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**Geology of the
Barrilla Mountains, Texas**

By
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BY G. K. EIFLER, JR.

ABSTRACT

The Barrilla Mountains, in the northeastern part of the Davis Mountains of Trans-Pecos Texas, are composed of Tertiary volcanic materials. Five tuffs and five lava flows, 1500 feet thick occurring throughout the mountains, persist in thickness and lithologic characteristics. Their upper surfaces show little erosion. The lavas are chiefly Silicic and soda rich.

The volcanic succession is underlain by a Tertiary sandstone above Upper Cretaceous marine formations. These were slightly deformed by the Laramide revolution, subsequently beveled, and everywhere covered by the sands of coalescing streams. The sandstone contains well-rounded chert and quartzite pebbles.

Broad folds and normal faults succeeded the extrusions of the youngest lava.

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INTRODUCTION AND ACKNOWLEDGMENTS

The Barrilla Mountains comprise a thick mass of Tertiary lavas and tuffs (Fig. 1) whose north and northeastern edges rise in bold cliffs,

2000 feet high in places. Structurally the mountains are a broad, locally domed anticlinal uplift. Longitudinal faults cut the folds.

Stratigraphically and structurally the moun-

tains resemble the more extensive Davis Mountains, which comprise alternating tuffs and lavas, and overlie marine Upper Cretaceous

August 1947 and June and July 1948 with assistance of Joseph A. Kennedy and Roger S. Plummer. Mrs. Kathryn O. Dickson of the

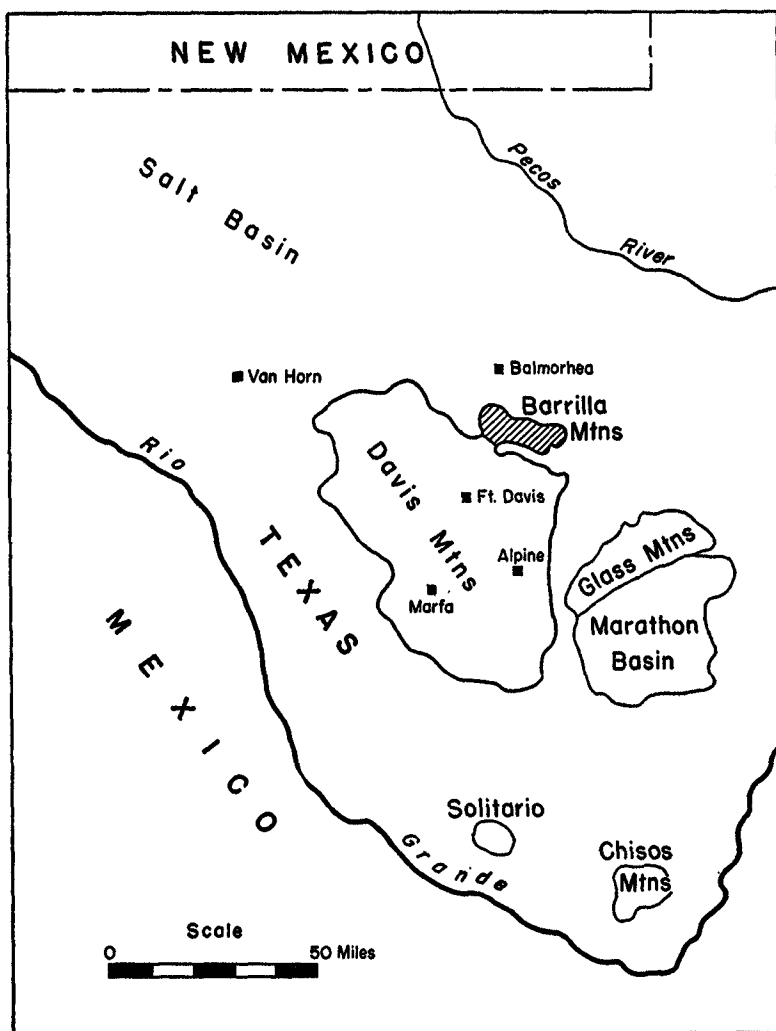


FIGURE 1.—INDEX MAP SHOWING LOCATION OF BARRILLA MOUNTAINS

strata in a structurally low area. Uplifts on the north, east, and west expose Lower Cretaceous and Permian rocks. Southward the Davis Mountains merge with well-dissected and alluvium-covered tuffs and flows. No doubt some uplift occurred after the lavas were formed. The volcanic rocks of the Davis and Barrilla mountains are generally considered early Tertiary, but diagnostic fossils are absent.

Field work was conducted during July and

Bureau of Economic Geology, The University of Texas, described the igneous rocks petrographically.

A grant from the Penrose Bequest of The Geological Society of America defrayed expense of part of the field work and cost of aerial photographs and thin sections. This paper is one of a series reporting results of a Trans-Pecos Texas project sponsored by the Bureau of Economic Geology, The University of Texas.

GENERAL STRATIGRAPHY

The oldest rocks cropping out in the Barrilla Mountains are Cretaceous, but wells drilled for oil have encountered rocks as old as Permian. Older Paleozoic rocks probably occur at greater depth. A thick Permian section comprises marine limestone, dolomite, subordinate shale, and evaporites near the top. The Leonard, Guadalupe, and Ochoa series have been identified. The Triassic comprises nonmarine red and gray shales and sandstones a few hundred feet thick. The Jurassic is absent. Approximately 1500 feet of marine sandstone, shale, marl, and limestone constitutes the Cretaceous. Although these rocks range from Trinity to Taylor in age, only Washita, Austin, and Taylor strata crop out. The Tertiary comprises thick tuffs and lavas with minor fresh-water limestone and sandstone. Thin gravels and alluvium constitute the Quaternary.

PERMIAN SYSTEM

In the Humble Oil and Refining Company No. 1 McCutcheon well east of Star Mountain, Skinner (1948, p. 61) identified alternating sandstone, limestone, and dolomite as Capitan (?) in age, the upper part of which possibly is Rustler.

In the Humble Oil and Refining Company No. 2 Flores well northwest of the Barrilla Mountains, Cretaceous rocks directly overlie the Permian, of which the Rustler formation, with possibly the Salado and Castile, the Capitan limestone, and the Word were identified. However, some of the beds assigned to the upper part of the Capitan may belong to the Tessey limestone. The identification of many of the formations is not too certain (Skinner, personal communication).

Northeast of the Barrilla Mountains in the Argo Oil Corporation No. 1 Dora Roberts well, Reeves County, W. A. Waldschmidt (personal communication) identified Cretaceous, possibly Triassic, Permian, and Pennsylvanian rocks. The Permian section, approximately 11,500 feet thick, includes well-developed Ochoa, Guadalupe, Leonard, and Wolfcamp series.

From available subsurface data Cretaceous, Triassic, Permian, and Pennsylvanian rocks underlie the Barrilla Mountains area.

CRETACEOUS SYSTEM

Comanche Series

Georgetown group.—The oldest Cretaceous strata crop out in the low hills of limestone 2–3 miles east of the U ranch. On the upthrown side of a fault trending northwest, limestone beds, white to light-gray, contain abundant rudistids, some *Toucasia* sp., and one specimen of a large *Neithea*. Fossils could not be broken out. These beds lithologically resemble the Georgetown rudistid facies limestone cropping out along the Fort Stockton-Balmorhea highway to the north. The lack of identifiable fossils precludes a definite correlation, but these beds are tentatively assigned to the Georgetown group.

Gulf Series

Austin group.—Upper Cretaceous marine strata crop out along the periphery of the mountains except to the southwest where covered by Tertiary volcanics along the axis of a syncline (Pl. 1). Good exposures are rare. No section justified measurement and description.

Outcrops are mostly blue green marls weathering ochre yellow, but locally a white to pearl-gray chalky limestone alternates with poorly bedded white indurated marl and marly limestone. These chalky and marly limestones crop out in several ravines about 7½ miles west of the U ranch. They contain fragments of a large *Inoceramus*, probably *Inoceramus undulato-plicatus*, with small cupped oysters attached. Parts of a large rudistid, either *Durania* sp. or *Sauvagesia* sp., are associated with the *Inoceramus*. The exposed section here is only about 20 or 25 feet thick and apparently underlies the yellow-weathering Taylor marls.

In a shallow ravine 6 miles northeast of the Jeff ranch a white chalky limestone, interbedded with cream marl, weathers into small flat chips. A few beds, 1–2 feet thick, resemble the Austin chalk of central Texas. *Gryphaea* sp. and a large *Inoceramus*, possibly *I. undulato-plicatus*, occur in these beds, which apparently underlie Taylor marl. The contact between the chalky limestone and overlying marl is not exposed. Chalky limestone crops out about 7

miles west of the Jeff ranch and about 3 miles southeast.

The chalky and marly limestones probably are Austin chalk. This correlation, however, is based upon the very meager evidence of a few fossils and uncertain field relations with the Taylor marl.

Taylor group.—Taylor marl is exposed along ravines by undercutting and slumping; elsewhere it is covered. It is massive and moderately well consolidated. It weathers ochre yellow and erodes into rounded smooth hills. About midway between the U ranch and Jeff ranch, yellow to brown sandstone concretions occur at an unknown stratigraphic level in the Taylor marl. Approximately 1.1 miles southeast of Star Mountain 85–90 feet of Taylor marl containing abundant *Gryphaea newberryi* (?) underlies Tertiary fluviatile sandstone. The marl is dark gray with interbedded marly limestone and indurated yellow to buff marl. Similar dark, flaky chalky marls and thin beds of limestone crop out on the north slope of a hill west of the Fort Davis-Toyahvale highway 4.74 miles south of Toyahvale close to an igneous intrusion. These dark marls may be stratigraphically higher than the Taylor marl.

Few species of fossils have been found. *Gryphaea newberryi* (?) and *Exogyra ponderosa* are abundant. East of the U ranch the zone of abundant *Exogyra ponderosa* directly overlies the zone of abundant *Gryphaea newberryi* (?). Since no complete section of the Taylor marl was found, these zones of abundance may alternate with each other.

TERTIARY SYSTEM

McCutcheon Volcanic Series

Introduction.—Volcanic rocks aggregating 1500–1700 feet overlie marine Cretaceous rocks. A succession of five lavas alternating with five tuffs, some of which contain sandstones, breccias, and fresh-water limestones, is here named the McCutcheon volcanic series. (Willis McCutcheon ranch 7 miles south of Toyahvale.) The base is the lowest sandstone and conglomerate which here overlie marine Upper Cretaceous. The top, the highest lava, is exposed along the syncline crossed by the Fort Davis-Toyahvale highway north of Star Mountain.

Apparently one unit succeeded another fairly rapidly. Some of the tuffs and lavas may have been slightly eroded, but nowhere is there evidence of channeling or other marked differential erosion. However, a few sandstones and conglomerates with lava fragments interbedded in the series indicate erosion elsewhere in the Davis Mountains area.

Apparently the lavas spread widely over fairly flat surfaces, yet they are silicic and presumably were viscous. Perhaps they erupted from fissures in the Davis Mountains. Each is fairly uniform in thickness and lithologic characteristics.

Age and correlation.—There is very little evidence concerning the exact age of the series. The few fossils are not diagnostic. The series is younger than the Taylor marl and probably is Tertiary. E. W. Berry (1919, p. 4) correlated plants from the lower tuffs of the Barrilla Mountains with those of the Raton and Denver formations (lower Eocene). The tooth of an Oligocene rhinoceros has been reported from the lower tuffs of the volcanic succession of the Davis Mountains about 11 miles west of Balmorhea. Land gastropods and fresh-water algae in the lower tuffs of the Barrilla Mountains near Barrilla Springs can be dated only as Tertiary, possibly early Tertiary. Goldich and Seward (1948, p. 15) assign Eocene, Oligocene, and possibly Miocene age to the volcanic series that overlies eroded Upper Cretaceous rocks in the southeastern part of the Davis Mountains. The tuffs of the Tierra Vieja Mountains, about 60 miles southwest of the Barrilla Mountains, contain vertebrate remains identified by Bryan Patterson as Oligocene (cited by Goldich and Seward, 1948, p. 18). No attempt is made to correlate the tuffs of the Barrilla Mountains with those of the southeastern Davis Mountains or of the Tierra Vieja Mountains.

The series is divided into three formations (from oldest to youngest): Huelster formation, Star Mountain rhyolite, and Seven Springs formation.

Huelster formation.—The Huelster formation forms the lower part of the McCutcheon volcanic series. The type locality is near the head of a deep ravine about 1½ miles south of the ruins of the Huelster ranch house in the northwestern part of the Barrilla Mountains. The

base is the lowest sandstone and conglomerate overlying marine Upper Cretaceous; the top is the highest tuff directly underlying the Star Mountain rhyolite. The formation, almost entirely tuff, contains thin layers of sandstone and conglomerate, lenses of fresh-water limestone, and of trachydoleritic lava. At the type locality it is approximately 400 feet thick, but it thins eastward.

The formation crops out widely about the Barrilla foothills except on the southwest where it dips below the surface in a broad syncline. In the interior parts of the mountains, outcrops occur in deep ravines eroded along major faults. The formation is eroded into low rounded hills. It forms no distinct topographic break with the underlying Cretaceous, but the overlying lava forms high rugged cliffs.

The Jeff conglomerate member, a sandstone and conglomerate unit constituting the lowest beds of the Huelster formation averages 25 feet thick. The type locality is in a tributary ravine on the left bank of Horse Thief Canyon about $3\frac{1}{2}$ miles upstream from its junction with Limpia Creek near the Jeff ranch.

The Jeff conglomerate member lies with slight angularity upon Cretaceous beds, mostly Taylor marl, but also Austin chalk. The contact is sharp and marks the Mesozoic-Cenozoic boundary, but is not well exposed. The member is overlain with apparent conformity by volcanic tuff, although a surface of erosion might separate the two.

The sandstone is moderately well sorted, medium- to coarse-grained, slightly angular, and varies from white to light tan to yellow. The conglomerate is composed mainly of well-sorted pebbles and cobbles, but boulders occur at some localities. Some beds are almost entirely pebbles and cobbles with little sandstone matrix (Pl. 2, fig. 2), and others are mainly sandstone with scattered pebbles and cobbles.

Bedding is poor, but in places indistinct cross-bedding occurs, and at a few exposures the sandstone is distinctly laminated. In general the basal beds are sandstones varying considerably in thickness and in places cross-bedded. Above are conglomerates with abundant pebbles and cobbles in a sparse, sandy matrix. At some localities beds of conglomerate are separated by a thin sandstone or by pudding-

stone. Above the conglomerates are sandstones with a few scattered pebbles.

Most of the pebbles, cobbles, and boulders are ellipsoidal to subspherical (Pl. 2, fig. 1), but some are greatly flattened. They are chiefly white to light lemon-yellow structureless quartzite. Others are gray and dark limestone, white, black, pink, and gray chert, chert conglomerate, and quartz. Some pebbles are composed partly of chert and partly of dark limestone. Fragmentary thick shells of *Inoceramus* (?) occur sparingly.

At the base of Santiago Peak about 70 miles south-southeast of Star Mountain the writer (Eifler, 1943, p. 1635) found a similar sandstone and conglomerate overlying eroded Boquillas formation (Upper Cretaceous) and underlying Tertiary volcanic ash. Most of the pebbles in the conglomerate are chert, but some are limestone. South of Alpine Goldich and Seward (1948, p. 13) report a similar conglomerate between the Boquillas formation and the Buck Hill volcanic series (Tertiary). The conglomerate is composed "... principally of well-rounded pebbles and cobbles of limestone, with some pebbles of marble, quartzite, chert, and chalcedony in a well-cemented matrix of tuffaceous sandstone" (Goldich and Seward, 1948, p. 18). The conglomerates south of Alpine and at Santiago Peak are probably the same and may be equivalents of the Jeff conglomerate.

The source of the pebbles and cobbles is certainly not the underlying Cretaceous formations. However, fragmentary shells of *Inoceramus* were probably locally derived; they show practically no abrasion. The quartzite pebbles increase in size toward the Van Horn uplift, but no extensive quartzite is known there. The chert, chert conglomerate, and dark limestone resemble some Paleozoic rocks of the Marathon basin. In the northeastern Glass Mountains J. T. Lonsdale (personal communication) found well-rounded quartzite pebbles in a Leonard conglomerate, which might be the source of the Jeff conglomerate.

The Jeff conglomerate member is thought to be continuous throughout the Barrilla Mountains and the northeastern part of the Davis Mountains. It was deposited on a fairly smooth erosion surface either by coalescing streams or by extensive sheetwash. It is too extensive to

be the veneer of a pediment. The thickness is uniform over too great an area for the deposit to be a piedmont alluvial fan, although the sandstone and gravel might have been spread very thin in front of a piedmont fan.

Sandstone, not typical of the Jeff conglomerate member, occurs between Cretaceous rocks and the volcanics at two localities. In a ravine 4½ miles S. 30° E. of the U ranch, sandstone overlies Taylor marl. The basal 6 feet of sandstone, which contains no pebbles, is ochre yellow to brown and is cross-bedded and laminated. The upper contact is not exposed. About 7 miles west of the Jeff ranch, 20 feet of yellow to white sandstone with no pebbles overlies the Austin chalk. The sandstone is cross-bedded and laminated. On the slope above are a few scattered pebbles and tuff beds, which may not be in place. The absence of pebbles and the yellow color of the basal sandstone are thought to be local characters, and the two sections are correlated with the Jeff conglomerate member.

At the type locality the upper contact of the Huelster formation is obscured. Highly generalized section of the lower 294 feet which is exposed is given below.

PARTIAL SECTION OF HUELSTER FORMATION SOUTH OF HUELSTER HOUSE RUINS

Unit	Description	Thickness in feet
6.	White to cream, fine to coarse tuffs. Petrified tree trunks 2-3 feet across. Upper part ends at top of hill covered by lava debris.	104
S.	Flinty-appearing cream tuffs. A few petrified tree trunks.	6
4.	Ledges 3-4 feet thick of hard, white to cream tuffs. Brown stains along sharp joints.	44
3.	White, buff, and cream tuffs.	63
2.	Cream to white tuffs. Yellow-brown stains along joints. Cross-bedded sandstone near top.	25
1.	Conglomerate and sandstone. Quartzite and chert pebbles near base; gray marls at top. Underlain by Taylor marl.	52
Total.		294

Approximately 100 feet of poorly exposed tuff with an interbedded lens of trachydolerite lies above unit 6 and below the Star Mountain rhyolite.

The Huelster formation varies more in thickness than any other dominantly tuff section of the McCutcheon volcanic series. At a point 3.5 miles north of the Jeff ranch the formation is 136 feet thick, and on the hill 3 miles south-east of the Jeff ranch it is only a few feet thick and locally is missing.

The tuffs are distinctly bedded in layers a few inches to 1 or 2 feet thick. The flatness and continuity of bedding may indicate lacustrine deposition.

At two observed localities, fresh-water limestone is interbedded with tuff near the base of the member. About 1.8 miles south-southeast of the Jeff ranch an unfossiliferous limestone layer 3-4 feet thick lies 50 feet above the Jeff conglomerate member. At the other locality, 1.6 miles north of the Jeff ranch, a 5-foot limestone layer crops out conspicuously along the foot of several low tuff hills. The limestone, light lemon-yellow to light and dark gray and compact, contains many irregular purplish-blue and ochre yellow cherts of secondary origin.

Petrified tree trunks and unidentified low- and high-spined gastropods occur sparingly in the exposed limestone. Concentric, fusiform to ellipsoid organic structures, 4 or 5 inches in longest diameter, compose a large part of the rock. They have been identified as algae by J. Harlan Johnson, whose description follows (personal communication):

Megascopic:

Rounded pellets, with irregularly banded, more or less concentric structure, which make up a large percentage of the limestone sample.

Microscopic:

An algal limestone formed by colonies of an undescribed type of algae, probably belonging among the green algae (Chlorophyta), possibly among the blue-green (Cyanophyta). Shows molds of coarse thread-like filaments which form rounded

PLATE 2.—JEFF CONGLOMERATE SOUTHWEST OF JEFF RANCH
FIGURE 1.—ROUNDED QUARTZITE AND CHERT PEBBLES IN SANDSTONE MATRIX
FIGURE 2.—MASSIVE CONGLOMERATE
Hammer gives scale.



FIGURE 1



FIGURE 2

JEFF CONGLOMERATE SOUTHWEST OF JEFF RANCH

and rosette-shaped colonies (bands and fans in section). Average size of filaments 0.005 mm.

Remarks:

Probably a fresh-water growth.

The algae closely resemble specimens which S. S. Goldich obtained from a fresh-water limestone near the base of the Pruett formation south of Alpine. Goldich and Seward (1948, p. 15) also report an Eocene gastropod, *Gonobasis tenera carterii*. These limestone beds, although not continuous, are probably of the same age.

Thick lenses of a dark igneous rock, probably lava, occur in the upper part of the formation in the western part of the Barrilla Mountains and at Wild Rose Pass in the Davis Mountains. The rock weathers into small brownish-yellow to buff chunks. Megascopically it is a black, fine-grained melaphyre; the microscope reveals a porphyritic, slightly ophitic texture. The rock can be called a porphyritic olivine trachydolerite.

Star Mountain rhyolite.—The thick rhyolitic lavas overlying the Huelster formation are named the Star Mountain rhyolite after Star Mountain. The base is the lowest lava above the Huelster formation and the top is the highest lava below the tuffs of the Seven Springs formation. The number of individual flows cannot be ascertained. In the high vertical cliff on the east side of Star Mountain there appears to be at least six distinct flows, but possibly there are more. At the type locality the formation is 496 feet thick, but it thins to the northeast. About 3.5 miles north of the Jeff ranch it is 262 feet thick. The rock is typically black to brownish black, but some parts, particularly the lower, are green, greenish gray, and purplish lavender.

Owing to its great thickness and resistance to erosion the Star Mountain rhyolite crops out widely throughout the area. The lava is exposed in vertical cliffs east of Star Mountain, along parts of Limpia Creek, and near the summit and northeastern part of the Barrilla Mountains. The formation is commonly surmounted by a distinct bench where the overlying tuff has been eroded.

The flows commonly exhibit Palisade structure, and columnar jointing is less commonly developed. Many joints, which essentially paral-

lel the Palisade structure, extend through several flows and must therefore be of tectonic origin. Flow structure is commonly developed. Some flows are highly vesicular at the top and poorly vesicular at the bottom. Blue to gray chalcedony fills many of the vesicles.

The rock is porphyritic with conspicuous phenocrysts in an aphanitic groundmass and is a riebeckite soda rhyolite porphyry.

Seven Springs formation.—The Seven Springs formation includes the lavas, tuffs, and interbedded sediments between the Star Mountain rhyolite and the top of the McCutcheon volcanic series. The formation is named for Seven Springs near the Willis McCutcheon ranch house 7 miles south of Toyahvale. A composite section near the type locality is 682 feet thick. The formation is completely exposed in the syncline north of Star Mountain. Elsewhere the upper beds are eroded. Where horizontal or with low dip the formation erodes into distinct benches.

The formation is divided into four lava members and four tuff members, which alternate with one another.

Tuff member No. 1, at the base of the formation, includes the tuffs and interbedded sediments between the top of the Star Mountain rhyolite and the base of the overlying lava member No. 1. It is 102 feet thick on the lower northeast slopes of Star Mountain but is considerably thinner in the Barrilla Mountains.

The tuff is evenly bedded in layers up to 2 feet thick. The beds are white, gray, blue green, and lemon yellow. At the west end of Kunz Mesa, tuff is interbedded with a well-cemented conglomerate which contains igneous boulders up to 2 feet in diameter. Similar conglomerates and breccias with igneous fragments are widespread but do not occur throughout the Barrilla Mountains. Associated with them, but not present everywhere, is a blue green, highly vesicular lava.

Lava member No. 1, which includes all lavas above tuff member No. 1 and below tuff member No. 2, consists of a thin, inconspicuous vitrophyre below and a thicker, prominent granophyre above, each representing a single flow.

The average thickness of the vitrophyre is 4-8 feet, but it is at least 30-40 feet thick about

1 mile southeast of Seven Springs. Although very thin, the vitrophyre must have spread over the entire region.

Typically the rock is black, grading in places into light greenish yellow phases. It is notably devoid of vesicles and columnar jointing. Large phenocrysts are included in a glassy ground-mass with perlitic structure. Some parts may be fragmental. It is classed as a soda rhyolitic vitrophyre.

The granophyre is persistently 30–40 feet thick with excellent columnar jointing and Palisade structure. The rock is purplish red, maroon, and reddish brown. At the top and bottom the flow is distinctly vesicular. The base is a conglomeratelike mass of pieces apparently derived from the granophyre while flowing. The rock can be called a spherulitic riebeckite soda granophyre.

Tuff member No. 2 includes all tuffs and sediments between the top of lava member No. 1 and the base of the overlying lava member No. 2. At Star Mountain the member is 105 feet thick, on top of the Barrilla Mountains east of the McCutcheon ranch it is 114 feet thick, on Kunz Mesa it is 90 feet thick, but in the eastern and northeastern part of the Barrilla Mountains the interval is much thinner. The tuffs are commonly white to gray and are well bedded in 1- to 2-foot layers. In places the tuff contains conglomerate and cross-bedded sandstone.

Lava member No. 2 includes all lavas above tuff member No. 2 and below tuff member No. 3. It ranges in thickness from 10 feet to 77 feet and forms no distinct topographic bench.

The base is a red lava (possibly a well-consolidated tuff) up to 2 feet thick, overlain at one locality by a 20-foot interval of tuff, but elsewhere by lava. The lava consists of three basaltic phases: a chocolate-brown with flow layers and blue chalcedonic amygdules, a blue-black, scoriaceous, conglomeratelike rock with chalcedonic amygdules; and a compact and specular phase. These phases are similar lithologically and can be called glassy basalt or trachybasalt porphyry.

Tuff member No. 3 includes all tuffs and sediments above lava member No. 2 and below the overlying lava member No. 3. It is 138 feet thick at Star Mountain, 227 feet on the mesas on top of the Barrilla Mountains east of

the McCutcheon ranch, 185 feet on Kunz Mesa, but it thins rapidly to the east and on Beard Mountain is only 25–30 feet thick.

The interval is mainly white to gray tuff and contains very little sediments.

Lava member No. 3 includes all lavas above tuff member No. 3 and below the tuff member No. 4. It forms the caprock of Star Mountain, of the two mesas on top of the Barrilla Mountains east of the McCutcheon ranch, and of Kunz Mesa. It is 42–65 feet thick.

The lavas have moderately well defined palisade structure and abundant platy flow layers. The rock is prevailing gray, but also red and black. The rock can be classified as granophyric rhyolite porphyry.

Tuff member No. 4 includes all tuffs, sediments, and interbedded lava above lava member No. 3 and below lava member No. 4. It is approximately 200 feet thick in the syncline between Star Mountain and the Barrilla Mountains. A single lava flow near the top is 5½ feet thick. This lava, a vitric rhyolite porphyry, is brown at the base and lavender to light purple at the top.

Lava member No. 4 includes all lavas above tuff member No. 4 and the top of the McCutcheon volcanic series. At the type locality of the series a thin tuff may overlie this lava member, but if so it is covered by alluvium. The lava crops out continuously along the flatirons north of Star Mountain. A few scattered outcrops occur in the extensive alluvial flat north-northeast of the junction of the Jeff ranch road with the Fort Davis-Balmorhea highway. The lava member is at least 41 feet thick. The rock is gray and is stratiform in intervals 4–6 inches thick; it is a granophyric rhyolite porphyry.

POSSIBLE INTRUSIONS

Igneous rocks of unknown relations crop out at two localities along the Fort Davis-Balmorhea highway, 4 and 5 miles south of Toyahvale. The northern occurrence, apparently a tabular body intrusive into the Taylor marl, is probably a dike. The southern body crops out more widely, underlying two hills west of the highway. Contact with the surrounding Taylor marl is not exposed, and it is impossible to tell whether the rock is intrusive or extrusive. Some

marl close to the igneous rock is darkened, perhaps by heat. This igneous body might be a sill whose roof has been removed by erosion, but more likely it is a dike. The rocks of the two occurrences are soda trachyte porphyries.

STRUCTURAL FEATURES

Introduction

There is only slight angularity between the Cretaceous rocks and the overlying McCutcheon volcanic series. The structural features of the volcanic series are probably quite similar to those of the Cretaceous rocks, but Cretaceous formations were slightly warped and faulted before the Jeff conglomerate was deposited. Because Paleozoic rocks do not crop out in the area and subsurface data are scarce, no attempt is made to interpret their structural relations with the Cretaceous or the volcanic rocks.

Folds

Broad folds trend northwestward in the region, the most conspicuous of which is a syncline separating the Barrilla Mountains from the Davis Mountains. The southwest limb with a dip of 18° – 20° has a structural relief of approximately 2500 feet and the northeast limb about 2000 feet. A few miles northwest of Seven Springs the syncline is mostly covered by the alluvium of Toyah Creek. About 2 miles north-northeast of the Jeff ranch road junction with the Fort Davis-Balmorhea highway a structural basin is superimposed on the northeast limb. The areal extent and structural relief of the basin is not determined because of alluvium. Near the Jeff ranch the northeast limb is almost horizontal, but the southwest limb dips steeply. Below the alluvium of Limpia Creek there is either the continuation of the syncline greatly narrowed or a fault upthrown to the northeast.

An anticline trends northwestward through Star Mountain, from which the volcanic beds dip steeply northeastward into the syncline, and southwestward at angles of 1° – 2° . This structural feature is probably a continuation of the Hovey anticline (King, 1937, p. 141). Another anticlinal uplift trends northwestward through the crest of the Barrilla Mountains.

The greatest structural height along this uplift is in the western part of the mountains.

Folding occurred after the outpouring of lava member No. 4 of the Seven Springs formation and is not related to the Laramide movements. The exact date is not yet determined.

Faults

Longitudinal high-angle faults cut the rocks of the McCutcheon volcanic series into long narrow blocks. These faults are fairly abundant in the Barrilla Mountains but do not occur in the syncline or in the adjoining part of the Davis Mountains. The crest of the Barrilla Mountains east of the McCutcheon ranch is a grabenlike block (Pl. 1). The fault bounding the block on the southwest dropped tuff member No. 3 of the Seven Springs formation against the Star Mountain rhyolite and has a throw of approximately 490 feet. The fault on the northeast has less throw but extends for two-thirds the length of the Barrilla Mountains. It is a rotary fault, and the rocks forming the graben become upthrown as they extend southeastward. The northeast slopes of the Barrilla Mountains may contain many small faults downthrown to the northeast, but the thick mantle of igneous debris prevents an interpretation of the structural relations. The lava-topped mesas at the northeast margin of the Barrilla Mountains are bounded on the southwest by faults downthrown to the northeast. This line of faults continues southeastward between Beard Mountain and the main body of the Barrilla Mountains. Narrow fault blocks on the northeastern slope of Beard Mountain have apparently resulted from landslide faulting. They are downthrown to the northeast and are tilted at steep angles to the southwest. A fault 2 miles east of the U ranch separates the Georgetown and Huelster formations. The upthrown side of this fault is probably part of an uplift paralleling the anticline along the crest of the Barrilla Mountains.

The structural relations are not clear in the foothills of the Barrilla Mountains north and east of the Kunz ranch. Here the Star Mountain rhyolite is apparently faulted against Taylor marl. The fault, if present, trends northwestward at the southwest foot of Kunz Mesa and

turns at 90° down the ravine for a short distance and then, making another 90-degree turn, resumes its northwestward trend. It is possible that the Huelster formation here is not faulted out but that the Star Mountain rhyolite rests directly on Taylor marl.

The faults displace beds as young as the tuffs and lavas of the Seven Springs formation, but whether the movement preceded or followed the folding is not clear. Faulting probably followed folding. If the faults are genetically related to folding, they would likely have formed along the anticlinal uplift through Star Mountain and be as abundant in the northeastern part of the Davis Mountains as they are in the Barrilla Mountains. Furthermore, if the faults formed in response to the anticlinal uplifts, then the fault block 3 miles east of the McCutcheon ranch would likely have been a horst instead of a graben.

GEOMORPHOLOGY

The Barrilla Mountains have not been extensively eroded. The highest parts essentially coincide with the greatest uplift. A cross section (Pl. 1) northeast from Star Mountain shows that topographic relief is not much less than structural relief. Nevertheless erosion has been sufficient to form several low fault-line scarps where the Star Mountain rhyolite was faulted against the less resistant Taylor marl and Huelster formation. This relation is well shown 2 miles north of the Jeff ranch and on the southwest side of the mesas which border the mountains on the northeast. The lavas are the most resistant rocks; they top the mesas and form the flat part of benches and scarps. The Star Mountain rhyolite, owing mainly to its great thickness, forms high vertical cliffs where undermined by the erosion of the Huelster formation and the Taylor marl.

ECONOMIC GEOLOGY

Subsurface water is the most important natural resource in the Barrilla Mountains. Small gravity springs are fairly abundant in the western part of the mountains. Practically all of them occur at the contact between the permeable Jeff conglomerate and the impermeable

Taylor marl. Where sufficiently large the springs are dammed, and the water is piped and used for watering stock, but each of these springs flows very little water and is fairly sensitive to fluctuations in rainfall.

The vitrophyre at the base of lava member No. 1 of the Seven Springs formation was found unsuitable as a lightweight aggregate because of the phenocrysts. Further exploration, however, might reveal a phase of the vitrophyre without phenocrysts.

Oil has not been produced commercially in the Barrilla Mountains, but the thick sequence of Permian rocks offers excellent opportunity for oil exploration. If structural relations between these rocks and the Tertiary lava flows can be established, perhaps the structural features of the lavas will aid in the discovery of structural oil traps in the Permian rocks.

PETROGRAPHY

BY KATHRYN O. DICKSON

General Statement

The igneous rocks of the Barrilla Mountains belong to the same Tertiary alkalic province as those of the Terlingua-Solitario, Big Bend, and southern Davis Mountains regions of Brewster and Presidio counties, Texas (Lonsdale, 1940; Goldich and Elms, 1949). Anorthoclase is the typical alkali feldspar. Plagioclase is negligible in the felsic members, and analcime is sometimes present in the mafic members. In the main, the lava flows are porphyritic quartz-poor soda rhyolites which grade to quartz trachytes. These lavas are characterized by soda pyriboles and granophyric, trachytic, or glassy groundmasses. The mafic types are more limited in occurrence. Aside from one extensive basaltic flow, they appear as local lenses which have diabasic texture and are composed principally of titaniferous augite, olivine, labradorite, and magnetite. The important rock types of the area are discussed, and rocks from specific localities are shown in Table 1. The percentages represented are estimates because of the highly altered state of most of the mafic minerals and the fine-grained groundmasses. Where volume percentages were practicable and informative, Rosiwal analyses were made.

Probably the major portion of the groundmasses is anorthoclase. However, as the data are not critical, all alkali feldspar is included in the table under one heading with a notation when anorthoclase phenocrysts are present.

Riebeckite Soda Rhyolite Porphyry

Lava flows of the Star Mountain rhyolite with very few exceptions are composed of this rock. It is fine-grained light gray to reddish with abundant feldspar phenocrysts 1–5 mm. in size and small grains of dark minerals visible in hand specimen. The groundmass is trachytic to micrographic with alkali feldspar laths 0.01–0.3 mm. in length, averaging 0.04 mm. Quartz occurs interstitially or in intergrowth. A basal flow (Table 1, No. 6) contains no quartz and is a trachyte. Occasionally a trace of riebeckite or other soda amphibole is present, but most of the original soda amphibole sponges have been altered to an opaque black mineral and hematite. There are discrete grains of iddingsite (?), a trace of fluorite, and a few prisms of apatite as accessories. Chalcedony and calcite appear in vesicles with hematite.

Spherulitic Riebeckite Soda Granophyre

This rhyolite makes the top of lava member No. 1 of the Seven Springs formation. Specimens are dull gray to brick red with distinct flow lines and a few minute vesicles. Some specimens have a fragmental appearance both in hand specimen and under magnification. Recognizable megascopically are anorthoclase phenocrysts 3–8 mm. in length oriented along flow lines. A few phenocrysts are feldspar and quartz intergrown micropegmatitically. The groundmass appears aphanitic in hand specimen but in several slides consists largely of spherulitic intergrowths of quartz and alkali feldspar averaging 0.2–0.3 mm. in diameter. Rarely riebeckite is found in needles in the spherulites. Rare fine aegirite grains and a few grains of iddingsite about 0.5 mm. in diameter are present in the groundmass. Opal and chalcedony are abundant in amygdules together with hematite and limonite. In the reddish fragmental type, there are spherulites but to a rather limited extent. The cryptocrystalline groundmass encloses euhedral feldspar phenocrysts, some of

which are much embayed. Patches and stringers of hematite are common. The spherulitic fragments as well as those of micrographic or trachytic texture apparently are inclusions incorporated in the rock during flow.

Granophyric Rhyolite Porphyry

The lava members No. 3 and No. 4 of the Seven Springs formation and one bed in the base of the Star Mountain rhyolite section fall under this heading. The rhyolite is purple to red gray, with a spotty appearance because of numerous light-colored feldspar phenocrysts and amygdules. Some flows or facies of flows are highly vesicular; others are dense and glassy. The groundmass ranges from granophyric quartz and alkali feldspar containing altered poikilitic ferromagnesian sponges to glass densely packed with felty (–0.05 mm.) feldspar laths and opaque ferromagnesian dust. The anorthoclase phenocrysts are stubby in habit, averaging about 4 mm. in length. The mafic phenocrysts, as well as the mafics in the groundmass, are altogether altered, but the phenocrysts have the general habit of a pyroxene and average 1 mm. in greatest dimension. One slide has in addition microlites of a green ferromagnesian, probably aegirite-augite, and a trace of biotite bordering the discrete ore grains. Hematite and limonite are present as alteration products, and zircon, apatite, and fluorite were found in trace quantities. Opal, chalcedony, calcite, and secondary quartz are common amygdules with cristobalite spherulites prominent in the vesicular rocks.

Soda Rhyolitic Vitrophyre

This glass occurs at the base of lava member No. 1 of the Seven Springs formation; it is a black and gray banded glass containing shining feldspar phenocrysts, 1–5 mm. in length, and fragments of basalt and rhyolite. Some samples are easily crumbled due to perlitic structure in the glass. The resinous black glass is pale brown in section; $n = 1.517, \pm 0.002$, which indicates an SiO_2 content of about 65 per cent. The glass has a lower silica content than the phenocrysts indicate, these latter being anorthoclase, quartz, graphically intergrown quartz and feldspar, augite, and aegirite-

TABLE 1.—PETROGRAPHY OF IGNEOUS ROCKS, BARRILLA MOUNTAINS

Sample No.	Anal-cime	Quartz	Alkali feldspar	Labradorite	Glass and opal	Augite	Soda pyroxene	Microclites and/or alter. prod. of olivine and pyroxene undifferentiated	Biotite	Olivine	Magnetite and/or ilmenite	Apatite	Fluorite	Zircon
1	—	—	9	66	—	9	—	—	1	8	7	Tr	—	—
2	—	—	Mo	Ch	—	Mo	—	—	Li	Li	Mo	Tr	—	—
3	Tr?	—	Li	Ch	—	Mo	—	—	—	Mo	Mo	Tr	—	—
4	Li	—	Mo	Ch	—	Mo	—	—	—	Mo	Mo	Tr	—	—
5	—	Mo	Ch*	—	Tr	—	Li	—	—	—	Li	—	Tr	—
6	—	—	Ch*	—	Li	—	Tr	—	—	—	Tr	—	Tr	—
7	—	Mo	Ch*	—	Tr	—	Mo	—	—	—	Li	—	Tr	—
8	—	Mo	Ch*	—	Tr	—	Li	—	—	—	Li	—	Tr	—
9	—	Li	Ch*	—	Tr	—	Mo	—	—	—	Li	Tr	Tr	—
10	—	Li	Ch*	—	Tr	—	Mo	—	—	—	Li	Tr	Tr	—
11	—	11	74*	—	3	—	9	—	—	—	3	—	—	—
12	—	Mo	Ch*	—	Tr	—	Mo	—	—	—	Mo	Tr	Tr	—
13	—	—	Mu*	—	Mu	—	—	—	Tr	—	Mo	—	—	—
14	—	—	Mo	Ch	Li	Li	—	—	—	Mo	Mo	?	—	—
15	—	Mo	Ch*	—	Li	—	Li	—	—	—	Mo	—	—	—
16	—	Li	Mu*	—	Ch	—	Li	—	—	—	Mo	—	—	—
17	—	Mo	Mu*	—	Ch	—	Li	—	—	—	Mo	—	—	—
18	—	—	Mo	Ch	Li	Mo	—	Mo	—	Mo	Mu	Tr	—	—
19	—	—	—	Ch	Mu	Mo	—	Mo	—	Mo	Mu	—	—	—
20	—	—	—	Ch	Mu	Li	—	Li	—	—	Mu	—	—	—
21	—	—	Mo	Ch	Li	Mo	—	Mu	—	Mo	Mu	—	—	—
22	—	—	Mo	Ch	Li	Mo	—	Mu	—	Mo	Mu	—	—	—
23	—	—	Mu	Ch	Li	Mo	—	Mu	—	Mo	Mu	—	—	—
24	—	—	6	70	Tr	—	—	20	—	—	4	—	—	—
25	—	Mu	Ch*	—	Li	—	Mo	—	—	—	Li	—	—	Tr
26	—	Mo	Ch*	—	Mo	—	Mo	—	—	—	Li	—	—	Tr
27	—	Mo	Ch*	—	Mo	—	Mo	—	—	—	Mo	—	—	Tr
28	—	?	Ch*	—	Mo	—	Mo	—	—	—	Mo	—	—	Tr
29	—	Mo	Ch*	—	Mo	—	Mo	—	—	—	Mo	—	—	Tr
30	—	Mo	Ch*	—	Mo	—	Mo	—	—	—	Mo	—	—	Tr
31	—	Mo	Ch*	—	Li	—	Mo	—	—	—	Li	Tr	—	Tr
32	—	Mo	Ch*	—	Mo	—	Mo	—	Tr	—	Mo	—	—	Tr
33	—	Tr	Ch*	—	Tr	—	Li	—	Tr	—	Li	Tr	—	—
34	—	Li	Ch*	—	Li	—	Mo	—	—	—	Li	Tr	—	—
35	—	Li	Ch*	—	Li	—	Mo	—	—	—	Li	Tr	—	—
36	—	—	Ch*	—	Mu	—	Mo	—	—	—	Li	Tr	—	—
37	—	—	Ch*	—	Mu	—	Mo	—	—	—	Li	Tr	—	—

Tr = trace; Li = little; Mo = moderate; Mu = much; Ch = chief.

* Includes anorthoclase phenocrysts.

Lenses in the upper Huelster formation:

1. Porphyritic olivine trachydolerite in tuffs of the Huelster formation, road cut in Wild Rose Pass.
2. Porphyritic olivine trachydolerite in tuffs of the Huelster formation, Wild Rose Pass.
3. Olivine trachydolerite in tuffs of the Huelster formation, western Barrilla Mountains.
4. Porphyritic olivine trachydolerite in tuffs of the Huelster formation, western Barrilla Mountains.

Star Mountain rhyolite:

5. Riebeckite soda rhyolite porphyry from Star Mountain.
6. Riebeckite soda trachyte porphyry, lower contact from basal lava in road cut between Fort Davis and Toyahvale north of Seven Springs.

7. Hornblende (?) soda rhyolite porphyry, gray-green flow.
8. Soda rhyolite porphyry, Hill P-1, base of Kunz Mesa.
9. Hornblende (?) soda rhyolite porphyry, southwest side of Kunz Mesa.
10. Soda rhyolite porphyry, base of formation on CCC road south of Toyahvale.
11. Soda rhyolite porphyry, igneous hill $\frac{1}{2}$ mile west of Kunz ranch.
12. Hornblende soda rhyolite porphyry, outlier west of U ranch.
13. Granophyric soda rhyolite porphyry, basal lava of Star Mountain rhyolite at contact with lower ash southwest of Jeff ranch.
14. Olivine trachydolerite, basal lava directly overlying "flinty" lava above Huelster tuffs south of Seven Springs.

Seven Springs formation:

15. Spherulitic riebeckite soda granophyre, Kunz Mesa.
16. Spherulitic riebeckite soda granophyre, Kunz Mesa.
17. Spherulitic riebeckite soda granophyre, Kunz Mesa.

Lava member No. 2:

18. Basalt porphyry, north slope of Star Mountain.
19. Basalt "conglomerate" lava, north slope of Star Mountain.
20. Basalt "conglomerate" lava, Beard Mountain.
21. Porphyritic olivine trachybasalt, Kunz Mesa.
22. Olivine trachybasalt porphyry, Kunz Mesa.
23. Olivine trachybasalt porphyry, north of Fort Davis-Toyahvale highway at entrance to McCutcheon ranch.
24. Olivine trachydolerite, north of Fort Davis-Toyahvale highway at entrance to McCutcheon ranch.

Lava member No. 3:

25. Granophyric soda rhyolite porphyry, east end of Barrilla Mountains.
26. Granophyric soda rhyolite porphyry, top of Kunz Mesa.
27. Soda rhyolite porphyry, road cut at Seven Springs.
28. Soda rhyolite porphyry, road cut at Seven Springs.

Lava member No. 4:

29. Granophyric soda rhyolite porphyry, north slope of Star Mountain.
30. Granophyric soda rhyolite porphyry along Limpia Creek, isolated hill just east of Jeff ranch turnoff from Fort Davis-Toyahvale highway.
31. Granophyric soda rhyolite porphyry, near McCutcheon ranch entrance.
32. Granophyric soda rhyolite porphyry, highway cut near McCutcheon ranch entrance.

Intrusives:

33. Soda trachyte porphyry, 4/10 mile toward Toyahvale from fork of old and new Fort Davis-Toyahvale highways.
34. Soda trachyte porphyry; same as No. 33.
35. Quartz soda trachyte porphyry, dike (?) in Cretaceous on Fort Davis-Toyahvale highway, south of locality for No. 33.
36. Aegirite-augite soda trachyte porphyry; same as No. 33.
37. Aegirite-augite soda trachyte porphyry; same as No. 33.

augite. Fragments of basalt, granophyric riebeckite soda rhyolite, and plagioclase are also present. The glass is devitrified in places bordering amygdules and cracks, and some otherwise euhedral crystals are deeply embayed. One specimen contains large amygdules of chalcedony 1-5 cm. long. Under the microscope this type shows a groundmass of spherulitic glass and numerous tiny amygdules (averaging 0.1 mm. greatest dimension) of chalcedony. No perlitic cracks are present.

Soda Trachyte Porphyry

There are two intrusives of trachyte. The rock is a light-gray quartz soda trachyte porphyry, with small (1-3 mm.) feldspar phenocrysts and narrow plates of reddish biotite and hematite. Brown concentric rings $1/8-3/4$ inch across result from weathering. The phenocrysts are anorthoclase. The groundmass is trachytic with alkali feldspar laths 0.04-0.2 mm. in length and a small amount of interstitial quartz

varying from a trace to 2 or 3 per cent. A sodic amphibole, riebeckite (?), occurs in the groundmass in sponges and shreds and is largely altered to an opaque black mineral. Some samples contain minute grains of a sodic pyroxene, probably aegirite-augite. Magnetite is present in discrete grains. Iddingsite (?), hematite, and reddish-brown biotite (?) are alteration products after mafics, and apatite is an accessory mineral. A facies of aegirite-augite soda trachyte porphyry occurs in the intrusives. This type is distinctive under the microscope but megascopically is similar to the weathered specimens of the main rock. This peculiarity makes the relations of the two kinds somewhat equivocal. In hand specimen it is a dark gray-green to black fragmental-appearing rock with darker-green fragments up to an inch in diameter seemingly imbedded in the lighter-colored matrix. In some specimens the darker material is apparently in bands which are separated from the light matrix by sharp boundaries. The groundmasses are glass filled with alkali feldspar laths and ferromagnesian microlites, and a greater concentration of the latter imparts the darker green color. The feldspar laths of the matrix are 0.01–0.2 mm. in length. The anorthoclase phenocrysts average 1 mm. in length. Veinlets of chalcedony 0.04–0.2 mm. wide cut through the rock, and augite and aegirite-augite occur in fine grains in the groundmass and in phenocrysts up to 1 mm. in greatest dimension. A yellow mineral has completely replaced some of the smaller grains and has formed an alteration rim around some of the larger pieces of the pyroxene. This mineral is pleochroic in yellow, $2V$ about 70° – 80° (–), $n_{\beta} = 1.68$, $n_{\gamma} - n_{\alpha} = 0.025$, with a prominent cleavage, length slow, extinction about 7° – 9° from the cleavage. It is tentatively identified as an amphibole. Small ore grains and apatite are accessories.

Porphyritic Olivine Trachydolerite

This is the principal rock occurring in lenses of lava in the upper Huelster formation; it ranges in some places to a labradorite microsyenite. Trachydolerite also makes one lens at the base of the Star Mountain rhyolite south

of Seven Springs (Table 1, No. 14). It is a fine-grained black rock with a finely crystalline groundmass and small phenocrysts which are rare in one occurrence (Table 1, Nos. 3 and 4). A few grains of mafic mineral are distinguishable megascopically. The phenocrysts are narrow, dark, shiny laths of plagioclase (An_{62}) commonly having an armor of anorthoclase. Labradorite is, for the most part, the dominant feldspar, but in some cases the alkali feldspar forms the bulk of the matrix as well as heavily armoring the phenocrysts. The groundmass feldspar grains are 0.02–0.3 mm. across, and the texture is hypautomorphic granular to trachytic with augite ophitic to the feldspar. The augite is pale gray to lavender with optically continuous patches measuring up to 2 mm. in greatest dimension. Olivine, largely serpentinized, is present between the feldspar laths in grains averaging 0.2 mm. in size. Magnetite is prominent, and some slides show brown biotite formed on the peripheries of a few grains. Apatite is a common accessory, and traces of calcite and analcime are present interstitially.

Basalt and Trachybasalt Porphyry

This is the type found in the flows of lava member No. 2 of the Seven Springs formation. It is dark gray to dull purple brown; some hand specimens are amygdaloidal, and a few show narrow plagioclase phenocrysts. Flow structure is prominent, and vesicles and amygdules are numerous. The groundmass ranges from glass containing barely visible plagioclase laths to plagioclase laths 0.01–0.3 mm. long, generally prominently armored by alkali feldspar. One specimen (Table 1, No. 24) is sufficiently coarse-grained to be considered a trachydolerite. The groundmass plagioclase is slightly less calcic than the labradorite (An_{58-60}) phenocrysts. Alkali feldspar also occurs in the interstices between groundmass laths and along cracks in phenocrysts. The texture is ophitic. Abundant microlites of augite and ore make the glassy matrix opaque to pasty. Iddingsite grains after olivine, abundant in the matrix, are rare as phenocrysts. Apatite is present in fine needles, and chalcedony, calcite, and serpentine (?) fill opal-lined amygdules.

Vitric Rhyolite Porphyry or Vitrolithic Tuff

Several lavas are partially vitric or vitrolithic tuff. These include a lava in the top of tuff member No. 1, the red lava at the base of lava member No. 2 (or top of tuff member No. 2), and a lava in tuff member No. 4, all of the Seven Springs formation. They are brick-red to purple-brown dense flinty rocks with notable glassy feldspar phenocrysts (usually anorthoclase) or fragments visible in hand specimen. The groundmasses are usually glassy, n^ccanadabalsam, with perlitic structure, or finely crystalline with prominent flow structure. The matrices enclose euhedral and corroded phenocrysts of alkali feldspar and quartz, and a few pieces of aegirine-augite, biotite, and magnetite along with inclusions of rhyolite and basalt. Broken fragments of alkali and plagioclase feldspar and quartz are common as are amygdules and stringers of calcite, chalcedony, or hematite. Hematite is also prominent in the groundmasses. The tuffaceous parts are similar in composition, except the major constituent is glass in the form of shards which occasionally exhibit a somewhat welded character.

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