rocks.

Plate 22 shows that the volcanic column present in the Schoolhouse Mountain area is similar to that discussed above, with andesites at the base, rhyolites in the middle and basalts at the top. Hence, by analogy, the andesitic rocks are considered by the writer to be Upper Cretaceous-Lower Tertiary, and the tuffs and tuff breccias and related rocks to be of Middle Tertiary-Upper Tertiary age. If the arguments presented for the Pliocene-Pleistocene age of the Stage Three gravels are accepted, then the Upper Tertiary-Quaternary age for the basalts that rest on them follows.

STRUCTURE

Introduction

The structural pattern of the Schoolhouse Mountain quadrangle is dominated by four major features: (1) a major, north-south trending fault dividing the quadrangle into two equal parts, and here called the Schoolhouse Fault, (2) an east-west trending fault system separating the volcanic rocks from Cretaceous and Precambrian rocks, and called the Wild Horse Fault, (3) lesser faults of varying trends, the most important of which is the Ira Creek Fault and (4) one major and two minor folds crossing the quadrangle in a north-northwesterly direction. Besides these features there are numerous other smaller faults and folds, as well as fracture zones and dikes which contribute to the structural fabric of the area and emphasize the trends established by the larger tectonic elements.

The gross structural picture of the quadrangle can be summed up by saying that it contains a north-northwest trending complex arch which is cut by a north-south fault and an east-west fault. In succeeding paragraphs will be found the descriptive detail needed to elaborate and embellish this picture.

Plate 1 shows that the volcanic rocks of the Schoolhouse Mountain quadrangle are located in the northern three-fourths of the quadrangle. The volcanics are abruptly terminated by an east-west trending fault, which has brought Precambrian granite, Cretaceous sediments and in some places, older volcanic rocks into contact with younger volcanic units.

Faults

The most prominent fault in the Schoolhouse Mountain quadrangle is the Schoolhouse Fault, which extends from the southern border of the quadrangle in sec. 12, T. 18 S., R. 17 W., almost due north to within a half mile of the northern border in sec. 35, T. 16 S., R. 17 W. Beyond this point the fault could not be traced, and it may either skirt the contact between the Stage Three gravels and the Mangas Creek formation in that section or pass under the Gamma formation to the vicinity of the volcanic domes mentioned above. In either case, it appears that the fault continues into an area of highly altered rocks which lie just beyond the northern boundary of the quadrangle.

Along most of its length, the Schoolhouse Fault is not marked by any great amount of gouge or alteration. However, in sec. 11, T. 17 S., R. 17 W., this is not the case, and a shattered, altered zone up to 1/4 mile wide is found. In the same section, a rather large block of the gray rhyolite member of the McCauley formation has been dragged up along the Schoolhouse Fault, and now exists as an isolated block, bounded on all sides by faults. In sec. 13, T. 17 S., R. 17 W., the Schoolhouse Fault appears to turn toward the southeast, again dragging up a sliver of the McCauley formation. A careful search in that direction revealed no extension of the fault beyond the mass of rhyolite. Another good exposure of the fault is found near the head of Ira Creek and its tributaries, along the base of Schoolhouse Mountain. Outcrops in sec. 14 and 23, T. 17 S., R. 17 W. are largely inferred and based on the presence of small shattered zones here and there, and on a prominent topographic low that follows the trend of the fault (See Plate 18, Fig. 1). In the southern half of the quadrangle, the fault is marked by altered and crushed zones in the Precambrian granite, and by the abrupt termination of Cretaceous sediments.

The nature of the movement on the Schoolhouse Fault can best be explained by considering it together with the Ira Creek Fault.

The Ira Creek Fault is located in sec. 22 and 23, T. 17 S., R. 17 W., and parallels the upper fork of Ira Creek (See Plate 18, Fig. 2). An analysis of the stratigraphic and structural features in these two sections and the sections adjoining to the north is critical to the understanding of the stratigraphic relationships between the McCauley, Mangas Creek and Cherokee Creek formations.

The sense of the movement along the Ira Creek Fault is revealed in sec. 22, T. 17 S., R. 17 W. Here, toward the southern half of the section, the rocks all dip to the west or southwest, and consequently it can be shown that the McCauley formation overlies the various members of the Mangas Creek formation. As mentioned above, the sandstone and breccia member of the McCauley formation is missing in sec. 22. In the northern half of the section, the lower members of the McCauley formation are abruptly terminated by the Ira Creek fault, and are in contact with the gray rhyolite member which lies on the opposite side of the fault. Considering the dip of the rocks on the south side of the Ira Creek Fault, it will be seen that one goes down section as he approaches the Schoolhouse Fault. Conversely, on the north side of the fault, one goes up section into the Cherokee Creek formation, as he approaches the Schoolhouse Fault. The diminishing throw along the Ira Creek Fault, in moving from east to west, necessitates that the fault be interpreted as a hinge fault, with the hinge line located in the northwest part of the section. The hinge line is marked by excessive jointing in the McCauley formation. A schematic diagram showing the nature of the movement and the result of erosion on the uplifted block to form the present outcrop pattern is shown in Figure 11.

The above analysis of the movement along the Ira Creek Fault reveals that the north side of the fault is relatively downthrown. Hence, in the vicinity of the Ira Creek Fault-Schoolhouse Fault intersection, the Cherokee Creek formation must be on the downthrown side, while the Mangas Creek formation east of the Schoolhouse Fault is on the

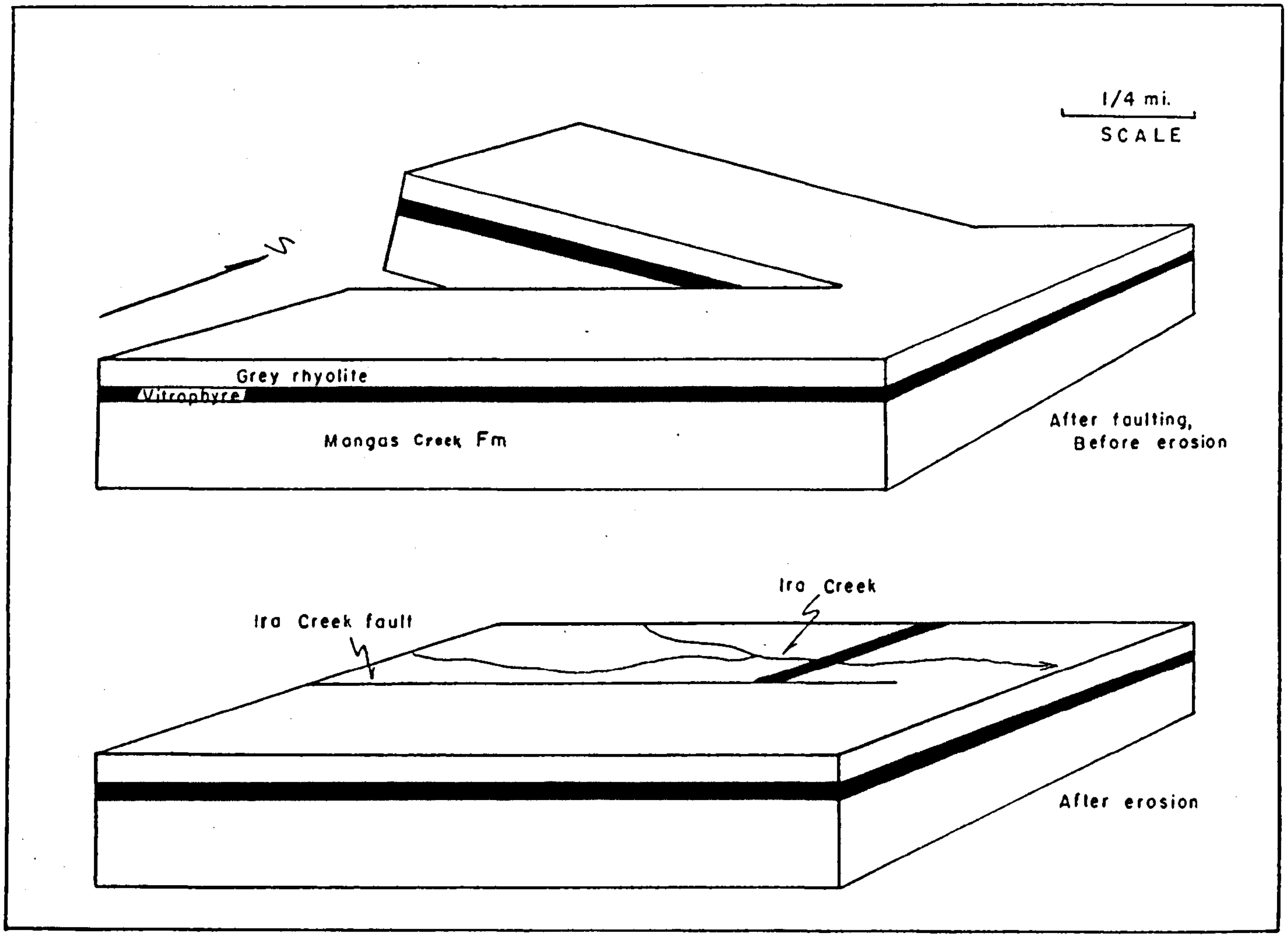


Fig. 11 Block diagrams showing hinge faulting and development of present outcrop pattern in the Ira Creek area. Topography omitted.

upthrown side. That the east side of the Schoolhouse Fault is the upthrown block is revealed elsewhere, for example in sec. 26, T. 17 S., R. 17 W., where the basal Saddle Rock Canyon andesites are exposed and in sec. 1 and 12, T. 18 S., R. 17 W., where the Colorado(?) shale lies on the west or downthrown side. It may also be significant that the highest point in the quadrangle, Schoolhouse Mountain, lies on the upthrown side of the fault. An analysis of the uplift in the Burro Mountains to the southeast supports the postulated sense of the movement on the Schoolhouse Fault. A schematic diagram showing the development of the Schoolhouse Fault is shown in Figure 12.

Another hinge-type fault is found in sec. 31, T. 16 S., R. 16 W., at the north end of the quadrangle. Relationships similar to those described for the Ira Creek Fault also are found here, with the lower units of the McCauley formation abutting against the higher members. Again, the fault disappears and hinges in a swarm of intersecting joint sets.

A second major fault separates the volcanic rocks from the non-volcanics in the southern part of the quadrangle. This east-west trending fault is called the Wild Horse Fault, after Wild Horse Creek, which it parallels for several miles. Near the Gila River, the Wild Horse Fault consists of a simple break, with a steep, eroded scarp carved into the volcanics (See Plate 19, Fig. 1). The Wild Horse Fault intersects the Schoolhouse Fault in sec. 36, T. 17 S., R. 17 W., and appears to be offset to the north; however, if the fault does not have a slight

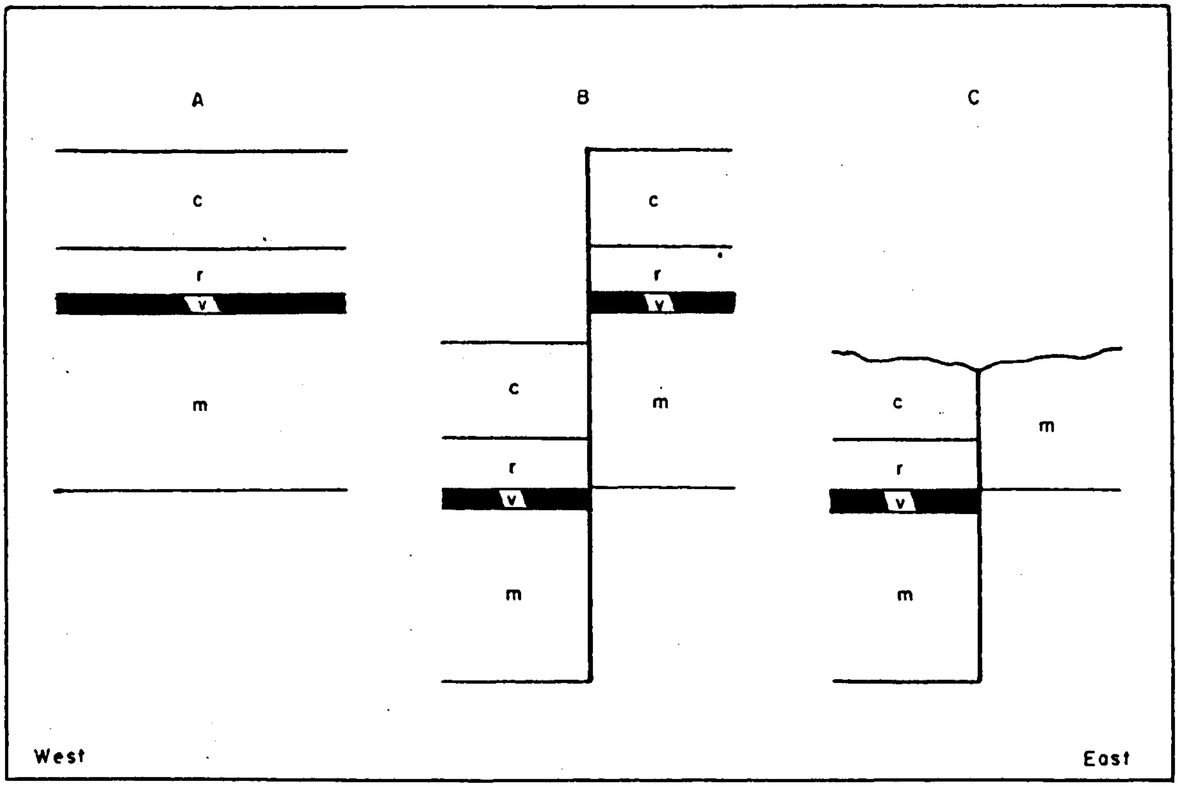


Fig. 12 Schematic diagram showing nature of faulting along the Schoolhouse fault. A--East-west cross section before faulting; B--displacement due to faulting; C--area after erosion. (c--Cherokee Creek formation; v--vitrophyre member of the McCauley formation; r--grey rhyolite member of the McCauley formation; m--Mangas Creek formation. (Not to scale)

dip to the north, the offset may be a consequence of a greater amount of erosion on the east side of the Schoolhouse Fault. East of its intersection with the Schoolhouse Fault, the Wild Horse Fault becomes more complex and, in sec. 36 at least, consists of two parallel faults. The Wild Horse Fault appears to die out to the east, and cannot be traced beyond Saddle Rock Canyon, in sec. 5, T. 18 S., R. 16 W. The throw on the Wildhorse Fault diminishes to the east. For example, in sec. 36, T. 17 S., R. 17 W., the Precambrian rocks are faulted against Cretaceous shales. A mile or two east, the Cretaceous formations are faulted against the overlying Saddle Rock Canyon andesite, and finally in sec. 5, the fault disappears.

The Wild Horse Fault appears to be a steeply dipping break with the south side upthrown. The nature of the throw can be inferred by the fact that the oldest rocks are present on the south side of the fault. In addition, some direct evidence of the movement can be seen in sec. 34 and 35, T. 17 S., R. 17 W., where Cretaceous quartzites are faulted against Tertiary volcanics.

Inter- and intra-formational faulting has been recognized in at least two places in the Schoolhouse Mountain quadrangle (See Figure 13). The presence of such faults suggests minor orogeny during the time when the volcanic rocks were being deposited, but there is insufficient evidence to build up any concrete pattern of faulting. Elston (1955, p. 1553), in his studies in the Dwyer quadrangle southeast of Santa Rita

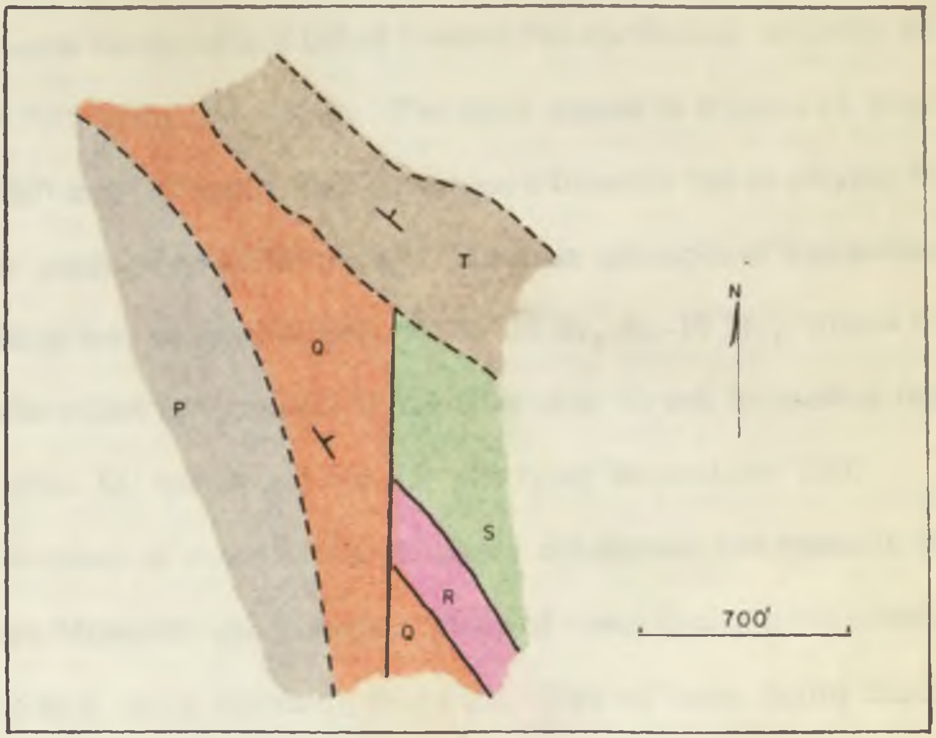


Fig. 13 Geologic map of a portion of Sec. 31, R16W, T16S, showing example of intraformational faulting. See text for explanation. (P,R,T--brown tuff breccia; Q,S--tuff)

notes at least three periods of intra-volcanic faulting.

The best example of intra-formational faulting is found in sec. 31, T. 16 S., R. 16 W. A sketch of the geology in part of this section is shown in Figure 13. At the present time, the brown tuff breccia and white tuff units involved are tilted toward the northeast, with the unit designated "P" being the oldest. The fault shown in Figure 13 displaces the "Q," "R" and "S" units, but disappears beneath the overlying "T" unit, hence must be pre-"T" in age. Another example of intra-formational faulting can be seen in sec. 5, T. 17 S., R. 17 W., where a number of faults offset the gravels in the Cherokee Creek formation (See Plate 15, Fig. 1), but do not cut the overlying Moonstone Tuff.

A number of other faults of lesser magnitude are found in the Schoolhouse Mountain quadrangle. Most of these faults have a northwesterly trend, as is shown on Plate 23. Two of these faults are found in sec. 1 and 12, T. 17 S., R. 17 W. One break in sec. 12 is actually a fracture zone up to 200 feet wide. No well developed fault plane could be found, and no offset has been recognized in the formations involved, but the brown tuff breccia of the Mangas Creek formation is shattered and somewhat altered. Manganese and iron oxides cement fractures in this area. In most places the nature and amount of throw on the fault planes are not known.

Folds

In the volcanic rocks, the distribution of strikes and dips indicates a broad arch crossing the quadrangle in a north-northwesterly direction (See Plate 1). Rocks in the east and northeast part of the quadrangle generally dip in that direction, while the opposite dip is present on the other side of the quadrangle. Locally, lesser folds are present on the eastern flank of the major arch, near the center of the quadrangle.

In the southern part of the quadrangle, folding is inconspicuous in the Cretaceous sediments, except in the vicinity of faults, where the Colorado(?) shale tends to be strongly contorted and broken. A broad shallow basin is present in the Wild Horse Mesa area. The outer rim of the basin is composed of the resistant Beartooth(?) quartzite while the softer shales of the overlying Colorado(?) formation floor the basin. A northwest-trending fault crosses the basin. The combination of resistant rim rocks and centripetal dips makes the area a topographic as well as a structural basin (See Plate 1, Cross-section BB', and Plate 19, Fig. 2).

Joints

Joint systems are well developed in various places in the volcanic rocks. Especially conspicuous are the joints which occur in the gray rhyolite member of the McCauley formation and in the welded tuffs in the Cherokee Creek formation. In sec. 31, T. 16 S., R. 16 W., a swarm of intersecting joint sets is found near the hinge line of a nearby fault. A similar swarm of joints is found in sec. 22, T. 17 S., R. 17 W., in the vicinity of the hinge line of the Ira Creek Fault. Columnar and slabby jointing often occur in various welded tuff and tuff breccia units, and are described elsewhere in this report.

Plate 24, Figure 1 shows that the strikes of most of the joint sets in the quadrangle trend toward the northwest. The possible significance of this is discussed in the paragraphs under "Analysis of Structural Elements."

Analysis of Structural Elements

On a regional scale, the Tectonic Map of the United States shows that the Burro Mountain uplift and the Schoolhouse Mountain quadrangle lie within a belt of northwest-trending faults and folds. The Burro Mountain Precambrian area is elongated in that direction and is partially bounded by faults on the northeast and southwest sides. Other manifestations of this northwesterly structural grain have been considered under "Regional Geologic Setting."

The most significant structural features in the Schoolhouse Mountain quadrangle are the faults and the north-northwest trending arch. In order to achieve a statistical summary of the trend of the faults in the area, a "rose" diagram showing the strikes of faults was plotted and is shown in Plate 23. The lengths of the various rays of the "rose" are proportional to the number of faults trending in that direction. In order to weigh the strength of the faults, the measurements were made in one square mile "samples," hence a long fault like the Schoolhouse Fault is included many times in the diagram. A glance at the diagram shows that a northwesterly trend to the faults is well developed.

Plate 23 shows that the lesser faults in the volcanics trend in approximately the same direction as those in the granite and sediments. Unfortunately, there is no way of determining the age relationships between the faults in the volcanics and those in the granite and sediments, and it cannot be stated with certainty that the faulting in the basement is reflected by faulting in the cover. In passing, it might be mentioned that Wisser (Pers. Comm., 1956) has emphasized the influence that pre-Laramide structures have had on the development of Laramide and post-Laramide structures, in the southwestern United States.

The strikes of the joints and the trends of dikes were subject to an analysis similar to that described for the faults, and the results are shown in Plate 24, Figures 1 and 2. Joint sets tend to have irregular trends, but again the northwesterly direction dominates. A similar situation holds true for the dike trends, although the number of samples is low.

A comparison of the data revealed in Plates 23 and 24 with the regional structural setting shows that the northwest trends continue past the Burro Mountains Precambrian area and into the volcanic rocks of the Schoolhouse Mountain quadrangle. The presence of a north-northwest trending arch may be a direct reflection of the uplift which affected the whole Burro Mountains area.

An explanation as to the cause of the faulting and the manner in which the various blocks moved relative to one another can be developed if one considers the Burro Mountains block to the southeast. The Burro Mountains Precambrian block is essentially a horst, bounded on two sides at least, by long, northwest-trending faults. Hewitt (1956) shows that the faults along the southwest side cut the Tertiary gravels, and Paige (1922) suggests the same for the faults on the northeast side. Since the gravels were deposited after the great bulk of the volcanics in the Schoolhouse Mountain area had been extruded, the latest faulting and accompanying uplift of the Burro block is post volcanic. Judging from the amount of Precambrian exposure, the greatest amount of uplift occurred 10-20 miles to the southeast of the Schoolhouse Mountain quadrangle.

The development of the structure in the Schoolhouse Mountain quadrangle is visualized as follows: As the uplift began, a north-northwest trending axis began to assert itself; this axis now being represented by the arch which crosses the quadrangle. Further uplift created shearing stresses in the rock, which ultimately exceeded their strength forming the east-west trending Wild Horse Fault. According to the theories proposed by Anderson (1951) this fault should be normal, and inclined at 45 degrees, under ideal conditions. Actually, the fault has a steep dip, but the sense of the movement is correct. The numerous northwest-trending faults and others in the quadrangle were probably formed at this time. Just why the Wild Horse Fault is located where it is, remains an enigma. One possibility is that the faulting was guided by a zone of weakness developed along the north side of the Sonoran geosyncline, which passes not far from this area (Fig. 2). Although the stresses were at first relieved, uplift continued until another break formed, this time trending north-south. Again, the upthrown side occurred on the side of the greatest uplift. That the Schoolhouse Fault was formed later than the Wild Horse Fault is inferred from outcrops in sec. 36, T. 17 S., R. 17 W., where the two faults intersect.

SEQUENCE OF GEOLOGIC EVENTS

Although it is not possible to pinpoint the exact time when some of the structures and rocks in the Schoolhouse Mountain quadrangle were formed, the succession of events is fairly clear. The following table represents a sequence of volcanic activity and tectonism that transpired here. The list reads from oldest to youngest.

Table 6

Sequence of geologic events in the Schoolhouse Mountain quadrangle, New Mexico.

Period	Event and remarks
Precambrian	Formation of igneous and metamorphic rocks which now crop out in the southern part of the quadrangle and in the Burro Mountains.
Precambrian-Upper Cretaceous	Unknown. Presence of Paleozoic rocks in the Silver City area to the east and in the Clifton-Morenci area to the west suggests that this area was covered as well; however, no rocks of this age are recognized in the Schoolhouse Mountain quadrangle.
Upper Cretaceous	Deposition of the Beartooth(?) quartzite on a rolling, rather deeply weathered granite surface.
Upper Cretaceous	Deposition of the Colorado(?) shales and sandstones.
Upper Cretaceous-Lower Tertiary(?)	First volcanic activity. Basal units of the volcanic column were deposited on the Colorado shale. Sills may have invaded the Cretaceous

	sediments at this time, or possibly a little later.
Lower Tertiary-Upper Tertiary(?)	Extravasation of tuffs, tuff breccias, welded tuffs and flows that make up most of the volcanic rocks of the column. Cessation of volcanic activity at intervals is suggested by the presence of intra- and inter-formational sediment lenses. Minor intra-formational faulting occurred in the northern part of the quadrangle. The last unit to be deposited was the Moonstone Tuff.
Upper Tertiary (Pliocene?)	Cessation of most volcanic activity, and subsequent erosion of the volcanics. The Stage Three gravels were deposited in the northwest part of the quadrangle.
Pliocene-Pleistocene(?)	Orogeny. Uplift of the Burro Mountains caused arching of the volcanics, formation of Wild Horse Fault, various northwest-trending faults and formation of Schoolhouse Fault, in that order. Uplift of the various blocks rejuvenated the streams, stripping the volcanics from the area south of the Wild Horse Fault, and generally exposing the older units elsewhere. Some dike intrusions occurred along fault planes.
Pleistocene-Recent(?)	Resumption of volcanic activity, with extrusions of basalt, especially in the region northwest of the quadrangle.
Pleistocene-Recent	Establishment of present drainage system, and formation of Stage One and Two gravels. Development of mature topography.

HYDROTHERMAL ALTERATION

Hydrothermal alteration of the volcanic rocks occurs in numerous places in the Schoolhouse Mountain quadrangle. The most extensive area of alteration is found in sec. 35, T. 16 S., R. 17 W., and in sec. 2, T. 17 S., R. 17 W., and affects the unit known as the Beta member of the Delta formation. In the extreme northern end of this area, the identity of the original rock has been all but obliterated by the development of clay minerals and iron oxides. Argillic alteration is the most common, producing a soft, cream and buff colored rock. That the iron oxides, at least, were formed after fracturing and may have been formed relatively near to the surface is deduced from the following observations: (1) the iron oxide stains form a "halo" on either side of the fractures, (2) in areas where the fracturing is closely spaced, the rock is apt to be thoroughly impregnated with iron oxides, as the various haloes coalesce and (3) talus rubble in some places is cemented by iron oxides.

In some places the dominant type of alteration involves the movement and re-distribution of silica. The rock is quite hard and resistant, owing to the presence of secondary quartz. In the more advanced stages, the rock is cut by numerous, irregular, anastamosing quartz veinlets.

Alteration is usually strongest in areas where fracturing is prominent, such as along fault planes and in places where jointing is well developed. The relationship between iron oxide staining and fracturing has already been mentioned. However, the overall fracturing also appears to have influenced the other types of alteration as well. A semi-quantitative expression of the relation between intensity of alteration and intensity of fracturing is shown in Figure 14. The term "intensity of alteration" is somewhat nebulous, but it refers here to the extent to which the rock has been replaced by alteration minerals. An alteration intensity of "1" is assumed for rocks in which the original feldspars are fresh and shiny, and the groundmass shows little evidence of de-vitrification or replacement by alteration minerals. An intensity of "2" is given to rocks in which feldspars are cloudy and partially decomposed, and biotite flakes have been partially altered to hydromicas. The original texture of the rock is still discernible. An alteration intensity of "3" is assigned to rocks in which the original texture has been obliterated and nearly all of the original minerals have been replaced by alteration products. In Figure 14, the cross bars on each vertical line locate the mean number of fractures per linear foot, in an altered area. The upper and lower part of the diamond indicates the maximum and minimum number of fractures counted, respectively. The data expressed in Figure 14 show that alteration intensity tends to be greater in areas where fracturing is strongest.

A thin section made across one side of an iron stained fracture

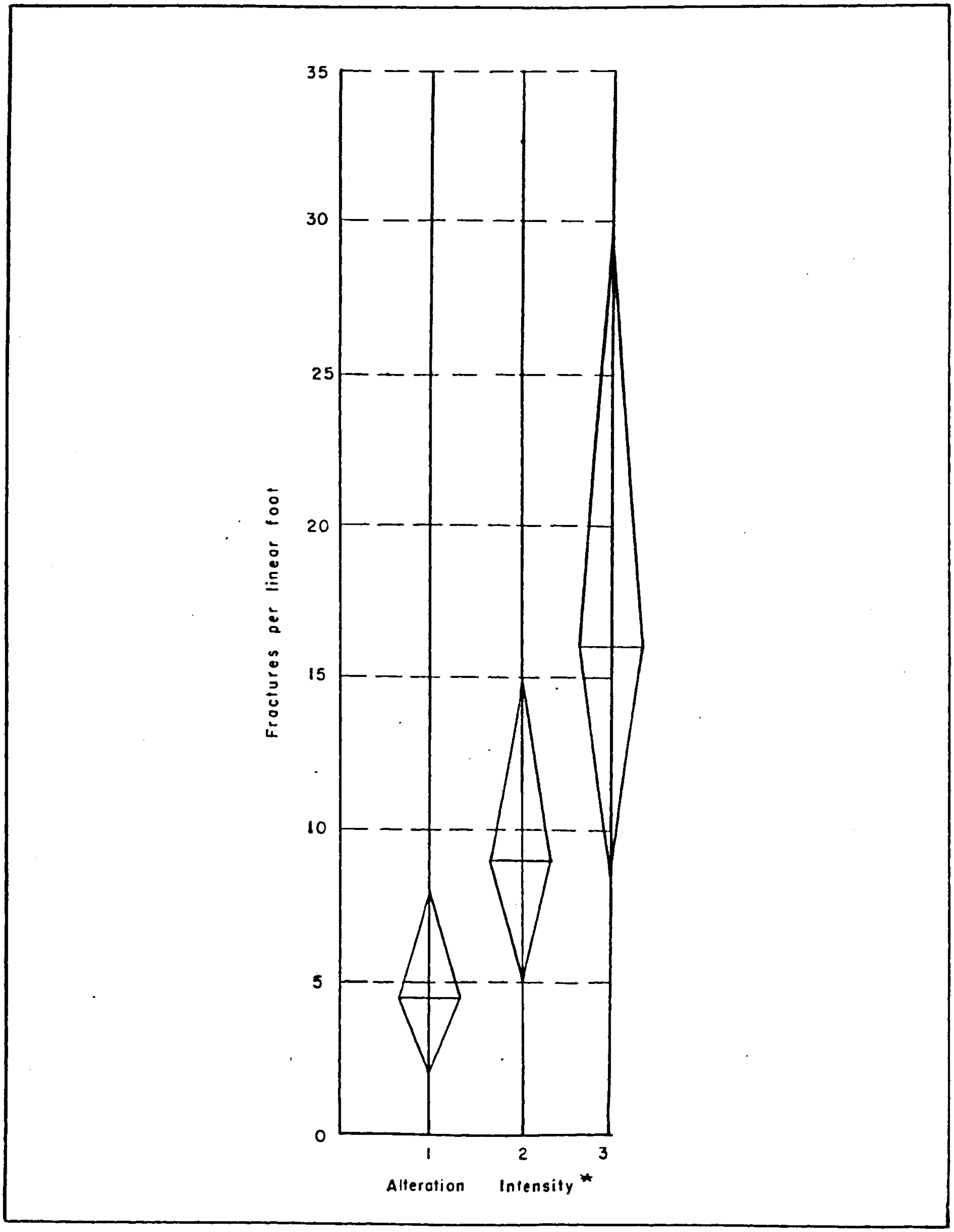


Fig. 14 Graph showing relationship between intensity of fracturing and intensity of alteration, Schoolhouse Mt. quadrangle. (* See text for explanation)

shows the effect of alteration on the rhyolite of the Delta formation. Near the fracture, the glassy groundmass has been de-vitrified and clouded with a dark aggregate of iron oxides and sericite. The rock is shot through with tiny (1/4 mm) jagged shards of quartz (See Plate 20, Figs. 1 and 2). These shards appear to be just as numerous in the regions removed from the fracture wall, as in the area close to the fracture. In one or two places the embayed quartz phenocrysts originally brought in with the lava flow have been partially rimmed by these irregular quartz shards, which are optically continuous with the larger crystal. The boundary between the phenocryst and the shard is marked by a thin line of brownish inclusions.

The small, irregular shards of quartz in the groundmass bear further mention. This phenomenon has not been seen in other rocks of the area, which have, for the most part, not been subjected to hydrothermal alteration. It is not likely, therefore, that the quartz shards are indigenous to the rock. The reason for the presence of these shards is not obvious. Three possibilities present themselves, each of which might explain the presence of the quartz, as well as its irregular shape:

1. The quartz shards represent embayed phenocrysts which have been resorbed during the cooling of the lava.

2. The quartz shards represent the development of the mineral from the de-vitrified groundmass.

3. The quartz shards represent and introduction by hydrothermal solutions.

The first two of these possibilities requires that the silica be present in the original rock since its deposition and the work of the solutions has been largely confined to re-mobilizing the quartz and re-distributing it in the rock. The third possibility pre-supposes a quartz laden solution traversing the rocks, depositing the mineral randomly.

The type of alteration seen here is not unlike that seen in many porphyry copper deposits, in that it involves the development of clay minerals, sericite and quartz, with concomitant obliteration of the original rock texture.

The source of silica in the silicified parts of altered porphyry copper deposits and in vein deposits has recently been the subject of a paper by Schmitt (1954). Schmitt concludes that "the silica represented by quartz... (of) porphyry coppers, epithermal and deeper seated veins and pyrometasomatic deposits logically can be said to have been derived from the alteration of the adjacent walls," thus pointing up the possibility that the solutions which are connected with hydrothermal alteration are probably not themselves heavily laden with silica. Martin (in press, 1958) in a study of the Santa Rita deposit bears out Schmitt's contention, and produces figures to show that the silica of the various alteration stages is actually only re-mobilized, and travels only short distances. The resemblance between the alteration in various mineral deposits and that seen here strengthens the surmise that the silica found in this volcanic rock has not been introduced by hydrothermal solutions.

A comparison of the shapes of the quartz shards with glass shards seen elsewhere in these volcanic rocks shows that both tend to be jagged, with sharp, sliver-like points and projections, and rounded, conchoidal embayments. The resemblance between the shapes of the quartz shards and the glass shards in general suggests that the quartz is retaining the original shape of the glass sliver. The high SiO_2 content of the glassy rocks has already been mentioned. It follows that a logical source for the quartz is from the glass itself.

From the discussion above, it seems that in the instant case the quartz has been derived by the re-mobilization of the SiO_2 of the glass, and that the initial effect of this re-mobilization has been to replace the glass shards with quartz. Further, the direct mechanical introduction of SiO_2 by hydrothermal solutions is not evident here.

It should be emphasized that the example cited represents a rock which is in a stage of incipient silicification. Elsewhere in this altered area, highly silicified rocks are to be found. In the silicified rocks quartz veinlets, drusy cavities lined with quartz, and quartz metacrysts are common. While these features indicate a rather marked movement of silica, they do not necessarily show that the quartz is exotic, or that it has been brought in by thermal solutions.

It is beyond the scope of this paper to treat this problem further, however the writer feels that in a study of silicified volcanic rocks, it is eminently proper to consider a source for the quartz within the rocks themselves, rather than from some outside source.

ORE DEPOSITS

Introduction

No ore deposits of consequence are known in the Schoolhouse Mountain quadrangle. A few small manganese prospects are found in the volcanic rocks along Schoolhouse and Mangas Creeks, and two small fluorite prospects are located on fluorite-bearing fractures in the Pre-cambrian granite.

Cora Miller Mine

The Cora Miller mine and associated workings are located on the south bank of Mangas Creek, approximately one mile west of Highway 260 and the Foster ranch. No access roads are present, but the mine can be reached most of the year by driving along Mangas Creek either from the Foster ranch or from the McCauley ranch.

The Cora Miller workings were driven along two or three manganese bearing veins. Two narrow veins cut brown tuff breccias and strike approximately N. 35° E., and dip vertically. A third vein or possibly a branch from one of the other veins strikes N. 75° E. and also has a steep dip. The veins appear to have developed in tight, narrow (12-18 inch) fracture zones in the tuff breccia. Crushed breccia fragments within the fracture zone have been cemented and partially replaced by black manganese oxides. Vein quartz occurs along portions of the vein.

The mine was developed by drifting along the vein, then by overhead stoping. Many of the stopes reach the surface. The workings are dangerously accessable, at the time of this writing. From scattered records, it appears that the mine was last operated during 1941-42 by J. T. Hackeley.

Fluorite Prospects

Two small prospects from which a little fluorite has been produced are located in sec. 2 and 3, T. 18 S., R. 17 W., in the southern part of the quadrangle. Access is provided by fair roads leading from Saddle Rock Canyon.

Both prospects are located on northwest-trending fractures in the Precambrian granite. The fluorite occurs as thin seams in the gouge zones. The mineral is usually white or light green or blue in color. No sulfides were seen. Judging from the limited underground workings and the nature of the deposits, not more than a few tons of ore was mined. The deposits are among those discussed by Gillerman (1951), and were probably formed at the same time as most of the other scattered fluorite deposits in the Burro Mountains farther to the south.

PART II —— CORRELATION METHODS

Introduction

The second part of this paper will be concerned with the brief description and analysis of various correlation studies made on the volcanic rocks of the Schoolhouse Mountain quadrangle.

The need for further work on the problem of correlation of volcanic rocks becomes evident as one works in the field and attempts to solve the usual problems of structural geology and stratigraphy. Although in many places the volcanic units are well exposed and moderately extensive, the geologist finds that in a particular area, the same type of rock may occur several times in the section. An example of this can be seen in sec. 6, T. 17 S., R. 16 W., where white tuff beds (Tmt) are interbedded with brown tuff breccias (Tmb). In order to effect a solution to structural problems it becomes imperative to be able to recognize a particular unit wherever it occurs. The obvious correlation methods are the best; i. e., tracing the outcrop, recognition of certain features characteristic of the unit, etc., however they are not always usable.

Being cognizant of the difficulties encountered in the mapping of volcanic rocks, the writer made a series of studies of: (1) some petrochemical aspects of selected rock units and (2) some geophysical properties of selected units, in order to determine if some chemical or geophysical entity is susceptible to analysis and usable as a correlation tool. The petrochemistry was studied by means of chemical analyses and refractive indices of the fused rock. Magnetic susceptibility was the geophysical property studied.

An evaluation of the success of such studies is not readily made from the study of one suite of rocks, such as those taken from the Schoolhouse Mountain quadrangle. In the case of the fusion studies, some measure of success of the work can be made by comparing it with similar work by others.

Sampling Techniques

In order to provide material for laboratory determinations of chemical composition and refractive indices of fused rocks, samples were collected in the field. The locations of each of the traverse and sample sites is shown in Plates 25 and 26. At each sample station, rocks were collected from within a circle having a 50-foot radius. Fresh, unaltered or unweathered rocks were chosen whenever possible.

About five pounds of rock were collected at each station. The rock samples were subsequently crushed and split and the various determinations made from the fractions.

The numbering of the specimens reflects: (1) the number of the traverse line, (2) the station in the traverse line and (3) the type of composite, if a composite was made. For example, a sample numbered 9-2 came from traverse line no. 9, at station no. 2. A sample numbered 9-1, 2, 3-C indicates that the sample was collected along traverse line no. 9 and was made by combining equal parts of samples taken at stations no. 1, 2 and 3. The addition of the letter "C" indicates that a partial chemical analysis was made of that sample. Composite samples were made in order to determine the gross chemical aspects of the unit. Lack of funds prohibited the making of a complete analysis of each sample.

Chemical Analyses

The chemical data for fusion studies and the magnetic susceptibility studies is provided by 39 chemical analyses of various specimens and composites. A complete list of the chemical analyses is presented in Table 7. The analyses were made at the Rock Analysis Laboratory of the University of Minnesota, under the direction of S. S. Goldich.

Table 7

Chemical analyses of some rocks from the Schoolhouse Mountain quadrangle.

Sample	*Mangas Creek Comp. (Tmb)	*Cherokee Creek Comp. (Tcl)	*McCauley Comp. (Tmcr)
SiO_2	72.68	72.09	75.45
Al_2O_3	14.28	14.18	13.02
Fe_2O_3	1.34	1.65	.85
FeO	.26	.23	.14
MgO	.32	.36	.21
CaO	.51	1.14	.34
Na_2O	3.50	3.94	3.82
K_2O	5.02	4.53	4.82
H_2O+	.79	.47	.30
H_2O^-	.29	.51	.35
TiO_2	.26	.31	.18
P_2O_5	.07	.09	.03
MnO	.05	.06	.05
Total	99.37	99.56	99.56

Table 7 (continued)

Sample	*1-1, 2, 3, 4, 5, -C	*2-1, 2, 3, 4, 5, -C	*4-1, 2, 3, 4, -C	*5-1, 2, 3, 4, -C
SiO_2	75.04	75.35	73.11	72.35
Fe_2O_3	.79	.81	1.26	1.29
FeO	.18	.21	.26	.27
MgO	.19	.18	.27	.27
CaO	.44	.34	.45	.56
Na_2O	3.63	3.98	3.53	3.54
K_2O	4.88	4.73	5.10	5.01

Sample	*6-1, 2, 3, 4, -C	*7-1, 2, 3, 4, -C	*8-1, 2, 3, 4, 5, -C	*8-6, 7, 8, 9, -C
SiO_2	73.59	70.28	73.39	72.69
Fe_2O_3	1.03	2.19	1.40	1.38
FeO	.19	.33	.15	.15
MgO	.27	.49	.27	.35
CaO	.69	1.73	.34	.54
Na_2O	3.79	4.12	3.67	3.29
K_2O	4.85	4.27	4.41	4.60

Table 7 (continued)

Sample	*9-1, 2, 3, -C	*9-4, 5, 6, -C	*10-1, 2, 3, 4, 5, -C	*10-6, 7, 8, 9, -C
SiO_2	71.44	71.65	70.53	69.40
Fe_2O_3	1.53	1.18	1.70	1.83
FeO	.17	.23	.26	.28
MgO	.48	.54	.45	.53
CaO	.83	.63	.74	.98
Na_2O	2.54	3.07	3.51	3.40
K_2O	4.96	4.80	4.47	4.42

Sample	*11-1, 2, 3, 4, -C	*11-5, 6, 7, 8, -C	*12-1, 2, 3, -C	*13-1, 2, -C
SiO_2	71.79	71.23	72.05	72.20
Fe_2O_3	1.27	1.42	.90	.76
FeO	.27	.24	.20	.30
MgO	.53	.44	.20	.11
CaO	1.09	1.39	.60	.65
Na_2O	2.65	3.60	3.82	4.07
K_2O	4.02	3.69	4.44	4.24

Sample	8-1-C	8-3-C	8-5-C	8-7-C	8-9-C	9-1-C	9-3-C
SiO_2	72.95	73.68	73.11	72.70	72.51	72.09	71.19

Sample	9-5-C	10-1-C	10-3-C	10-5-C	10-7-C	10-9-C	11-1-C
SiO_2	71.45	69.66	70.55	60.81	70.14	69.49	72.51

Table 7 (continued)

Sample	11-3-C	11-5-C	11-7-C	12-1-C	12-2-C	12-3-C
SiO_2	62.29	71.08	71.08	72.29	71.89	72.33

*Doris Thaemlitz, analyst

Comments on the Chemical Analyses

A study on the chemical data in Table 7 makes apparent similarities and differences in the various rocks analyzed. One of the outstanding features of almost every specimen is the rather high SiO_2 content, which generally averages about 71%, but which is as high as 75%. In many of the rocks, the high silica content is not obvious either in thin section or in the hand specimen. The silica is bound up in high silica glass rather than in quartz or silicates. This is shown by the Rosiwal analyses and crystal-lithic-vitric ratios in Tables 5 and 4 respectively. These tables show that the amount of glass in most specimens is substantial, but that the amount of quartz and silicate minerals is small. As has been mentioned, the proper identification of such rocks would be difficult, owing to the inability to determine the SiO_2 content petrographically.

A detailed study of two tuff breccia units and two tuff units (E, F, G and H on Plate 1) in the Mangas Creek formation shows that certain chemical data can be used to distinguish these units. Plate 27 shows graphically among other things: (a) the silica content of samples taken from all the traverses (b) $CaO/Na_2O + K_2O$ ratios of a number of composite samples and (c) the total iron content of a number of composite samples.

The silica plots for traverses 8, 9, 10 and 11 (i. e., units E, F, G and H respectively) show that units E and G, although apparently identical in thin section and hand specimen, have a substantially different silica content. On the other hand, the units F and H, which also appear identical do not differ in silica content. The E and G units are brown tuff breccia and the F and H units are white vitric-crystal tuff. On the basis of silica content, it should be possible to differentiate between the two tuff breccias, but not between the tuff beds.

Similar plots of the $CaO/Na_2O + K_2O$ ratios and total iron contents are shown in Plate 27. Again, drawing attention to traverses 8, 9, 10 and 11, it can be seen that in the case of the alkali ratio plot, each of the two tuff breccias has a distinct ratio. The tuff units also have different alkali ratios, although the difference is not as great as between the tuff breccia units.

Sampling on a much larger interval (up to 3/4 mile) in other places in the quadrangle yielded mixed results. A comparison of the SiO_2 content, alkali ratios, and iron content of samples taken in traverses 1 and 2 (gray rhyolite member, McCauley formation) shows close agreement, even though the traverse lines are separated by a distance of 4-1/2 miles. This agreement is to be expected, since the two outcrops which were sampled are the same member of the same formation, and tends to be homogeneous throughout. In a similar fashion, the samples on traverses 13 and 14 (vitrophyre member, McCauley formation) are closely related —— again reflecting the apparent homogeneity of this unit.

Less satisfactory results are obtained when traverses 4 and 5 are compared. These two traverses are both taken across the thick "A" unit of the brown tuff breccia member of the Mangas Creek formation. Finally, a comparison of the silica contents of traverse 6 with traverse 7 (both taken in the red rhyolite member of the Cherokee Creek formation) yields no correlation at all. In these latter four traverses the difference in the silica contents is likely to be related to the inhomogeneity of the units sampled.

The foregoing observations are summarized below:

1. The silica contents of all the rocks are high — on the average 71%.

2. A comparison of the silica contents taken from closely spaced (400 feet) samples and composites in the brown tuff breccia member and the tuff member of the Mangas Creek formation indicates that the tuff breccia units, although essentially similar in appearance megascopically and microscopically, have a distinctly different silica content. The tuff units, on the other hand, cannot be differentiated by a study of the silica content.

3. A comparison of total iron content and alkali ratios for the closely spaced samples indicates that these quantities can be used to distinguish between units essentially similar in appearance.

4. Silica contents of a gray rhyolite flow taken from two different outcrops are similar, substantiating the geologic data which correlates these two outcrops.

5. Silica contents of a vitrophyre unit taken from two different outcrops are similar, again substantiating the geologic data which correlates these two outcrops.

6. Wider spaced sampling (up to 3/4 mile) in other places in the quadrangle does not yield results consistent enough to allow its use in correlation.

Magnetic Susceptibility Studies

A study of the magnetic susceptibilities of some of the volcanic rocks in the Schoolhouse Mountain quadrangle was undertaken in order to: (1) obtain data on the values of magnetic susceptibilities of rhyolitic pyroclastic rocks and (2) determine the value of magnetic susceptibilities in the correlation of volcanic rocks.

In order to determine the susceptibilities of the rocks involved, 55 separate stations were occupied in the quadrangle. The location of these stations is shown on Plate 25. The data obtained from the measurements are given in Table 8. Sample numbers are listed in the same manner as discussed under "Chemical Analyses," with the traverse number first, followed by the station number.

The instrument for measuring susceptibilities was provided by the Bear Creek Mining Co., and built by the Mt. Sopris Instrument Co. of Boulder, Colorado. Plate 21, Figure 1 is a photograph of the component parts of the susceptibility meter. Essentially, the instrument consists of three coils, a battery and a bridge circuit. Measurement of susceptibility is made by determining the inductance between the coils when they are on a tripod at some distance from the outcrop, and again when they are placed on the outcrop. The difference in inductance, which is due to the presence of magnetic material in the rock, is calibrated in terms of susceptibility and the actual susceptibility values are read from a calibration chart provided by the Bear Creek Mining Co.

A complete description of the theoretical principles involved in the construction of the instrument is beyond the scope of this report. An analysis of the theories involved, along with a description of the circuitry of the instrument can be found in a paper by Mooney (1952).

Plate 27 gives a list of all the magnetic susceptibility readings made in the field, plotted on a vertical axis. The numbers along the bottom refer to the number of the traverse line. Traverse lines 3, 5, and 7 were not occupied, owing to inaccessability.

Plate 27 shows that the susceptibility values are quite erratic, ranging from 0 to 825 cgs units. In addition, there appears to be no simple relationship between the various rock types, when their susceptibilities are considered. Indeed, the variation within a given unit may be considerable, as in the case of traverses 6 and 9. Thus, by making a series of susceptibility measurements on units at random, it would be unlikely that one could make adequate correlation. As a consequence of these studies, it seems that the use of magnetic susceptibility as a correlation tool, in a gross manner and without regard to rock type or geology is not practical.

If one considers the use of magnetic susceptibilities in a limited sense, the possibilities of correlation are better. Traverses 8, 9, 10 and 11 (units G, F, E and H respectively shown on Plate 1) were run in order to test the possibility of distinguishing between two sets of beds which appear the same in the field. Beds G and E and brown tuff breccia and beds F and H are vitric-crystal tuff. Plate 27 shows that the susceptibilities of the tuff beds (traverses 9 and 11) are about the same, thus cannot be used to distinguish between these beds. Considering beds G and E (traverses 8 and 10), one finds a somewhat different situation. The average susceptibility of bed G is substantially different than that of bed E. Hence, it appears that magnetic susceptibility measurements in these rocks will provide a basis for differentiating these two units. The difference between the two tuff breccia units, incidentally, is substantiated not only by geologic evidence, but also by chemical analyses of these rocks, and by fusion studies.

Table 8

Magnetic susceptibility data sheet.

Traverse	Station	Mag. Susc. $x10^6$ cgs.
1	1	485
1	2	365
1	3	375
1	4	435
1	5	400
2	1	0
2	2	415
2	3	300
2	4	160
2	5	115
4	1	235
4	2	190
4	3	-
4	4	115
6	1	230
6	2	25
6	3	825
6	4	535
8	1	170
8	2	20
8	3	55
8	4	50
8	5	15
8	6	0
8	7	0
8	8	0
8	9	0
9	1	0
9	2	0
9	3	115
9	4	0
9	5	0
9	6	0
10	1	635
10	2	465
10	3	350
10	4	300
10	5	60
10	6	195
10	7	230
10	8	160
10	9	0
11	1	0
11	2	95
11	3	0
11	4	0
11	5	0
11	6	0
11	7	110
11	8	0
12	1	170
12	2	200
12	3	0
13	1	0
13	2	200

The Fusion Method

The process of fusing powdered volcanic rock to a glass and the subsequent determination of the refractive index of the glass shall be termed the fusion method.

The historical and theoretical aspects of the method are treated by Callaghan and Sun (1956) and only brief mention of these items will be made here. The relationship between the chemical composition of a glass and its refractive index has been noted by George (1924), and Mathews (1951), among others. George (1924) studied the chemical compositions and refractive indices of natural glasses and obtained a rather rough correlation between these variables. Mathews (1951) made chemical analyses of rocks, then fused the rock and determined the index of the glass, and gave a comprehensive discussion of the relationships between index and composition. Callaghan and Sun (1956) used Mathews' methods to study rocks varying in composition from rhyolite to basalt and developed curves showing the relationship between SiO_2, FeO, Fe_2O_3, Al_2O_3, CaO, Na_2O, K_2O and MgO content and the refractive index of the fused rock.

In order to develop additional data for the rhyolitic pyroclastics the writer studied the refractive indices of fused specimens from the Schoolhouse Mountain quadrangle. The immediate practical aim of the work was (a) to study the effectiveness of the fusion method in determining SiO_2 content of the rhyolitic pyroclastics and (b) to determine whether the fusion method might be adapted as a correlation tool for rocks of nearly equivalent compositions.

The following steps were followed in the preparation of the rock samples:

1. Collection of the samples. Each sample consisted of several rock chips taken from within a 50 foot circle about the sample station. About 8 pounds of rock was collected at each sample station (See Plate 25).

2. Crushing the sample to "pea" size or smaller.

3. Splitting the sample to obtain a fraction for chemical analysis. About 3/4 pound of rock was sent for analysis. This fraction was subsequently crushed and split by the chemist, leaving about 250 grams for analysis.

4. The reject sample from "3" was ground and split to form 80 mesh and 200 mesh fractions.

5. The 80 mesh and 200 mesh fractions were split to form 100 gram samples for fusion and reference.

The heat for the fusing of the powdered samples was provided by a Lincoln arc torch holding carbon electrodes. A Lincoln "Idealarc 180" welder unit operating at 160 amps, 25 volts supplied the current. About 0.1 gram of powdered rock was placed on a 6" x 1-1/4" x 1-1/4" copper block. The arc was struck over the powder, causing the powder to melt. The high conductivity of the copper allowed rapid heat escape, so that the bead cooled rapidly to a glass. At no time was the arc brought so close to the copper that melting of the block could occur. Examination of the block revealed no sign of pitting. The fact that the bead formed in a bed of rock powder further reduced chances of contamination. The arc temperature was estimated to be about 4000°C.

The arc was maintained for the following times, for each sample:

a. 80 mesh fraction .... 3 seconds
b. 200 mesh fraction .... 3 seconds
c. 200 mesh fraction .... 6 seconds

A schematic diagram of the apparatus is shown in Figure 15.

The glass beads formed in the operation described above were subsequently crushed to about 150 mesh in a ceramic mortar and examined with a high power lens under a petrographic microscope. Refractive indices were determined by the use of oils, at a temperature of about 25°C. The light source was a Shannon sodium lab-arc, which provided monochromatic sodium light. Only the beads made from the 200 mesh powder arced for 6 seconds are considered in this report. A cursory examination reveals no significant difference between the 200 mesh--6 second beads and the 200 mesh--3 second beads. The beads made from 80 mesh material arced for 3 seconds tend to be cloudy and incompletely fused.

All the beads were made by John Russell, in the Bear Creek Mining Co. geochemistry laboratory, Denver, Colorado.

Examination under a high power lens reveals that the crushed beads are usually clear and isotropic, and have jagged outlines. An occasional sample may contain a few spherical bubbles or inclusion of opaque materials. Birefringent fragments of stained(?) glass are present in small quantities.

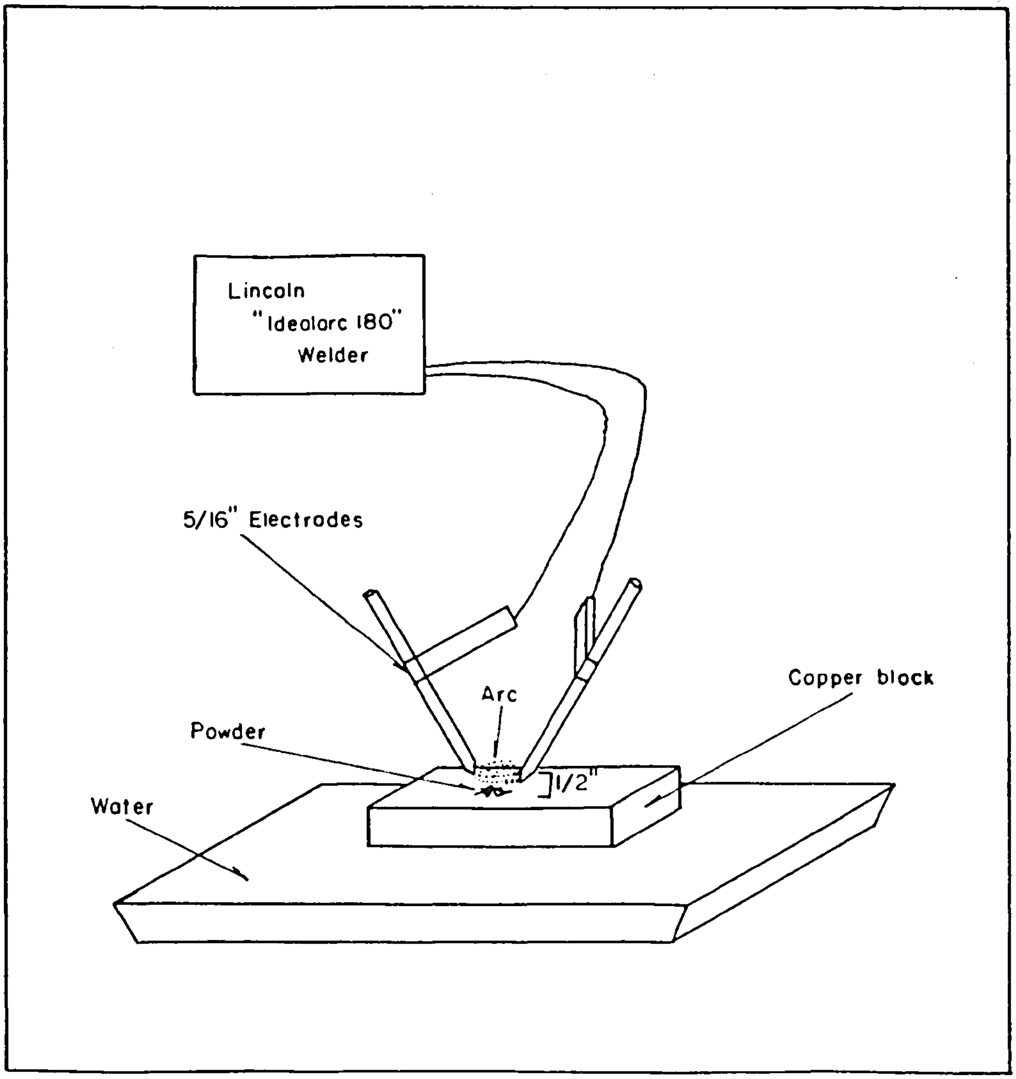


Fig. 15 Schematic diagram of the fusion apparatus. Not to scale.

Comments on the Fusion Method

Sources of Error

Callaghan and Sun (1956) point out that the composition of the bead is not necessarily the same as the composition of the powder from which it was made. This may be due to incomplete fusion of certain constituents, or to loss of the more volatile constituents during fusion. The effect of contamination of the bead by the atmosphere has not been studied. The small size of the sample may contribute a random error to the process, although fine grinding tends to reduce the error. Errors due to contamination during sample preparation have been minimized by thorough cleaning of the equipment before crushing the rocks fragments and before splitting.

Although the errors mentioned above may be reduced by more attention to detail —— i. e., fusion in an inert atmosphere, finer crushing, etc., the inherent accuracy of the method seems to obviate the need for such care. All the data from the literature and from this study indicate that the SiO_2 content can be estimated with confidence up to within 3% of the actual SiO_2 content. This range of accuracy is sufficient to provide a reasonable estimate of the rock type involved and in some instances, is accurate enough to allow the use of the fusion method as a correlation tool in rocks of apparently equivalent composition.

Relationship between Refractive Index and SiO_2 Content

Figure 16 shows a plot of refractive index vs. SiO_2 percentage for 37 samples. The distribution of points in the scatter diagram is somewhat difficult to interpret in terms of a single regression line, however it is apparent that the line would slope to the right, indicating a higher refractive index as the amount of SiO_2 decreases, if one disregards the three points in the upper right hand corner of the diagram. This slope is in accordance with the curves plotted by Callaghan and Sun (1956), and the values of the refractive index for a given silica percentage are also equivalent to that curve. Four or five points fall well beyond the limits of the central group of points. No reason can be given for this departure from the norm.

Use of Refractive Index as a Correlation Tool

The refractive indices of the rocks for which chemical analyses are available are plotted on Plate 27. In traverses 1, 2, 4, 5, 6, 7 and 13, only a single composite analysis was available for each traverse line. For traverses 8, 9, 10 and 11, several analyses were available. The top and bottom points of the diamond shown in the plots on Plate 27 represent maximum and minimum values while the cross bar indicates the position of the arithmetic average.

A comparison of the refractive indices of traverse lines 1 through

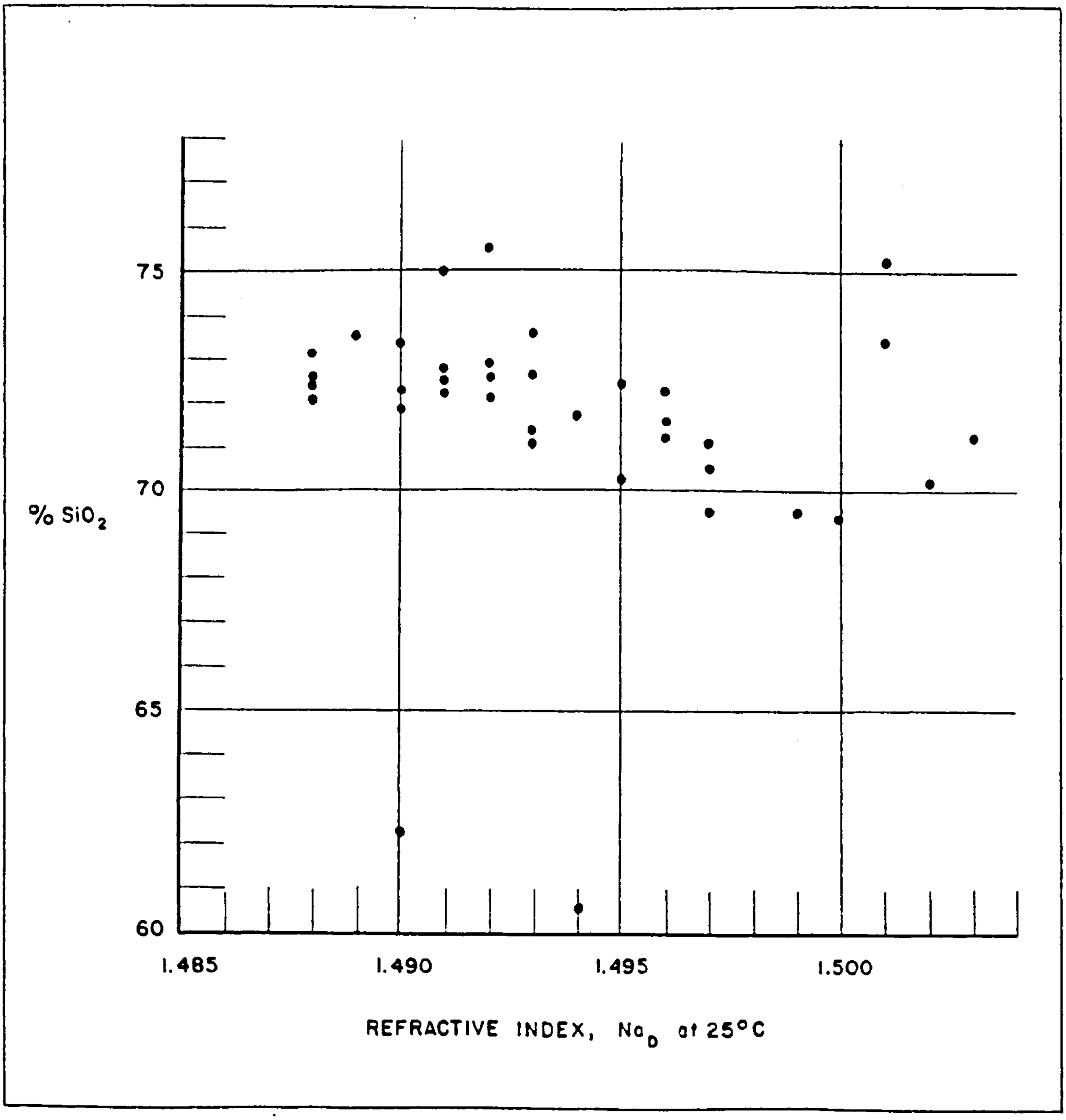


Fig. 16 Plot of refractive index of glass vs. SiO_2 content. 37 samples.

7 indicates no striking similarities or differences. The conclusions from a study of the refractive index of these traverses follow those based on a study of chemical compositions, namely: (a) mere comparison of fusion data without regard for rock type is ineffective and (b) more than one sample is needed to allow conclusions to be made regarding effectiveness of correlating widely spaced outcrops.

A study of traverses 8, 9, 10 and 11, where more data are available, indicate partial success of the fusion method as a correlation tool. Plate 27 shows that the average of the refractive indices for traverse 8 is noticeably different than for traverse 10; yet, as has been mentioned, these two units cannot be distinguished in the hand specimen or in thin section. The difference in the units shown by the fusion studies bears out the differences noted in a comparison of SiO_2 content of the units and, incidentally, the difference shown by comparison of magnetic susceptibility values. These data lead to the conclusion that the brown tuff breccia pyroclastics in the Schoolhouse Mountain quadrangle can be effectively correlated by the three methods mentioned above, under the conditions of sampling specified.

On the other hand, the inability to distinguish between the white tuff units (traverses 9 and 11) is also shown on Plate 27. The average refractive index for traverse 9 is very close to that for traverse 11. In turn, the SiO_2 contents and the magnetic susceptibility values are also shown to be equivalent for the two units.

CONCLUSIONS

Geology

The rocks of the Schoolhouse Mountain quadrangle consist of (1) Precambrian granites and associated metamorphic and igneous rocks located in the southern part of the quadrangle, (2) Cretaceous shales and quartzites also located in the southern part of the quadrangle, (3) a thick series of volcanic units covering the northern three fourths of the quadrangle and (4) miscellaneous gravels and unconsolidated sediments. The volcanic column is characterized by the presence of a thin basal andesite formation, a thick sequence of rhyolitic pyroclastics and flows overlying the andesites and a thin flow of basalt overlying the rhyolite. This sequence of andesite-rhyolite-basalt is common over a large part of southwestern New Mexico.

The structure of the area is dominated by a broad, complex north-northwest trending arch in the volcanic rocks. Two major faults cross the quadrangle. One, the Schoolhouse Fault, trends north-south, with the west side downthrown. The other, the Wild Horse Fault, trends east-west and separates the Tertiary volcanics on the north side from the Cretaceous sediments and Precambrian granitic rocks on the south side. Other faults include the Ira Creek hinge fault and faults of lesser magnitude, most of which trend in a northwesterly direction. The uplift and deformation of the volcanic rocks is thought to have occurred in late Tertiary time, and the area mapped probably represents only a small part of the total area uplifted in this part of New Mexico.

The nature of the basement underlying the volcanic rocks is unknown, and the question as to whether Paleozoic sediments occur at depth remains unsolved. However, the fact that Cretaceous rocks are found resting directly on Precambrian granites in the southern part of the quadrangle suggests that similar conditions obtain beneath the Tertiary volcanics.

Hydrothermal alteration of the volcanic rocks adjacent to faults and closely spaced joint sets is common. The rocks have been altered to an aggregate of iron oxides and clay minerals, and locally quartz is abundant. Thin section studies indicated that the quartz was derived from the devitrified high silica glass in the rocks, during the alteration phase.

Ore deposits in the quadrangle are small and of minor consequence. Some fractures filled with manganese oxides are found in the volcanic rocks, and two small fluorite prospects are located on mineralized fractures in the Precambrian granite.

Correlation Studies

Three methods of correlation were surveyed in order to determine their effectiveness in pyroclastic rocks. These methods are: (1)

comparison of magnetic susceptibilities, (2) comparison of chemical analyses and (3) comparison of refractive indices of fused rock. The general conclusions drawn from these studies are:

1. Comparison of magnetic susceptibility values from stations spaced at 200-foot intervals in two brown tuff breccia units affords a moderately reliable method of distinguishing between the two units.

2. Comparison of SiO_2 content and refractive index of fused rocks taken from closely spaced stations in two brown tuff breccia units permits distinguishing between the two units.

3. Two white tuff units sampled at 200-foot intervals along strike were too similar in composition and magnetic properties to allow distinguishing by the three correlation methods tested.

4. Widely spaced sampling (up to 1/4 mile) in general does not yield data consistent enough to allow use of the correlation methods cited.

5. In no instance would the correlations mentioned in 1, 2, or 3 above be of value without adequate geologic knowledge of structure and general petrography.

6. The plot of SiO_2 content vs. refractive index yields information consistent with that obtained by other workers. Using curves developed from such a plot, it should be possible to determine the SiO_2 content of a fused specimen from this area to an accuracy of about $\pm$ 3 percent SiO_2.

PLATE 2

FEATURES OF THE BEARTOOTH(?) QUARTZITE

Figure 1. Pebble conglomerate lens in the Beartooth(?) quartzite.

Figure 2. Contact between Beartooth(?) quartzite and Pre-cambrian granite.

PL. 2

PLATE 3

FEATURES OF THE COLORADO(?) FORMATION

Figure 1. Alternating sandstone and shale beds in the Colorado(?) formation.

Figure 2. Small anticlinal fold in the Colorado(?) formation.

PLATE 4

UPPER AND LOWER CONTACTS OF THE MOONSTONE TUFF

Figure 1. Contact between the Moonstone Tuff (upper) and rubble derived from the Cherokee Creek formation (lower).

Figure 2. Contact between the Stage Three gravels (upper) and the Moonstone Tuff (lower).

PL. 4

PLATE 5

GRAVEL AND BASALT CONTACTS

Figure 1. Contact between basalt (upper) and Stage Three gravels (lower).

Figure 2. Stage Two gravels in the Mangas Valley. Dotted line shows contact with Stage One gravels. Silver City range volcanics on the skyline.

PL. 5

PLATE 6

GRAVELS AND GRANITE-AMPHIBOLITE CONTACTS

Figure 1. Bedding in Stage Two gravels.

Figure 2. Contact between granite (light colored) and amphibolite (dark colored).

PL. 6

PLATE 7

FEATURES OF THE SADDLE ROCK CANYON ANDESITE

Figure 1. Contact between Saddle Rock Canyon andesite (upper) and Precambrian granite (lower).

Figure 2. Fault separating blue andesite member (in hill) and Kerr Canyon formation (in the foreground).

PL. 7

PLATE 8

TUFF CONTACT AND PHOTOMICROGRAPH OF ANDESITE

Figure 1. Contact between the white tuff member of the Kerr Canyon formation (upper) and Saddle Rock Canyon formation (lower).

Figure 2. Photomicrograph. Blue andesite member, Saddle Rock Canyon formation. Limonite and magnetite pseudomorph after amphibole. m--magnetite and limonite, g--fine grained groundmass. Plane light, 230X.

PL. 8

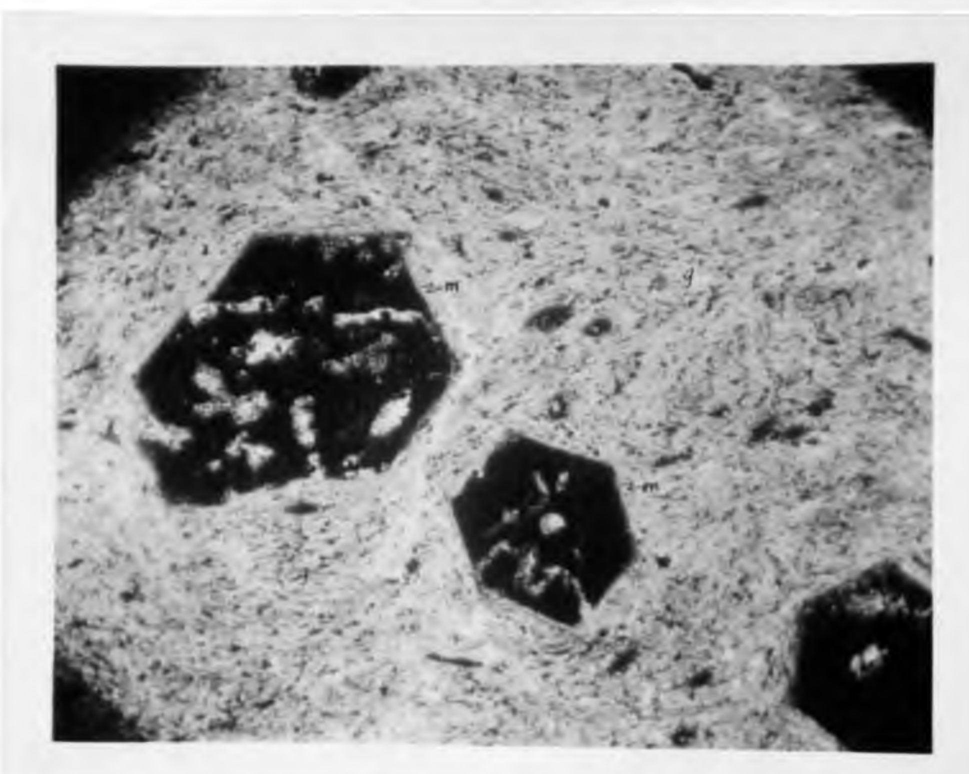


PLATE 9

FEATURES OF SOME RHYOLITE, BRECCIA AND ANDESITE UNITS

Figure 1. Contact between rhyolite and breccia member (upper) and white tuff member (lower), in the Kerr Canyon formation.

Figure 2. Andesite porphyry member of the Saddle Rock Canyon formation, in Saddle Rock Canyon.

PLATE 10

SILLS IN THE KERR CANYON FORMATION AND LOWER CONTACT OF THE MCCAULEY FORMATION

Figure 1. Fine grained sill-like intrusions in the Kerr Canyon formation.

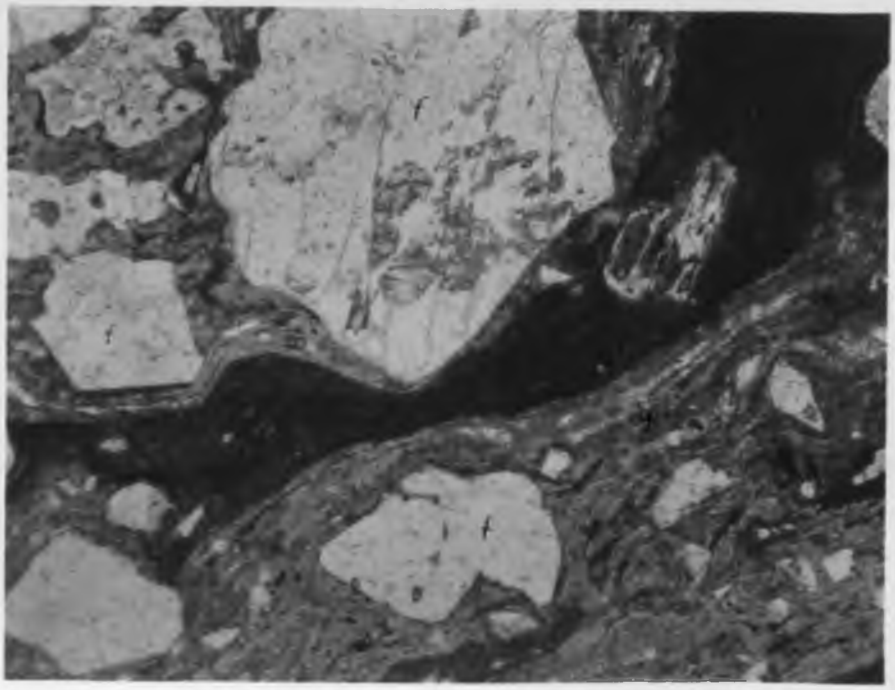
Figure 2. Contact between the gray rhyolite member of the McCauley formation (upper) and the brown tuff breccia member of the Mangas Creek formation (lower).

PLATE 11

PHOTOMICROGRAPHS OF MANGAS CREEK FORMATION ROCKS

Figure 1. Photomicrograph. Brown tuff breccia member, Mangas Creek formation. Note dark, glassy streak squeezed between two feldspar grains. f--feldspar, g--glassy groundmass. Plane light, 230X.

Figure 2. Photomicrograph. Breccia member, Mangas Creek formation. Example of a lithic-crystal breccia. l--lithic fragments, p--plagioclase and quartz. Plane light, 230X.



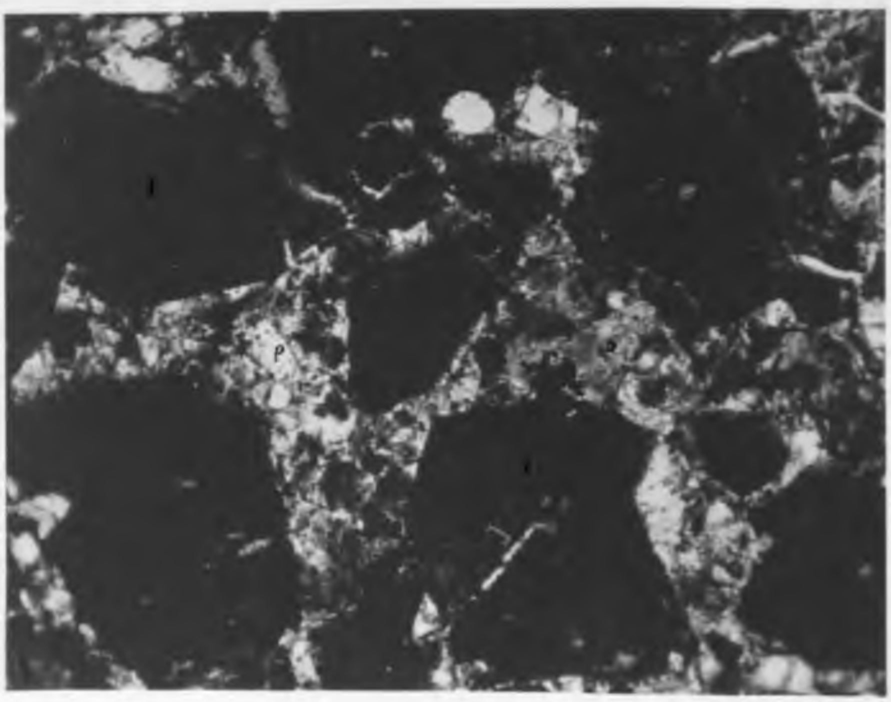


PLATE 12

MANGAS CREEK FORMATION CONTACTS AND
PHOTOMICROGRAPH OF MCCAULEY FORMATION ROCKS

Figure 1. Contact between the "G" brown tuff breccia unit (upper) and the "F" white tuff unit (lower), in the Mangas Creek formation.

Figure 2. Photomicrograph. Sandstone and breccia member, McCauley formation. Sub-angular feldspar crystals and lithic fragments set in a fine grained matrix. f--feldspar, l--lithic fragments, m--matrix. Plane light, 230X.

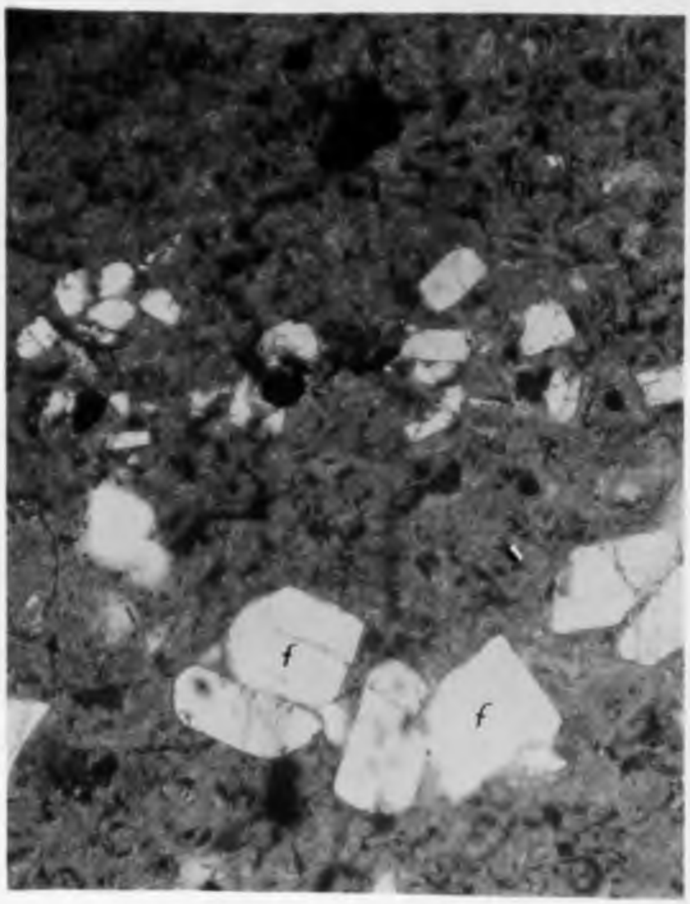
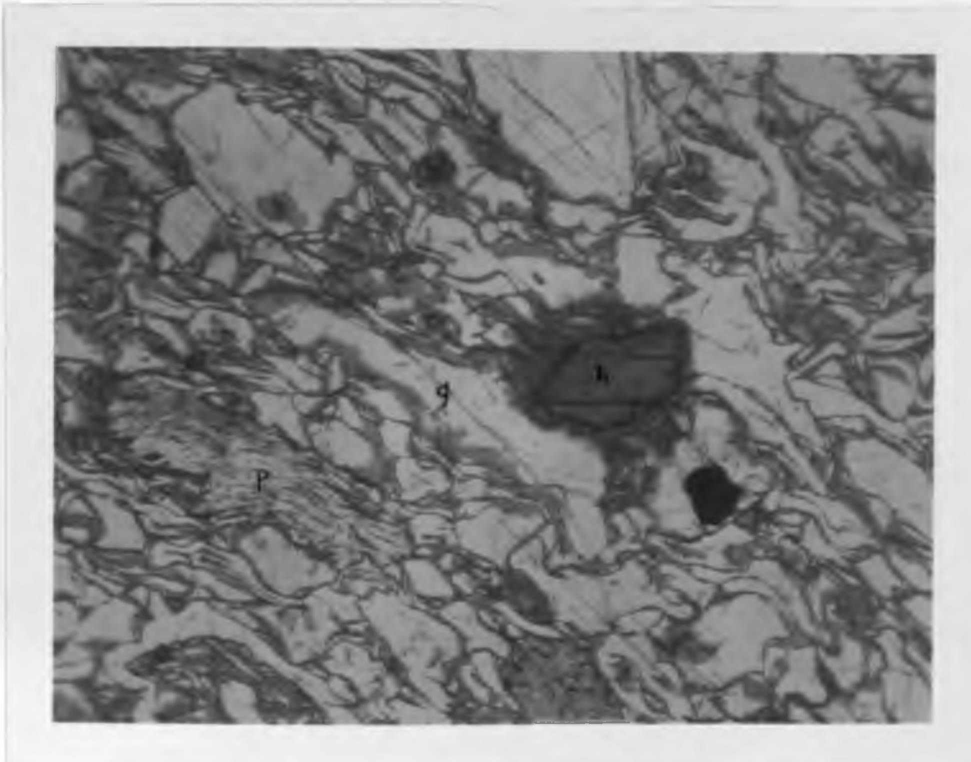

f
f

PLATE 13

PHOTOMICROGRAPHS OF MCCAULEY FORMATION ROCKS

Figure 1. Photomicrograph. Vitrophyre member, McCauley formation. Section is mostly glass. Note incipient de-vitrification along cracks. g--glass, h--hornblende, p--pumice fragment. Plane light, 230X.

Figure 2. Photomicrograph. Gray rhyolite member, McCauley formation. Fine grained, quartz-laden groundmass with elongate, streaky vugs lined with quartz crystals. g--groundmass, v--vug, q--quartz. Crossed polaroids, 230X.


h
q
p


q
q

PLATE 14

PHOTOMICROGRAPH OF MCCAULEY FORMATION ROCKS AND JOINTING IN THE CHEROKEE CREEK FORMATION

Figure 1. Photomicrograph. Gray rhyolite member, McCauley formation. Same as Fig. 2, Plate 13, except that picture was taken in Plane light.

Figure 2. Slabby jointing in the red rhyolite member of the Cherokee Creek formation, in Cherokee Creek.

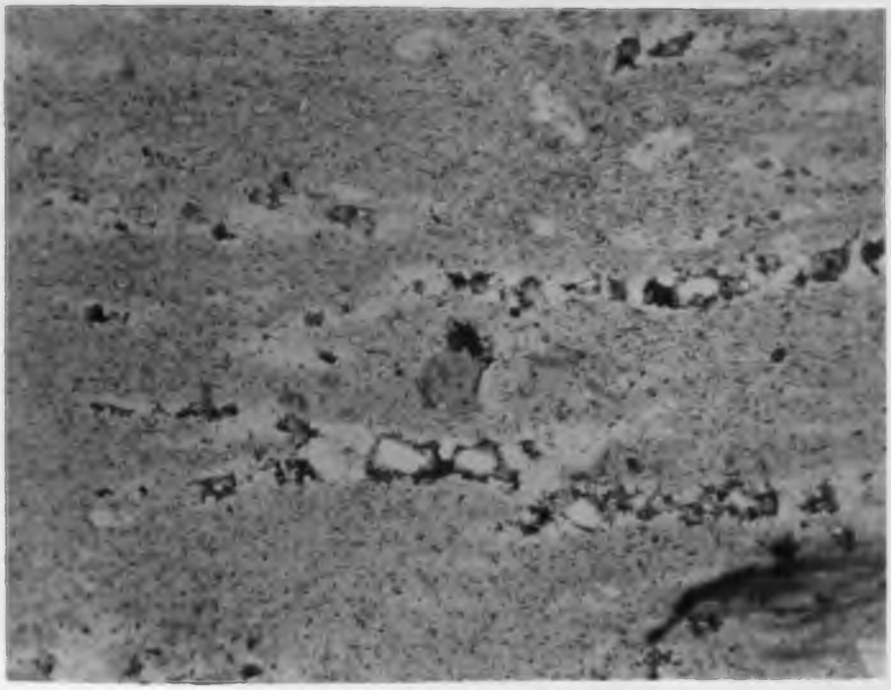


PLATE 15

GRABEN IN THE CHEROKEE CREEK FORMATION AND PHOTOMICROGRAPH OF CHEROKEE CREEK FORMATION ROCKS

Figure 1. Small graben in tuff and gravel, in the Cherokee Creek formation.

Figure 2. Photomicrograph. Red rhyolite member, Cherokee Creek formation. Welded tuff. Note squeezed and deformed shard in area between feldspar crystal and lithic fragment. p--plagioclase, l--lithic fragment, g--glass shard. Plane light, 230X.

PL. 15

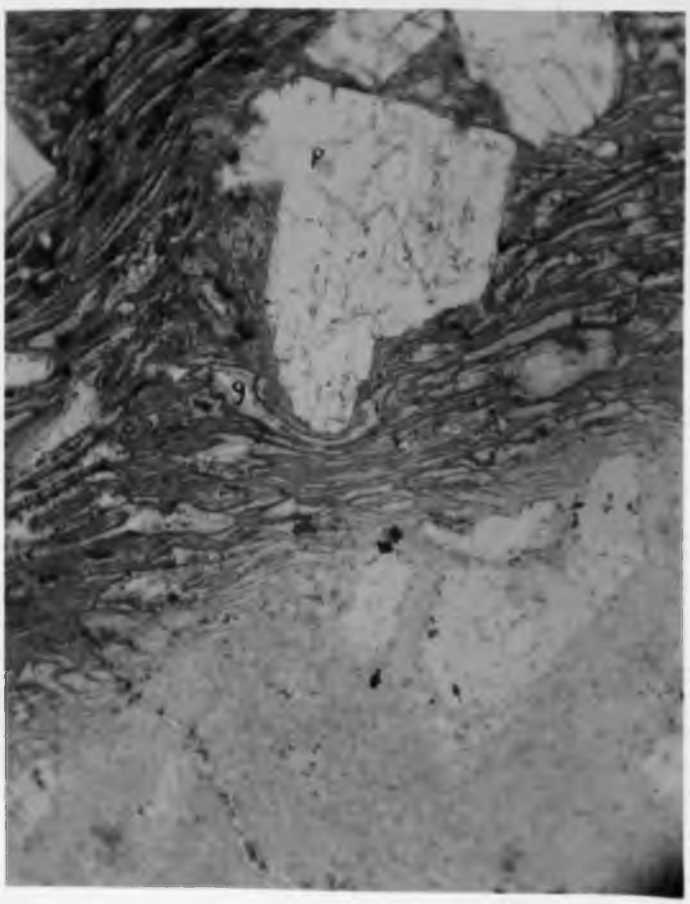


PLATE 16

VITROPHYRE IN TUFF

Figure 1. Vitrophyre blebs in tuff. Picture taken perpendicular to plane of foliation. Note absence of lineation. v--vitrophyre, t--tuff.

Figure 2. Vitrophyre blebs in tuff. Picture taken parallel to foliation. Note dark borders on vitrophyre blebs. Compare with Fig. 1, above. v--vitrophyre, t--tuff.

PLATE 17

PHOTOMICROGRAPHS OF CHEROKEE CREEK FORMATION ROCKS

Figure 1. Photomicrograph. Vitrophyre member, Cherokee Creek formation. Note glass charged plagioclase phenocryst set in glassy groundmass. p--plagioclase, g--glass. Plane light, 230X.

Figure 2. Photomicrograph. Same as Fig. 1, above, except that picture was taken through crossed polaroids.

PL. 17

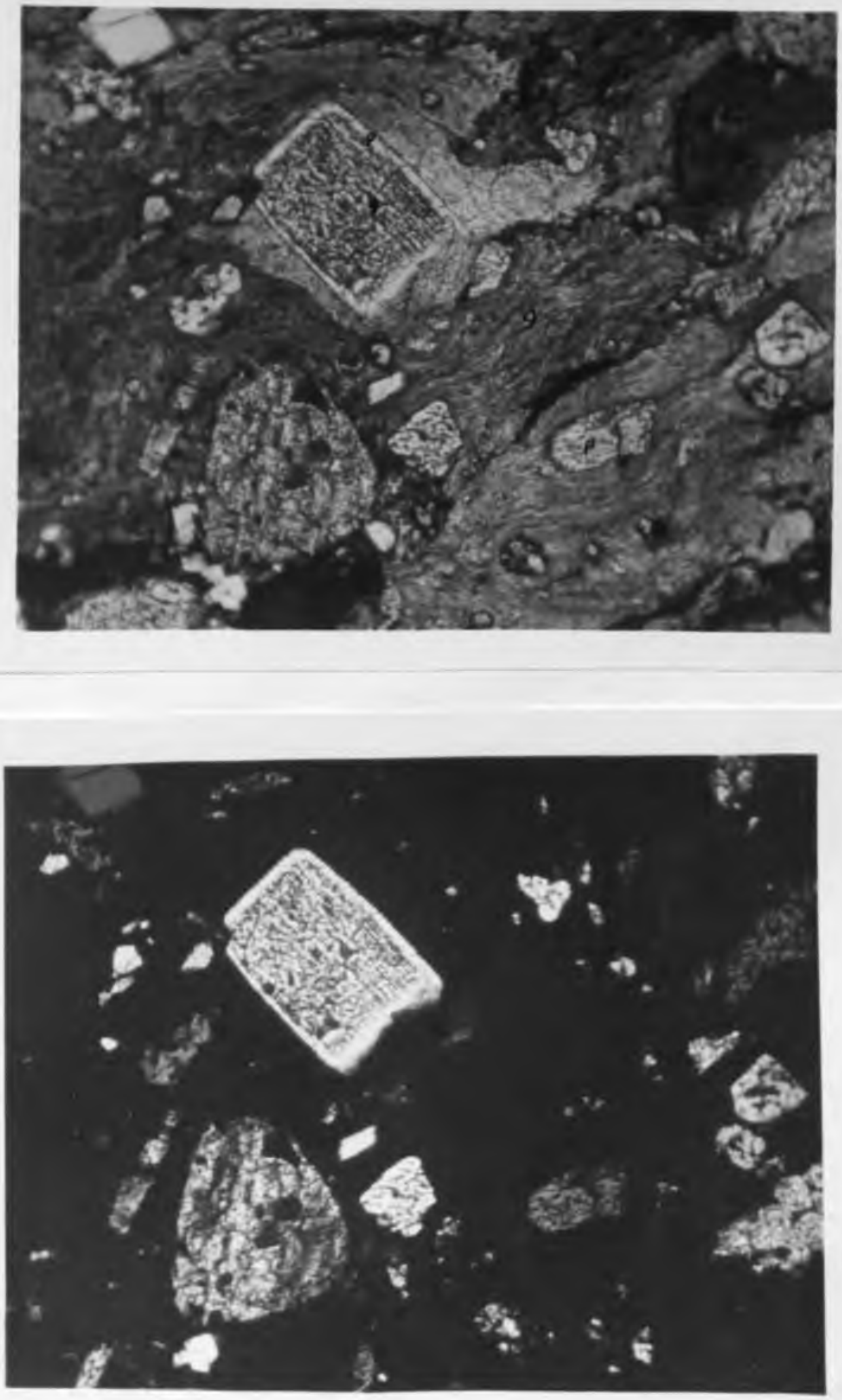


PLATE 18

SCHOOLHOUSE AND IRA CREEK FAULTS

Figure 1. Looking north along the Schoolhouse Fault.

Figure 2. Looking west along the Ira Creek Fault.

PL. 18

PLATE 19

WILD HORSE FAULT AND WILD HORSE MESA

Figure 1. View along the Wild Horse Fault. Granite in foreground, volcanics in the distance.

Figure 2. Looking north over Wild Horse Mesa. Hills on the skyline consist of Beartooth(?) quartzite.

PLATE 20

PHOTOMICROGRAPHS OF DELTA FORMATION ROCKS

Figure 1. Photomicrograph. Beta member, Delta formation (altered). g--glassy and somewhat de-vitrified groundmass, q--quartz, l--lithic fragment. Plane light, 230X.

Figure 2. Photomicrograph. Similar to Fig. 1 above, except that picture was taken through crossed polaroids.

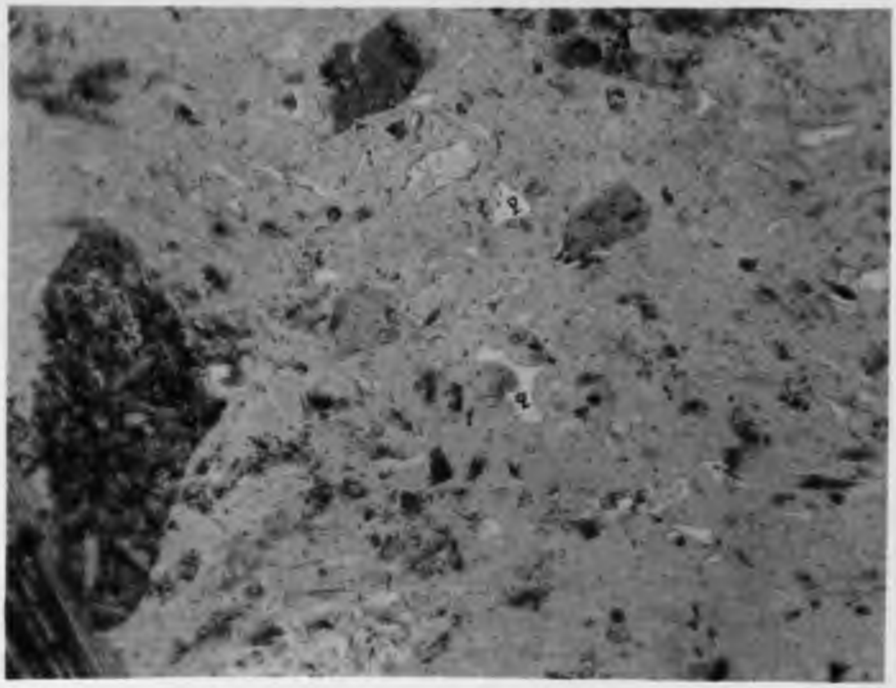


PLATE 21

MAGNETIC SUSCEPTIBILITY METER

Figure 1. Magnetic susceptibility meter. a--tripod, b--battery and instrument cases, c--coils. The coils are in position for taking a susceptibility reading on the outcrop.

PL. 21

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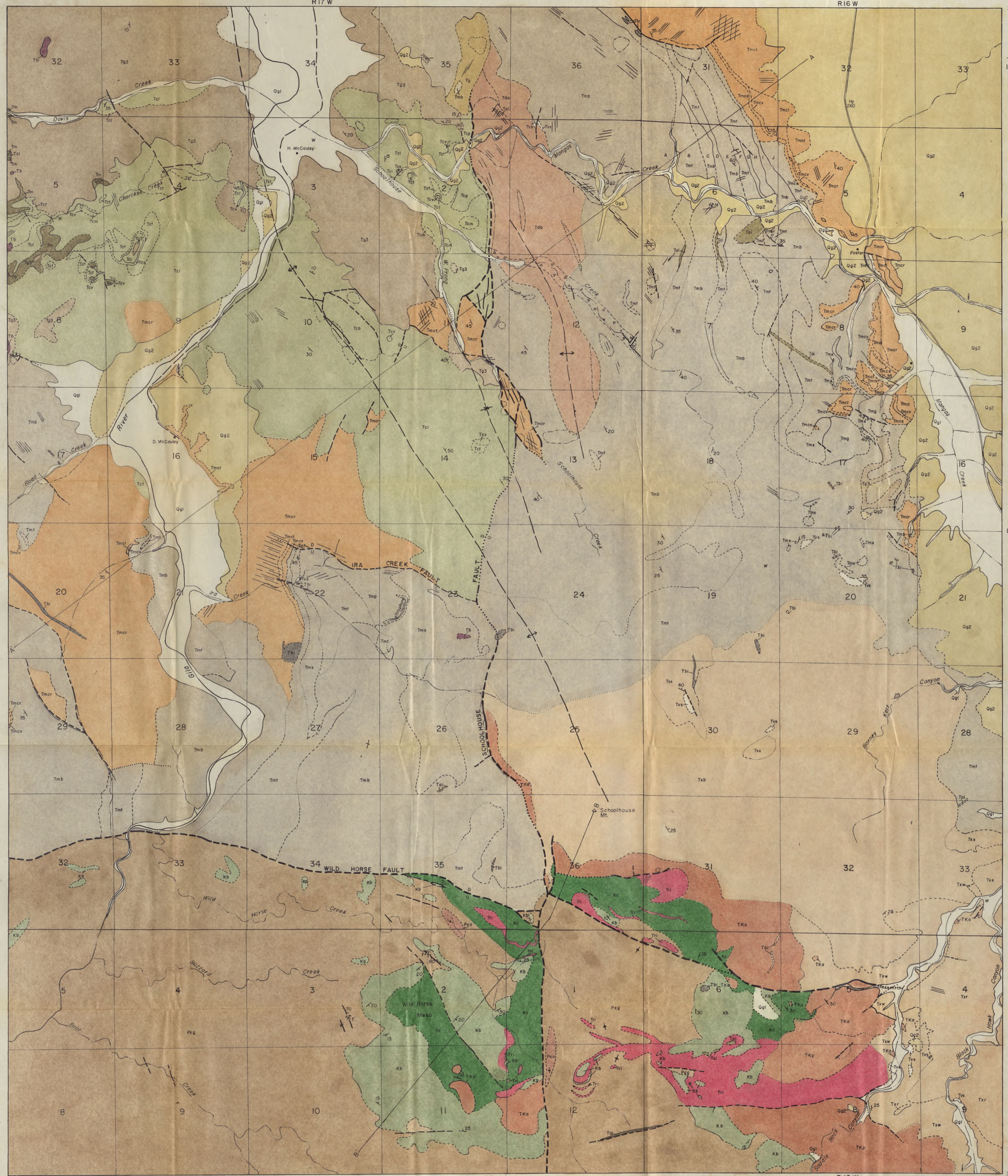
PLATE I



EXPLANATION

GEOLOGIC COLUMN

Quaternary and Tertiary

- Qg1 — Stage 1 gravels
- Qg2 — Stage 2 gravels
- Tb — Basalt
- Tg3 — Stage 3 gravels

Tertiary

- Tmt — Moonstone tuff
- Tg — Gamma formation

Cherokee Creek formation:
- Tcv — Vitrophyre member
- Tct — Tuff member
- Tcb — Breccia member
- Tcm — Megabreccia member
- Tcr — Red Rhyolite member
- Tcp — Porphyry member

McCauley formation:
- Tmcr — Grey rhyolite member
- Tmcl — Pink Rhyolite member
- Tmcv — Vitrophyre member
- Tmcs — Sandstone and breccia member

Mangas Creek formation:
- Tmp — Pink Rhyolite member
- Tma — Andesite breccia member
- Tmg — Grey andesite member
- Tmt — White tuff member
- Tmx — Brown breccia member
- Tmb — Brown tuff breccia member

Delta formation:
- Tda — Alpha member
- Tdb — Beta member

Kerr Canyon formation:
- Txx — Breccia member
- Txb — Brown tuff breccia member
- Txr — Rhyolite and breccia member
- Txw — White tuff member

Saddle Rock Canyon formation:
- TKa — Blue andesite member
- TKp — Andesite porphyry member

Cretaceous

- Kc — Colorado (?) formation
- Kb — Beartooth (?) quartzite

Precambrian

- Peg — Granite
- Pea — Amphibolite

MISCELLANEOUS UNITS

- Tbi — Basic dikes and sills
- Tai — Acid and intermediate dikes
- Tri — Rhyolite sill (in southern part of Quadrangle)
- Tvs — Inter- and intra-formational sediments

SYMBOLS

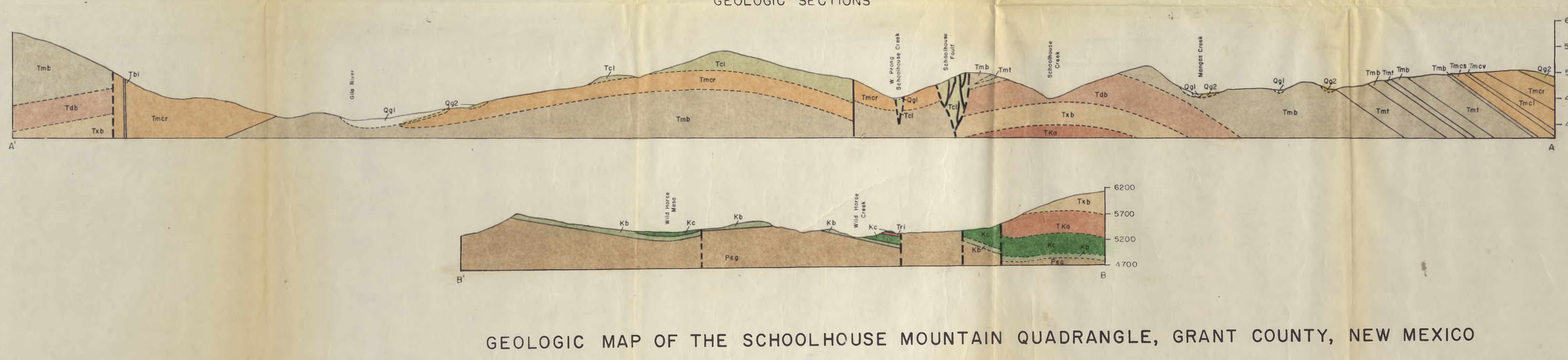
- Fault; dashed where approximate dotted where inferred (D-downthrown, U-upthrown)
- Fracture zone
- Anticlinal axis
- Synclinal axis
- Contact; dashed where approximate dotted where inferred
- Joints
- Altered area
- Vertical foliation
- Strike and dip of beds
- A — A' Line of section
- Roads; solid line-paved, dashed line-gravel
- Intermittent stream
- McCauley Dwelling
- W Windmill
- S Spring
- F, M Prospect (F-Fluorite, M-Manganese)

N 13°

0 1/2 1 MILES

SCALE 1:15 840

GEOLOGIC SECTIONS



GEOLOGIC MAP OF THE SCHOOLHOUSE MOUNTAIN QUADRANGLE, GRANT COUNTY, NEW MEXICO

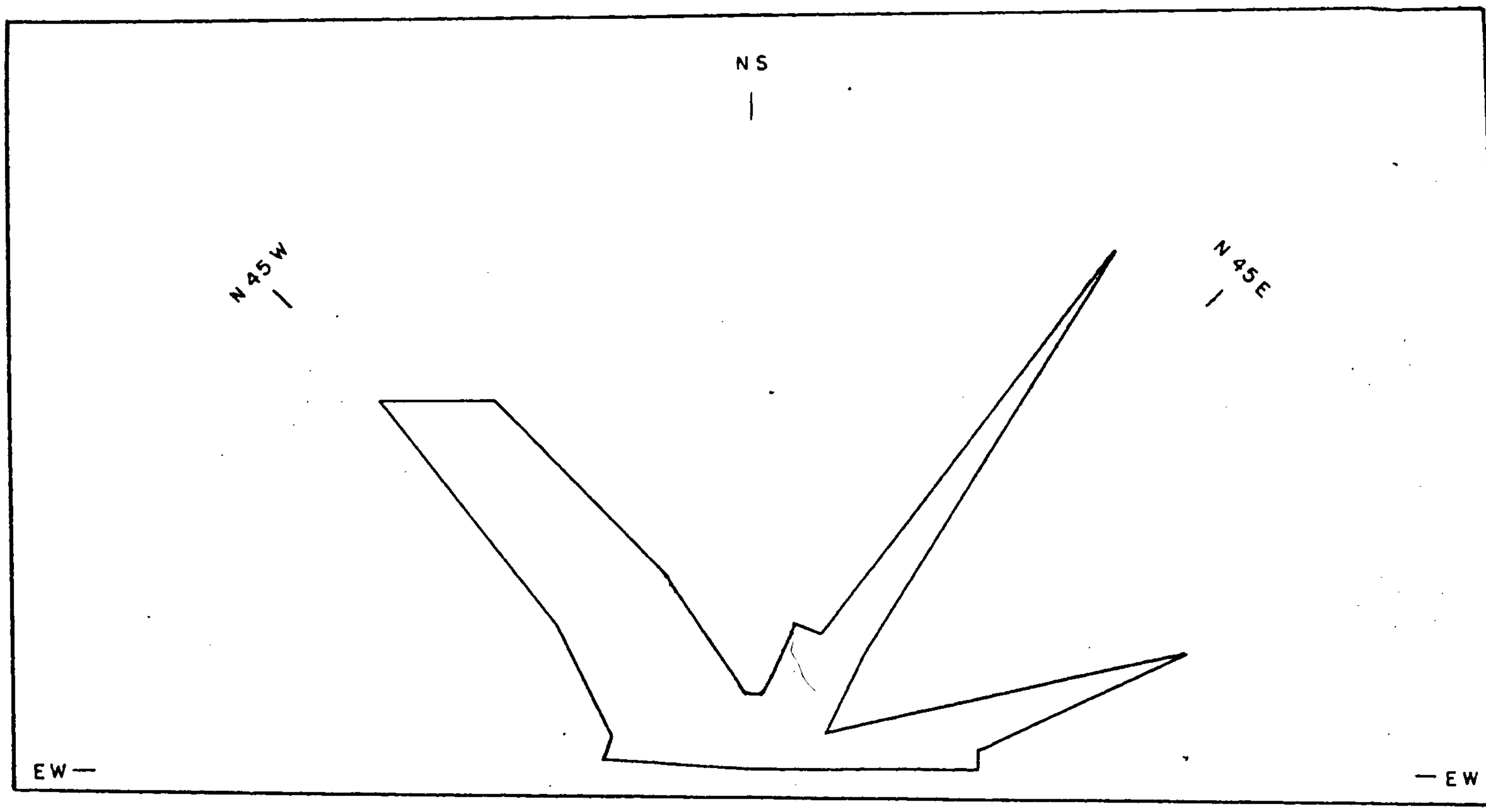


Fig. 1 Rose diagram showing strikes of joint sets in the Schoolhouse Mt. quadrangle.

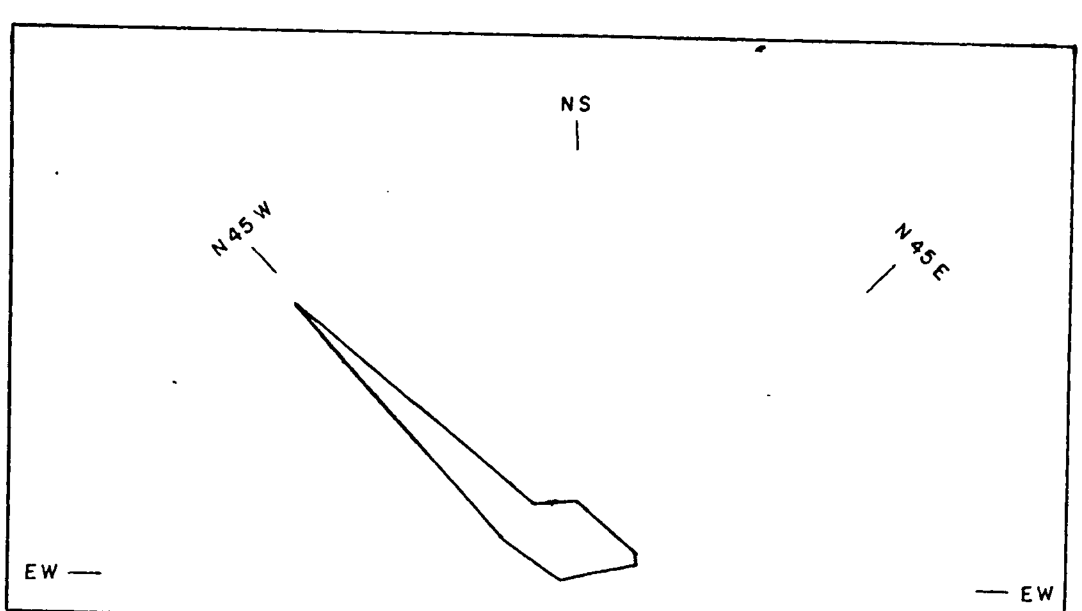


Fig. 2 Rose diagram showing strikes of dikes in the Schoolhouse Mt. quadrangle.

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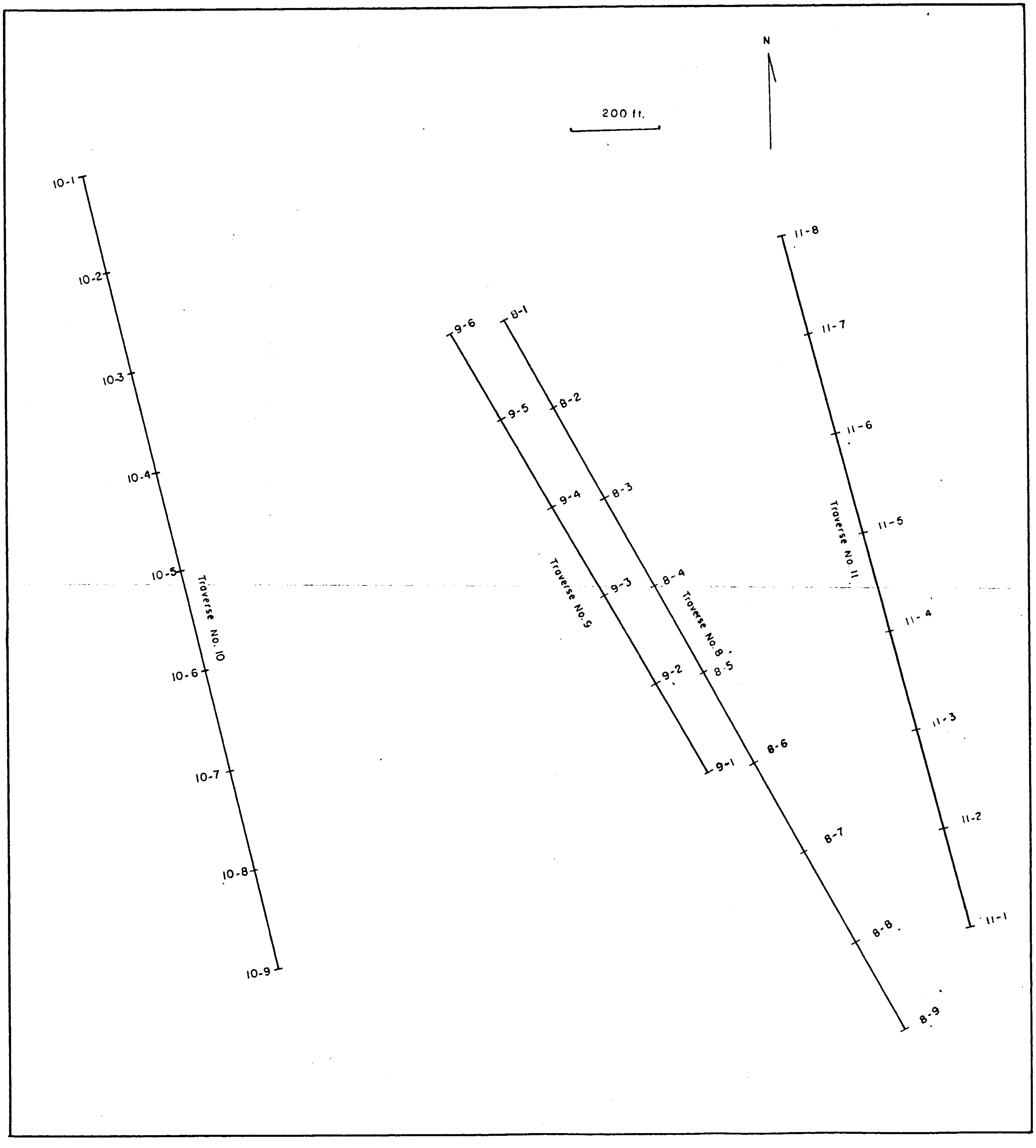
PLATE 26



Sketch Map showing relative position of traverses no 8, 9, 10, and 11

PLATE 27

Magnetic susceptibility, chemical and optical data for some rocks from the Schoolhouse Mountain quadrangle. See text for explanation.

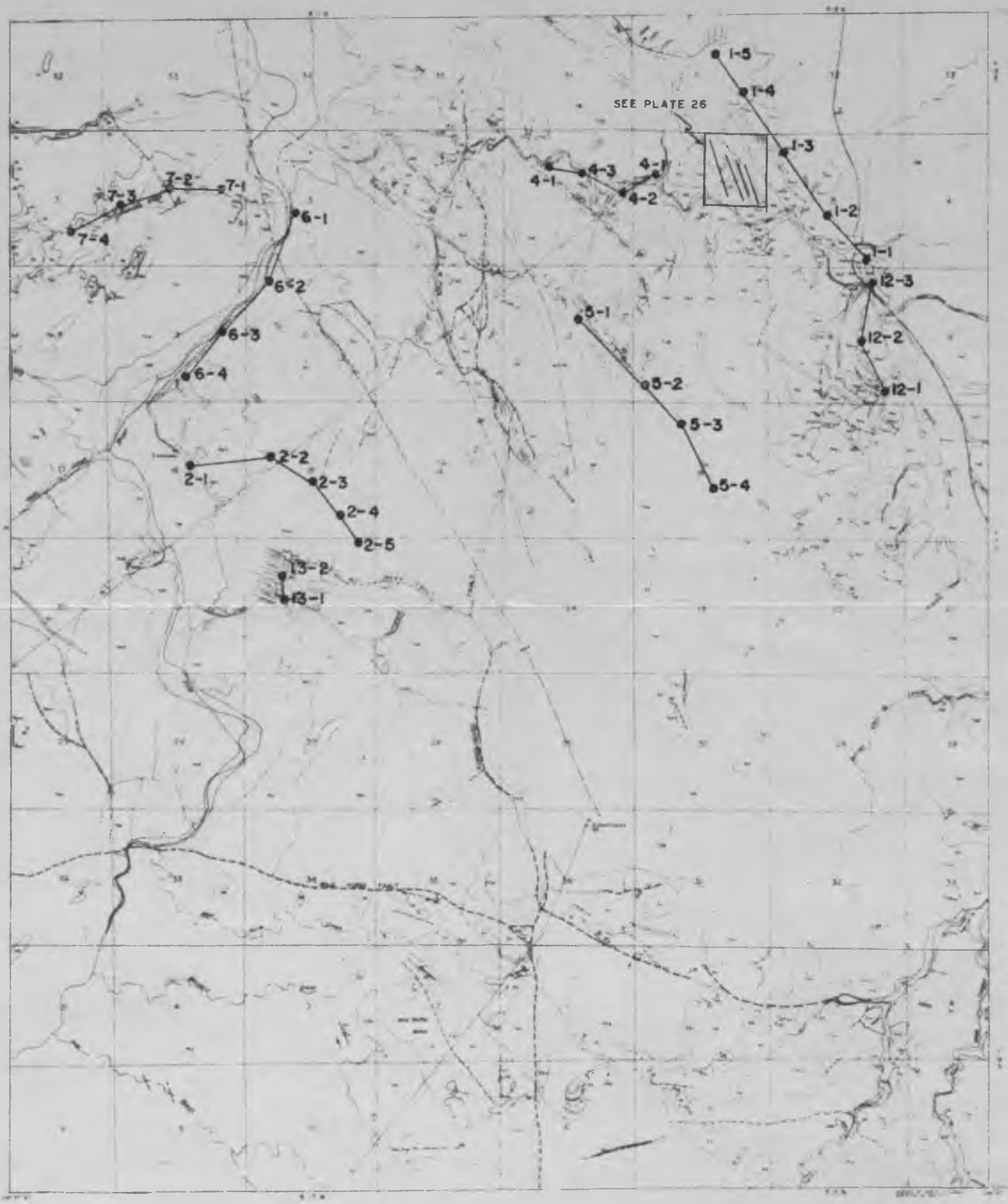
Note: Traverse line No. 3 omitted.

PLATE 22

GENERALIZED GEOLOGIC SECTION IN THE SCHOOLHOUSE MOUNTAIN QUADRANGLE, GRANT COUNTY, NEW MEXICO

AGE	FORMATION	MEMBER	LITHOLOGY AND REMARKS	THICKNESS	SYMBOL
Recent	Stage 1 gravels		Poorly consolidated gravels, stream debris; some talus gravels.	0-20'	Qg1
Recent	Stage 2 gravels		Moderately well consolidated gravels in higher terraces; usually well bedded.	0-100'	Qg2
Pleistocene-Pliocene (?)	Basalt		Dense, scoriaceous dark basalts.	50'	Tb
Pleistocene-Pliocene	Stage 3 gravels		Well consolidated gravels with fair to good bedding; abundant fragments of rhyolite member of McCauley formation.	0-250'	Tg3
Tertiary	Moonstone tuff		Light grey, porphyritic, sanadine-bearing tuffs; many of the phenocrysts show iridescent play of colors.	50'	Tm
	Gamma formation		Purple and brown tuff breccia.	50'	Tg
	Cherokee Creek formation	Vitrophyre member	Dense, black, glassy vitrophyre.	1500'	Tcv
		Tuff member	White crystal vitric tuff and pumice.		Tct
		Breccia member	Dense, brown breccia and white tuff breccia.		Tcb
		Megabreccia member	Large blocks of latite, rhyolite and tuff cemented with reddish tuff.		Tcm
		Red Rhyolite member	Streaky, brick red latite and rhyolite flows and welded tuffs.		Tcl
		Porphyry member	Grey, porphyritic latite and rhyolite.		Tcp
	McCauley formation	Grey rhyolite member	Dense, grey rhyolite with streaky flattened vesicles.	1125'	Tmcr
		Pink Rhyolite member	Pink latite and rhyolite with blocky fracturing.		Tmcl
		Vitrophyre member	Dense black glassy vitrophyre.		Tmcv
		Sandstone and Breccia member	White and buff bedded sandstone and reddish breccia.		Tmcs
	Mangas Creek formation	Pink Rhyolite member	Pink welded tuff and brown breccia.	4500'	Tmp
		Andesite breccia member	Dark red, fine grained andesite breccia.		Tma
		Grey andesite member	Grey, porphyritic andesite and latite.		Tmg
		White tuff member	White and buff crystal vitric tuffs and tuff breccia.		Tmt
		Brown breccia member	Hard, angular brown breccia, with fragments less than 1" in diameter.		Tmx
		Brown tuff breccia member	Brown tuff breccia; some brown latite and rhyolite flows.		Tmb
	Delta formation	Alpha member	Grey, pink, brown and red flows and agglomerates.	1000'	Tda
		Beta member	Hard, porphyritic latite and rhyolite; generally altered.		Tdb
	Kerr Canyon formation	Breccia member	Hard, dense grey breccia.	600'	Txx
		Brown tuff breccia member	Brown tuff breccia; some dense red flows and sills.		Txb
		Pink rhyolite-breccia member	Pink rhyolite; brown breccia.		Txr
		White tuff member	White and buff crystal vitric tuff and tuff breccia.		Txw
Tertiary and Cretaceous (?)	Saddle Rock Canyon formation	Blue andesite member	Fine grained, dark blue andesite.	500'	Tka
		Andesite porphyry member	Green andesite porphyry.		Tkp
Cretaceous	Colorado formation		Fine grained, fissle black and green shales; olive green and buff sandstones.	560'	Kc
	Beartooth quartzite		Hard, buff quartzite with minor granulite and quartzite conglomerate lenses.	135'	Kb
Precambrian	Granite		Pink and green coarse grained granite; some gneiss and schist.		Pєg
	Amphibolite		Dark, medium to fine grained amphibolite, biotite schist and biotite gneiss.		Pєa
			MISCELLANEOUS UNITS		
Tertiary			Basic dikes, sills and irregular intrusives.		Tbi
			Acid and intermediate dikes.		Tai
			Rhyolite sill in southern part of quadrangle.		Tri
			Inter- and intra-formational sediments.		Tvs

PLATE 25



Location of sample stations for correlation studies. See Plate 1 for explanation of symbols

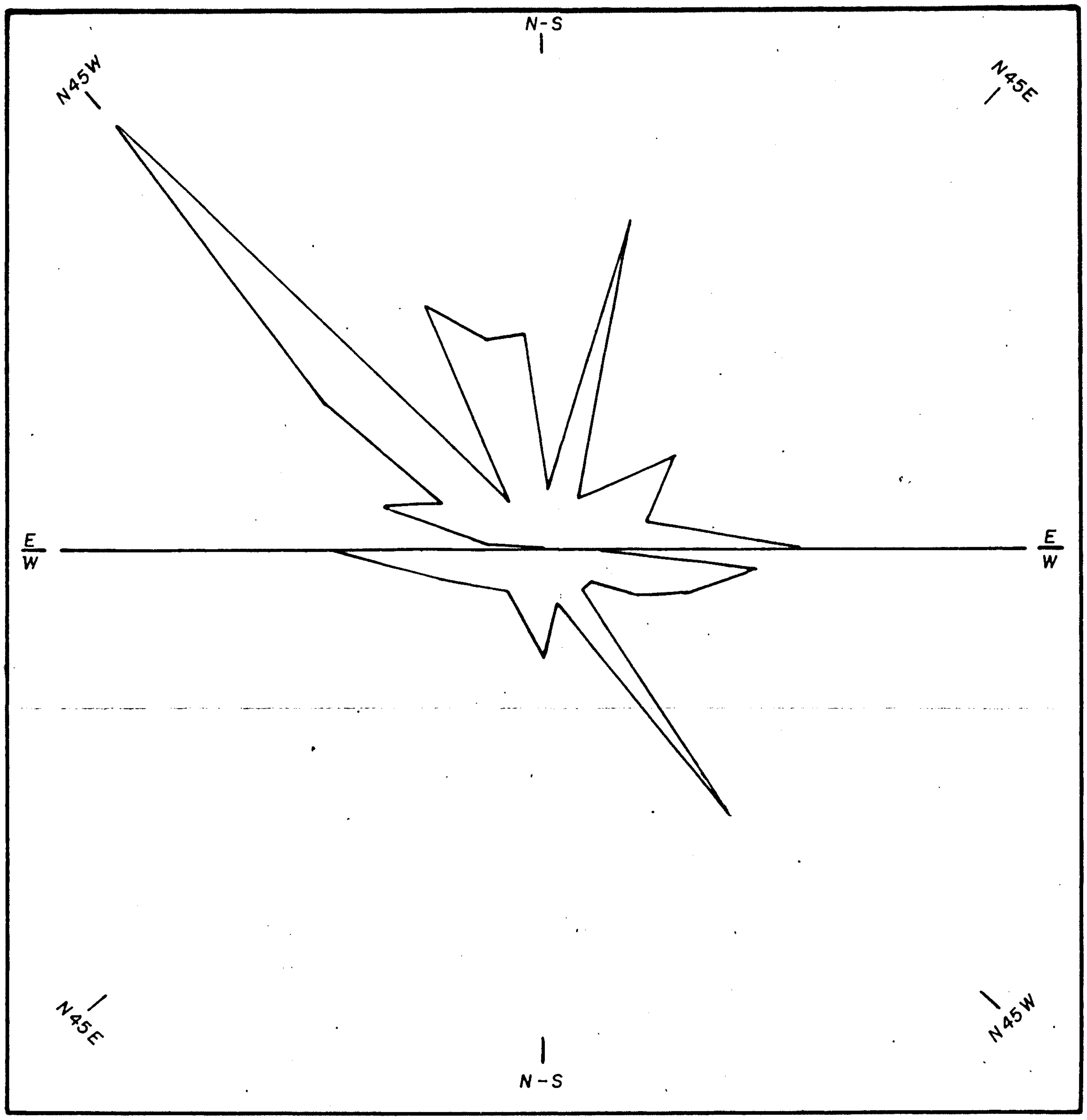


Fig. 1 Rose diagram showing strikes of faults in the Schoolhouse Mt. Quadrangle. The upper part of the diagram refers to faults in the volcanic rocks and the lower part to faults in the sediments and granite.