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Stratigraphy and Petrology of the Tascotal Mesa Quadrangle, Texas

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STRATIGRAPHY AND PETROLOGY OF THE TASCOTAL MESA QUADRANGLE, TEXAS

BY RALPH L. ERICKSON

ABSTRACT

The Tertiary Buck Hill volcanic series, about 4000 feet thick, covers most of the Tascotal Mesa quadrangle in Presidio and Brewster counties, Texas. The regional dip in the northern part of the quadrangle is 2°–4° SW., and differential erosion has developed three prominent levels. Green Valley in the northeastern part is underlain by Pruett and Duff beds. Rising approximately 800 feet above the level of Green Valley is Bandera Mesa capped by the resistant Mitchell Mesa tuff flow. Tascotal Mesa rises 800 feet above Bandera Mesa and is capped by flows of the Rawls basalt that form a dip slope to the western boundary of the quadrangle.

The southern third of the quadrangle, set off from the northern part by east-west faults, is characterized by rugged topography developed chiefly on the Rawls basalt flows. In the southeast corner Cretaceous strata that dip to the north off the Solitario uplift form hogbacks and cuestas.

The Solitario uplift, initiated in late Cretaceous time, continued during the deposition of the Tertiary volcanic series which thins and wedges against the dome. Uplift probably was not at a uniform rate; a period of marked uplift accompanied or followed shortly the intrusion of riebeckite soda rhyolite which forms numerous hills in the southeast part of the area.

The intrusives contributed abundant large boulders to the conglomerate of the upper beds of the Tascotal formation that lap on the slopes of the rhyolite hills. Boulders of Caballos novaculite and of black chert suggestive of the Maravillas formation indicate an appreciable contribution from the folded Paleozoic rocks that were uncovered by erosion of the Solitario complex.

Late Tertiary orogenic movements resulted in compressive forces acting on the structurally downwarped Marfa basin in which the Buck Hill volcanic series accumulated. The volcanic series was folded in a broad anticlinal structure, and the southwestward-dipping beds in the northern part of the quadrangle are the west limb of this large structure. Uplift was accompanied or followed by normal faulting.

The igneous rocks of the Tascotal Mesa quadrangle are alkalic. Analcime and soda-rich pyroxene and amphibole are characteristic. Both extrusive and intrusive rocks show a silica range from 46 to 73 per cent.

Quaternary deposits are related to the physiographic history of the region; gravel-capped pediments in Green Valley are now being dissected.

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INTRODUCTION

Location

The Tascotal Mesa quadrangle is in southeastern Presidio and southwestern Brewster counties, Trans-Pecos Texas (Fig. 1). Bandera Mesa and Tascotal Mesa are reached most easily from Marfa, 50 miles north, by the Marfa-Lajitas road which traverses the quadrangle from north to south. Green Valley in the northeastern part of the area is most easily reached from Marfa by the 02 Ranch road in Paradise Valley; an alternate route is from Alpine by the Terlingua highway and the 02 Ranch road.

Scope of Work

The geologic work in the Tascotal Mesa quadrangle is part of a project of geologic studies in southern Trans-Pecos Texas conducted by the Bureau of Economic Geology, The University of Texas. Workers in this region include Goldich and Elms (1949) in the Buck Hill quadrangle, Goldich and Seward (1948) and Goldich, Elms, and Seward (1949) in the Jordan Gap quadrangle, R. R. Bloomer (Unpublished manuscript, 1949) in the Christmas and Rosillos Mountains, Moon (1953) in the Agua Fria quadrangle, R. W. Graves (Unpublished manuscript, 1949) in the Hood Spring quadrangle, G. M. Stafford (Open-file manuscript, 1952) in the Nine Point Mesa quadrangle, W. N. McAnulty (Unpublished manuscript, 1953) in the Cathedral Mountain quadrangle, and C. C. Rix (Unpublished manuscript, 1953) in the Chinati Mountains. Lonsdale (1940) studied and mapped the igneous rocks of the Terlingua-Solitario region, and with Ross A. Maxwell is preparing a report on the geology of the Big Bend National Park.

This investigation is primarily concerned with a thick succession of volcanic tuff and and related sediments with intercalated lava flows which Goldich and Elms (1949, p. 1143) named the Buck Hill volcanic series. Six months was spent in the field during the summer of 1949 and the spring of 1950. Mapping was done on aerial photographs and later transferred to the U. S. Geological Survey topographic quadrangle map (ed., 1944; surveyed in co-operation with the War Department).

Acknowledgments

The field work and a large part of the cost of the chemical analyses were financed by the Bureau of Economic Geology, The University of Texas, and the writer is indebted to Dr. John T. Lonsdale, Director, for this support and for his personal interest in all phases of the work. The laboratory work was done in the Department of Geology and Mineralogy, and the chemical work in the Rock Analysis Laboratory of the University of Minnesota. The writer is indebted to Dr. S.S. Goldich for suggestions and useful criticism. Darwin Cedarleaf assisted during the field season in 1949, and Conrad Appledorn in 1950. Robert B. Haynie was helpful in the identification of the Cretaceous formations. The ranchers of the area were generous in their co-operation.

CLIMATE AND VEGETATION

The Tascotal Mesa quadrangle is in the driest climatic province of Texas. Daytime temperatures often reach 100°F. in the summer months, but the relative humidity is usually below 10 per cent, and the nights are cool. The rains come chiefly in July and August when short thundershowers, many accompanied by violent winds, occur almost daily; 2–3 inches of rain may fall within a few hours.

Various forms of cacti, yuccas, and other hardy plants are common and show a close relationship to rock type and topography. Ocotillo grows on weathered flats and gentle slopes, particularly on the flows. Tuff outcrops are commonly covered with the spiny lechu-

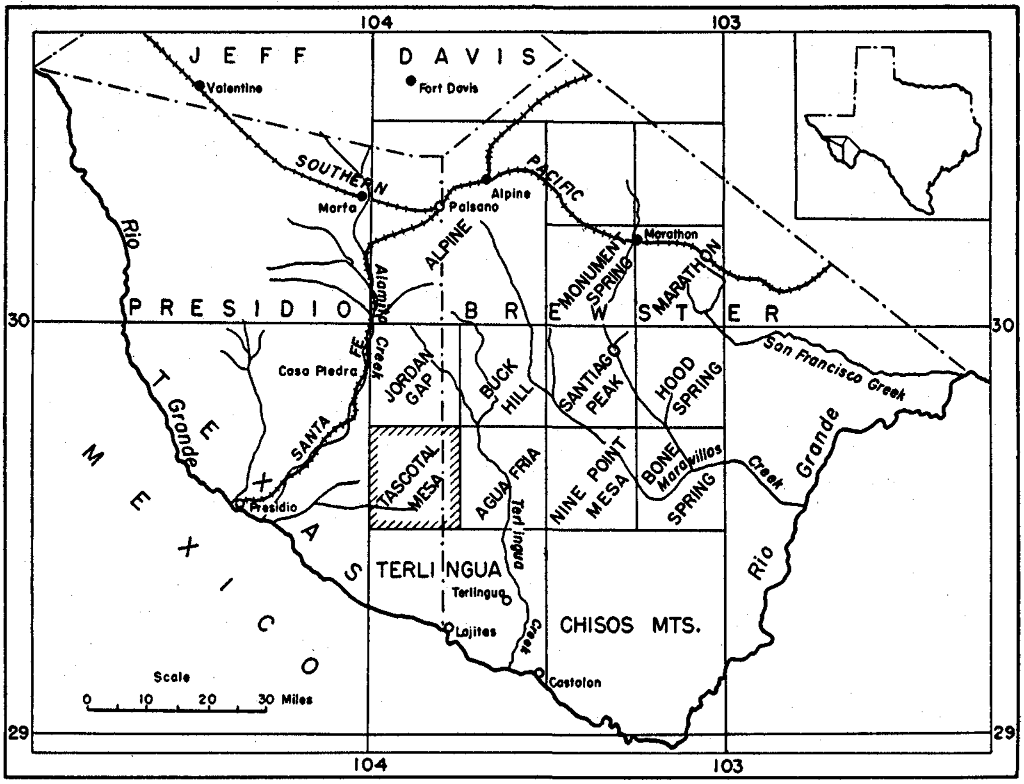

FIGURE 1.—INDEX MAP OF PART OF TRANS-PECOS TEXAS

Showing Tascotal Mesa and adjacent quadrangles mapped as part of the West Texas project of the Bureau of Economic Geology, The University of Texas: Buck Hill, Goldich and Elms (1949); Jordan Gap, Goldich and Seward (1948); Agua Fria, Moon (1953).

guilla. Sagebrush and creosote bush are found on the valley flats, and catclaw grows near the waterways. Bunch grass is the principal natural forage of the livestock and is abundant on mesa tops if there is enough rain.

TOPOGRAPHIC DEVELOPMENT

The topography in the Tascotal Mesa quadrangle was largely developed by differential erosion. Rock types and structure are the controlling factors in the development of mesas (Pls. 4, 5) in the northern two-thirds of the quadrangle and of rugged hills and steep valleys in the southern third.

Green Valley, which occupies the northeastern part of the quadrangle, has an altitude of 3600–3700 feet. Igneous intrusives form Needle Peak (Pl. 4, fig. 2) and The Dike, two prominent landmarks on this flat lowland. Green Valley is drained by creeks that flow eastward and join Terlingua Creek in Agua Fria quadrangle.

Facing Green Valley is the 700- to 800-foot scarp of Bandera Mesa (Pl. 4, fig. 1), capped by the resistant Mitchell Mesa rhyolitic tuff flow that dips 2° SW. Small, intermittent consequent streams follow the dip slope and are captured by subsequent streams which flow north and south and divert the drainage into South Canyon. The scarp of the mesa has also been breached by streams which flow eastward to Green Valley and form Middle and North canyons.

San Jacinto Mountain in the northwest part of the quadrangle is a basaltic intrusive that rises 700 feet above the level of Bandera Mesa. La Viuda, 2½ miles southwest of San Jacinto, is a smaller intrusive.

The west-central part of the quadrangle is occupied by Tascotal Mesa which rises approximately 800 feet above Bandera Mesa to form the third major erosional level in the quadrangle. The mesa is capped by a thick series of basalt flows which are more resistant than the underlying Tascotal tuff but which weather more readily than the silicic tuff flow capping Bandera Mesa. The Rawls flows on Tascotal Mesa dip southwest, and the drainage is westward to Alamito Creek. A dendritic drainage pattern is developed on the Rawls basalt in contrast with the more linear drainage pattern on the rhyolitic tuff flow of Bandera Mesa, reflecting the different weathering qualities of the two caprocks. The highest point on the quadrangle, 5184 feet above sea level, is on the scarp of Tascotal Mesa south of the center of the quadrangle.

The porphyritic Rawls flows weather to irregular scarps and steep slopes, whereas the fine-grained nonporphyritic flows weather to thin slabs which generally from gentle slopes (Pl. 5, fig. 2). The alternation of porphyritic and nonporphyritic flows produces a rugged topography marked by many canyons, buttes, and peaks.

There is a great topographic contrast between the southern third and the rest of the quadrangle because the surface rocks in the southern part are chiefly Rawls basalt which have been displaced along the east-west Tascotal Mesa fault. Numerous small faults associated with igneous intrusive masses further complicate the structure and have influenced the topographic development. The major westward drainage is Torneros Creek, whose course is guided by the Tascotal Mesa fault. The eastward drainage through Alamo de Cesario Creek is guided by a secondary fault zone which trends roughly east-west and which is thought to be related to the larger Tascotal Mesa fault. The drainage divide between these two streams is approximately along the 103°50′ longitude line (Pl. 1).

The Alazan Hills are dissected, plateaulike remnants of flows capped by trachyandesite porphyry. Steep-walled canyons characterize the upper reaches of the creeks. La Mota Mountain near the western boundary of the quadrangle is a smaller plateaulike remnant with very steep slopes. On the west side of La Mota Mountain a large toreva block has been displaced vertically about 200 feet. Northwest of La Mota Mountain is a symmetrical domical uplift, the La Mota dome, which has been breached and eroded to a basin. Resistant plugs of microsyenite and, gabbro form small spires in the basin.

The southeastern corner is the most rugged and inaccessible part of the quadrangle. The dip slope of Cretaceous rocks off the Solitario uplift (Pl. 2, fig. 1) has been complicated by rhyolitic intrusives and by intricate faulting. Steep hills formed by the intrusives rise to altitudes approaching 4900 feet.

PEDIMENTS

Pediments slope gently to the east away from the receding scarps of Bandera and Tascotal mesas. The largest "rock cut" surface beveled the Duff and Pruett tuff in Green Valley and marks a former base level of erosion in the development of Green Valley. The pediment is now being dissected by renewed active down-cutting in the area. The pediment remnants form prominent gravel-capped ridges in the northeastern part of the quadrangle which extend across Green Valley parallel to the present drainage system. These ridges are 30 to 40 feet high and are capped with 3 to 5 feet of unconsolidated gravels. Southward along the eastern border of the quadrangle, the pediment is being dissected by Point Draw and its tributaries. To the south, the rim of Alamo de Cesario canyon is capped with 15 feet of pediment gravels, but all traces of the pediment south of the canyon have been removed except for an isolated, narrow, three-pronged, gravel-capped ridge of tuff on the north side of Tascotal Mesa fault (Pl. 1). This ridge is level with the rim of Alamo de Cesario canyon.

Smaller isolated pediments are forming on Bandera Mesa south and northwest of Wire Gap by the recession of the scarp of Tascotal Mesa. The soft sand and tuff units below the caprock weather easily and promote sapping of the caprock so that large blocks give way and tumble to the bottom of the slope where they disintegrate to a gruss. The writer believes these pediments are the result primarily of weathering and retreat of the mesa scarp by marginal fragmentation, sapping, sheet wash, and rill wash. Lateral planation by streams probably has been a minor process.

CRETACEOUS SYSTEM

General Statement

A thick section of Cretaceous rocks, principally limestone, is exposed in the southeast corner of the quadrangle for approximately 8 square miles. Along the south boundary of the quadrangle the Cretaceous strata form the northeastern flank of the Solitario uplift; dips are high (20°–30°), and hogbacks are developed in the thick-bedded limestones of the Comanche series (Pl. 2, fig. 1). North of the Solitario the regional dip is 10° or less, and cuestas result from the erosion of the Boquillas formation of the Gulf Series. (Pl. 2, fig. 2).

The pattern of the Cretaceous strata is complicated by faults and by numerous rhyolitic intrusives. The structural complications together with the rugged topography and general inaccessibility of this part of the area have limited the field studies of the Cretaceous formations, and few reliable observations of thicknesses could be made. It is estimated that the Cretaceous rocks exposed in the quadrangle exceed 2500 feet in thickness (Table 1). The formations, from youngest to oldest, differentiated on the geologic map (Pl. 1) are: Boquillas limestone, Buda limestone, Grayson clay, Devils River limestone, Glen Rose limestone.

Glen Rose Limestone

The single exposure of the Glen Rose limestone in the quadrangle, on the southern boundary, is best seen along the road that leads into the Solitario. In the inner rim of the Solitario basin the lowermost Cretaceous strata were measured by Scott (1939, p. 985) who found nearly 3000 feet for the Trinity section at Fresno Peak on the southwest side of the Solitario, approximately 5 miles south of the quadrangle boundary.

Only the upper part of the Glen Rose occurs in the Tascotal Mesa quadrangle. A 4-foot thickness of hard, reddish-pink, siliceous limestone, in beds averaging 8 inches thick, marks the top of the formation (Robert Haynie, personal communication, 1949). Hard, dark-gray, fine-grained limestone alternates with softer beds of marl and marly limestone. Some beds contain numerous *Orbitolina texana;* the uppermost of these is 30 feet below the ledge-forming, hard, siliceous limestone.

Weathering of the Glen Rose limestone is influenced by widespaced joints. Exposures are etched and corroded to rough irregular surfaces, and where the beds dip steeply a typical

TABLE 1.—GEOLOGIC FORMATIONS IN THE TASCOTAL MESA QUADRANGLE

Age	Group and formation		Thickness in feet (exposed)	Correlation	Lithology and remarks
Quaternary		Alluvium	10±		Valley fill and recent stream alluvium
		Gravel	15±		Pediment and high-level gravels
		Angular unconformity			
Tertiary (Miocene?)	Buck Hill volcanic series	Rawls basalt	50–937	Probably equivalent to Chisos beds, Vieja series, Square Peak volcanic series, McCutcheon volcanic series	Interfingering flows and volcanic breccia ranging from basalt to trachybasalt and trachyandesite porphyry with intercalated tuff, sandstone, and conglomerate
	Buck Hill volcanic series	Tascotal tuff	797		Sandstone and conglomerate member in upper part; grades to massive conglomerate and fresh-water limestone facies laterally. Light-colored rhyolitic tuff in lower part
Tertiary (Oligocene)	Buck Hill volcanic series	Mitchell Mesa tuff-flow	0–70		Pink to gray rhyolitic tuff flow
Tertiary (Eocene?)	Buck Hill volcanic series	Duff tuff - - - - - - - - Pruett tuff	2000±		Duff; light-colored rhyolitic tuff with minor conglomerate and fresh-water limestone; intercalated basalt flows in upper part. Pruett; dull-colored rhyolitic tuff with minor sandstone and conglomerate. Contact uncertain.
		Angular unconformity			
Gulf		Boquillas	600±	Eagle Ford	Alternating flaggy limestone and shale; calcareous shale predominant in upper part
Cretaceous Comanche		Buda	61	Buda	Massive nodular limestone
		Grayson	65	Grayson	Clay-shale with thin sandy limestone layers
		Devils River	500–600	Georgetown Kiamichi Edwards Walnut-Comanche Peak	Massive limestone with abundant chert nodules
		Glen Rose	1500±	Maxon Glen Rose	Massive, dark-gray limestone

development of solution furrows forms lapies (Smith and Albritton, 1941, p. 73).

Devils River Limestone

Udden (1907a) gave the name Devils River limestone to thick-bedded, fine- to coarse-grained limestone exposed along the Devils River in Val Verde County. These beds are equivalent to the Edwards and Georgetown formations of central Texas. In the Shafter district Ross and Cartwright (1934, p. 596) included beds in the Devils River limestone that originally were referred by Udden (1904) to the Edwards and that were described by him to include the Comanche Peak, Edwards, and Georgetown formations. Eifler (1943, p. 1626) included the beds above the Maxon sandstone and below the Del Rio (Grayson) formation in the Santiago Peak quadrangle in the Devils River limestone.

The writer has mapped as Devils River limestone all the beds above the Glen Rose and below the Grayson. The sequence of alternating hard, thick-bedded limestone, soft nodular limestone, and marl is so similar in over-all appearance that subdivision in the badly faulted exposures seemed impractical. There are two areas of outcrop; the smaller and more accessible one can be reached by the road to the Solitario. At this locality about 135 feet of marly limestone grading upward to limestone is included in the lower part of the Devils River. The marly beds, which probably are equivalent to the Walnut and Comanche Peak formations, contain numerous *Exogyra texana*. They are succeeded by 400–500 feet of thick-bedded, fine-grained, gray to buff limestone that locally contains abundant chert nodules. The beds dip about 20° NW, and their truncated surface is overlain by gently dipping flows of the Tertiary Rawls basalt.

The second and larger area of Devils River limestone is in the southeastern corner of the quadrangle and is not readily accessible. The outcrops here are largely the dip slope off the Solitario uplift and represent the upper part of the Devils River. Along the east boundary remnants of the Grayson formation are capped by Buda limestone, but the Devils River-Grayson contact generally is covered by slumped material.

The thickness of the beds mapped as Devils River limestone is not known. Adkins (1932, p. 346) gives 800 feet for the thickness of the Edwards formation in the inner rim of the Solitario. Robert Haynie (personal communication, 1950) states that the measured thickness of the Georgetown limestone in Santa Elena Canyon of the Rio Grande is 950 feet. It is unlikely that these thicknesses are exceeded in the Tascotal Mesa area. The Kiamichi formation, between the Edwards and the Georgetown in other areas, was not recognized in the quadrangle.

Grayson Clay

The Grayson (Del Rio) is composed of light greenish-yellow to yellow-brown calcareous clay-shale with thin layers of hard clayey and calcareous sandstone. The latter commonly contain abundant *Haplostiche texana* (Conrad). In the southeastern part of the quadrangle the Grayson is repeatedly exposed by small normal faults. Except where protected by the overlying thick-bedded, resistant Buda limestone, the Grayson is easily eroded, and exposures are typically gentle slopes of hills and ridges (Pl. 2, fig. 2).

South of elevation 4038 the Grayson crops out in gentle slopes beneath the Buda. Here the formation is about 65 feet thick; colluvium covers much of the slope and obscures the lower contact. On the east boundary, about three quarters of a mile north of the southeast corner, the Grayson and Buda are exposed in a 30-foot section of which the lower 10–12 feet is Grayson. The base of the Buda is an oyster shell bed, 4 inches thick, and the uppermost bed of the Grayson is a laminated, light-yellow clay, 3 inches thick. The fine-grained claystone is jointed and slickensided; the fractures are marked by thin seams of dark reddish-brown to purplish clay similar to that of the main body except for color.

Buda Limestone

The thick-bedded, fine-grained Buda is more resistant and more persistent cuesta- and ridge-forming unit than either the underlying Grayson clay or the overlying flaggy limestone of the Boquillas. The lower limestone beds, 6 or more feet thick, form steep to vertical walls and overhanging ledges (Pl. 2, fig. 2) where the underlying Grayson clay has been eroded. Fresh, massive-appearing Buda is white to gray, but it weathers to dark-gray nodular forms. In many places the limestone is shattered and weathered exposures have a rubble of sharp angular pieces. The lighter color and weathering characteristic generally distinguish it from the thick-bedded limestone of the Devils River, but, where the two formations are brought together along faults, the distinction is not always easily made. South of elevation 4038 the Buda is 61 feet thick, and this thickness appears to be rather uniform in all exposures.

The contact of the Buda limestone and Grayson clay is well exposed at the locality on the east border of the quadrangle, three quarters of a mile north of the southeast corner where a 4-inch bed of oyster-shell coquina marks the base of the Buda. The shells are fragmentary and broken, and the coquina probably is a basal conglomerate. Locally small pieces of the Grayson containing *Haplostiche texana* were found in the lowermost beds of the Buda. Although the Grayson and the Buda appear to be concordant, their relations probably are disconformable (Goldich and Elms, 1949, p. 1140). The upper contact of the Buda generally is covered with float derived from the weathering of the overlying Boquillas. It is well exposed, however, in a canyon cut through these formations in the vicinity of BM 4088. The undulating contact (Pl. 3, fig. 1) is marked by a change from the thick-bedded, fine-grained, cream-colored Buda to the thin-bedded, sandy limestone of the Boquillas.

The Buda is fossiliferous and contains nautiloids, ammonites, gastropods, and pelecypods. Fossils in the thick-bedded lower and upper units are difficult to remove, and the middle marly unit yielded little identifiable material.

Boquillas Formation

The Boquillas is the youngest Cretaceous formation exposed in the quadrangle. The largest outcrop, arcuate in shape, is part of the Cretaceous dip slope and is 3 miles long and about 1¼ miles wide. A small erosional remnant of the Boquillas on the eastern boundary extends a short distance into the Agua Fria quadrangle and measures less than half a mile across. Two small outcrops are related to domical structures. An arcuate-shaped outcrop of Boquillas limestone that almost surrounds a small intrusive of riebeckite soda rhyolite is believed to have been pushed up by the intrusive action. This outcrop is in a small upthrown block approximately 1 mile south of the Holland-Meriwether ranch house (near BM 4224). A symmetrical dome of the Boquillas surrounded by Tertiary tuff beds occurs three quarters of a mile north of the Tascotal Mesa fault near the eastern border of the quadrangle.

A maximum thickness of 600 feet is estimated for the Boquillas formation in Tascotal Mesa quadrangle. The lower beds of the Boquillas are well exposed in the creek near BM 4088 (Pl. 3, fig. 1). Thin-bedded, fine-grained limestone persists up from the base for about 65 feet with a relatively minor amount of interbedded calcareous shale. Higher in the section, thicker beds of limestone become numerous, and the amount of calcareous shale gradually increases.

PLATE 2.—CRETACEOUS FORMATIONS

FIGURE 1. SOLITARIO UPLIFT

Steeply dipping Lower Cretaceous limestones on the northeast flank of the Solitario.

FIGURE 2. GRAYSON-BUDA CONTACT

Clay slope of the Grayson formation capped by ledge of thick-bedded Buda limestone.

PLATE 3.—BOQUILLAS FORMATION

FIGURE 1. BUDA-BOQUILLAS CONTACT

Thick-bedded nodular Buda limestone overlain by flaggy Boquillas limestone. In canyon at BM 4088.

FIGURE 2. BASAL PRUETT CONGLOMERATE

Close-up of basal Pruett conglomerate resting on the dissected surface of the Boquillas dome.

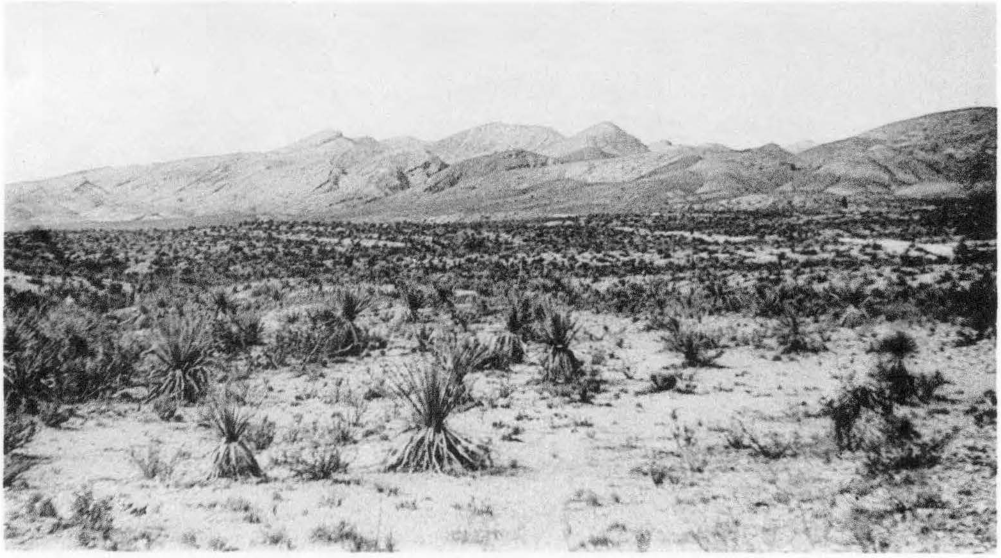

FIGURE 1

FIGURE 2

CRETACEOUS FORMATIONS

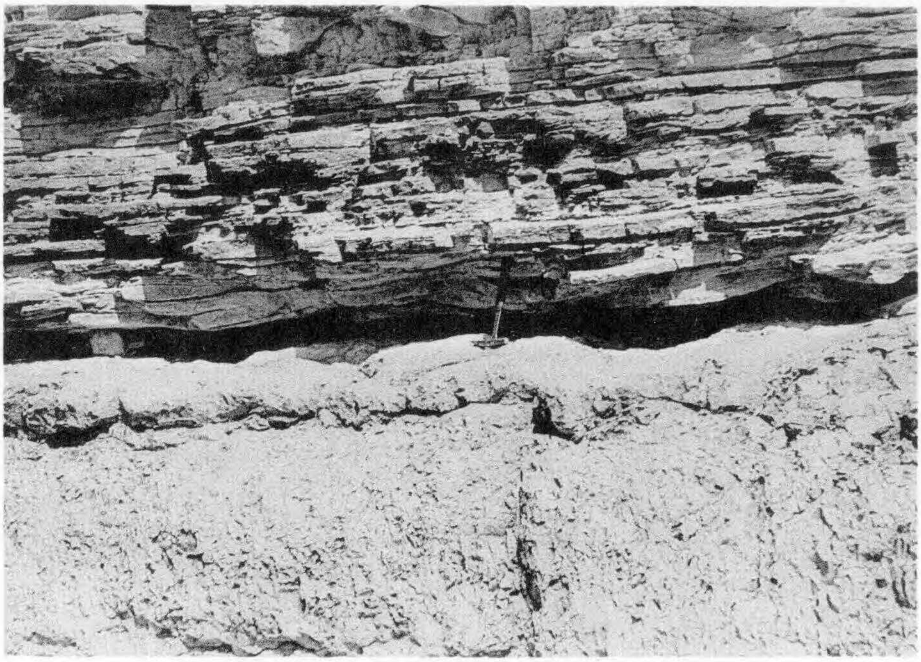

FIGURE 1

FIGURE 2

BOQUILLAS FORMATION

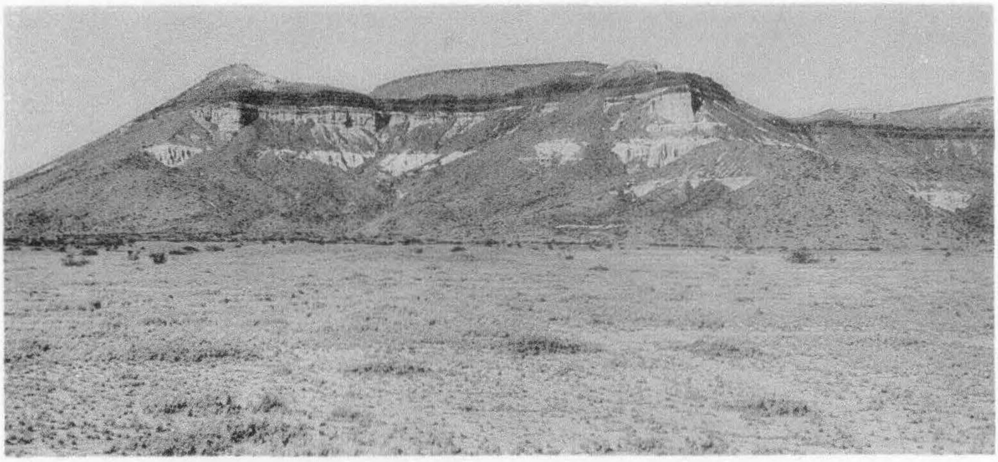

FIGURE 1

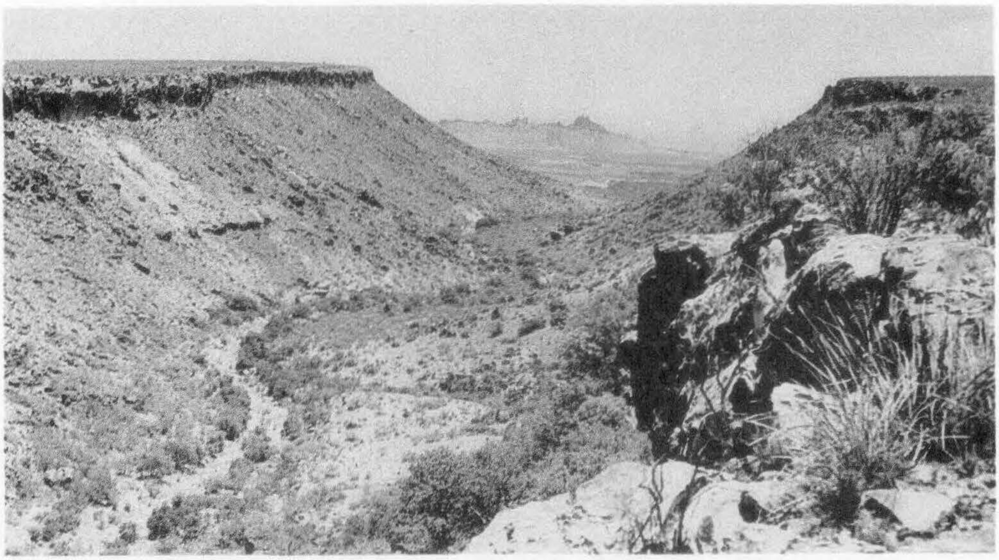

FIGURE 2

DUFF FORMATION

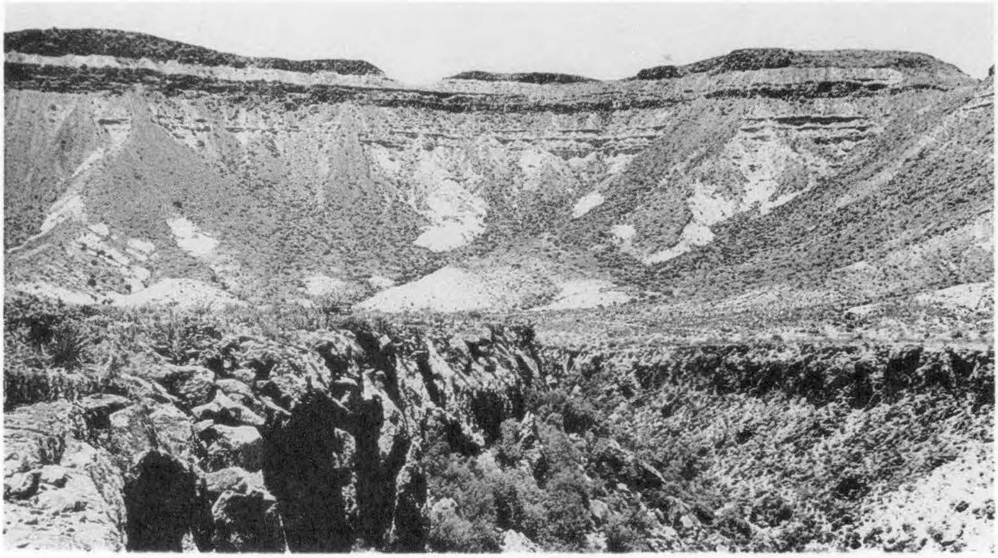

FIGURE 1

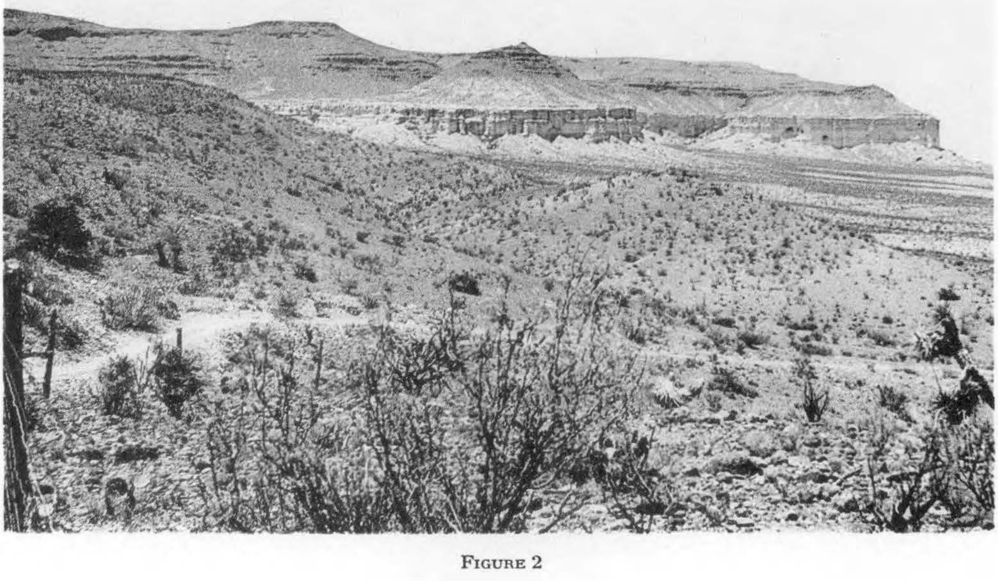

FIGURE 2

TASCOTAL FORMATION AND RAWLS BASALT

The Boquillas is well exposed in the canyon east of Hill 4220 and south of the Solitario fault. In the lower part of this section the beds dip 11° N., but to the north, in the vicinity of the fault, the dip increases to 34°. Imprints of *Inoceramus* are numerous in the Boquillas limestone exposed in the canyon south of the Solitario fault. Fragments of a fish with well-preserved teeth and jaw were collected from the outcrop around the small rhyolite intrusive south of the Holland-Meriwether ranch house.

The upper contact of the Boquillas is an erosion surface overlain by different rocks of the Buck Hill volcanic series. At Hill 3837, north of the Tascotal Mesa fault, limestone-pebble conglomerate of the Pruett rests on the Boquillas. In the area of the largest Boquillas outcrop, the formation is overlain by relatively thin beds of the upper Tascotal conglomerate capped by flows of the Rawls basalt. On the east slope of Hill 4850 the Boquillas is overlain by the upper conglomerate member of the Tascotal formation.

TERTIARY SYSTEM

Buck Hill Volcanic Series

The Buck Hill volcanic series was named by Goldich and Elms (1949, p. 1133) for outcrops in the Buck Hill quadrangle (Fig. 1). The succession of tuff, sandstone and conglomerate, breccia, fresh-water limestone, and intercalated lava flows was divided into a lower tuff formation, the Pruett, 900–1000 feet thick; and an upper tuff, the Duff, 1000–1400 feet thick. Separating the Pruett and the Duff are the Cottonwood Spring basalt flows, 50–325 feet thick.

Capping the Duff tuff on Mitchell Mesa in the northwestern corner of the Buck Hill quadrangle is a silicic rock that Goldich and Elms named the Mitchell Mesa rhyolite. This rock is genetically related to the welded tuffs or ignimbrites and is here referred to as Mitchell Mesa tuff flow.

The younger tuff beds that rest on the Mitchell Mesa tuff flow and the flows that cap these rocks west and southwest of the Buck Hill quadrangle were included by Goldich and Seward (1948) in the Buck Hill volcanic series. The tuff beds are well exposed in the scarp of Tascotal Mesa and so were named the Tascotal formation. The flows were named the Rawls basalt for the Rawls ranch on the mesa.

The Pruett formation crops out in Green Valley (Pl. 1). The Duff formation, with unnamed intercalated basalt flows in the upper part, is exposed in the scarp of Bandera Mesa and trends northwest across the northern two-thirds of the area. In the present mapping, however, it was not practicable to map the contact between the two formations in Green Valley because of the lack of differentiating criteria and because so much of Green Valley is covered with gravel and alluvium.

The Mitchell Mesa tuff flow caps Bandera Mesa and is overlain in the central and western parts of the quadrangle by the Tascotal formation. At the type locality, Wire Gap (Pl. 5,

PLATE 4.—DUFF FORMATION

FIGURE 1. DUFF TUFF IN SCARP of BANDERA MESA

Duff formation capped with Mitchell Mesa tuff flow below elevation 4475 in Green Valley. Dark layer near top of section consists of three basalt flows, 72 feet thick.

FIGURE 2. SOUTH CANYON, BANDERA MESA

Upper part of the Duff formation capped by Mitchell Mesa tuff flow. Microsyenite dike forming Needle Peak in Green Valley in background.

PLATE 5.—TASCOTAL FORMATION AND RAWLS BASALT

FIGURE 1. TASCOTAL FORMATION AT WIRE GAP

Type section of the Tascotal formation, 800 feet thick, capped by Rawls basalt porphyry. Mitchell Mesa tuff flow in foreground.

FIGURE 2. TASCOTAL FORMATION AND RAWLS BASALT

Upper sandstone-conglomerate member of the Tascotal formation overlain by 338 feet of Rawls basalt. View from highway, looking northwest at southern end of Tascotal Mesa.

fig. 1), the Tascotal formation is divided into a lower sandy tuff member and an upper tuffaceous sandstone and conglomerate member, but these are not shown separately on the map. In the southern part of the quadrangle where the volcanic series thins and wedges against the Solitario uplift, the upper member grades to thick, coarse conglomerate and fresh-water limestone. This facies is differentiated on the map (Pl. 1).

The writer divides the Rawls basalt flows into four types; trachybasalt porphyry, basalt, trachyandesite porphyry, and volcanic breccia (Pl. 1). The various units of the Buck Hill volcanic series are summarized in Table 1. The aggregate thickness of approximately 3800 feet of the Tertiary volcanic succession is progressively exposed from northeast to southwest in the Tascotal Mesa quadrangle.

Pruett Formation

The gray to reddish-brown tuff, tuffaceous sandstone, and conglomerate of the Pruett formation exposed in the beds of Crystal Creek, Dogie Creek, Point Draw, and unnamed intermittent streams can be traced eastward into the Agua Fria quadrangle where Moon (1953) mapped the basal conglomerate. The regional dip is 1°–3° SW., and, although the alluvial cover in Green Valley obscures the structural relationships, a minimum thickness of the order of 2000 feet is indicated for the tuff beds between the basal conglomerate, 5–6 miles to the east in the Agua Fria quadrangle, and the Mitchell Mesa tuff flow on Bandera Mesa. This thickness corresponds to the combined thickness of the Pruett and Duff formations in the type area to the northeast.

Gray to brown and reddish-brown tuff with some beds of calcareous, medium-grained to conglomeratic sandstone are exposed in Crystal Creek. The tuff is well stratified in beds up to 1 foot thick and has a well-developed joint system. The more prominent set of joints trends N.30°–35°W. Weathering results in nodular forms that are characteristic of the Pruett.

Two fossil localities which yield large low-spired, fresh-water snails are indicated on Pl. 1. The first is an exposure of tuff in a small hill just north of the old Cotter ranch house north of Needle Creek; the second is in an old stone corral about 1½ miles west, on the south side of the creek. At both localities the poorly preserved snails appear to be similar. Unidentifiable bone fragments were found with the snails in the sandy tuff in the old corral. Above the tuff is cross-bedded, crudely ripple-marked sandstone and conglomeratic sandstone in which white tuff fragments contrast sharply with the dark reddish-brown matrix. These beds are mapped as undifferentiated Pruett-Duff (Pl. 1). The snail-bearing beds at the Cotter ranch are mapped as Pruett, but positive identification is not possible, and they may be equivalent of either the Pruett or the Duff formations to the north.

Duff Formation

The Duff formation in the scarp of Bandera Mesa in the northeastern part of the quadrangle is dominantly thick-bedded, fine-grained, variegrated tuff. Colors range from light gray to buff, brown, pink, and red. Locally the tuff is sandy, grading to tuffaceous sandstone, conglomeratic sandstone, and boulder conglomerate. The most persistent conglomerate beds are near the top of the formation. The tuff is chiefly rhyolitic glass in various stages of alteration and is similar to the beds in the northern parts of the Buck Hill and Jordan Gap quadrangles (Goldich and Elms, 1949, p. 1610), but in several respects the Duff in the Tascotal Mesa quadrangle differs from the formation farther north. The beds commonly are calcareous, and there are layers of fresh-water limestone as well as intercalated basalt flows in the upper part which have not been found in either the Jordan Gap or Buck Hill quadrangles.

Three sections of the Duff beds were measured in the scarp of Bandera Mesa, and these give many of the lithologic details. A section, 764 feet thick, was measured with the plane table below elevation 4475 (Pl. 4, fig. 1) west of Needle Peak.

	Thickness (feet)
Mitchell Mesa tuff flow	
(19) Rhyolitic tuff flow with iridescent feldspar and quartz crystals in fine-grained groundmass.	11
Duff formation	
(18) Covered interval, probably tuff.	53
(17) Tuff, chalky white, fine-grained, speckled, sandy, massive; pitted and weathered to roughly rounded nodular forms.	15

	Thickness (feet)
(16) Tuff, sandy and conglomeratic with large calcareous tuff concretions; upper part fine- to medium-grained tuff in successive receding benches 4–6 feet thick. Tops of benches are hard calcareous tuff layers about 2 feet thick; weathers to earthy mud-flow slopes. Lower part sandy and conglomeratic with local lenses of limestone, and cherty limestone cobbles, and felsitic igneous pebbles. Lenses about 4 inches thick	68
(15) Basalt intercalations	
Basalt flow No. 3: black, fine-grained, amygdaloidal, green-stained; calcite fillings; weathers spheroidally	30
Basalt flow No. 2: black, fine-grained, locally stained green; well-developed flow breccia at top; weathers spheroidally	11
Basalt flow No. 1: dark-green, fine-grained, vesicular, thick flow breccia at top with numerous quartz fillings	31
(14) Tuff, white to buff, conglomeratic to fine-grained; upper part massive, thick-bedded, fine-grained; baked hard, red at contact with overlying flow; lower part well stratified, chalky white, black-speckled, hard, locally conglomeratic	11
(13) Conglomerate, conglomeratic sandstone, and sandstone, reddish-brown, poorly stratified, poorly sorted; base is conglomeratic with pebbles of tuff, porphyritic felsites, fossiliferous limestone, black chert, red vesicular basalt fragments; grades to thin, cross-bedded lenses of medium-grained, buff, calcareous sandstone; upper 10 feet hard, massive conglomerate with boulders up to 15 inches in diameter; cliff former	14
(12) Tuff, variegated, light-gray, buff and pink, fine-grained, numerous tuffaceous limestone concretions up to 1 inch in diameter; massive beds, 2–10 feet thick, separated by buff, earthy, soft tuff. Forms massive, sheer cliff	86
(11) Tuff, light-gray, fine-grained, containing numerous gray limestone concretions up to 6 inches in diameter; mottled tuff breccia near top with light-gray calcareous matrix containing angular pink tuff fragments up to 1 inch in length	35
(10) Tuff, salmon-red, fine-grained, three 6-inch conglomeratic layers near top with pieces of tuff and felsites, 1/8–1/4 inch long; thin-bedded, weathers to irregular slope with many ledges	20
(9) Tuff, calcareous, massive, buff to light-gray, fine-grained, forms steep cliff with pitted surface	106
(8) Tuff, in part calcareous, variegated pink and light gray; base marked by hard 4-inch bed of fine-grained white, black-speckled tuff, weathers gray; upper part sandy, weathers to irregular slopes of large nodular forms	29
(7) Tuff, sandy, buff, fine-grained, black-speckled, massive, weathers with steep faces; two pink, hard, calcareous tuff bands in the upper part	52
(6) Tuff, calcareous, alternating light pink and light gray with occasional purple bands, thin- to thick-bedded; purple bands finely fractured with yellow-green alteration along fractures; weathers to irregular nodular pieces; thicker calcareous beds weather spheroidally	60
(5) Tuff, variegated pink and light gray, massive, cut by small clastic dikes; pitted surface; weathers to small irregular pieces	21
(4) Tuff, in part calcareous, predominantly pink with few gradational light-gray bands; calcareous beds hard and concretionary	7
(3) Covered interval, probably tuff	42
(2) Tuff, calcareous, variegated pink to light gray, fine-grained; more calcareous strata stand out prominently in thick massive beds, less calcareous tuffs occupy slopes between	38
(1) Covered interval, probably tuff, to floor of Green Valley	24
Total thickness measured	764

The upper Duff beds were measured in the first canyon north of Middle Canyon, on the spur that forms the west wall of the creek just north of the Seminole Trail. A basalt flow caps the spur, and the main bed of conglomerate, here 15 feet thick, is 146 feet below the base of the flow. Tuff and conglomerate beds aggregate 254 feet in this section.

In the northwest wall of South Canyon at a point opposite the debouchment of the northwestward-flowing tributary, 22 feet of conglomerate is exposed at the base of the section in the stream bed. Ten feet above the top of the conglomerate is a basalt flow, 22 feet thick. About half way up the slope 4 feet of limestone, in beds about 4 inches thick, forms a resistant ledge (Pl. 4, fig. 2).

The conglomerate beds in the upper part of the Duff are lenticular; the bed which occurs 88 feet below the caprock in South Canyon is not found to the north below elevation 4475 where the first prominent conglomerate is 219 feet below the tuff flow. Coarse red conglomerate, approximately 50 feet thick, is the caprock of the small butte east of Smugglers Gap about 300 feet below the level of Bandera Mesa. The cobbles and boulders in this conglomerate include limestone, cherty limestone, marble, quartzite, black chert, epidote rock, riebeckite felsite, trachyte, scoria, vesicular and amygdaloidal andesite or basalt, and tuff pieces. The conglomerate is underlain by a basalt flow and tuff beds in which, near the base of the hill, are beds of hard, fine-grained, white, tuffaceous limestone.

In the southeastern part of Bandera Mesa and in the north walls of Alamo de Cesario canyon a red conglomerate marks the top of the Duff formation. The conglomerate, up to 50 feet thick, is poorly sorted with a range from small pebbles to boulders 2 feet in diameter. The base of the conglomerate commonly exhibits a well-developed scour-and-fill structure. Channels scoured in the tuff beds are filled with gravel showing cross-lamination, with a concentration of larger cobbles in the troughs.

An unusual conglomerate developed on the northeast flank of the Solitario uplift was described by Moon (1953, p. 182) in the Agua Fria quadrangle. The poorly sorted conglomerate has a yellow, calcareous, sandy cement, and "yellow conglomerate" used by Moon is a convenient name for reference. This conglomerate was traced from the Agua Fria quadrangle along the Tascotal Mesa fault to South Fork in the Tascotal Mesa quadrangle. A maximum thickness of about 50 feet is developed on the eastern boundary. Moon described one locality in the Agua Fria area where a "welded tuff" of rhyolitic composition is included in the conglomerate. Similar relations exist in the Tascotal Mesa quadrangle, half a mile east of Hill 4202, where the writer mapped the "welded tuff" as the Mitchell Mesa rhyolite tuff flow. The yellow conglomerate is a local lentil in part older and in part younger than the tuff flow.

Basalt flows were mapped at two horizons in the Duff formation (Pl. 1). One lower flow, 200–300 feet below the rim of Bandera Mesa, east of Smugglers Gap, is a dark-gray, fine-grained basalt with a well-developed friction breccia at the base. This flow has a maximum thickness of about 50 feet, and its outcrop is about 2 miles in length. The upper basalt intercalations are much more extensive and can be followed in the scarp from a point 2½ miles southeast of Smugglers Gap northwestward to a point south of North Canyon near the north boundary.

The flows at the upper level are variable in number. In the measured section at elevation 4475 (Pl. 4, fig. 1) three flows total 72 feet in thickness. Vesicular and amygdaloidal zones at the tops and friction breccias at the bottoms are characteristic. Only one flow, 20–25 feet thick, is present in Middle Canyon and South Canyon.

In thin section the flows are fine-grained, diabasic olivine basalt and trachybasalt. The rock consists of small slender laths of labradorite, 60–70 per cent, with intersertal olivine, augite, and magnetite-ilmenite. Hydrothermal alteration formed much serpentine, hematite, secondary magnetite, and calcite.

Pruett-Duff Beds

The outcrops between the Tascotal Mesa fault and the north rim of Alamo de Cesario canyon are designated Pruett-Duff. This area is a westward extension of the Devil's Graveyard of the Agua Fria quadrangle and is a desolate and barren badlands. The scarp of Alamo de Cesario canyon is composed of variegated, light-pink to light-gray, nodular, calcareous tuff with minor coarse, light-gray, cross-bedded sandstone. At Hill 3837 near the eastern boundary, a conglomerate similar to the typical basal Pruett conglomerate laps unconformably on the dissected surface of a small structural dome in the Boquillas limestone. The conglomerate (Pl. 3, fig. 2) is made up of well-rounded pebbles and cobbles of limestone with a few of chert, but none of igneous rocks. It is poorly cemented and pinches out up dip against the dome.

	Thickness (feet)
Pruett-Duff	
(7) Tuff, calcareous, brown, soft, bentonitic; weathers to gentle slopes	12
(6) Limestone, tuffaceous, light gray, fine-grained, well-bedded, brown on weathered surface	3
(5) Tuff, sandy, light gray, flaky; weathers to mud-cracked, sandy, clayey slopes	36
(4) Limestone, brown, fine-grained	3
(3) Sandstone, light gray, medium-grained, conglomeratic	1
(2) Conglomerate, well-rounded, dark gray and gray limestone pebbles and cobbles most abundant; black chert pebbles few; igneous pebbles wanting	9
Boquillas limestone	
(1) Limestone, yellowish-gray, thin-bedded, silty. To base of section in creek bed	13
Total thickness measured	77

Mitchell Mesa Tuff-flow

The Mitchell Mesa tuff flow covers about 35 square miles of Bandera Mesa. Small patches of the tuff flow crop out south of the rim of Bandera Mesa as remnants on small hills. There are two other minor areas of outcrop; the larger of these is the thin ribbon of "rhyolite" which parallels Tascotal Mesa fault on the downthrown side near the eastern border of the quadrangle. To the south, in the creek bed on the northwest side of Hill 4850, a rhyolitic rock very similar to typical Mitchell Mesa tuff flow forms a small fault block which has been dropped down against Boquillas limestone.

The "rhyolite" is resistant to erosion and exhibits well-developed columnar jointing. It has a pinkish to bluish-gray and white groundmass with numerous pyramidal quartz and opalescent, tabular feldspar crystals. The fresh rock is fine-grained and breaks with an even fracture. The weathered rock is greasy black to reddish brown and commonly is pitted or cavernous. The weathered surface usually is rough due to the protuberance of quartz and feldspar crystals which are more resistant than the matrix. Locally the matrix is vesiculated and in a few localities exhibits flow structure around inclusions. Both the inclusions and vesiculated patches tend to be elongated.

The upper and lower contacts of the tuff flow commonly are marked by a soft, soapy, bentonitic clay containing quartz and feldspar crystals and retaining the texture of the fresh rock. The clayey material represents weathered zones from a few inches to 18 inches thick, ranging from white to pink and green. The clay is not an ancient soil but resulted from chemical alteration of the glassy groundmass following deposition of the overlying Tascotal formation. The Tascotal beds were deposited on a hummocky erosion surface of the Mitchell Mesa tuff flow, and it is unlikely that conditions favored preservation of the soft bentonitic clay on the surface. The development of the clay at the base of the formation likewise precludes surface weathering.

Along the Tascotal Mesa fault in the southeastern part of the quadrangle, the tuff flow strikes west and dips 70° S. At the contact with the underlying yellow conglomerate is an 18-inch layer of decomposed rhyolite. The fresh rock differs from the typical tuff flow in that it is softer and feels distinctly ashy or gritty.

The maximum thickness of tuff flow in Tascotal Mesa quadrangle, 60–70 feet, is in the rim of North Canyon at the northern border of the quadrangle. The sheet thins to the south and is only 24 feet thick in the southeast rim of Bandera Mesa.

In thin section, the Mitchell Mesa rhyolitic tuff flow consists of a fine-grained matrix of glass shards and their devitrification products, and crystals of anorthoclase (2V = 40°) and quartz. Magnetite and apatite are accessory minerals. Alteration and secondary products include hematite, leucoxene, calcite, and chalcedonic quartz. The anorthoclase crystals are embayed and rounded; faint gridiron structure can be detected.

Tascotal Formation

Description.—At the type section at Wire Gap (Pl. 5, fig. 1) the Tascotal formation is 797 feet thick and is divided into two members, a lower member of tuff and sandy tuff beds and an upper member of sandstone, tuffaceous sandstone, and conglomerate. A section was measured at Wire Gap.

	Thickness (feet)
Rawls basalt	
(26) Trachybasalt porphyry (Trbp), dark brownish gray, porphyritic with occasional stubby plagioclase phenocrysts; lower 2 feet vesicular and amygdaloidal with fillings of chalcedony and calcite; base is reddish brown and ropy. To top of mesa.	60
(25) Tuff, sandy, pumiceous, some 1- to 2-inch beds almost entirely light-green pumice; color changes from grayish brown through yellow brown to baked red at the contact with overlying flow; weathers irregularly to alternating small ledges and slopes. The ledges have a greater abundance of pumice	49
(24) Conglomerate and coarse sandstone, alternating, well bedded ranging from 6-inch layer of sandstone to 2-foot layers of conglomerate; middle conglomerate is dark brown containing many vesicular flow fragments; forms ledge	8
(23) Tuff, sandy, fine-grained, brown, with scattered light-green pumice fragments up to 3 inches long; weathers to thinly laminated shaly appearance	2
(22) Sandstone, soft, buff, conglomeratic with scattered igneous pebbles; weathers to soft, irregular slope making bedding.	12
(21) Trachybasalt porphyry, dark gray, porphyritic, with numerous plagioclase laths; weathers to brown resinous appearance in which light plagioclase phenocrysts are conspicuous; surface disintegrates irregularly to small angular fragments ap-	

	Thickness (feet)
proximately 1 inch in diameter. Forms massive, dark-brown, sheer cliff........	65
(Thickness of Rawls basalt 196 feet)	
Tascotal formation	
Upper sandstone and conglomerate member	
(20) Covered interval; probably sandy tuff...	30
(19) Tuff breccia, soft, crumbly, light gray, contains tuff fragments, weathered pumice, feldspar crystals....................	5
(18) Conglomerate and coarse sandstone, alternating; contains well-rounded pebbles	28
(17) Tuff, sandy, pumiceous, light gray......	2
(16) Conglomerate and coarse sandstone, alternating, light gray to buff; conglomerate beds usually not over 2 feet thick, with some beds of coarse sand 4-6 feet thick; pebbles and cobbles similar to unit No. 13	20
(15) Conglomerate, predominantly cobbles, roughly bedded, cemented with coarse sand, forms prominent ledge; cobbles roughly concentrated in 2-inch to 1-foot parallel bands; many flat cobbles oriented parallel to the bedding plane; igneous cobbles predominate, chiefly trachyte, andesite, vesicular basalt; phanerites scarce. Sedimentary cobbles chiefly light-gray chert and well-rounded, flattened crystalline limestone.........................	5
(14) Sandstone, tuffaceous, soft, buff, contains few thin conglomeratic lenses 2–3 inches thick. Upper 6 feet hard and fritted on surface; weathers to soft slope covered with talus..........................	25
(13) Conglomerate, light gray to buff; considerable range in size, well-rounded pebbles, cobbles, boulders of igneous felsites, scoria, chert, hard tuff fragments; cemented with coarse tuffaceous sand; many flat pieces roughly oriented in parallel alignment; moderately stratified with interbedded and lensing coarse sand layers; faintly cross-bedded; variable thickness laterally due to channeling. One scoria boulder 15 inches in greatest diameter...	10
(Note: Line of section for remainder of Tascotal tuff is offset 200 yards north)	
(12) Sandstone, soft, poorly cemented, fine-grained, buff; weathers to soft, treacherous slope in upper 20 feet; lower part more tuffaceous and forms vertical ledge with pitted surface; beds thick, massive, but bedding planes masked by disintegration on surface.....................	36
(11) Sandstone, tuffaceous, soft, buff, becoming light gray near top; disintegrates to fine sand on surface; massive, predominantly thick-bedded. Interbedded conglomeratic sands 1 foot thick occur at 25- to 30-foot intervals; weathers to steep, smooth slopes.....................	194
(10) Tuff breccia-conglomerate, distinctive pink and white weathered pumice fragments, few scattered hard tuff pieces; forms steplike benches about 3 feet thick..................................	10
(9) Sandstone, tuffaceous, soft, light gray, fine-grained; weathers to smooth massive gentle slope; bedding obliterated.......	24
(8) Sandstone, tuffaceous, buff to sandy tuff; weathers to large roughly rounded nodular forms; forms massive steep-faced ledges about 25 feet high in sharp contrast to soft, gentle-sloped units above and below	46
(7) Sandstone, tuffaceous, soft, poorly cemented, brownish gray, fine-grained to locally coarse-grained; weathers to soft sandy, gentle slopes; middle 25 feet well indurated............................	71
Lower tuff member	
(6) Tuff, sandy, light gray, forms gentle slopes with some irregularly spaced ledges 3–4 feet thick; weathers to small roughly rounded, scaly, nodular pieces; more resistant ledges form boulder nodules; bedding fairly well developed with right-angle jointing system striking N.27°W. and N.70°E...........................	113
(5) Tuff, sandy, light gray, fine-grained, thick-bedded, forms ledges 5–6 feet thick in steplike fashion; weathers to large, roughly rounded pieces; jointed in same manner as unit No. 6...........	31
(4) Tuff, sandy, poorly cemented, light gray; forms uniform gentle slope; weathers to flaky, spalled surface	37
(3) Tuff, sandy, variegated light gray, and red, well stratified; becomes increasingly more red toward top....................	60
(2) Tuff, light gray, thin-bedded with local massive beds, fine- to medium-grained; thin beds weather to typical tabular flags	37
(1) Covered interval, tuff beds away from line of section to top of Mitchell Mesa rhyolite tuff flow..	13
(Thickness of Tascotal formation 797 feet)	—
Total thickness measured..........	993

Lower tuff member.—The lower tuff member, 291 feet thick at Wire Gap, consists of light-gray to pink, sandy tuff with some small discontinuous lenses of conglomerate at the base. Locally the tuff is coarse-grained and speckled with biotite flakes. The beds are predominantly thin and weather to tabular blocky pieces. At Wire Gap local thick beds are channel fillings; the thick beds cut abruptly across the thin strata giving the impression of faulting, but the beds above are undisturbed.

The contact with the underlying Mitchell Mesa tuff flow is poorly exposed in the type section but is clearly exposed northwest of Wire Gap along a small normal fault southeast of BM 4075. The top of the rhyolitic tuff flow is a soft, bentonitic clay with numerous quartz and feldspar crystals preserving the original texture of the rock. The base of the Tascotal is a soft, crumbly conglomeratic sand containing fragments derived from the underlying tuff flow. A section was measured.

	Thickness (feet)
Tascotal formation	
(6) Tuff, light gray, medium-grained, sandy; weathers to 2- to 4-inch slabs	2.5
(5) Tuff, soft, cream-colored, bentonitic, crumbles easily	5.0
(4) Tuff, light gray, sandy, hard; contains white tuff pieces; locally stained green	5.0
(3) Tuff, bentonitic, chocolate brown near base to light gray near top; contains soft soapy green bentonite pieces	6.5
(2) Tuff, conglomeratic, red, contains white tuff pieces	0.3
Mitchell Mesa tuff-flow	
(1) Clay, bentonitic, soft, soapy, brown, with quartz and glassy feldspar crystals	1.5
Total thickness measured	20.8

The lower part of the Tascotal formation is fairly uniform throughout the quadrangle, but there is considerable variation in the thickness and coarseness of the conglomerate near the base. One thousand feet south of elevation 3869 in the small creek at the eastern edge of the northwest rectangle a thick basal conglomerate contains boulders of syenite, vesicular basalt, and riebeckite rhyolite, up to 3 feet in diameter. Approximately 0.4 mile west across a wide stream bed and on the north side of the road, the conglomerate contains abundant riebeckite rhyolite cobbles in a sandy red matrix.

Upper sandstone and conglomerate member.—At Wire Gap, the upper sandstone and conglomerate member of the Tascotal formation, 506 feet thick, consists of soft sandstone, tuffaceous sandstone, and conglomerate. There is considerable channeling, lensing, and cross-bedding. The conglomerates consist of well-rounded pebbles, cobbles and boulders of felsites, scoria, chert, hard tuff fragments, and limestone. At the southern end of Tascotal Mesa west of the Marfa-Lajitas road, a poorly sorted, massive, and well-indurated conglomerate contains black ribbon chert and white novaculite derived from the Maravillas chert and Caballos novaculite formations of Ordovician and Devonian age. These rock types disappear to the north and were not found in the upper conglomerate at Wire Gap. One boulder of novaculite measured 1 foot in diameter. Gray to greenish-blue riebeckite rhyolite, red and yellow jasper, limestone pebbles and cobbles, and hard, white marble pieces are present. Silicic felsites, up to 1 foot in diameter, are abundant. On the average, the pieces are subrounded to subangular; however, limestone pebbles and cobbles are well rounded. A few basaltic flow pieces were noted. The cementing material is calcium carbonate.

The massive, thick conglomerate is cut by the major fault which strikes northwest across the face of the southern end of the mesa. Because this unit is a local development adjacent to the Solitario, it must have been derived from the uplift, which indicates that this great dome was a structural high being eroded during the deposition of the upper Tascotal. Associated with the conglomerate beds at this locality is fresh-water limestone, marking the first appearance of limestone in the Tascotal formation. Silicified plant stems found in tuffaceous limestone above the conglomerate were examined by Mr. Roland Brown of the U. S. Geological Survey who made this memorandum (January 25, 1950):

> "Fine striations and fluting on the stemlike specimens in this sample indicate that the specimens represent remains of plants, but whether grasses, sedges, or other kinds, is not determinable. Little or no cellular structure can be seen in cross-sections, the replacement by silica being practically complete."

East of the Marfa-Lajitas road, the Tascotal thins appreciably, and limestone becomes relatively more abundant. In the northwest corner of the southeast rectangle, a section measured below Hill 4681 included 77 feet of fresh-water limestone.

	Thickness (feet)
Rawls basalt	
(6) Basalt flows to top of hill	407
Tascotal formation	
(5) Tuff breccia, dark brown, baked hard and brittle, pops apart when struck with hammer	11
(4) Limestone, light yellow, medium-grained, sugary-textured, flaggy; beds average 1 to 4 inches thick; weathers gray	72
(3) Limestone, light yellow, medium-grained, lower part bedded grading into soft, nodular, massive limestone in upper part; weathers gray	5
(2) Conglomerate, yellow, poorly sorted, poorly indurated, massive with calcareous cement; contains chiefly black chert and novaculite pieces up to 8 inches in diameter; limestone cobbles up to 4 inches; soda rhyolite boulders up to 1 foot; and pieces of tuff	3
(1) Tuff, sandy, medium-grained; to creek bottom	2
Thickness of Tascotal beds	93

Between the Tascotal Mesa fault and the Agua Fria Trail, the upper member consists of fresh-water limestone and conglomerate. In all exposures examined the conglomerate contains abundant black chert, novaculite, limestone, and silicic felsites. The conglomerates are interbedded with yellow, thin-bedded (1–2 inch) clayey limestone which resembles the upper part of the Boquillas.

Fresh-water limestone is less abundant to the south and is not present in the upper member south of the Agua Fria trail; massive conglomerate is the chief rock type and is well exposed south of Hill 4850 where boulder conglomerate rests on a Boquillas erosion surface. Huge blocks of Glen Rose (?) limestone and rhyolite up to 8 feet in diameter as well as 3- to 4-foot Boquillas flags are abundant. The large rhyolite blocks were derived from the intrusive of Hill 4850. This fact coupled with the absence of any basaltic flow pieces in the conglomerate offers convincing evidence that the rhyolite intrusives antedate the upper Tascotal beds and the Rawls basalt flows.

A similar relationship exists around the small intrusive hill 1 mile south of the Holland-Meriwether ranch house (west of BM 4224) where the Boquillas is domed by an intrusion of rhyolite. In the creek bed on the west side of the hill, the Boquillas is overlain concordantly by a hard, fine-grained, thick-bedded, fresh-water limestone. Both the Boquillas and the fresh-water limestone dip 12° off the hill. A single specimen of a fossil snail resembling *Helix hesperarche* was found in the fresh-water limestone. Below the exposure of the fresh-water limestone, a 50-foot thickness of coarse conglomerate laps on the domed Boquillas beds and encircles the hill. Locally derived pieces of the Boquillas limestone are abundant at the base of the conglomerate. Large cobbles of Caballos novaculite and of black chert are numerous, but particularly instructive are the abundant large pieces of rhyolite which were derived from the intrusive. The conspicuous absence of basaltic pieces in the conglomerate leaves little doubt that the conglomerate is older than the Rawls basalt with which it is faulted into juxtaposition.

The beds of fresh-water limestone at this locality are a remnant of the Tertiary beds that at one time rested on the Boquillas and that formed part of the succession into which the rhyolitic magma was intruded. Uplift accompanying the igneous activity accelerated erosion, and the Tertiary beds were largely eroded. The exposed intrusive and Boquillas beds supplied float that was incorporated in the younger conglomerate of the upper Tascotal which on the south side of the hill is succeeded by beds of tuff and fresh-water limestone and finally by flows of the Rawls basalt.

Basalt intercalation.—West of Wire Gap, a black, fine-grained basalt flow is intercalated in the upper part of the Tascotal about 50 feet below the top of the formation. The basalt has a limited lateral extent of 3–4 miles and does not occur at Wire Gap nor at the western border of the quadrangle. The thickness ranges from a maximum of 17 feet down to 1 foot. The lower 3–4 inches is vesicular, and the top is amygdaloidal with fillings chiefly of calcite. The broken amygdaloidal top contains fills of sand with angular pieces of basalt. The flow is overlain by conglomerate containing amygdaloidal fragments up to 5 inches in diameter.

Stratigraphic relations.—The Tascotal formation in the northern three-fourths of the quadrangle rests on the Mitchell Mesa tuff flow, but in the southeast rectangle, south of the Tascotal Mesa fault, it lies unconformably on Boquillas limestone and on older Cretaceous formations. The Tascotal thins to the southeast against the flank of the Solitario uplift, and only the upper conglomerates and limestone were deposited in this area (Fig. 2). Evidence suggests that the lower units of the Buck Hill volcanic series may have once been present on the flank of the uplift but were eroded before deposition of the Tascotal.

Rawls Basalt

Description.—The Rawls basalt flows cover approximately 110 square miles of the quadrangle. Four rock types were recognized in the field: (1) trachybasalt porphyry or "birds-eye" porphyry which usually contains abundant plagioclase phenocrysts up to 2 inches long and weathers to rough, dark-brown surfaces; (2) a fine-grained, dark-gray basalt which weathers to thin slabs; in the outcrop, it characteristically forms gentle-sloped, round-topped hills covered with platy talus pieces; (3) dark, reddish-brown, hard, dense, volcanic breccia particularly well developed in the northern part of the southwest rectangle; and (4) a dark-gray to greenish-gray trachyandesite porphyry in which the plagioclase phenocrysts are much smaller and considerably less abundant than in the "birds-eye" porphyry. In the trachyandesite small phenocrysts of pyroxene are common.

Although the rock types interfinger, the trachybasalt porphyry is usually basal, the basalt in the middle, and the trachyandesite porphyry uppermost and nowhere covered by younger flows. The volcanic breccia is restricted to the southwestern part of the quadrangle and interfingers with flows of basalt. The section at La Mota Mountain in the southwestern part of the quadrangle was measured.

	Thickness (feet)
Rawls basalt	
(6) Trachyandesite, thick, massive, fine- to medium-grained; numerous small phenocrysts of pyroxene and plagioclase; weathers brown. To top of La Mota Mountain	356
(5) Basalt, dark gray; weathers to thin slabby pieces; slopes covered with talus	40
(4) Trachybasalt porphyry, abundant plagioclase phenocrysts up to 1 inch long; weathers to irregular angular pieces	81
(3) Volcanic breccia, massive, hard, dark brown, containing twisted and contorted basalt pieces	30
(2) Trachybasalt porphyry, massive; numerous light to dark feldspar phenocrysts up to ¼ inch long; forms first massive outcrop in La Mota Mountain	129
(1) Trachybasalt porphyry, consists of several flows with abundant plagioclase phenocrysts up to 1 inch in length. To base of exposure	301
Total thickness measured	937

Trachybasalt porphyry. — Trachybasalt porphyry is the most abundant of the lavas. The flows range from 48 to 300 feet in thickness on the rim of Tascotal mesa, increase to an average of 350 feet to the southwest in the central part of the mesa, and attain their greatest thickness, 511 feet, in La Mota Mountain. The rock forms massive, sheer cliffs in contrast to the gentle-sloped hills of fine-grained basalt. The texture is diabasic, and glassy plagioclase phenocrysts, ½ - 2 inches in diameter, are abundant. Some of the rock contains small pyroxene phenocrysts. The groundmass weathers to a dark-brown, resinous color in which the light-colored plagioclase phenocrysts are conspicuous. The surface disintegrates irregularly to small angular fragments. Well-developed amygdaloidal tops and bottoms have calcite and chalcedony fillings.

The rock at Wire Gap is olivine-augite trachybasalt porphyry. The plagioclase phenocrysts, 30–40 per cent, are labradorite. Some phenocrysts exhibit pronounced zoning in which the zoning bands are contorted, fractured, and displaced; these range from andesine to labradorite. Other phenocrysts (An_{55}) are fresh and unzoned although fractured and corroded. The augite, 15 per cent, is pale purple and slightly pleochroic. Olivine is largely altered to iddingsite or bowlingite. Magnetite-ilmenite is abundant, 10–15 per cent of the rock. The groundmass contains orthoclase, 15 per cent, and a plagioclase, oligoclase-andesine, 15 per cent. Apatite is an accessory mineral, and hematite and calcite are alteration products. A pale-brown interstitial material is probably devitrified glass. Thin sections of the "birds-eye" porphyry from other localities show variations from olivine trachybasalt to olivine trachyandesite.

The trachybasalt flows moved into the Tascotal Mesa quadrangle from the southwest, and just west of the quadrangle boundary in the dome at La Mota dikes of the trachybasalt porphyry ("birds-eye" porphyry) cut the Tascotal tuffs. These dikes were perhaps the feeders of the flows.

Basalt.—Basalt flows are extensive in the southern third of the quadrangle. The rock is uniformly fine-grained, dark-gray basalt that weathers to thin slabs and commonly forms talus slopes where it underlies porphyritic rocks of the other units. In the northwest corner of the southeast rectangle, the Rawls flows consist entirely of basalt, 320 feet thick. This is the greatest development of this unit in the quadrangle.

The succession at Hill 4633 about 1½ miles south of the Alazan ranch house includes 155 feet of basalt. The flows thin westward and are missing on the west side of the Alazan Hills although 40 feet is recorded in the 937-foot section at La Mota Mountain.

A thin section of the analyzed specimen (Table 3, col. 1) collected just east of elevation 4307 about three quarters of a mile west of the Holland-Meriwether ranch house contains 60–70 per cent labradorite (An_{62}). The rock has a diabasic texture, and the plagioclase laths are mantled with orthoclase. Augite, 15 per cent, is slightly pleochroic; olivine crystals have been completely altered to bowlingite or iddingsite. Small grains of a dark red-brown mineral may be lamprobolite. Magnetite-ilmenite is abundant, and patches of secondary calcite are common.

Volcanic breccia.—This unit is the least abundant of the four types mapped and is restricted to the southwestern part of the quadrangle. The best exposure is on the north side of Torneros Creek opposite elevation 4003 where the breccia forms the rimrock and is 60–70 feet thick. The rock is hard, dense, reddish brown, and contains basalt fragments up to 4 inches long which locally are in parallel alignment. The pieces commonly are curved and contorted. In thin section, broken feldspar crystals and rock fragments are common in a matrix of glass fragments which appear fused. The feldspar crystals are rimmed with orthoclase, and basic rock fragments are oxidized. This rock is classified as a welded breccia.

Seventy-four feet of volcanic breccia is exposed on the north side of Torneros Creek; 30 feet, at La Mota Mountain; 21 feet, in the Alazan Hills; and 27 feet, at Hill 4633. The unit is conspicuous in the field and is a useful marker bed. It is restricted to the upper part of the Rawls and usually underlies trachyandesite porphyry.

Trachyandesite porphyry.—A dark-gray, fine-grained rock with small phenocrysts of plagioclase and pyroxene is well developed in the southwestern part of the quadrangle and attains a thickness of 356 feet in La Mota Mountain. A thickness of 91 feet caps the Alazan Hills, and the flows extend northeastward to Hill 5184 on the rim of Tascotal Mesa where a thickness of 125 feet was measured. There is one other small outcrop, 27 feet thick, on the rim of the mesa at VABM 4125 (stamped 4132). The flows weather light brown and develop blocky talus slopes. Near the top of La Mota Mountain huge blocks, 50 by 25 feet, contain angular pieces up to 6 feet across. There is no vesiculation, and the breccia is restricted to the east side of the mountain. This locality may represent a conduit from which the trachyandesite lavas were extruded. The trachyandesite flows are restricted to the upper part of the Rawls formation and nowhere are overlain by younger volcanic rocks.

The rock from Hill 5184, on the rim of Tascotal Mesa, consists of fine-grained orthoclase and oligoclase, 80 per cent, with well-defined flow structure. There are a few corroded phenocrysts of oligoclase (An_{27}). Olivine has been altered to iddingsite or bowlingite. An unusual yellow-green amphibole, 5 per cent, with low birefringence and extinction of about 28° has not been identified. Small grains of augite are contained in the groundmass. Magnetite-ilmenite and apatite are accessory. This rock is assigned Johannsen number 2211 E, olivine trachyandesite porphyry.

At La Mota Mountain the plagioclase is slightly more silicic, and the rock is coarser-grained. Thin sections from other localities show variations in the amount of augite, but the plagioclase remains in the medium range. Two chemical analyses are given in Table 3.

Tuff and breccia beds.—The succession of Rawls flow rocks is interrupted by thin beds of tuff, volcanic breccia, sandstone, and conglomerate in addition to the mapped volcanic breccia. At Wire Gap, two porphyritic basalt flows, totaling 125 feet in thickness, are separated by a unit, 72 feet thick, which consists of tuff, pumiceous tuff, sandy tuff, and conglomerate. The tuff beds are commonly baked red at the contact with overlying flows. They thin to the southwest and are rare in the southwest rectangle.

At Hill 4633, 1-3/4 miles south of the Alazan ranch, there are a number of thin conglomerate, breccia, and hard, fine-grained tuff beds between the flows, including two 1-foot beds of hard, brittle, grayish-green and red rock containing a few scattered, reddish-brown volcanic pieces averaging a quarter of an inch in diameter.

Half a mile southwest of BM 4224 near the

Holland-Meriwether ranch house in the southeast rectangle, a hard, compact tuff breccia, 3 feet thick, lies between flows of basalt. The rock grades from a tuff breccia at the base to a banded, baked, dense, highly oxidized rock at the contact with the overlying flow. In thin section the lower rock is a mixed tuff containing anorthoclase crystals, quartz, silicic plagioclase laths, lamprobolite, pyroxene and apatite grains, and rock fragments in a groundmass of glass shards which appear partly fused. The fragments and crystals are rounded and corroded.

The upper part of the bed is banded, brownish-red and black. Anorthoclase, quartz, silicic plagioclase, and rock fragments are imbedded in a groundmass of brownish-red to black glass which has flowed and molded around the crystals and fragments. The thin sections reveal a gradation from an indurated and baked tuff-breccia to a rock partly fused by the heat of the succeeding lava flow as it moved across the tuff bed. Selective fusion of the more silicic pieces produced a soft glass which responded to the movement and pressure of the overlying lava and developed a striking flow texture. Chemical analyses of these rocks are given in Table 5.

Stratigraphic relations.—The Rawls basalt flows are the youngest member of the Buck Hill volcanic series in the Tascotal Mesa quadrangle, and their upper erosion surface is locally overlain by Quaternary gravel deposits. The flows rest on the Tascotal formation and in places interfinger with beds of tuffaceous sandstone, breccia, and conglomerate. In the southeastern part of the quadrangle, overlap on the flanks of the Solitario uplift brings the flows on the Devils River limestone.

Age and Correlation

The age and correlation of the Buck Hill volcanic series has been discussed by Goldich and Elms (1949, p. 1143–1145) and by Goldich, Elms, and Seward (1949, p. 67). They assigned the Pruett to the Eocene and the Duff to the Oligocene. The Tascotal formation, younger than the Duff, may also be of Oligocene age, but the probability that these beds and the overlying Rawls flows are Miocene cannot be dismissed. Fresh-water snails, bone fragments, and plant remains collected on the Tascotal Mesa quadrangle are of no correlative value.

The Buck Hill volcanic series is equivalent in part to the Chisos beds (Udden, 1907b) in the Big Bend National Park area, the Square Peak volcanic series (Huffington, 1943, p. 1027) in the Quitman Mountains, the McCutcheon series in the Barilla Mountains (Eifler, 1951, p. 342), and the Vieja series (Vaughan, 1900, p. 77) in the Tierra Vieja Mountains.

QUATERNARY SYSTEM

The Quaternary deposits are divided into gravel and alluvium. The gravel deposits are thin veneers on pediments and channel and basin fills at higher levels above the present base level of erosion. The alluvium is valley fill and recent deposits along stream courses.

Gravel is most widespread in Green Valley where it forms thin protective sheets on a pediment which was formed as the scarp of Bandera Mesa retreated. Renewed downcutting has dissected this surface leaving gravel-capped ridges that parallel the present stream courses. These deposits are seldom more than 3–4 feet thick, and all are mapped as gravels, although there is much finer material. Similar pediment gravels are found on Bandera Mesa extending away from the scarp of Tascotal Mesa.

High-level gravels are present on Tascotal Mesa and are conspicuously exposed on the west side of the Marfa-Lajitas road where it ascends the basalt hills. At this locality the gravel clearly represents an old narrow channel deposit and consists chiefly of dark-gray basalt boulders up to 3 feet in diameter. The boulders are cemented with secondary calcium carbonate, caliche, so that the well-indurated rock might easily be mistaken for an older Tertiary conglomerate.

The largest gravel-covered area on the mesa is in the south-central rectangle. These gravels probably were deposited in a shallow structural basin as a result of the erosion of surrounding upthrown fault blocks. The deposit of hard caliche-cemented silt and gravel is being dis-

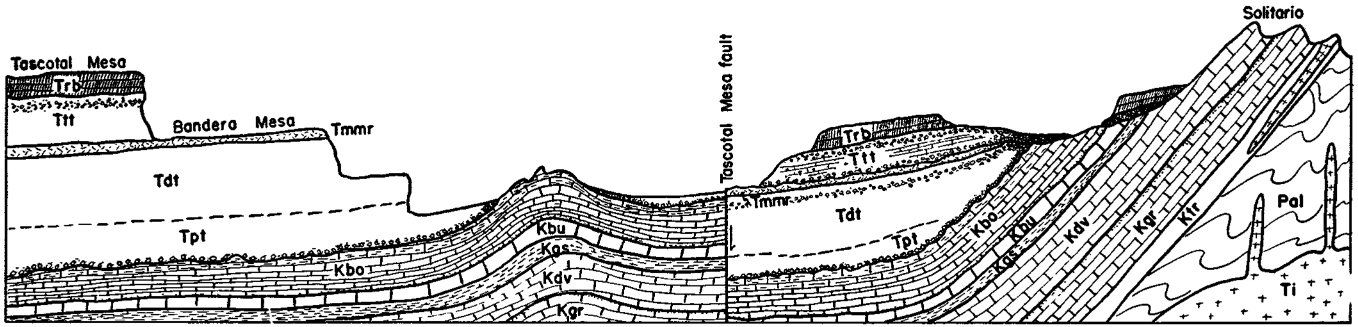

FIGURE 2.—DIAGRAMMATIC CROSS SECTION

Showing stratigraphic relations of Buck Hill volcanic series to Cretaceous rocks on the northeast flank of the Solitario uplift: (Pal) Paleozoic, undifferentiated; (Ktr) Trinity conglomerate and coarse sandstone; (Kgr) Glen Rose limestone; (Kdv) Devils River Limestone; (Kgs) Grayson clay; (Kbu) Buda limestone; (Kbo) Boquillas limestone and calcareous shale; (Tpt) Pruett tuff; (Tdt) Duff tuff; (Tmmr) Mitchell Mesa rhyolite tuff flow; (Ttt) Tascotal tuff; (Trb) Rawls basalt flows.

sected by numerous, small, intermittent tributaries of Torneros Creek.

Alluvial deposits are mapped in Green Valley and in the northwestern part of the quadrangle on Bandera Mesa. The deposits are chiefly fine-grained silty material, and in many places in Green Valley the creeks have well-developed meanders where they flow on this material. Steep-walled banks expose a thickness of as much as 10 feet of alluvium.

The writer often observed the rapid deposition of stream alluvium in the vicinity of the old San Jacinto ranch on Bandera Mesa. During heavy thundershowers torrential streams, carrying a tremendous load of silt and sand, would overflow their banks, spread out in braided pattern, and deposit 2–3 feet of sediment in a few hours. Much of this material was then removed by wind erosion during protracted dry spells.

INTRUSIVE IGNEOUS ROCKS

Rhyolitic Intrusives

The soda rhyolite forming Hill 4778 on the southern border just east of the road leading into the Solitario is the largest silicic intrusive in the quadrangle; it covers about 1 square mile. The body is concordant with Glen Rose limestone on the south, but elsewhere it cuts the limestone, and small apophyses of rhyolite have nearly vertical contacts. The fresh rock is creamy white, fine-grained rhyolite porphyry with glassy feldspar phenocrysts as much as a quarter of an inch in length. The outcrop weathers brown.

In thin section, the analyzed specimen (Table 2, col. 2) is porphyritic with a fine-grained groundmass of feldspar and quartz. The feldspar in the groundmass is orthoclase and silicic plagioclase. The phenocrysts are chiefly anorthoclase. Optical data for the anorthoclase are $\gamma = 1.530 \pm .002$, (-) 2V small to moderate, $X \Lambda a = 10°$. Quartz phenocrysts are less numerous and usually occur in anhedral aggregates. Mafic minerals are restricted to fine shreds largely altered to iron oxides. Kaolinite is a weathering product.

Rhyolite forming Hill 4850, 1½ miles north of the quadrangle border, and the hill just to the northeast, has a dark speckled appearance caused by aggregates of small riebeckite grains. Hill 4850 is about 1 mile in length and rises approximately 600 feet above the surrounding Cretaceous and Tertiary rocks. Upper Tascotal conglomerate and Rawls flows lap against the intrusive mass on the eastern and southern edges. At the north end of the northernmost hill, the intrusive has baked the Boquillas limestone to a hard marble. Rhyolite vitrophyre, exposed on the northwest flank, is probably related to a former vent which served as a zone of weakness for the later emplacement of riebeckite soda rhyolite.

Tascotal Mesa fault cuts through the middle of a riebeckite soda rhyolite mass just west of the Presidio-Brewster county line. A zone of brecciated rhyolite, 20 feet wide, marks the fault. The fine-grained, gray to pink rhyolite at the border of the intrusive grades to coarser-grained, typical riebeckite rhyolite near the top of the hill. The upper Tascotal conglomerate that surrounds the hill laps up on the rhyolite slopes and is younger than the intrusive.

Flows of Rawls basalt surround the riebeckite rhyolite intrusive in the southeast corner of the south-central rectangle and are clearly younger. The rhyolite is variable in color and patchy in appearance. Light-purplish patches contain shreds of a mafic mineral, probably originally riebeckite, that have been oxidized to a reddish brown. Deeper blue areas contain fresh riebeckite. This relation suggests bleaching of the rock as a result of alteration.

On the south edge of the intrusive, rhyolite vitrophyre is closely related to the riebeckite rock, but the precise relations could not be determined. The brown perlitic glass contains euhedral phenocrysts of feldspar and quartz, which constitute about 20 per cent of the rock. Optical data for the anorthoclase follows: $\alpha = 1.524$; $\gamma = 1.530 \pm .002$; (-); $X \Lambda a = 10°$. Spherulites of silicic feldspar are abundant, and there are a few euhedral crystals of aegirin-augite and magnetite. The index of the glass, $1.505 \pm .002$, is similar to that of the glass at Hill 4850 and in La Mota dome.

Thin sections of the riebeckite soda rhyolite from the several intrusives show little variation. The riebeckite is strongly pleochroic from deep lavender blue to dark green to yellow green. The mineral occurs in spongelike dendritic masses and poikilitically includes quartz and feldspar grains. Phenocrysts of anorthoclase range from a maximum of 2 mm. down to sizes only slightly larger than the feldspar in the groundmass. Quartz is restricted to the groundmass in which it is abundant.

Basaltic Intrusives

San Jacinto Mountain, with a relief of approximately 800 feet, is the most imposing intrusive structure in the area; it rises to an altitude of 4750 feet. Most of the mountain including the tall spire is in Jordan Gap quadrangle. It was formed by the intrusion of a fine-grained analcime-olivine trachybasalt that punched up a large block of the Buck Hill volcanics approximately 400 feet above the level of Bandera Mesa. The flanks are Tascotal tuff through which the magma rose, pushing ahead of it a segment of the Duff tuff, Mitchell Mesa tuff flow, and Tascotal tuff.

La Viuda is a small, roughly circular hill, 2 miles southwest of San Jacinto, composed chiefly of basaltic vent agglomerate that cuts the Tascotal tuff beds. The hill is cut by two vertical, highly fractured and weathered dikes at right angles to each other striking N. 60° W. and N. 30° E. The top of La Viuda is composed of agglomerate including large pieces of a dark-gray basalt similar to the dike rock. The vent material is amygdaloidal; fillings are primarily calcite. The rock is an olivine basalt composed of slender labradorite needles with intersertal augite and olivine. Much of the olivine is altered to green serpentine. Apatite and magnetite are accessory, and carbonate is the chief alteration product.

The Dike in Green Valley, just north of Needle Peak, is a fine-grained, black basalt with chilled borders. It trends northeasterly and extends into the Jordan Gap quadrangle making a prominent ridge over a mile long which at some points rises 200–300 feet above the valley floor. It ranges in thickness from a few feet to 20 feet and commonly shows highly polished slickensides. The tuff is baked and indurated to a hard, red rock at the contact.

The dike rock is diabasic and consists of labradorite laths mantled with orthoclase. Subhedral olivine crystals are unusually fresh with minor alteration to green serpentine. Augite is purplish and pleochroic. Analcime is intersertal to the plagioclase laths; magnetite is abundant. This rock is analcime olivine trachybasalt, similar in composition to the San Jacinto intrusive.

Near the southeastern end of Bandera Mesa, a small volcanic vent cuts the Duff tuff and is exposed in the scarp of the mesa. The rock is a dark, reddish-brown, vesicular and scoriaceous agglomerate with vertical scarps up to 100 feet in height. On the east side of the vent, and near the base, a huge boulder of black basalt, approximately 30 feet across and 20 feet high, is included in the agglomerate. This rock is olivine basalt with a microporphyritic texture. Labradorite laths (An_{60}) show flow structure. The plagioclase phenocrysts contain inclusions of magnetite, serpentine, and tiny rods of pyroxene. Much of the olivine is altered to a greenish-brown serpentine. Small shreds of brown biotite, associated with magnetite and serpentine, are deuteric.

A smaller basaltic vent area crops out just south of the rhyolite body cut by the Tascotal Mesa fault. The exposure is about 200 feet wide and 300 feet long. The rock is a brecciated mass of vesicular and amygdaloidal material. Some of the blocks are 8 feet long. The vent cuts upper Tascotal thin-bedded, clayey, fresh-water limestone, and a light-green, soapy bentonite is formed along the contact. The basalt dike west of the vent cuts flows of the Rawls basalt.

Olivine basalt forms a small hill just west of Hill 4850, 1½ miles north of the south boundary. This small, circular, pluglike mass with well-developed columnar jointing intrudes Boquillas limestone and is overlain by the upper Tascotal conglomerate. The Boquillas is baked to a hard marble.

Syenitic Intrusives

A syenite dike northeast of the Wilson ranch house in Green Valley forms Needle Peak, a prominent curved ridge extending northwestward for approximately 1 mile. Differential erosion has produced sharp pinnacles, the highest of which rises 500 feet above the floor of the valley and gives the mass its name. The dike, ranging in thickness from 1 foot at the southern end to 300 feet at the northern end, has baked and hardened the intruded Duff tuff at the contacts. The indurated tuff is resistant to weathering and forms a thin, wall-like sheath around the dike. Slickensides are well developed within the dike rock and at the contact with tuff.

The Needle Peak dike is an alkalic microsyenite. Silicic feldspar makes up 75 to 85 per cent of the rock. The mafic minerals are fine-grained alkalic pyroxene and amphibole that were not specifically identified, and pale biotite.

Southeast of the Cotter ranch, a small dike, forming a vertical wall 1–15 feet high, extends southeast into the Agua Fria quadrangle. It probably extends to the northwest in the subsurface and connects with the syenite dike that intersects The Dike just to the north on Jordan Gap quadrangle. The southeastern tip of this dike is in Tascotal Mesa quadrangle. The rock, altered to a uniform brown, is fine-grained and diabasic with well-developed flow lines. The plagioclase laths (oligoclase near andesine) are mantled with orthoclase. Magnetite and mafic silicates in large part have been oxidized to hematite, but biotite is fresh and unaltered. A deep reddish-brown mineral may be serpentinous alteration after iron-rich olivine. Abundant calcite encloses and partly replaces the feldspar. A fine-grained clay mineral belongs to the montmorillonite group. Magnetite and needlelike crystals of apatite are accessory. This dike is classified as plagioclase microsyenite or latite.

A greenish-gray dike rock with biotite phenocrysts cuts the Duff tuff about half a mile south of the mouth of North Canyon near the base of the scarp of Bandera Mesa. The weathered rock is brown and contains much limonite. The dike, ranging from a few feet to 15 feet thick, makes a vertical east-west wall, 200 yards long. Baked red tuff adheres to the walls and has highly polished slickensides. The rock is very similar to the plagioclase microsyenite described above.

Near the southern end of Bandera Mesa along the Brewster-Presidio county line, fine-grained microsyenite intrudes the Mitchell Mesa tuff flow forming Hill 4718 and the smaller hill to the north. The outcrop shows columnar jointing which has localized weathering. Hill 4718 is capped with a 10-foot thick remnant of Mitchell Mesa tuff flow that was carried upward by the intruding magma to its present position, 200 feet above the level of Bandera Mesa. This structure is comparable to the trapdoor domes described by Moon (1953, p. 185) in Agua Fria quadrangle. The rock is alkalic microsyenite and in thin section consists of about 90 per cent silicic feldspar in small bundlelike aggregates of laths with well-developed flow structure. Mafic minerals are small shreds of brown biotite and minor amphibole. Magnetite and apatite are accessory.

Syenitic intrusives occur in the small basin formed by erosion of the dome west of La Mota Mountain. The main syenite mass at the south and north peaks in the basin is light colored and medium-grained with small hornblende crystals up to an eighth of an inch in length. On the surface the rock is pock-marked due to weathering and removal of hornblende crystals. The effect of contact metamorphism and soaking of the country rock by the syenite magma is well exhibited in the flanks of the south peak. Sandy, calcareous tuff and conglomerate have been altered to hard, dark-green marble and silicate rock which resembles diorite or gabbro in the hand specimen. The highly metamorphosed contact zone grades to bluish-green, light-colored marble and marbleized conglomerate and finally to unaltered sediments and pyroclastics. The conglomerate at the north peak has not been so intensely altered but is baked and hardened.

The two peaks are connected by a microsyenite dike which continues to the southwest into Shafter quadrangle cutting the Rawls basalt flows. The rock is light grayish green with miarolitic cavities in 3- to 4-inch bands parallel to the trend of the dike. The intruded tuffs and conglomerates are baked and adhere to the dike rock.

Numerous other microsyenite dikes occur in the southwestern part of the quadrangle and appear to radiate from a high, rugged region 4–5 miles southwest of the quadrangle.

In thin section, the analyzed specimen (Table 4, col. 2) from the La Mota dome is an alkalic microsyenite with a hypautomorphic-granular texture. The feldspar, 70–80 per cent, is anorthoclase and albite. The most abundant mafic mineral, 10 per cent, is aegirin-augite. Soda-rich amphibole, probably arfvedsonite, is present in minor amounts. Tiny shreds of a purple-brown strongly pleochroic mineral have not been identified. Apatite is accessory.

In some specimens the dark-green aegirin-augite is altering to greenish-brown hornblende. Some of the larger grains of hornblende contain feldspar inclusions. Magnetite crystallized late in the interstices of the feldspar grains, and hematite and carbonate are alteration products.

Gabbro of La Mota Dome

Two small hills of dark-gray, medium-grained gabbro at the north end of La Mota dome are roughly circular and about 100 feet in diameter. Green to black rhyolitic obsidian is associated with the gabbro, but the relations could not be determined.

Thin sections of the analyzed specimen from La Mota dome (Table 4, col. 1) show a medium-grained, hypautomorphic-granular texture. Labradorite (An_{60}), 50–60 per cent, is mantled with orthoclase. Fresh, euhedral olivine with some green serpentinous alteration, probably antigorite, and augite in small subhedral to euhedral crystals each make up about 10 per cent of the rock. Magnetite-ilmenite is abundant. Analcime is intersertal to feldspar in the groundmass and forms euhedral crystals on the borders of zeolite patches. Other secondary minerals are calcite and kaolin. This rock is an analcime-olivine syenogabbro.

CHEMISTRY AND PETROLOGY

Extrusive Rhyolitic Rocks

Rhyolitic glass and its alteration products are the major constituents of the tuffaceous sediments that make up the bulk of the Buck Hill volcanic series. The refractive index of the glass is consistently below 1.50, indicating a silica content in excess of 70 per cent. The tuffs, however, have an admixture of other materials and grade to sandstone, conglomerate, and fresh-water limestone. The sand admixture is particularly evident in the Tascotal formation. Variability in composition under these conditions is to be expected, and samples of the tuff beds in the Tascotal Mesa quadrangle were not chemically analyzed.

The original analysis (Goldich and Elms, 1949, p. 1162) of a sample of the Mitchell Mesa tuff flow from Mitchell Mesa is included in Table 2. Two unpublished analyses of samples from the Jordan Gap quadrangle are plotted in the variation diagram (Fig. 4) and illustrate the potassic character of the rhyolitic tuff flow.

A number of features indicate that the Mitchell Mesa rock is not a typical rhyolitic lava. Wherever the top and the base of the rock have been examined there is a marked absence of vesiculation or brecciation. The upper surface is irregular, and undoubtedly some material has been eroded; nevertheless, the apparent uniformity from top to bottom in numerous exposures is striking. Inclusions of foreign rock have been noted in many places, but the pieces are relatively small and rare.

The presence of glass shards and pumiceous pieces suggests a fragmental rock. Rocks of similar composition and structure have been variously described as welded tuffs (Mansfield and Ross, 1935; Gilbert, 1938), ignimbrites (Marshall, 1935), and tuff flows (Fenner, 1923, 1948). Such rocks are thought to be indurated by recrystallization through pneumatolytic action, and the origin of the Mitchell Mesa rhyolitic tuff flow is ascribed to a similar process. The pumiceous inclusions and the columnar structure are characters which the Mitchell Mesa rock has in common with the tuff flows described by Fenner.

Recrystallized tuff flow may grade from a well-indurated rock to types in which the fragments have been little altered, so that they are more tufflike but are still sufficiently coherent to maintain vertical walls. The writer believes that this explains the soft ashy character of the "rhyolite" on the downthrown side of the Tascotal Mesa fault.

Small amounts of vitrophyre are closely associated with what are considered former

TABLE 2.—CHEMICAL ANALYSES OF RHYOLITIC ROCKS

	1	2	3	4	5	6
SiO_2	73.85	73.10	74.72	75.53	76.71	78.83
Al_2O_3	11.43	14.74	14.12	12.26	12.15	9.95
Fe_2O_3	1.42	.49		1.56	.94	1.40
			.38			
FeO	.86	.10		.73	.60	.10
MgO	.05	.05	.19	.07	.18	.16
CaO	.14	.38	.26	.16	.05	.35
Na_2O	4.22	4.44	3.77	5.24	4.73	1.78
K_2O	4.66	5.65	4.57	4.05	3.88	6.34
H_2O+	2.53	.38	.95	.00	.31	.41
H_2O-	.14	.12	.33	.13	.11	.11
CO_2	.01	.09	n.d.	n.d.	n.d.	.27
TiO_2	.12	.18	.12	.10	.09	.20
P_2O_5	.00	.02	.02	.01	.02	.03
MnO	.03	.00	n.d.	n.d.	n.d.	.08
BaO	n.d.	tr.	n.d.	n.d.	n.d.	tr.
F	.34	n.d.	n.d.	n.d.	n.d.	n.d.
Cl	.20	n.d.	n.d.	n.d.	n.d.	n.d.
	100.00	99.74	99.99*	99.84	99.77	100.01
Less O ≡ F & Cl	.19					
	99.81					

* Includes 0.56 ignition loss (organic matter).

1. Rhyolite vitrophyre from south slope of large riebeckite soda rhyolite intrusive in southeast corner of south-central rectangle of Tascotal Mesa quadrangle, (field No. TM 294). J. J. Engel, analyst.
2. Soda rhyolite from Hill 4778 on southern border of Tascotal Mesa quadrangle (field No. TM 284). J. J. Engel, analyst.
3. Sodipotassic rhyolite, southwest part of Solitario. R. B. Ellestad, analyst (Lonsdale, 1940, Table 17).
4. Paisanitic riebeckite soda rhyolite, Mountain 4500, Terlingua district. R. B. Ellestad, analyst (Lonsdale, 1940, Table 17).
5. Paisanitic riebeckite soda rhyolite, east of Mountain 4500, Terlingua district. R. B. Ellestad, analyst (Lonsdale, 1940, Table 17).
6. Rhyolite tuff-flow capping Mitchell Mesa, Buck Hill quadrangle. S. S. Goldich, analyst (Goldich and Elms, 1949, p. 1162).

pyroclastic vents now occupied by intrusive masses in the southern part of the quadrangle. Pieces of obsidian, limestone, and other rock types are included in tuff and breccia deposits that mark one of these vents well up on the side at the southern end of Hill 4850, a riebeckite soda rhyolite intrusive. Northeast of Hill 4850, on the north side and near the base of a hill of rhyolite, there is a larger outcrop of obsidian. A third exposure of vitrophyre is on the south edge of the riebeckite soda rhyolite intrusive approximately 4 miles to the southwest near the southern boundary, and this rock is represented in Table 2 (col. 1). A small outcrop of rhyolitic glass is in close proximity to the gabbro intrusive in La Mota dome. In each case it appears that the vitrophyre issued from a vent that later was the site of intrusive action.

The chemical analysis of the vitrophyre shows large relative amounts of water, fluorine, and chlorine. It demonstrates that the vents in the southern part of the quadrangle probably are not the source of the Mitchell Mesa tuff-flow. In contrast, the composition of the glass is similar to that of the analyzed specimens of soda rhyolite and riebeckite soda rhyolite (Table 2).

Intrusive Rhyolitic Rocks

Only one specimen of the intrusive rhyolites was analyzed (Table 2, col. 2) and represents

TABLE 3.—CHEMICAL ANALYSES of RAWLS FLOWS

	1	2	3	4
SiO_2	45.86	52.06	60.10	60.36
Al_2O_3	16.52	18.67	17.11	17.69
Fe_2O_3	7.93	5.25	3.35	4.71
FeO	5.03	3.56	2.35	1.36
MgO	4.16	1.97	.97	.79
CaO	8.27	7.07	2.49	1.77
Na_2O	3.83	4.37	5.58	6.34
K_2O	1.66	2.65	5.30	4.89
H_2O+	.86	.54	.32	.32
H_2O-	.74	.69	.18	.14
CO_2	.72	.01	.35	.00
TiO_2	3.43	2.17	1.09	.71
P_2O_5	.56	.71	.35	.32
MnO	.17	.16	.17	.19
BaO	.06	.10	.13	.20
S	.00	.01	.01	.02
	99.80	99.99	99.85	99.81
Less $O \equiv S$				.01
				99.80

1. Basalt (Trb) east of elevation 4307, west-central part of southeast rectangle (field No. 291).
2. Trachybasalt porphyry (Trbp), lower flow at Wire Gap (field No. TM 29).
3. Trachyandesite porphyry (Tra), top of Hill 5184 on rim of Tascotal Mesa (field No. 81).
4. Trachyandesite porphyry, top of La Mota Mountain (field No. 176).

Nos. 1–3, R. L. Erickson, analyst; No. 4, John Thatcher, analyst.

the soda rhyolite at the southern border. The rock is similar in composition to a sodipotassic rhyolite (Table 2, col. 3) described by Lonsdale (1940, p. 1566) from the southwestern part of the Solitario.

The riebeckite soda rhyolite intrusives in the quadrangle, although chemical data are not available, can be expected to be somewhat more sodic than the soda rhyolite and probably will fall within or close to the range indicated in the two analyses (Table 2, cols. 4 and 5) of riebeckite soda rhyolite from the Terlingua district (Lonsdale, 1940, table 17).

Extrusive Basaltic Rocks

The oldest flows in the Tascotal Mesa quadrangle are basalt intercalations in the upper Duff beds and are exposed in the scarp of Bandera Mesa. A possible feeder is the small pluglike mass of basaltic agglomerate at the southeastern end of the mesa. No chemical analyses of these rocks were made.

The term basalt is used as a field name for the fine-grained, dark Rawls flows which range from basalt to trachyandesite. Chemical analyses of the three types of flows differentiated on the map (Pl. 1) are given in Table 3. In the sequence, basalt-trachybasalt-trachyandesite, there is a progressive decrease in the relative amounts of iron oxides, magnesia, lime, and titania, and a progressive increase in silica, alkalis, and baria.

On casual inspection the analyzed basalt flow (Table 3, col. 1) appears similar to the analyzed analcime syenogabbro (Table 5, col. 1) from La Mota dome, but the norms (Table 6) emphasize the difference. The undersaturated La Mota rock contains analcime that *is* represented in the norm in 4.8 per cent of normative nepheline. The Rawls basalt is similar to analyzed samples of the Sheep Canyon basalt flows in the Buck Hill area (Goldich and Elms, 1949, Table 5).

The Rawls flows mapped as trachybasalt porphyry are variable in composition as is indicated in the petrographic description. The single analysis (Table 3, col. 2) of the lowermost flow at Wire Gap sets it off from the analyzed samples of the basalt and the trachyandesite flows, but additional analyses of selected samples would probably show compositions approaching that of the trachyandesite.

The two analyzed samples of the trachyandesite porphyry flows (Table 3, cols. 3 and 4) suggest a high degree of uniformity in composition. Sample No. 3 represents the flow capping Hill 5184 on the rim of Tascotal Mesa where a thickness of 125 feet of trachyandesite flows was measured. Sample No. 4 is from the flow capping La Mota Mountain, 9 miles to the southwest, where the trachyandesite flows are 356 feet thick.

The differences in composition of the Rawls flows may be in part a progressive change resuiting from some process of magmatic differentiation; however, the field work shows that the basalt and the trachybasalt porphyry flows alternate and were extravasated from different sources.

TABLE 4.—CHEMICAL ANALYSES OF SYENOGABBRO, MICROSYENITE, AND PLAGIOCLASE SYENITE

	1	2	3
SiO_2	45.98	62.35	51.08
Al_2O_3	16.83	17.37	17.61
Fe_2O_3	3.45	3.48	3.62
FeO	8.94	1.62	.89
MgO	5.12	.31	.72
CaO	6.76	1.41	8.79
Na_2O	4.49	6.43	5.30
K_2O	1.79	5.38	3.66
H_2O+	1.90	.31	.65
H_2O-	.28	.32	.34
CO_2	.19	.00	3.67
TiO_2	3.41	.38	1.52
P_2O_5	.57	.13	1.35
MnO	.16	.14	.12
SrO	n.d.	n.d.	.11
BaO	.05	.04	.24
S	.04	.00	.00
SO_3	n.d.	n.d.	.12
	99.96	99.67	99.79
Less $O \equiv S$	.02		
	99.94		

1. Analcime syenogabbro from La Mota dome (field No. TM 319). J. J. Engel, analyst.
2. Alkalic microsyenite from La Mota dome (field No. TM 317). J. J. Engel, analyst.
3. Plagioclase syenite dike on east border of quadrangle, 1 mile southeast of Cotter ranch. Sample from northeast end of dike. Eileen H. Oslund, analyst.

Intrusive Basaltic Rocks

A chemical analysis of the medium-grained analcime syenogabbro from La Mota dome is given in Table 4. The relative coarse grain of the gabbro in the La Mota dome suggests that the exposure may be part of a large mass. None of the dikes or pluglike masses of basalt have been analyzed.

Intrusive Syenitic Rocks

The chemical analysis of the intrusive microsyenite in La Mota dome (Table 4, col. 2) is similar to analyzed samples of microsyenite from Buck Hill (Goldich and Elms, 1949, p. 1166) and from Santiago Peak (Clarke, 1904, p. 75).

TABLE 5.—CHEMICAL ANALYSES OF INDURATED AND PARTIALLY FUSED TUFF-BRECCIA BED BETWEEN FLOWS OF RAWLS BASALT

	1	2
SiO_2	69.55	64.66
Al_2O_3	12.28	15.80
Fe_2O_3	4.42	4.62
FeO	.08	.48
MgO	.63	.45
CaO	1.79	1.15
Na_2O	3.08	5.30
K_2O	4.09	5.71
H_2O+	1.25	.42
H_2O-	2.04	.37
CO_2	.04	.07
TiO_2	.69	.68
P_2O_5	.18	.13
MnO	.11	.18
	100.23	100.02

1. Indurated tuff breccia near base of bed resting on Rawls basalt (Trb), half a mile southwest of BM 4224, southwest rectangle (field No. TM 292). S. S. Goldich, analyst.
2. Partially fused tuff breccia, 2 feet above sample No. 1 (field No. 290). R. L. Erickson, analyst.

The unusual composition (Table 4, col. 3) of the dike of plagioclase syenite on the eastern border southeast of the Cotter ranch, is not closely matched in any published analyses of rocks from southern Trans-Pecos Texas. Two analyses of somewhat similar composition represent analcime-plagioclase syenite from the Terlingua district and analcimitic microsyenite from the Solitario (Lonsdale, 1940, Table 17). The Tascotal Mesa dike rock contains a large amount of calcite which may have formed in part from original analcime.

The plagioclase syenite differs from the microsyenite of La Mota dome not only in its

TABLE 6.—CHEMICAL ANALYSES of TASCOTAL MESA ROCKS AND NORMS OF IGNEOUS ROCKS
Analysts: Nos. 1, 4, 5, 11, R. L. Erickson; Nos. 2, 7, 8, 9, J. J. Engel; No. 3, Eileen H. Oslund; No. 6, John Thatcher; No. 10, S. S. Goldich

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	45.86	45.98	51.08	52.06	60.10	60.36	62.35	73.10	73.85	69.55	64.66
Al_2O_3	16.52	16.83	17.61	18.67	17.11	17.69	17.37	14.74	11.43	12.28	15.80
Fe_2O_3	7.93	3.45	3.62	5.25	3.35	4.71	3.48	.49	1.42	4.42	4.62
FeO	5.03	8.94	.89	3.56	2.35	1.36	1.62	.10	.86	.08	.48
MgO	4.16	5.12	.72	1.97	.97	.79	.31	.05	.05	.63	.45
CaO	8.27	6.76	8.79	7.07	2.49	1.77	1.41	.38	.14	1.79	1.15
Na_2O	3.83	4.49	5.30	4.37	5.58	6.34	6.43	4.44	4.22	3.08	5.30
K_2O	1.66	1.79	3.66	2.65	5.30	4.89	5.38	5.65	4.66	4.09	5.71
H_2O+	.86	1.90	.65	.54	.32	.32	.31	.38	2.53	1.25	.42
H_2O-	.74	.28	.34	.69	.18	.14	.32	.12	.14	2.04	.37
CO_2	.72	.19	3.67	.01	.35	.00	.00	.09	.01	.04	.07
TiO_2	3.43	3.41	1.52	2.17	1.09	.71	.38	.18	.12	.69	.68
P_2O_5	.56	.57	1.35	.71	.35	.32	.13	.02	.00	.18	.13
MnO	.17	.16	.12	.16	.17	.19	.14	.00	.03	.11	.18
SrO	n.d.	n.d.	.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
BaO	.06	.05	.24	.10	.13	.20	.04	tr.	tr.	n.d.	n.d.
S	.00	.04	—	.01	.01	.02	.00	.01	n.d.	n.d.	n.d.
SO_3	—	—	.12	—	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
F	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	.34	n.d.	n.d.
Cl	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	.20	n.d.	n.d.
	99.80	99.96	99.79	99.99	99.85	99.81	99.67	99.75	100.00	100.23	100.02
Less O ≡ S		.02				.01					
Less O ≡ Cl									.04		
Less O ≡ F									.15		
	99.80	99.94	99.79	99.99	99.85	99.80	99.67	99.75	99.81	100.23	100.02
Q				2.22	3.00	.66	1.98	24.68	32.97		
or	10.01	10.56	22.09	15.57	31.14	28.94	31.72	33.39	27.27		
ab	32.49	28.82	44.57	36.68	47.16	53.48	54.52	37.75	33.03		
an	22.80	20.57	13.07	23.63	6.12	5.56	2.50	1.95	.46		
ne	—	4.83	—	—	—	—	—	—	—		
di	7.99	6.80	—	5.18	1.73	1.08	1.79	—	.25		
wo	—	—	—	—	—	—	.58	—	—		
hy	2.50	—	.60	2.50	2.11	2.01	—	—	.40		
ol	2.94	8.77	.84	—	—	—	—	—	—		
mt	6.73	5.10	—	5.57	4.87	3.01	4.40	—	1.85		
hm	3.36	—	3.67	1.44	—	2.71	.48	.48	—		
il	6.54	6.54	2.13	4.10	2.13	1.37	.76	—	—		
ru	—	—	.40	—	—	—	—	.16	—		
co	—	—	.20	—	—	—	—	.61	—		
ac	—	—	—	—	—	—	—	.46	—		
ap	1.34	1.34	3.02	1.68	.67	.67	.34	—	—		
cc	1.60	.40	8.31	—	.80	—	—	—	—		
hl	—	—	—	—	—	—	—	—	.35		
f	—	—	—	—	—	—	—	—	.31		

1. Rawls basalt flow (Trb); 2. La Mota gabbro; 3. Plagioclase syenite southeast of Cotter Ranch house; 4. Rawls trachybasalt porphyry (Trbp); Wire Gap; 5. Trachyandesite (Tra), from Hill 5184; 6. Trachyandesite (Tra), top of La Mota Mountain; 7. La Mota syenite; 8. Soda rhyolite from Hill 4778; 9. Rhyolite vitrophyre from Hill 4850; 10. Tuff-breccia, half a mile southeast of BM 4224; 11. Fused tuff-breccia, 2 feet above sample No. 10.

greater content of CaO but also in greater relative amounts of TiO_2, P_2O_5, and BaO. Both rocks show some similarity to the analyzed samples of the Rawls flows, but their relationship to the extrusives is speculative.

Welded Tuff and Breccia

Chemical analyses of two samples selected from near the base and from near the top of a 3-foot bed of tuff breccia between flows of the Rawls basalt are given in Table 5.

The origin of the welded tuff and breccia beds between the Rawls flows is problematical. Because the well-indurated breccia is as much as 74 feet thick, it is improbable that the induration or welding of the rock can be attributed solely to the baking action of the hot lava that covered it. Possibly the material was very hot at the time of eruption and retained sufficient heat to effect the welding.

Variation Diagram

The chemical analyses made for this study are brought together in Table 6 which also contains the norms calculated for the igneous rocks. The analyses of the igneous rocks together with published analyses of rocks from the Terlingua-Solitario region (Lonsdale, 1940, Table 17) and from the Buck Hill area (Goldich and Elms, 1949, Table 10) and eight unpublished analyses of rocks from the Jordan Gap quadrangle are plotted in a silica-variation diagram (Fig. 3). The curves representing the variations of constituents are similar to the earlier curves presented and discussed by Goldich and Elms (1949, Fig. S).

STRUCTURAL GEOLOGY

Regional Setting

The major structural features of Trans-Pecos Texas have been discussed by Baker (1934, p. 137) and King (1935) and are shown in Figure 4 reproduced from the Structural Map of Texas (Sellards and Hendricks, 1946). The structural history starts with the pre-Cretaceous deformation of the Llanoria geosyncline (King, 1935, fig. 2) and with the development of the northeast-southwest trends in the Paleozoic rocks which are now exposed in the Marathon and Solitario uplifts.

The Cretaceous strata which were deposited on the eroded surface of the Paleozoic rocks were folded in an orogeny (Laramide) which probably began in late Cretaceous time and produced an ancestral range of the present Del Norte-Santiago-Carmen Mountains. West of this range or highland, downwarping formed the Marfa basin (Fig. 4), in which Tertiary volcanic and related rocks accumulated. The Solitario dome was initiated at this time, and probably also the Marathon dome. The folded Cretaceous rocks were eroded and contributed to the lower beds of the Buck Hill volcanic series. The basal Pruett conglomerate rests on the Boquillas limestone (Eagle Ford age) in the Buck Hill quadrangle and on successively younger Cretaceous formations to the south.

Following the accumulation of the Buck Hill volcanic series, 4000–5000 feet thick, in the Green Valley region, deformation in late Cenozoic time resulted from compressive forces which acted on the structural downwarp to produce an upwarp or broad fold in the Tertiary beds. The southwest dip of the Buck Hill volcanic series in the northern two-thirds of the Tascotal Mesa quadrangle is the result of this folding, and these beds form the southwest limb of a large anticlinal structure. The northern part of this structure has been mapped in the Jordan Gap and Buck Hill quadrangle by Goldich and Seward (1948) and Goldich, Elms, and Seward (1949).

Northern Part of Quadrangle

The northern two-thirds of the Tascotal Mesa quadrangle is characterized by the regional dip of 2°–4° S.W. The dip is somewhat steepened along the western boundary, and in the vicinity of Torneros Creek, where the dips are as much as 11°, the steeper inclination of the beds is caused by the Tascotal Mesa fault. A series of parallel normal faults, with small displacement, on Bandera Mesa trends southeast from San Jacinto Mountain. The two most prominent faults are 3 miles long and form a small graben half a mile wide. The displace-

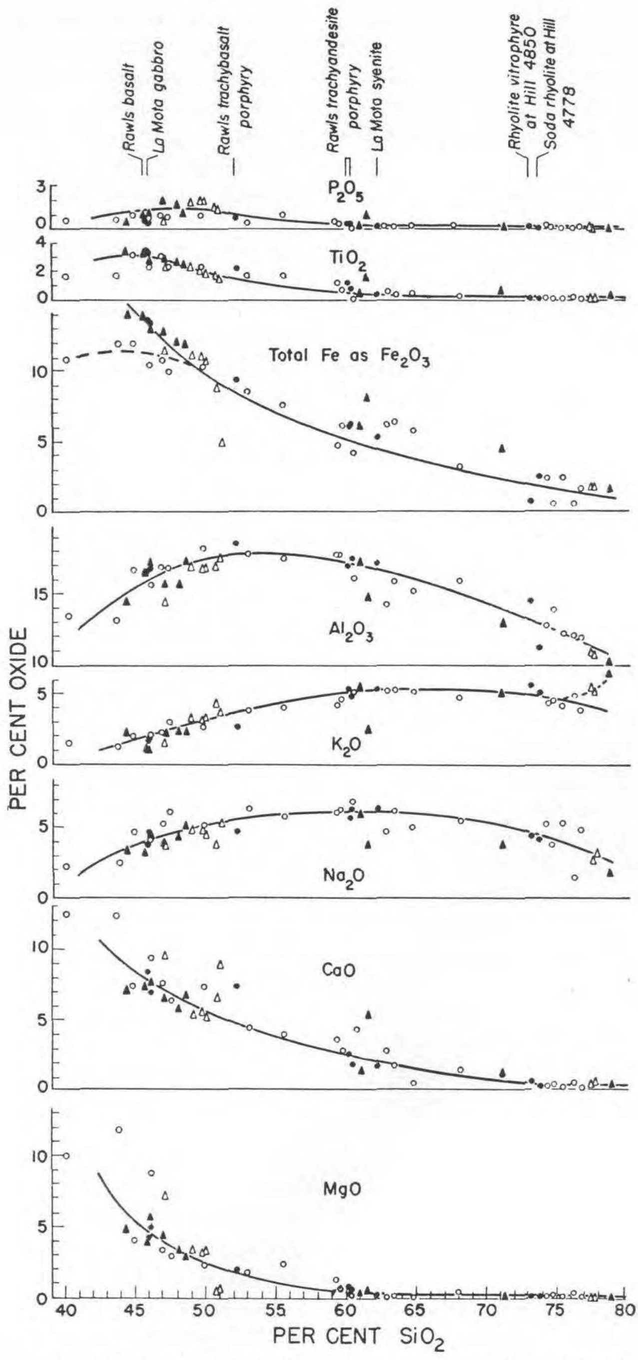

FIGURE 3.—VARIATION DIAGRAM OF IGNEOUS ROCKS FROM THE TASCOTAL MESA QUADRANGLE AND ADJACENT AREAS

Dots represent rocks from the Tascotal Mesa quadrangle; circles, Terlingua-Solitario region (Lonsdale, 1940); solid triangles, Buck Hill area (Goldich and Elms, 1949); open triangles, unpublished analyses of rocks from the Jordan Gap quadrangle.

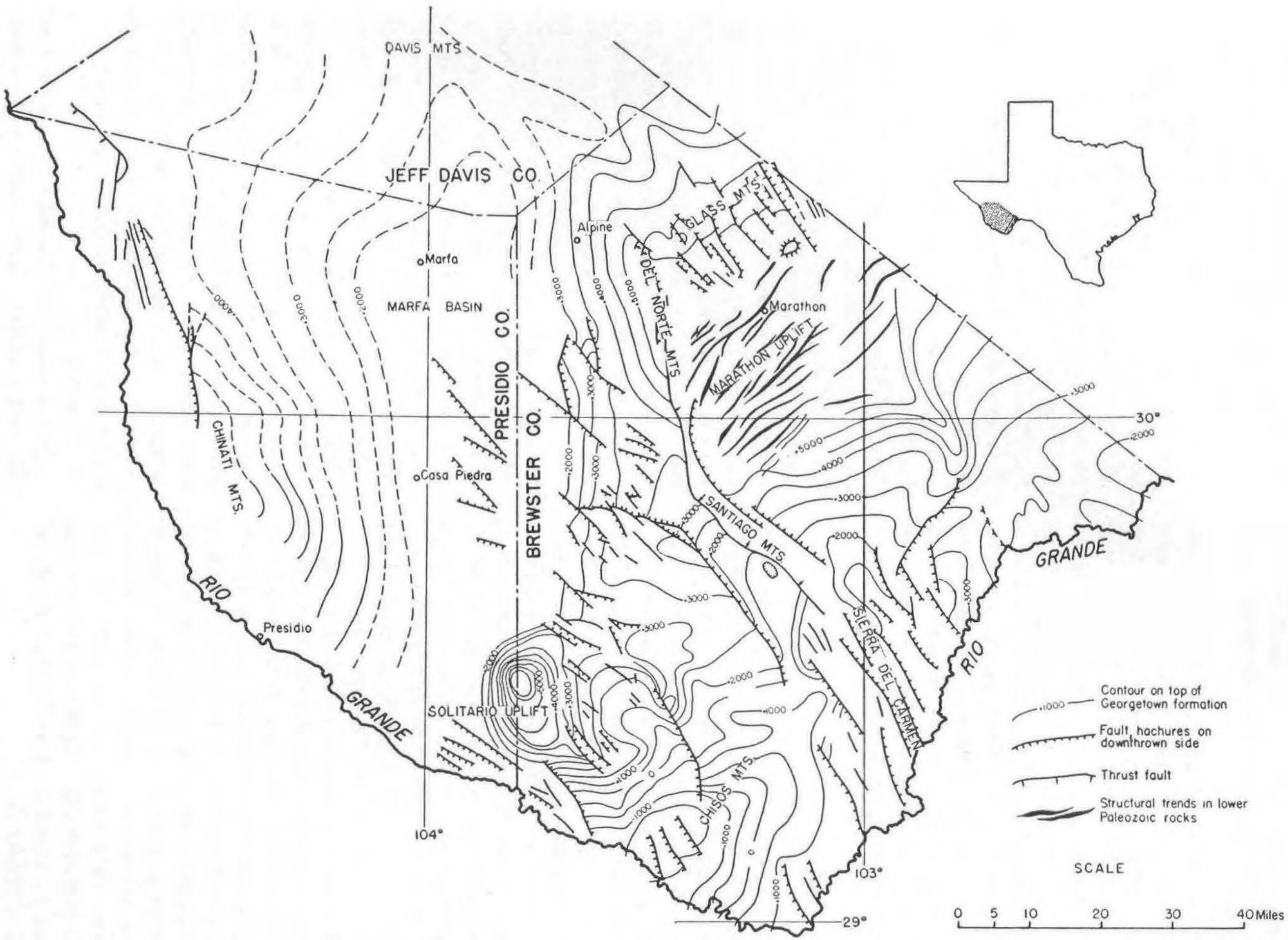

FIGURE 4.—STRUCTURE OF SOUTHERN TRANS-PECOS TEXAS

From Structural Map of Texas, 3rd ed. by E. H. Sellards and Leo Hendricks, Bureau of Economic Geology, The University of Texas, 1946.

ment is measured in tens of feet. These normal faults are thought to be the result of adjustments accompanying and following the folding, and undoubtedly similar faults occur in Green Valley where they are not easily recognized in the tuff beds.

The northwest structural trend is also displayed in the syenite dikes at Needle Peak and southeast of the Cotter ranch in Green Valley. In contrast the basalt forming The Dike near the northern boundary trends northeast. Minor structures are the result of igneous intrusives that have pierced the Mitchell Mesa tuff flow on Bandera Mesa. Basalt intrusives formed San Jacinto Mountain and La Viuda. Two small syenitic intrusives cut the tuff flow in the southeastern part of the mesa, and the larger forms a trapdoor structure.

Southern Part of Quadrangle

The southern third of the quadrangle is structurally dominated by the Solitario uplift and the complicated peripheral fault system. Lonsdale (1940, p. 1623) has emphasized the role of igneous action in the development of the Solitario, but certain features of the northeast flank of the uplift indicate that the huge dome has a complicated history with more than a single period of uplift and intrusive activity.

The regional dip of the Cretaceous rocks in the southeastern part of the quadrangle is northward, but the dip slope shows minor folds. A domical structure near the southern boundary is indicated in the reversal of dip (Pl. 1). North of the Tascotal Mesa fault, Hill 3837 near the eastern boundary, a dome in the Boquillas formation, was dissected prior to the deposition of the basal Pruett conglomerate. This structure is believed to date back to the Laramide orogeny. In contrast, the domical structure in the Boquillas south of the Holland-Meriwether ranch house is definitely younger and is related to intrusive action in later Tertiary time which can be dated as pre-Rawls basalt. Similar rhyolitic intrusives near by can be dated as post-Mitchell Mesa tuff flow and pre-Rawls.

The largest normal fault is the Tascotal Mesa fault which traverses the quadrangle and extends beyond its boundaries. This fault was mapped and named by Moon in the Agua Fria quadrangle to the east. The Tascotal Mesa fault is a scissor fault with the pivotal area covered by gravel in the central part of the south-central rectangle where the displacement in the Rawls flows is considered relatively small. Westward, the north side is downdropped, and a maximum displacement of 500–700 feet is attained near the west boundary. To the east, the south side is downdropped, and the Mitchell Mesa tuff flow capped by the upper conglomerate-fresh-water limestone facies of the Tascotal is in juxtaposition with the Pruett-Duff beds. The displacement near the east boundary may be of the order of 800 feet.

North of the Tascotal Mesa fault a large fault sets off the basalt hills on the south from Bandera Mesa on the north. The fault is crossed by the Marfa and Lajitas road at a point half a mile south of BM 4207. West of the road a shear zone, 2 feet wide, is filled with calcite. East of the road the displacement on the fault may be as much as 200 feet, but the throw diminishes northwestward, and the fault dies out near Hill 4944.

The area south of the Tascotal Mesa fault is cut into numerous blocks by complicated faults that are best explained as local adjustments to differential movement between the Solitario complex on the south and the gently folded Buck Hill volcanic series on the north. The Solitario fault, mapped and named by Moon in the Agua Fria quadrangle, is half a mile south of and roughly parallel to the Tascotal Mesa fault. It is a strike fault with the principal displacement parallel to the steeply dipping beds of the Boquillas.

Moon estimated that the stratigraphic displacement on the Solitario fault in the Aqua Fria quadrangle is about 2200 feet, but interpretation of the relations in the Tascotal Mesa area, based on the thinning of the Buck Hill volcanic rocks against the Solitario uplift, rules out any displacement of this magnitude and favors a displacement of the order of a few hundred feet.

Just south of the Tascotal Mesa fault near the west boundary, igneous action has domed the volcanic rocks. Farther south, northward dips as high as 20° in the Rawls basalt are the result of a large dome that lies just south of the quadrangle.

SUMMARY GEOLOGIC HISTORY

The field evidence seems conclusive that the Solitario uplift south of the quadrangle was initiated in late Cretaceous time (Laramide) and was gradually rising during the deposition of the Buck Hill volcanic series.

Igneous rocks are absent or scarce in the basal Pruett conglomerate. If, as earlier writers have suggested, the Solitario was domed up by a large intrusive, this intrusion must have been at depth, and igneous rocks in appreciable quantity did not reach the surface. However, the possibility that the initial stage in the development of the Solitario was a wholly structural deformation unrelated to igneous intrusion cannot be dismissed. In contrast with the basal Pruett conglomerate, the conglomerates in the Duff and Tascotal formations contain a variety of igneous types, and in many areas certain cobbles and boulders can be traced to near-by igneous masses, and so date the intrusives.

The Buck Hill volcanic series thins and wedges against the flank of the Solitario uplift. The wedging is accompanied by pronounced changes in lithologic characters. As the tuff beds in the Green Valley area are traced southward they interfinger and merge with lentils of coarse conglomerates and fresh-water limestone beds that were derived by erosion and weathering of the Solitario complex. The tuff beds in the Tascotal Mesa quadrangle commonly are calcareous due to the available source of carbonate in the exposed Cretaceous formations. Local ponding explains the fresh-water limestone beds in the Duff and in the Tascotal. Farther north, in the northern parts of the Buck Hill and Jordan Gap quadrangles which were relatively removed from exposed Cretaceous rocks, the Duff contains little calcium carbonate (Goldich and Elms, 1949, p. 1160).

The accumulation of the thick succession of Tertiary tuff beds and related sediments was not continuous and the tuff locally was eroded as is indicated by the scour-and-fill structure at the base of the thick bed of conglomerate in the upper part of the Duff formation. In the upper Duff beds, in the scarp of Bandera Mesa, are also found the first or oldest basalt flows exposed in the quadrangle. These flows were followed shortly by the extrusion of the Mitchell Mesa tuff flow. Light-colored sandy tuff beds were deposited on the eroded hummocky surface of the tuff flow over most of the northern two-thirds of the quadrangle, although locally conglomerate beds mark the base of the Tascotal formation.

The most southerly remnant of the Mitchell Mesa tuff flow is west of Hill 4850, 1½ miles north of the south boundary. The tuff flow probably extended south of this point originally, but it was removed by vigorous erosion that followed a period of uplift and intrusion during which the rhyolitic masses in the southeastern part of the quadrangle were emplaced. One small remnant of the beds that rested on the Mitchell Mesa tuff at the time the rhyolite was intruded is mapped on the southern end of Hill 4850 at an altitude of 4700 feet.

The tuff and breccia into which the rhyolite magma was intruded was easily and quickly eroded. The rugged topography was favorable for the accumulation of local coarse conglomerates to which the high peaks of rhyolite contributed heavily. By this time, the Solitario dome had been breached and eroded extensively so that the Paleozoic formations supplied material that was transported northward and incorporated in the upper Tascotal conglomerate. Large, angular to subrounded boulders of Caballos novaculite and black chert suggestive of the Maravillas formation are conspicuous in the conglomerate.

The upper sandstone and conglomerate beds of the Tascotal formation are succeeded by the flows of the Rawls basalt. The flows overrode the conglomerate at the southern edge of the quadrangle and came to rest on the upturned and eroded Devils River limestone. Basaltic intrusives such as San Jacinto and La Viuda in the north and the two small plugs and dike in the southeastern part of the area may be related to the flows, but the main bulk of the lavas, the trachybasalt porphyry and the trachyandesite porphyry flows, appear to have moved into the quadrangle from the southwest.

A later period of intrusive activity followed the extrusion of the Rawls lavas, and syenitic dikes cut the flows in the southwest corner in the La Mota area. Possibly the syenitic dikes in Green Valley and the small plug on Bandera

Mesa are related to this period of activity, but there is no way of correlating the intrusives.

The Buck Hill volcanic series was folded, probably in late Tertiary time when the northwest structural trends were developed in Trans-Pecos Texas. The folding was accompanied by regional uplift, and large-scale faulting resulted. Minor faults in the northern part of the area trend northwest and are closely related to the axis of folding. The major faulting in the southern part is believed to be due to differential movements in which the Solitario complex acted, more or less, as a positive structural element about which a complicated fault pattern was developed.

Volcanic extrusives younger than the Rawls flows do not occur in the quadrangle, and search for such rocks is best directed to the region to the southwest. Younger sediments include gravels and other alluvial deposits. Gravel-capped pediments occur at different levels, and in Green Valley the older pediments are now being actively eroded.

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