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THE TEXAS LINEAMENT

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the Chihuahua Tectonic
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p. 15-23

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The University of Texas at Austin

INTRODUCTION

The Texas lineament, has been a bone of contention (or a zone of controversy) since it was first suggested by R. T. Hill in 1902.

It seems clear that, in their discussions of the Texas lineament, Hill (1902, 1928), Ransome (1915), and Baker (1927, 1935) were referring to a linear anomaly between more-or-less aligned structural and stratigrphic anomalies of regional significance, which were detactable on the ground and on the small-scale regional geologic and topographic maps available then. They variously described the Texas lineament as a line of faulting, a linear zone of faulting or fracturing, or a linear zone between contrasting geologic provinces, but they never suggested or implied strike-slip movement as the origin of the lineament.

Albritton and Smith (1957), in a masterful review of the subject, restated Baker's (1935) concept of the lineament in terms of a broad, eastward continuation of the Murray fracture zone. Their illustration (Fig. 4, p. 511) shows a 60- to 90-mile-wide zone extending eastward from the Transverse Ranges of California along the southern base of the Colorado Plateau to Trans-Pecos Texas as constituting the lineament. In accord with stratigraphic practice, they also proposed a type locality: " . . . the segment of about 55 miles in length which runs along the corridor of Eagle Flat." This topographic corridor extends from about 10 miles south of Van Horn, Texas, N.60° W. through Sierra Blanca and for another 20 miles beyond toward El Paso. It separates two regions having strongly contrasting geologic history: the Diablo platform to the north and the Chihuahua trough to the south (Fig. 1).

REGIONAL TECTONIC SETTING

Along the north side of Eagle Flat, the Carrizo Mountain Formation in the upper plate of the Streeruwitz thrust fault, was thrust northward over the younger Allamoore and Hazel Formations which had been deformed and tectonically mixed during Late Precambrian deformation. One margin of the Diablo platform was differentiated along this old boundary late in Paleozoic time and again late in Mesozoic time. The southern border of Eagle Flat and Hueco Bolson marks approximately the maximum northward extent of a Permian or older seaway (Lopez-Ramos, 1969), of thick Cretaceous sedimentation in the Chihuahua trough, the maximum northward transport by thrust faults during Laramide deformation in the Chihuahua tectonic belt, and probably the northern edge of pre-Albian evaporite deposition.

The topographic corridor of Eagle Flat, and probably the topographic corridor of Hueco Bolson as well, satisfy the definition of a lineament: aligned structural and-or stratigraphic anomalies that produce topographic lines. Moreover, this zone of structural and stratigraphic discontinuity is the Texas lineament as originally proposed. The incontrovertible fact of the Texas lineament in Trans-Pecos Texas and the popular hypothesis of its origin by wrench-faulting along the Texas or any other direction must not be confused.

The Hillside fault, the type fault of the Texas direction of wrench-faulting as interpreted by Moody and Hill (1956, p. 1223), extends from Van Horn N.70° W. toward Sierra Blanca where a fault with a slightly more northerly strike continues toward El Paso. These faults, and a presumed near due-east extension to Kent, Texas, constitute the clearest expression of the Texas lineament as described by Baker (1935, p. 207).

Systematic geologic mapping has covered most of the region critical to an evaluation of the type regions for both the Texas lineament and the Texas direction of wrench faulting. Regional gravity and magnetic studies between Sierra Blanca and Van Horn by Wiley (1970) contribute additional data and assists in the delineation of the principal tectonic blocks.

The Hillside fault is exposed or can be inferred for a distance of about 8 miles between Van Horn and Allamoore. P. B. King (1965, p. 115) stated, " . . . the Hillside fault has been ascribed an inordinate role in the tectonics of the region . . ." He showed that along the outcrop of the Hillside fault, the basal Permian Powwow Conglomerate unconformably overlies Van Horn Sandstone and that both are in fault contact with metarhyolite intruded into the Carrizo Mountain Formation. The Powwow contains numerous coarse, angular fragments of metarhyolite near the fault, but northward, the fragments are fewer and less angular. These fragments must have originated from a high-standing Early Permian or Late Pennsylvanian north-facing Hillside fault scarp. Because the metarhyolite fragments in the Powwow are exposed directly adjacent to their probable source, King (1965, p. 115) concluded that no significant strike-slip movement could have occurred along the Hillside fault since Early Permian time and we concur. A post-Lower Cretaceous displacement puts Precambrian metarhyolite on the south against Permian and Cretaceous rocks on the north. The downthrow to the north, according to King, is as much as 1,000 feet and possibly more.

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[1] Present address: The Atlantic-Richfield Company

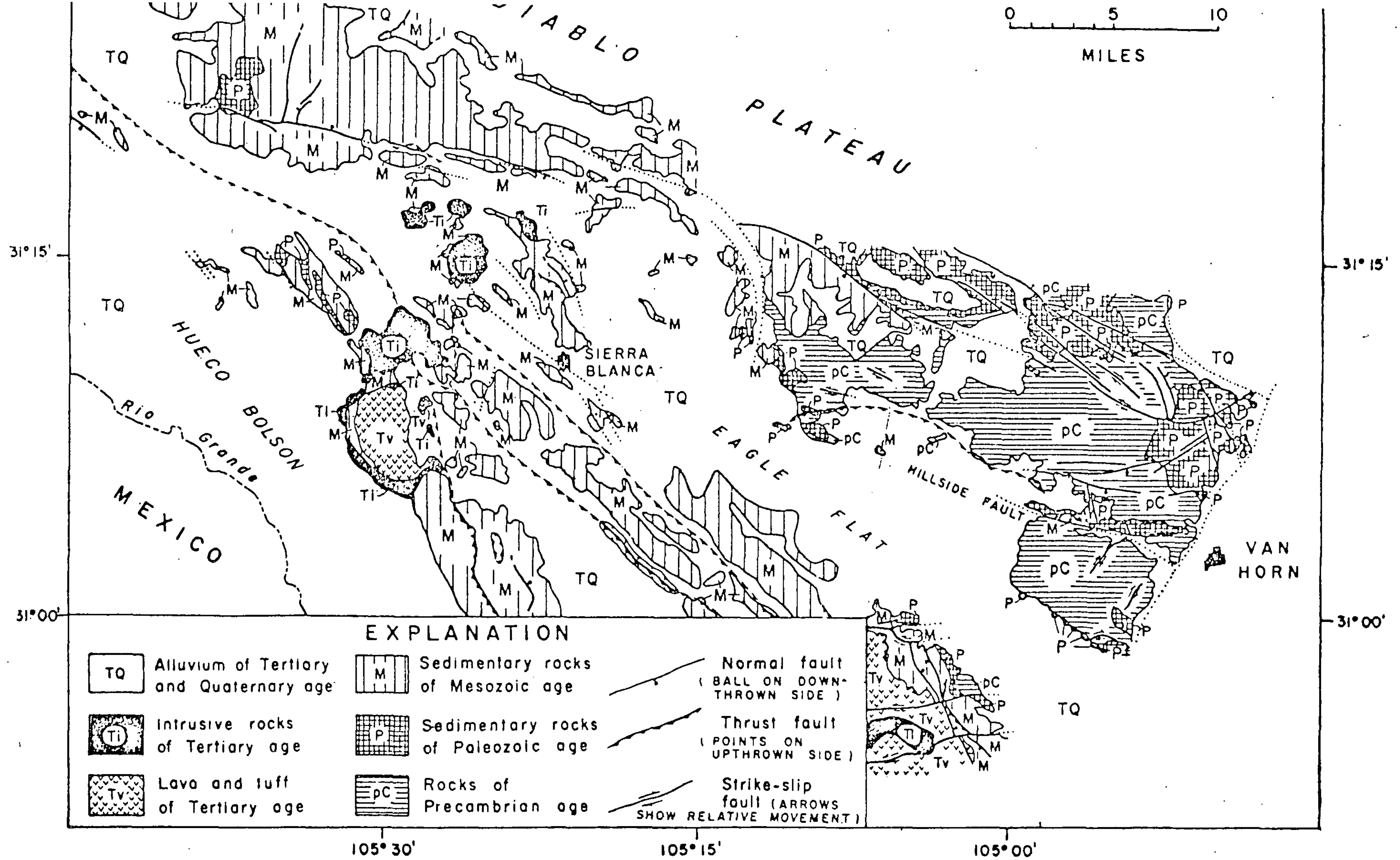


Figure 1. Generalized geologic map of the type region of the Texas lineament (From Albritton and Smith, 1957, fig. 5)

A high-angle fault, the Texan Mountain fault, is downthrown northward, strikes N.60° W., and cuts Cretaceous rock at Sierra Blanca, Texas. Moody and Hill (1956, p. 1124, fig. 12) proposed that this fault and the Hillside fault comprised part of a large left-lateral wrench fault that passed south of the Streeruwitz Hills in central Eagle Flat. Although the Texan Mountain and Hillside faults have similar strikes and a similar sense of displacement, strict projection of their strikes does not connect them. Even though the throw of such a fault is in the wrong direction, Albritton and Smith (1965, p. 111) conceded that the Hillside and Texan Mountain faults could be parts of a broad zone of en-echelon fracture, perhaps encompassing all of Eagle Flat. They found no evidence of strike-slip movement at Sierra Blanca or eastward.

They did not believe that the zone of faulting could be traced through or across the Salt Basin graben east from Van Horn because a similar structural border zone had not been found in that direction. They concluded, "This abrupt ending (east of the Carrizo Mountains) makes it doubtful that large strike-slip movement occurred along the zone in this region" (Albritton and Smith, 1965, p. 112). They reiterated their earlier (1957) conclusions but added that the strongest evidence for the Texas lineament or for the Texas direction of wrench faulting comes from the Van Horn-Sierra Blanca region and the remarkable and long-enduring geologic and physiographic differences between opposite sides of Eagle Flat (Albritton and Smith, 1965, p. 112).

The Hillside fault may have gained undue attention in tectonic theory because a major transcontinental highway and railroad traverse the valley formed along the fault. A second railroad traverses Eagle Flat. This convenient and rapid access to this region of striking geologic contrast and mineral potential may have exaggerated the value of geologic concepts developed here and which were then extrapolated across the continent and into the adjoining ocean basins.

DeFord (1969) briefly reviewed the history of thought concerning the Texas lineament and called attention to some of the striking contrasts between the north and south sides of the line between El Paso and Van Horn, Texas. He noted (p. 61) that the international boundary between the United States and Mexico follows a structural discontinuity for about 275 miles between El Paso-Juarez and the common corner of Texas, Chihuahua, and Coahuila and emphasized that "the first hundred miles downstream from Juarez include the type locality of the Texas lineament."

DeFord (1969, p. 63-64) inferred that the lineament must be thought of as a zone rather than as a single line and that parts of this zone may have been active at different points in geologic time. He also suggested (p. 64) that the Texas lineament and other northwest-trending airphoto lineaments in Chihuahua may be old basement (Precambrian?) faults that have later histories of movement.

STRUCTURAL AND GEOPHYSICAL INTERPRETATION

The k

region (fig. 1), supplemented by the trend and style of the geophysical anomalies, permits subdivision of the region into four elements. These are: the Salt Basin graben in the eastern third of the region having north-trending surface structure and low amplitude anomalies; the Diablo Plateau in the northcentral part of the region having west and northwest-trending surface structures and anomalies of zero to low amplitude; the Devil Ridge - Quitman Mountains part of the Chihuahua Tectonic Belt in the southwest part of the region which has a northwest-trending surface structure and low to medium amplitude anomalies; and the Carrizo Mountains-Eagle Flat area which extends northwest through the south-central and central parts of the region (fig. 1). The largest gravity anomalies trend west and west-northwest in Eagle Flat. The largest magnetic anomalies are associated with the metamorphic rocks of the Carrizo Mountains.

The largest gravity anomaly in the Van Horn-Sierra Blanca region trends southeastward across Eagle Flat from north of Sierra Blanca to the Van Horn Mountains where it turns southward out of the region (fig. 3). It is a near-linear, two-to-three-mile-wide feature, along which Bouguer gravity anomaly values decrease abruptly southwestward. North of Sierra Blanca, the amplitude of the anomaly is about 10 mgals, but the amplitude increases going eastward to about 14 mgals at the Streeruwitz Hills and about 22 mgals along the south end of the Carrizo Mountains. This anomaly closely follows the southern scarp of the Carrizo Mountains toward Scott's Crossing, then turns southward and closely parallels the mid-Tertiary Rim Rock fault along the west side of the Van Horn Mountains. Gravity profiles normal to the anomaly all have the open "S"-shaped, or step, curve that is the typical gravity response to high-angle faults. Using an average density contrast between 0.4 and 0.5 gm cm^{-3}, gravity interpretation suggests that the fault is downthrown southwestward about 4,000 feet south of the Carrizo Mountains, 3,000 to 4,000 feet in central Eagle Flat, and 2,000 to 3,000 feet west of the Streeruwitz Hills (Wiley, 1970, figs. 14, 15).

The southeastern part of Eagle Flat, between the Carrizo Mountains and the northeastern Eagle Mountains, is a true graben that is probably floored by thin Permian carbonate rocks overlying the Carrizo Mountain Formation and filled with at least 3,600 feet of Tertiary to Holocene fill. An unnamed fault, downthrown northeastward about 1,700 feet, is indicated by gravity interpretation along the northeast front of the Eagle Mountains (Wiley, 1970, p. 124-125). This fault is the southern boundary of the graben and has a recognizable length of about five miles.

The Rim Rock fault crops out in the 78 miles between the north end of the Van Horn Mountains near Van Horn and the Chinati Mountains, 28 miles north of Presidio, Texas (fig. 2). The fault strikes north to north-northwest and is downthrown westward throughout its length. In the northern Van Horn Mountains, its stratigraphic separation exceeds 3,000 feet and possibly exceeds 4,000 feet in the Tertiary volcanic rocks of this belt (Twiss, 1959, p. 110). A reconnaissance gravity profile through the southern Van Horn Mountains 23 miles south of Van Horn indicates a 14 to 16 mgals

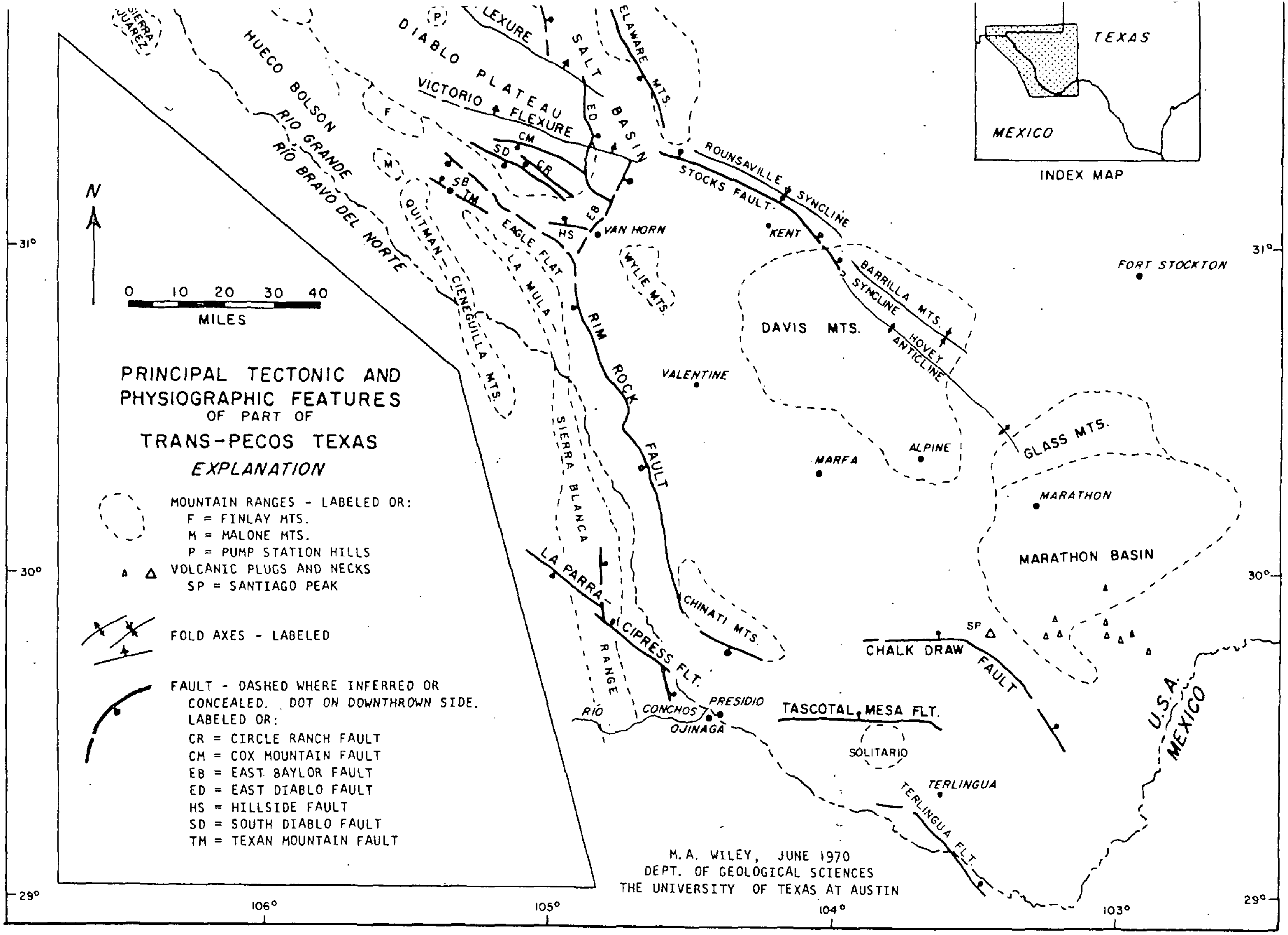
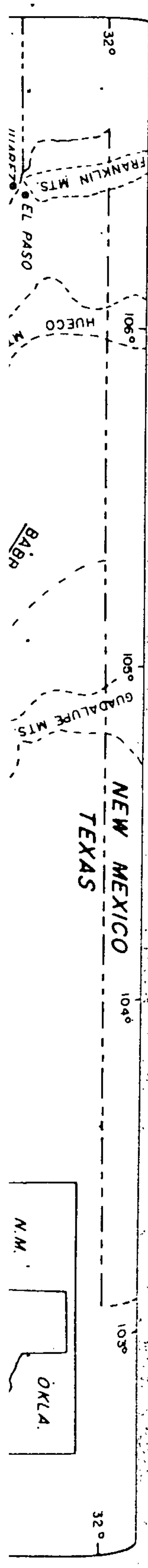


Figure 2. Principal tectonic and physiographic features of part of Trans-Pecos Texas (from Wiley, 1970).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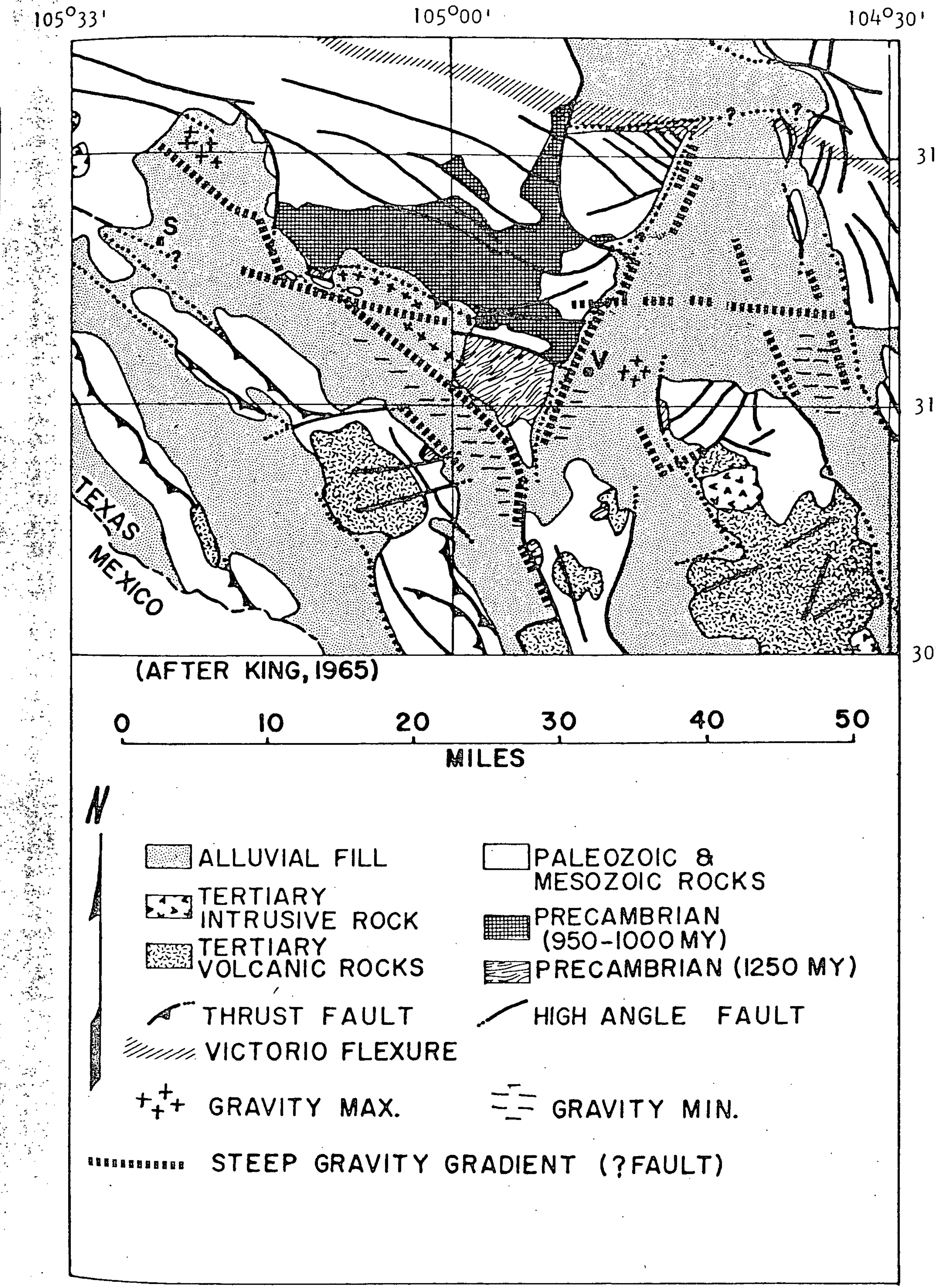
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The anomaly in the Van Horn Mountains is strikingly similar, in many respects identical, to the major anomaly along the north side of Eagle Flat. From this and from the seeming association of the north end of the Rim Rock fault with the Eagle Flat anomaly, Wiley (1970, p. 121) concluded that the Rim Rock fault turned west-northwest at the north end of the Van Horn Mountains and continued about N.50° W. for at least 40 miles from its last known outcrop.

Thus Eagle Flat - the type region for the Texas lineament - is bounded by a major fault, downthrown to the west, and which connects with the Rim Rock fault, a north-trending fault. The Rim Rock fault (as extended herein) is the northern boundary of the graben. Farther west, Eagle Flat is a half-graben because the southern bounding fault apparently dies out westward.

The Rim Rock fault and its northwestward continuation along Eagle Flat marks the approximate boundary between the Chihuahua tectonic trough and the more stable platforms on the Texas side. This then constitutes the Texas lineament (if we consider it to consist of a single fault zone) from the late Mesozoic to the present. The location of the Permian equivalent structure is less certain but must lie to the southwest of Eagle Flat. As shown in other papers in this symposium there are no Paleozoic, pre-Permian stratigraphic data that support the concept of an active fault zone in this location during that time interval.

Study of Figure 2 suggests that the Rim Rock fault at its south end turns eastward along the south side of the Chinati Mountains. Both the Chalk Draw and Tascotal Mesa faults mark major boundaries in the Big Bend region. The principal structural boundary between Chihuahua trough structures and the more stable Texas side, however, extends from the southeastern end of the Presidio bolson down the Rio Grande to the Terlingua fault; this then is the probable continuation of the late Mesozoic and younger Texas lineament.

Small gravity anomalies mark the border faults as well as the major interior faults of the Salt Basin graben system.

Gravity and magnetic anomalies related to the Hillside fault range in amplitude from 2 to 5 mgals and from 300 to 400 gammas, respectively. The anomalies are discontinuous and difficult to delineate along the nine mile length of the known or inferred trace of the fault. Poorly defined anomalies that might suggest extensions of the fault can be recognized as far as eight miles east of Van Horn. No geophysical expression of the Hillside fault was detected west of Allamoore (Wiley, 1970, p. 153; pl. I).

Using an average density contrast of 0.2 gm cm^3 between the north and south sides of the fault, interpretation of the gravity anomaly indicates 1,700 to 2,000 feet of total northward downthrow (Wiley, 1970, p. 154) in reasonable agreement with King's (1965) estimate of more than 1,000 feet of displacement. Stratigraphic relations require that at least 600 feet of this total displacement be accomplished during each of the two recognized episodes of movement; proper allocation of the remaining movement has not been determined.

The principal magnetic anomalies are associated either with igneous bodies (Fig. 4)

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King (1953, p. 102, 103) mapped a
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Figure 1. In all these exposures, the Carri
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of slip on this thrust plate was slightly east

The Carrizo Mountains, the Precar
south of the Hillside fault on Figure 1, are
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About 2,100 feet of rhyolite intruded
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phism about 1,250 m.y.b.p. (Denison and l
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m.y. ago. About 5,600 feet of diorite
formation as sills and was metamc
amphibolite during this orogeny (D
Hetherington, 1969; Flawn, 1953, p. 63).

The Allamoore Formation consists of
feet of deformed but little metamorphose
coarse clastic, and volcanic rocks and m
phyllite. The Hazel Formation, also defor
places, tectonically mixed with the Allamc
of more than 5,000 feet of interbedded sa
conglomerate (King, 1965, p. 23-27). Thes
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Streeruwitz thrust fault.

The sinuous, generally northwest-tren
magnetic maximum anomaly (Fig. 4) t
across northern Eagle Flat from the cen
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Carrizo Mountains and the Streeruwitz
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anomaly, nowhere more than a mile wi
average closure of about 300 gammas and lc
with 900 to 1,200 gammas closure (Wiley,

The large magnetic anomaly associate
outcrop of the Hillside fault is missing both
Horn and west of Allamoore. Although
anomaly (perhaps as much as 40 percent)
the Steeruwitz thrust fault which is cut by
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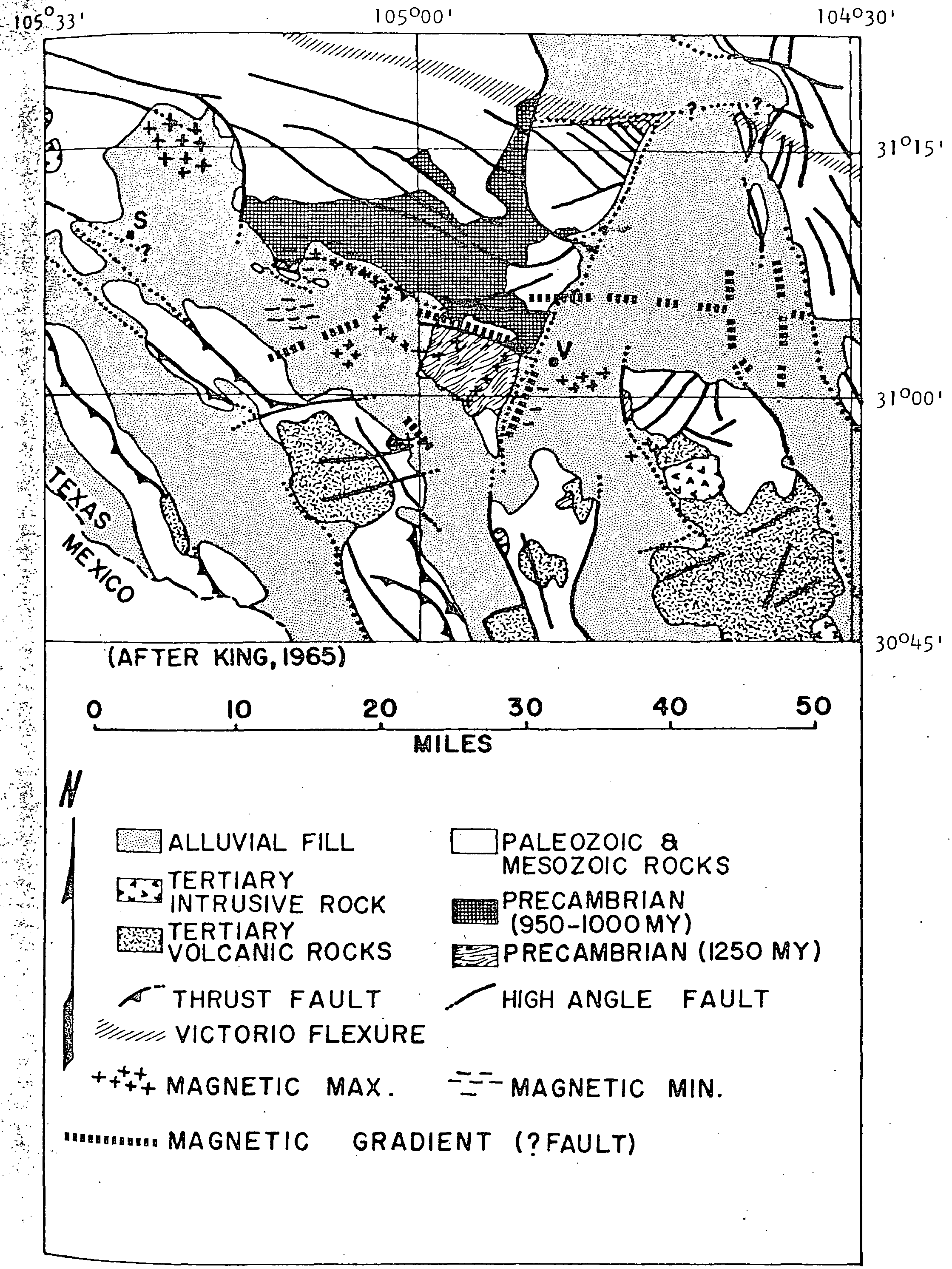

Figure 4. Principal magnetic anomalies of the Van

suggests that the thrust plate may be bent or curved into a broad trough trending west-northwest (Wiley, 1970, p. 138-142). Flawn (1953, p. 68-69), using poorly exposed outcrop data in the southern Carrizo Mountains, suggested such a trough or syncline but could not map it with confidence.

TECTONIC SYNTHESIS

The concept that the Texas lineament is a wide zone of fracturing and is the onshore extension of the Murray fracture zone (Albritton and Smith, 1957) deserves further discussion. The oceanic fracture zones are represented as bands of disturbed topography that originate as transform faults at offsets in the midocean ridges and which become passive (aseismic-atectonic?) as it migrates past the midocean ridge.

The precise physiogrphic appearance of these fracture zones is inferred by the geologist making the interpretation because the available data consists of sparker profiles taken at wide spacing and with uncertain navigational errors. The continental extension of fracture zones will be different in appearance from its oceanic counterpart because of the addition of continental crust and the rapid (geologically speaking) modification of the original topographic form by the many erosional processes. Even with these modifications we can recognize analogies to the topographic forms inferred at sea: narrow ridges separated by deep linear valleys trending parallel to the fracture zone (Transverse Ranges of southern California); high escarpments facing the fracture zone (Colorado Plateau - Mogollon Rim of Arizona - New Mexico); termination and deflection of topographic elements against the fracture zone (Chihuahua tectonic belt against the type region of the Texas lineament).

If the Texas lineament since the late Mesozoic has been part of the Murray fracture zone, then throughout this period of geologic time the Texas lineament has been beyond the ocean ridge and should be in the stable or atectonic portion of the spreading plate. Actually the Texas lineament marks a prominent zone of tectonic activity and suggests that the fracture zone concept is an oversimplification. Displacements cease along the fracture only in the ideal case of mathematical perfection and the idealized discussions of the major plates of the world. Slight changes in movement directions will cause reactivation of these older tectonic lines of weakness. Although the displacements along the Texas lineament are large, they are minor compared to plate translation or to the activity when they are between the offset portions of the ocean ridges. Dip-slip displacements are the only provable type of major faulting in the type region of the Texas lineament.

Major strike-slip motion can be proposed for the Precambrian age boundary offset - but it might have been born offset! On the other hand, maybe all of the structures that we see in the late Mesozoic (Permian?) and younger structural elements of the Eagle Flat region are later reactivations of a Texas direction fracture zone of the 1000 m.y. ("Grenville") orogenic period.

The literature on sea-floor spreading, transform faults, ocean ridges, etc. that

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CONCLUSION

In the Van Horn-Sierra Blanca
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faulting. Two through-going fault tren
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Rim Rock fault and Salt Basin boundar
northwest-trending segment of the Rim
Eagle Flat. These are Cenozoic structur
are more-or-less superposed on parts of
of the Diablo platform of Permian a
time. For many reasons, but chiefly b
distribution of Permian and later rocks
Texas, it is most improbable that m
displacement occurred in the region afte
of the Cambrian Period. Thus, the evide
to demonstrate wrench-faulting alon
lineament must be in rock older than
contrast to the late Paleozoic interpr
earlier by Muehlberger (1965). Much o
missing in Trans-Pecos Texas, either be
deposition or erosion, and much of that
covered. Moreover, the several tectonic
in the region, ranging from Precambrian
and metamorphism to Cenozoic bl
strongly suggest a fundamental crustal
but also tend to obscure evidence of its
structural complexity. With the presen
data, it is possible to state only that this
zone of lineaments, extends about N
most of Trans-Pecos Texas, that the Van
Blanca region lies athwart this zone, and t
and remarkable straightness of the lineam
a wrench fault origin (landward extension
zone?.).

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Texas Bureau of Economic Geology.

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BASEMENT ROCK FRAMEWORK OF PARTS OF TEXAS, SOUTHERN NEW MEXICO AND NORTHERN MEXICO

by

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1970
in Geol Framework of the
Chihuahua Tectonic Belt
West TX Geol Soc

INTRODUCTION

The basement rock framework of Texas and New Mexico is clearly Precambrian in age where isotopic data permit its determination. However, at the margins of these well defined blocks of Precambrian rocks we find evidence of Phanerozoic thermal events. Some of these events definitely involve the basement. Whether or not others do depends on the definition of basement. The discussion here includes all known descriptions of pre-Tertiary igenous and metamorphic activity. We are dealing with only a few data points that are so geographically scattered that there is not enough information available to define basement.

PRECAMBRIAN OF TEXAS AND NEW MEXICO

Areas of Arizona and northern Sonora can be characterized by basement rock ages in the 1500-1700 m.y. range (see Livingston and Damon, 1968). This age range is represented as scattered mineral ages in younger terranes in New Mexico (Muehlberger and others, 1966). However, there are no published ages on rocks from the New Mexico outcrops closest to this 1500-1700 m.y. Arizona terrane. It seems clear that there will be areas in New Mexico that will be characterized by this older age (possibly in the Burro Uplift of southwest New Mexico), but the location and distribution of these areas await definition.

The basement rock ages and composition in far West Texas and south-central New Mexico have recently been described by Denison and Hetherington (1969). We have obtained a few additional ages on some rock units, but these have only substantiated the conclusions previously reached.

The oldest ages that can be defined with confidence are 1350 ± m.y. Massive granitic rocks, gneisses of granitic to dioritic composition and lesser volumes of metasedimentary rocks comprise this terrane. The orthogneisses yield metamorphic ages in the 1350 m.y. range and have an undefined older age of intrusion. The age of deposition for the later metamorphosed sedimentary rocks is thought to be about 1460 m.y. based on long range correlations with rocks in central New Mexico. These rocks have been grouped into the Chaves Granitic Terrane and are exposed along the San

It is these rocks that provide a framework for the intrusion or deposition of younger rocks.

Evidence for a period of volcanism and the deposition of a thick clastic sequence occurring about 1250 m.y. ago is found in the Van Horn area in Texas The Carrizo Mountain Group is reported to be as much as 19,000' thick and does not appear to be repeated. Apparent ages in this same age range have been determined in Lea County, New Mexico, but the relationship of these rocks to those found in the Van Horn-Carrizo Mountain area is unclear. Rocks of the Carrizo Mountain Group must have extended over a considerable area but a lack of control precludes tracing the rocks to the south and they are covered by younger Precambrian rocks to the north.

The period centering about 1150 m. y. is marked by enormous outpourings of rhyolite and synchronous granite intrusions. The Panhandle Volcanic Terrane includes the segmented rhyolite fields that stretch from Lea County, New Mexico, to southwest Kansas (Muehlberger and others, 1967). The granites associated with the rhyolites, the Amarillo Granite Terrane, are typical of shallow epizone intrusions. Rock types characterizing the activity do not crop out. However, a sequence of alkalic intrusions of equivalent age are found at Pajarito Peak, Otero County, New Mexico.

The period centering about 1000 ± 50 m.y. is one of intense and widespread sedimentation and igenous and metamorphic activity. In the Llano area of central Texas, massive granitic rocks intruded into a layered sequence of clastic and volcanic rocks at about 1020 ± m.y. (Zartman, 1964). The Valley Spring Gneiss yields a whole rock ischron age of 1120 ± 25 m.y. (Zartman, 1965) and is interpreted as the metamorphosed equivalent of the Panhandle Volcanic Terrane. The very thick overlying Packsaddle Schist was, therefore, deposited in the interval between 1120 ± 25 and 1020 ± 15 m.y.

To the west at a slightly later time a different sequence of events were taking place in a contrasting environment. During the period after the extrusion of the Panhandle rhyolites and probably beginning about 1,000 m.y. ago a sequence of clastic rocks and younger limestones and dolomites were deposited along a broad N-S axis in central New Mexico and far West Texas. These rocks, the DeBaca Terrane, are associated with basaltic rocks, both as intrusive dikes and sills and are found at the base of the Sacramento Mountains, Bent Dome, relicts in the San Andres Mountains, the Franklin Mountains (the Castner Marble, Mundy Breccia and Llanoria Quartzite) and the Diablo Platform (the Hazel and Allamore Formations.)

This sequence of layered rocks is intruded by granites and covered by comagmatic rhyolites in the Franklin Mountains area. In contrast to the passive environment of the Franklins, the Van Horn area was undergoing strong compression and regional metamorphism as well as granitic and pegmatite intrusions. The metamorphic ages on rocks of the Carrizo Mountain Group are in the 950-1000 m.y. range. We have determined three additional K-Ar ages on metamorphic minerals from the Car Group in order to more accurately def deformation-heating. Two hornblend phibolites interbedded with quartzofel yield ages of 990 ± 20 and 970 ± 20 m muscovite from a quartzofeldspathic originating as a rhyolite) gave an age of The rocks of the younger DeBaca Ter disturbed and converted to low rank me g., the talc of the Allamore Formation) n Mountain Group but are relatively un the northern limit of exposures on the D

The age determined for the granite the Franklin Mountain area is about 95

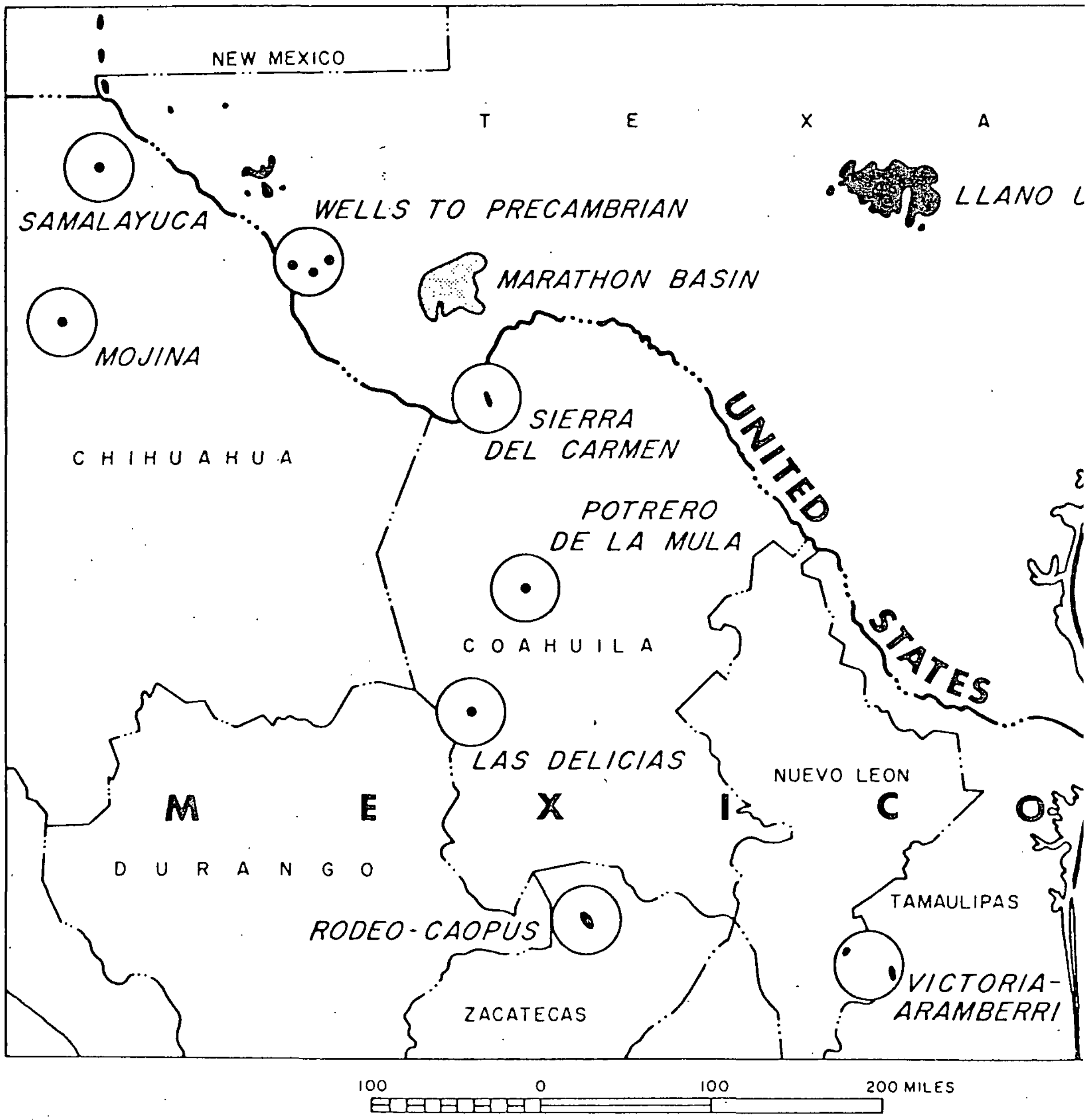

FIGURE I. MAP SHOWING LOCATION OF BASEMENT OUTCROPS AND DATED SAM

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Table 1. K-Ar Ages from Rocks in Northern Mexico and West Texas

Sample No. & Type	%K	Sample Size gms.	Ar^{40*} $X 10^{-9}$	Ar^{40*} / Ar^{40} Total	Age $X 10^6$ Yrs.	Location & Rock Type
1124H	1.136	1.563	3.510	93	874	Peregrina Canyon,
						granite
		1.499	3.338	93	868	gneiss
1127M	5.031	.342	3.622	99	920	Peregrina Canyon,
						micaceous
		.340	3.595	98	919	marble
1130M	6.219	.808	2.857	97	295	Novillo Canyon,
						graphitic
		.838	2.932	98	292	Schist
1131H	1.496	1.573	4.873	96	907	Novillo Canyon, banded
		1.501	4.676	98	912	granitic gneiss
1082M	4.034	.155	.367	68	304	Peregrina Canyon,
		.142	.339	80	306	graphitic schist
1142M	3.991	.493	1.023	89	271	Graphitic schist
		.501	1.027	89	269	Aramberri area
1144M	3.996	.483	1.089	91	293	Graphitic schist,
		.502	1.133	87	294	Aramberri area
431M	3.705	2.040	1.118	87	81.5	Outcrop phyllite
		1.996	1.103	92	82.1	Sierra Samalayuca
1158M	5.036	1.204	.9271	81	84.1	Outcrop phyllite
		1.201	.9267	95	84.3	Sierra Samalayuca
1366M	2.023	1.204	.4011	89	90.4	Phyllitic interval
		1.242	.4247	64	92.5	446.7-447.5 meters
		.801	.2698	60	91.4	Pemex A-1 Samalayuca
1499M	3.395	.101	.0485	39	77.7 ± 2.3	Metagraywacke
		.401	.1938	59	78.5	1365-1372.5 meters
						Pemex 1-A Samalayuca
963H	1.022	.3861	0.910	.96	987	Amphibolite, Wylie Mts.
	1.002		0.896	.97	993	Culberson Co., Texas
965H	1.000	.1770	0.400	.94	971	Amphibolite, Van Horn
						Mountains
	1.051		0.416	.88	964	Culberson Co., Texas
967M	.873	8.668	17.23	.98	978	Muscovite biotite,
						quartzofeldspathic
	.853		16.55	.99	965	Schist, Van Horn Mts.
1155M	.191	3.733	.0733	.67	56.9	Muscovite schist,
						Caopus
	.182		.0658	.63	53.6	Zacatecas (anomalous
						age)
1157-14M	.130	8.166	.4645	.46	231 ± 6	Three muscovite schists
	.112		.4084	.36	235 ± 8	boulders from Sierra
1157-8M	.113	8.304	.4751	74	266	de la Mojina Chihuahua
1157-13M	.111	5.976	.3072	68	244	Mexico
			.3339	76	255	

H = Hornblende

M = Muscovite

Ar^{40*} is radiogenic argon

All errors are estimated
to be 2 per cent of the
age except where noted.

additional ages from the granite on the western flank of the Franklin Mountains, Table 11). Petrographically similar rocks in the Hueco Mountains, Pump Station Hills, and samples from drill holes in the surrounding area have yielded ages in this range. This rhyolite extrusion and epizone granite intrusion is the western most occurrence of a band of the segmented rhyolite-granite complexes of different ages stretching from Indiana to far West Texas. This period of activity represents the last well defined igneous or metamorphic event in the Precambrian of Texas-New Mexico.

There are hints of younger Precambrian and Phanerozoic thermal activity in Texas and Mexico. The times of activity can be defined by suitable samples but the geographic spread of the data points precludes defining the significance of these periods. Some of this information is derived from dating igneous and metamorphic boulders and cobbles from conglomerate. This technique leaves much to be desired but nevertheless it can yield extremely interesting results.

HAYMOND BOULDERS

Igneous and metamorphic boulders from a conglomeratic zone in the Pennsylvanian Haymond Formation in the Marathon Basin yield Devonian ages (Denison and others, 1969). The evidence indicates that these boulders were derived from a mountainous area southeast of the Marathon Basin. Our interpretation is that this source area, the Llanoria Mountains, had a core of granitic material formed by partial melting of a geosynclinal sequence. The partial melting took place, along with associated volcanism, during the Devonian.

Our search for a source for these boulders proved fruitless and remains so. However, in our search, we found several things of interest.

1. The Precambrian rocks found in Presidio County, Texas, are of a type and age which is common to the north and east. This is the last outpost of hard information close to the vast areas in Mexico from which
no information is a
Precambrian.
2. Schists at Sierra del
yield an apparent age of
metamorphic micas. This
rocks are, as had been p
part of the interior zon
system.
3. The metamorphic s
Caopus - Rodeo area in n
yield anomalously youn
added another anomalo
already determined. A
from the Rodeo Schist (
apparent age of 55 ± 5 n
sequence is overlain b
deformed and co
metamorphosed rocks de
Jurassic and possibly as ol
Caopus Metarhyolite
whole rock ages of form
220 m.y. from samples
single small outcrop.
similarity of the metarhy
boulders found in the Ha
is the closest approxima
source area yet found. T
ages are so anomalous as
any conclusion reached as
The Caopus-Rodeo area
most critical and puzz
northern Mexico.
4. Two massive granodio
the Coahuila Peninsula,
and Potrero de la Mula, h
of intrusion (~200 m.y.).
may have played a signi
evolution of the Peninsu
element but with only two
dated, there is not enou
reach a firm conclusion.
pears to be a major but ill-
igneous activity through

Table 11. Rubidium-Strontium Ages from the Franklin Mountains and Northern Mexic

Sample Number	rb, ppm	Sr, ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	Age x 10^6 Years	Rock T
1439F	52.4	17.9	8.45	.8663	1270 ± 45	Granite Sierra J
1250F	268.7	17.5	44.2	1.322	935 ± 20	Granite Park ar
1251F	276.9	38.2	20.9	1.002	950 ± 25	Frankli
1082W	24.3	41.6	1.69	7.224	315 ± 30	Isochro
1082	208.6	78.9	7.64	.7502		Granjen Peregri

F = feldspar
W = whole rock

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Mexico and extending around the Gulf Coast to Florida (Moody, 1949; Kidwell, 1949; Flawn and others, 1961; Mixon, 1963; Milton and Grasty, 1969).

SIERRA JUÁREZ

At the suggestion of In. Diego Córdoba, we have dated granite clasts collected from the conglomeratic zone in the Cuchillo Formation at Sierra Juárez (Córdoba, 1968; 1969). The vast majority of clasts are of fossiliferous limestone, and it is difficult to identify postively any large igneous or metamorphic boulders on the outcrop. However, in thin sections taken from the conglomerate, small igneous pebbles are readily identified. The pebbles are mostly from a granite source but quartzite, polycrystalline quartz (possibly quartzite), chert and possibly altered diabase have been found. The granite is quite distinctive. It appears to be coarse grained, showing little evidence of metamorphism. Microcline and quartz make up the majority of the pebbles. The petrography of the pebbles suggests a source decidely different from the rocks cropping out just to the north in the Franklin Mountains.

We separated microcline from several of the larger petrographically identical pebbles. The Rb-Sr age of 1270 ± 45 m.y. is probably a minimum age for the time of formation of the microcline (Table II). The age shows that the pebbles are not derived from the Franklin Mountain 950 m.y. province but from some older sequence of rocks. The closest possible source area known to contain rocks of this type and general age is the Burro Uplift of southwest New Mexico. Whether this was a possible source in Cuchillo time is not known.

SIERRA SAMALAYUCA

The rocks at Sierra Samalayuca, about 55 km south of Juárez have been the source of much speculation. Because of the low rank metamorphic features evident from the outcrop, the rocks have been regarded as "old," possibly Precambrian.

Berg (1969) has described the rocks of the Sierra. The exposed fold is 19 km. long striking N60W and rises about 410 m. above the surrounding area. Pemex measured a sequence consisting of approximately 1080 m. of sandstone, conglomerate, and shale. The conglomerates and sandstones are from a few centimeters to 3 m. in thickness, whereas the shale beds are 2 to 20 cm thick. Shales are widespread. The conglomerate is more common on the northeast flank of the southeast half of the anticline. Lithologic boundaries are sharp with no evidence of graded beds. No channeling or scouring was found. Where sandstones overlie shales, load casts are common. Berg suggested all these features were indicative of a submarine fan with a source to the northeast. Fossil shells have been found in limestone clasts in the conglomerate but no other fossils have been found.

The metamorphic effects are of low rank but are ubiquitous. Berg reports chlorite, sericite-muscovite and phengite (a variety of muscovite) as metamorphic minerals. The foliation is parallel to the axial plane of the fold.

We have examined numerous thin sections of samples from the several intervals from the well drilled by Pemex at Sierra Samlayuca. The following conclusions and observations can be based on the petrographic study.

The rocks are rather coarse and poorly sorted, shaly (phyllitic) intervals are relatively minor and nearly lacking as well defined beds in the subsurface samples examined. Most of the samples are here classified as metagraywackes. Diverse sand size clasts are set in a recyrstallized clay matrix now a mosaic of sericite and chertose quartz. Sericite shreds invade the rims of sandsize quartz clasts. Foliation is marked in the phyllitic beds but is poorly defined in the sandy intervals. Foliation is parallel to bedding in every thin section examined. The subsurface samples are characterized by an abundance of a colorless to pale green chloritic mica present as large clast-like masses of superior size. These average 0.4-0.7 mm in length and are composed of coarsely crystalline colorless chloritic mica interlayed with lesser sericite. These clast-like entities are about the size of the largest quartz grains; they are elongated in the plane of bedding-foliation but the mica cleavage is generally at a high angle to foliation. These chlorites are not interpreted as detrital as they are now but may have been detrital chlorite recyrstallzied and sheared during metamorphism.

Quartz is the most abundant recognizable sand-size clast. Plagioclase is considerably less common; microcline is rare. Many quartz clasts are highly angular. Opaque clasts are common, they appear to be mostly magnetite-ilmenite and pyrite. The opaque minerals outline bedding on a delicate scale. Carbonaceous material is found as specks in the sericitic bands. Calcite is irregular in occurrence but locally abundant in intergranular masses as well as distorted clast size pellets. Former clay pellets, probably rip up clasts, are now highly distorted and squeezed. Minor amounts of the heavy minerals sphene, zircon, tourmaline and epidote are found in addition to abundant opaque grains. Anhydrite is found as a secondary mineral in the core at 1365-1372.5 m.

The lithic debris in the cobble and boulder size fractions represents a number of types. Chert is the most common rock types. These cherts are not lineated but have equigranular quartz mosaic between 0.02 and 0.07 mm in diameter. Dolomite rhombs are common scattered through the chert. Clasts of igneous origin are more common than chert in some beds but are generally subordinate. These are of diverse rock types but are characteristically of a quartz-poor composition. Trachyte porphyry, diorite, altered basalt-andesite, and lesser tonalitic, rhyoltic and granitic clasts have been identified. Quartzite pebbles are also present. There are metamorphic effects in the igneous clasts (particularly true in the core at 1365-1372 m). These are *most marked in the fine grained clasts such as trachyte* porphyry and are characterized by sericite shreds formed in the groundmass in the general plane of rock foliation.

Although there is no difference in the assemblage of metamorphic micas on the surface and in the drill samples, the subsurface samples have a considerably higher degree of crystallinity with the lowermost core showing the most marked metamorphic effects.

establishing the age of deposition more precisely than Phanerozoic or the age of deformation as other than post-Neocomian. The isotopic evidence (Table 1) is reasonably consistent when the divergent samples are considered. The youngest apparent age is 78 ± 2 m.y. from the Pemex 1-A Samalayuca bottom hole core at 1365-1372 m. Two outcrop samples collected at the southeast end of the Sierra have micas giving ages of 82 ± 2 and 84 ± 2 m.y. A core taken at 446.7-447.5 m. contained micas yielding an age of 91 ± 3 m.y. The three younger ages had between 3.4 and 5.0 percent potassium, whereas the mica giving the older age had only 2.0 percent potassium. This suggests that the samples giving the younger ages were more pure mica separates. If this is the case, then the younger ages should be more reliable. These apparent ages are mid-Late Cretaceous (Santonian-Coniacian) in the timescale proposed by Casey (1964) and this age is regarded on the available evidence as the most likely time of metamorphism of these rocks.

We interpret the metamorphic effects as having been imprinted on the rocks while they were under substantial load and undergoing higher-than-normal temperatures. The lack of these features in the Neocomian rocks exposed immediately to the north leads us to three conclusions. First, they are in fault contact. Second, that fault is most likely a thrust fault. Third, the age of deposition is Jurassic or older. The first conclusion is based on the horizontal juxtaposition of metamorphosed and unmetamorphosed rock. The second conclusion is reached on the premise that during strong compression, shown by the low rank metasediments, the most likely type of fault is a thrust dipping under the Sierra. The second conclusion is based on the idea that high temperatures and pressures indicate deeper burial - deeper than the unmetamorphosed Neocomian age sedimentary rocks.

Thus, we conclude that the sedimentary rocks at Sierra Samalayuca were deposited in pre-Neocomian time as a possible submarine fan with a source to the northeast that is not exposed. These rocks were subsequently folded, thrust and metamorphosed in early to mid Upper Cretaceous time and brought to their present level in juxtaposition with unmetamorphosed rock of Neocomian age.

SIERRA DE LA MOJINA

Bridges (1964) described the conglomerate at the base of Sierra de la Mojina. The conglomerate lies beneath Cretaceous (Albian) limestone. Bridges estimated the composition of boulders as: 70 percent quartzite, 20 percent schist and gneissic quartzite and 10 percent vein quartz at the south end of the outcrop and 30 percent quartzite, 60 percent gneissic quartzite and schist, 5 percent limestone, and 5 percent vein quartz in a locality farther to the north. The largest boulder found by Bridges is about 30 cm. in diameter, whereas the average is about 8 cm. A few clasts of pink rhyolite as large as 15 cm. were identified by Birdges at the northern location. Only a few thin sections were studied by Bridges, the estimates and identifications being based on megascopic examination.

We collected

km. north of Bridges' localities and mad of each. Most of the boulders collecte metarhyolites or were quartzofeldspathic have a rhyolitic bulk composition but in igneous texture can be identified. A fe metamorphosed rhyolite were collected

Thirty-five clasts were examined pe from the conglomerate in the vicinity so manganese mine at the base of the Sier mine road south of the mine. These boul collected to show distribution of rock t selected from the larger boulders which they might be suitable for dating. The cl are mostly quite uniform - they are mus zofeldspathic schists. Relict phenocrysts o recrystallized quartz, plagioclase and perthite are set in a groundmass of oriented to granoblastic quartz-micro These textures show a clear-cut origin rhyolites. Muscovite is in variable amou than 5 percent to more than 20 percent. crease in muscovite the evidence of relic fades. Several boulders have compar feldspar and very abundant muscovite; th properly called muscovite schists. The mineral of significance in the quartz schists is hematite as small granules an between grains. Calcite is an irregula mineral in replacement masses and veins. pronounced and is generally marked by m bands. The bands are locally deformed amplitude microfolds.

A few specimens of rhyolite s metamorphic effects can be found in the c These clasts have quartz and feldspar phen a fine quartz-feldspar groundmass. Sericiti iron oxides are common in the groun sericite is not dimensionally oriente groundmass is a structureless felsophyric Calcite is an irregular replacement and v

Bridges generously loaned his thin s boulder collection so it might be compare collected along strike to the north. Seven t cut from these boulders show a different ro is common to the north. These are mo muscovite in composition - essentially schists. Foliation is well marked and this i into well defined chevron folds. One rh (collected by Robert Pavlovic) in Bridges (our No 1416, Table III) was dated as Per age of formation. *Thus there appears* significantly different suite of boulders al even taking into account the smaller boulders collected to the south.

We have dated eleven whole rock sa metarhyolites in order to determine the time extrusion. The results (Table III) yield a isochron.

A least square fit of all points yields an is of 747 ± 74 m.y. with an initial Sr87-86 valu .017. The extremely low value for the in obviously in error and is caused by les samples falling well below the isochro

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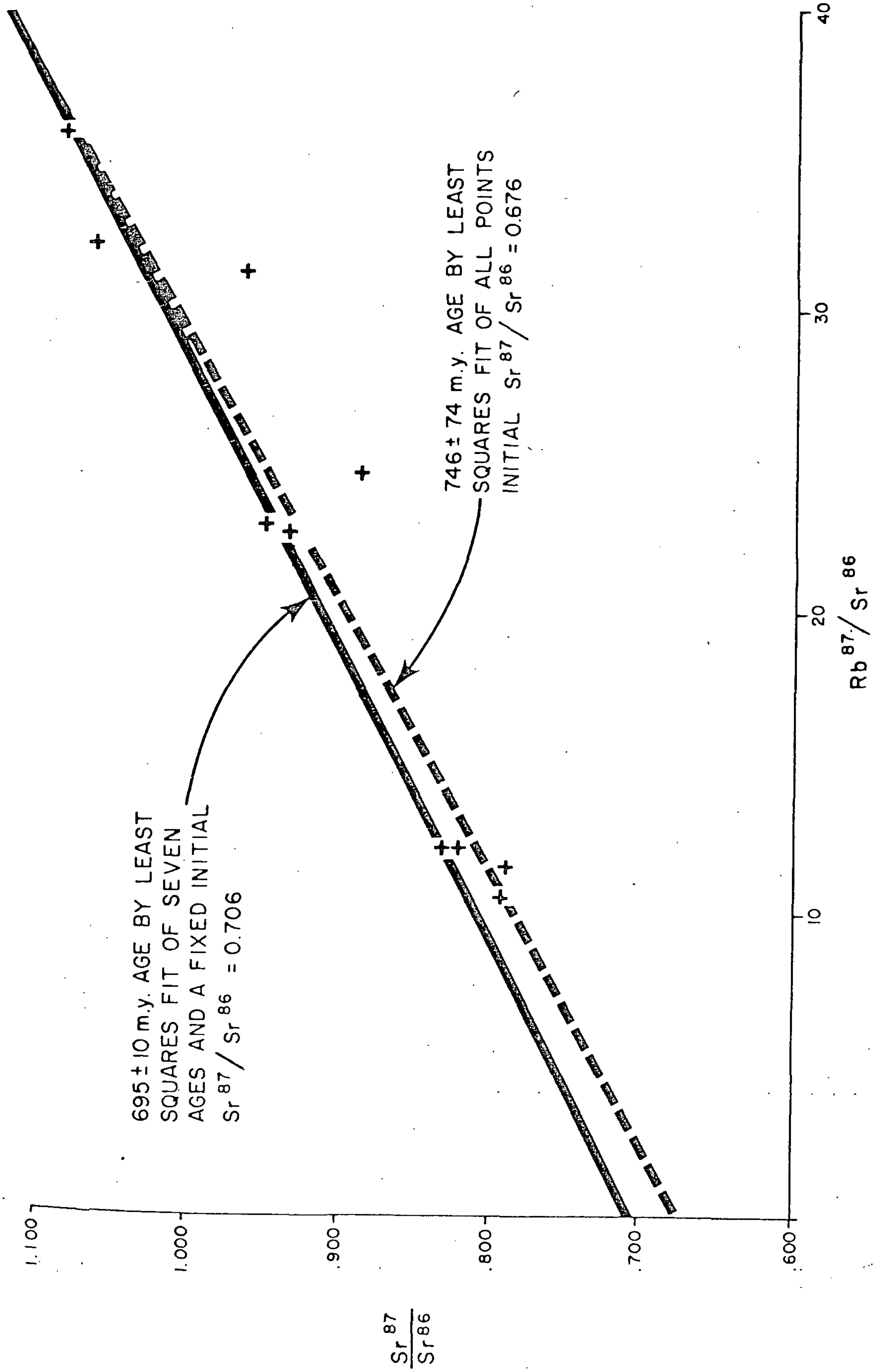

FIGURE 2. ISOCHRON PLOT OF WHOLE ROCK DETERMINATIONS FOR METARHYOLITES FROM SIERRA DE LA MOJINA. SEE TABLE III FOR ANALYTICAL DATA.

most nearly falling on a single line and a fixed initial ratio of .706. The fit of these seven points yields an isochron age of 695 ± 10 m.y. We do not attach any significance to the very small error in the slope calculation because four points were rejected for the calculation.

Isochron plots are based on the assumptions that all the samples have the same age and the same initial Sr87-86 ratio. In the present case of the 11 boulders either or both of these assumptions may very well be false and this could explain why the 11 points do not all fall along a straight line. Perhaps a more likely explanation is weathering, a process to which boulders are, of course, particularly vulnerable. It is well known that weathering tends to lower measured isotopic ages and that whole rocks are especially susceptible.

The 11 boulders were chosen for petrographic similarity. In spite of the fact that they were also chosen for apparent freshness, the petrographic similarity is great enough that we believe the point scatter is entirely due to weathering and that all the boulders were originally part of a single rhyolite which was formed approximately 700 m.y. ago, say 700 ± 100 m.y.

One whole rock age from an unmetamorphosed rhyolite boulder yielded an age of 246 ± 42 m.y. (Permian). Bridges (1964, p. 87) had suggested that these rhyolite clasts were derived from Las Delicias, Coahuila and Minas Plomosas where the stratigraphic age is Permian.

Muscovite was separated from five boulders in order to determine the time of metamorphism. Three K-Ar determinations (Table 1) yielded ages of 233 ± 5, 249 ± 10, and 266 ± 5 m.y. Two Rb-Sr muscovite-whole rock isochron ages (Table III) were in general agreement with the K-Ar results, 258 ± 6 and 287 ± 5 m.y. Thus, although there is considerable spread in our muscovite dates, they are all Permian within analytical error.

The results are interpreted to indicate that the source of the boulders is a crystalline area in which late Precambrian rhyolites were common. These rhyolites later underwent a regional metamorphic event in Permian time which changed them
character. Some unmetamorphosed
likely with a Permian age of extrusion
source area.

The Precambrian age of forn
metarhyolites was anticipated by Brid
age of metamorphism was not. She
Company determined an Rb-Sr isochr
15 m.y. (reduced to the decay constai
fractions from boulders at Mojina (repc
1970). We cannot say with certainty
significantly different because we did n
suite of rocks collected from the sam
two muscovites dated by Rb-Sr are su
favorable for analysis than those c
Although one of our K-Ar ages is sub
than the Rb-Sr determinations, the ot
good agreement. We conclude that,
available data, Permian is the most prob
time of metamorphism.

We interpret the metamorphic effec
boulders to indicate a basement-inv
metamorphism involving intense co
deformation. The abundance of the bou
and distribution suggest a nearby source
a hearty type - those most likely to with
However, the apparent difference in cor
strike suggests that there was incomple
lack of mixing may be due to separate
example, coalescing fluvial fans. We
evidence of a "nearby" source which is
not more than 25 miles distant.

We know of no other evidence to
Permian orogenic-metamorphic episoc
we know of none against it - there are ve
the character of the Paleozoic in nortl

CUIDAD VICTORIA ARE

In several deep canyons northwest o
toria, Tamaulipas a wide variety

Table III. Rubidium-strontium ages of boulders from Sierra de la Mojina, Chihuahua

Sample Number	Rb ppm	Sr ppm	Rb 87 Sr 86	Sr 87 Sr 86	Age of y
1157-2W	263.6	62.6	12.15	.8236	652
1157-6W	228.5	63.2	10.44	.7942	559
1157-10W	415.9	61.4	19.56	.9127	711
1157-15W	147.6	36.4	11.69	.7915	493
1157;18W	295.6	37.3	22.87	9480.	712
1157-21W	527.0	48.6	31.28	.9615	550
1409-1W	305.3	38.9	22.68	.9339	655
1409-1M	832.5	17.4	137.9	1.373	258
1409-2W	473.4	38.0	35.97	1.082	703
1409-3W	524.6	46.9	32.23	1.061	740
1409-5Z	225.6	28.8	22.58	.9197	-
1409-m	907.8	11.1	236.8	1.827	187
1409-6W	441.1	51.8	24.60	.8865	495
1409-8W	328.7	77.9	12.17	.8293	681
1416W	151.4	41.4	8.49	.7369	246

W = whole rock
M = Muscovite
Z whole rock

Initial Sr 87 86 = .706
* Isochron age based on slop

metamorphic rocks are exposed. These rocks are in fault contact with unmetamorphosed sedimentary rocks of Paleozoic age. All these rocks are unconformably overlain by folded Jurassic and Cretaceous rocks.

Carrillo (1961) has provided the definitive work on these older rocks. The general description that follows is taken from Carrillo, except where noted.

There are two types of crystalline rocks exposed in the canyons, granitic gneisses and graphitic schists. The sequence of granitic gneisses is exposed in Novillo, Peregrina, Caballeros and Santa Lugarda Canyons. Fries and Rincon-Orta (1965) named the sequence the Novillo Gneiss. These banded gneisses contain abundant hornblende, biotite and garnet. The foliation in the gneisses is generally NW-SE with high to moderate dips, generally to the northeast. Fries and Rincon-Orta cite a N45°-70° W strike with consistent dips of 70°-80° to the northeast in Novillo Canyon.

The gneisses and other rocks are always in fault contact except for minor rocks intrusive into the gneiss sequence. Numerous basic dikes are found paralleling foliation in Canon del Novillo. At the headwaters of Canon de Caballeros there is a mass of granite intruding the gneisses.

The gneisses had been regarded as Precambrian by previous workers due to their proximity to unmetamorphosed Paleozoic sedimentary rocks. Fries and others (1962) discuss in considerable detail the age relationships and the opinions of previous workers in the area.

Fries and others provided the first conclusive evidence that the gneiss is of Precambrian age. A biotite from a granitic gneiss in Canon de la Peregrina yielded a K-Ar age of 740 ± 25 m.y. Another biotite from a sheared granitic rock intrusive into the gneiss yielded an age of only 150 ± 10 m.y. It should be noted that this biotite yielding the apparent young age contained only 1.76 percent potassium which suggests an impure separation or alteration.

We have determined three K—Ar ages, two on hornblende separates and another from a phlogopitic white mica. These results are shown in Table I. The two hornblende ages 871 ± 18 m.y. and 910 ± 18 m.y., are in general agreement with the white mica age of 920 ± m.y. The hornblendes are from granitic gneisses, the white mica from a marble zone within the gneiss sequence. We regard these ages as indicating the age of metamorphism for the gneissic sequence is about 900 m.y. The age of sedimentation or original igneous intrusion for the rocks from which the gneisses were derived is unknown but is clearly at some earlier time. The determination of the earlier age of intrusion will be no easy task due to the difficulty in obtaining fresh, homogeneous and representative whole rock samples from the available exposures. There is no satisfactory isotopic method by which the possible age of sedimentation can be determined.

In the samples examined in this study the grade of metamorphism is generally high. The rocks are typically banded with femic minerals segregated into bands alternating with more pure quartzo-feldspathic zones. The textures are generally hypidiomorphic granular with dimensional orientation of quartz and other minerals

in others.

The typical assemblage for the quartzo-feldspathic gneisses is quartz-plagioclase-microcline (perthite) - garnet - pyroxene-hornblende. The identification of the assemblages is made difficult by severe to incipient retrograde effects. This is manifested in chloritization of femic minerals and garnet. The plagioclase is commonly turbid with alteration but appears to range in composition from intermediate oligoclase to calcic andesine where the composition can be determined. Both relatively pure microcline and well defined perthite are present. The garnet is typically red in color and is partially to extensively chloritized.

Calcareous rocks are interlayered with the quartzofeldspathic gneisses. These have a diverse assemblage but are generally characterized by carbonate-magnesian white mica and irregular amounts of garnet, and diopside. The garnet is extensively to totally converted to a colorless chlorite in several samples. The assemblage is interpreted as indicating high partial water pressure during metamorphism and during retrogressive cooling but the assemblage is not diagnostic as to metamorphic rank because the bulk composition did not allow the formation of rank sensitive minerals.

The assemblages of both the calcareous and quartzofeldspathic rocks suggest that the metamorphic grade is near the amphibolite-granulite facies boundary. The critical and diagnostic mineral assemblage of Buddington (1963) which is accepted by Turner (1968) as defining the boundary is that of a basalt bulk composition. This rock type has not been examined and may not be present in the represented starting compositions of the terrane. The assemblages found in the Victoria area are typical of those found elsewhere in what Turner (1968) described as the amphibolite-granulite transitional facies. It is concluded that the gneissic rocks in the Victoria area are most nearly in this facies. This is a higher metamorphic rank than is found in basement rocks in the southern continental interior of the United States. The Novillo Gneiss is much more typical of shield rocks and represents a deep erosional surface cut into the basement.

The origin of the gneissic rock is equivocal but there is evidence to bear on the question. The relatively massive character of the gneiss sequence and its almost totally granitic composition are suggestive of an igneous origin. However, the interlayered calcareous bands are difficult to explain with an igenous origin. A small but consistent piece of evidence seen in thin section is interpreted as definitive. The shape of the zircons in virtually every sample seen in the gneissic rocks are rounded. The size, shape and distribution of these zircons are much more typical of sedimentary than of igneous rocks. It is concluded that the larger part of the gneiss sequence found in this area is of sedimentary origin. The bulk composition would dictate a sequence of quartzo-feldspathic rocks with lesser pelitic and calcareous intervals. This does not preclude the possibility that there are some igneous rocks in the gneissic sequence. Indeed Carrillo (1961) reports that there appear to be some massive premetamorphic intrusions of the gneisses.

Graphitic micaceous schists are found in fault rocks. The schists are exposed in several canyons where the gneisses are not present. This sequence of rocks was named the Granjeno Schist by Carrillo (1961, p. 7) for the exposures at Cuchillo del Granjeno in Peregrina Canyon.

The strike of foliation shown in the map of Carrillo is very consistently northwest-southeast with vertical or steep dips in either direction. Fries and Rincon-Orta cite a N 30° to 45°W strike with general dips to the southeast at variable inclination in Novillo Canyon. The general structural grain of the schists is, therefore, roughly parallel to that of the gneiss although somewhat discordant where Fries and Rincon-Orta made measurements in Novillo Canyon. The reported assemblage is sericite-chlorite-quartz-feldspar with iron sulfides, calcite and some graphite. Numerous deformed quartz veins are present in the dark schists.

Carrillo was not able to establish an unequivocal stratigraphic relationship of the schist to the surrounding rocks. But it seemed reasonable to conclude that the schists were older than the lower Paleozoic sedimentary rocks (definite Silurian is present and possibly rocks as old as Cambrian-Ordovician) and perhaps younger than the gneisses.

The samples collected for this study from the Granjeno Schist show a consistent mineralogy. The typical assemblage is quartz-muscovite-chlorite-(albite-rutile - iron sulfides-graphite-garnet). Albite occurs as porphyroblasts as well as a mosaic with quartz. These porphyroblasts have trails of opaque specks which show they have been rolled during growth. Muscovite is in well formed books or in a sheaf of shreads having very marked preferred orientation. The muscovite is found both free of opaque material and heavily masked by graphitic specks. Small garnets and rutile are locally present. Chlorite makes up a lesser part of the mica fraction and is generally less well crystallized than the muscovite.

The assemblages are typical of the lower greenschist facies. It is concluded the Granjeno schist is a product of low rank metamorphic processes. This is in contrast to the much higher grade of metamorphism seen in the gneisses.

A K-Ar age was determined on a muscovite from a schist found in Caballeros Canyon (Fries and others, 1962, p. 63-64). The apparent age of 315 ± 10 m.y. was not fully understood and Fries and others suggested that it might be due to a local heating in Mississippian time, although a metamorphic event could not be discounted. There were too few data to support a firm conclusion.

Later field studies by Fries and an additional age of 310 ± 10 m.y. on a muscovite from a pegmatite (Fries and Rincon-Orta, p. 99-103) led to a reevaluation of the available information. The muscovite was collected from a pegmatite at the contact between the gneiss and the schist. Fries and Rincon-Orta noted that the Novillo gneiss was a very much higher metamorphic grade (they described it as granulite facies) than the greenschist facies exhibited by the Granjeno schist. The muscovite formation was later than the schist formation and, in Fries' and Rincon-Ortas' opinion, after faulting. They concluded that the determined ages from the schist were caused by local intrusive activity, that the most probable age for the schist formation was

in the Precambrian, and the faults separatin
and schist were of great magnitude (th
meters).

We have determined three K-Ar ages (T
one Rb-Sr age on rocks from the schist. Th
ages from the Victoria area are on the
fractions of graphitic micaeous schists. Th
305 ± 6 and 294 ± 6 m.y. are in substantial
with the Rb-Sr age determined from the are
rock muscovite isochron of 316 ± 30 m.y. w
on the same schist which gave a 305 m.y
(Table III). Another schist was dated fro
about 65 km northwest of Cuidad Victo
(1963) has described and mapped two s
outcrops between Aramberri and La Escond
Leon. These schists are well exposed benea
Limestone (Jurassic) in Arroyo Cantader
extensively calichefied by calcite.

The isotopic results from two sampl
moderate disagreement. Two mica sepa
samples collected within 10 meters of one an
K-Ar ages of 270± 5 and 294 ±6 million
older age falls well within range of those dete
the Granjeno schist. We believe the two schi
were formed synchronously and that they sh
yielded identical ages. The apparently low
tributed to weathering (calichefication) alth
is no significant petrographic difference in t
nor is the potassium content of the dated
substantially different.

Though lacking precise consistency, the
suggest strongly that the graphitic schists fr
area were metamorphosed in Permian-Pen
time. This raises a problem of how a sequence
arrived at their present location in juxtapos
Precambrian rocks which show no isotopic e
reheating and pre-Pennsylvanian sedimentary
showing recognizable metamorphic effects.
the gneiss, schist and Paleozoic sedimentary
always in individual fault blocks, there is not a
of defining the vertical sequence of rock u
clear that one or more of the units have been t
this area. The schists must be in fault contact
the gneisses and Paleozoic sedimentary rock
neither unit records the metamorphic event c
the schist. If the true vertical sequence is the
the bottom, Paleozoic sedimentary rocks in t
and schists thrust on top, then only one fault is
- at the base of the schists. Any other ex
requires a series of imbricate thrusts. If the
explanation is correct it follows that the schi
are grabens, not horsts.

Only detailed structural work will de
direction from which the schists came. Ho
seems clear that the schists represe
Pennsylvanian sedimentary rocks (dominant
and a significantly different facies and thickne
found in pre-Pennsylvanian of the Ciudad
area. It is concluded that the schists have been
considerable distance to their present posit
schistose sequence has all the characteristi
interior zone of the Ouachita system. The sir
the Granjeno Schist in composition, appearan
and age of metamorphism to the interior zone

and are not implying any relationship between the two rock units. It is over 400 km. from the Aramberri area to the nearest well penetrating interior zone Ouachita rocks. Any correlation over such vast distances must fall into the realm of speculation.

The NW-SE structural grain of the Precambrian rocks is similar, if not exactly parallel to every other structural direction. This includes schist foliation, dike directions, Paleozoic fold axes, pre-Upper Jurassic fault directions and Laramide fold axes as shown in Carrillo's work.

Similar Precambrian granite gneisses are exposed about 250 km. south in northeastern Hidalgo. The structural grain of these rocks is also generally NW-SE with northeast dip from 15-70° (Carrillo, 1965 and Fries and Rincon-Orta, 1965). The only age from these rocks, a 1210 ± 140 m.y. lead-alpha age on zircon, may be a maximum if these zircons are detrital in origin from a paragneiss.

These two outcrops are the closest occurrences of Precambrian rocks to the present Gulf of Mexico. Any synthesis of the evoluation of the Gulf must take into account both these ages and structural directions.

CONCLUDING REMARKS

We can see from the foregoing that the basement rock history in this Texas and northern Mexico area is complex but not completely indecipherable. The greatest factor which presently limits our understanding is the extremely wide geographic separation between the various pieces of hard information. There is no obvious ready solution for this. No known outcrops in this area are unstudied, although some, such as the Caopus-Rodeo, remain enigmatic. Few holes are likely to be drilled to basement in the near future in areas peripheral to the known Precambrian areas. There remains the technique of dating boulders from conglomerates. With all the shortcomings (both in principle and detail) of this type of dating, it nevertheless offers the best immediately applicable method for obtaining information about the basement. It may be particularly helpful in northern Mexico.

The southwestern United States and northern Mexico show widespread igneous activity at several periods in the Mesozoic and Tertiary. These periods of activity are just now being unraveled as the results of more detailed field work in association with isotopic dating become available. For the most part this activity does not appear to be of the "basement" forming type, being for the most part characterized by localized epizone intrusions and associated vulcanism. The activity has continued essentially to the present as evidenced, for example, by numerous very recent basaltic cores and flows in New Mexico.

ANALYTICAL TECHNIQUES

Preliminary determination of Rb and Sr contents were made by x-ray-fluorescence analysis. Samples selected for this study were spiked with enriched Sr86 and Rb87 and dissolved in HF, allowed to dry, and brought back into solution by complexing the fluorides with a mixture of H_3BO_3 and HCl. Unspiked portions of the samples with low radiogenic Sr enrichment were dissolved in the same manner. Separations were made on ion-exchange columns with the aid of Rb and Sr tracers.

All strontium isotopic measurements were made on a 13-inch-radius 60° magnetic sector, 15.8-inch-radius 91° electrostatic sector, second-ordor double-focusing mass spectrometer, using triple faraday cup collectors. Rubidium measurements were made on a symmetric 6-inch 60° single-focusing Nier type mass spectrometer equipped with dual faraday cup collectors.

The argon measurements were made on a 4.5 inch Reynolds-type mass spectrometer. The samples were fused by induction heating in tungsten or columbium crucibles and purified with liquid nitrogen and calcium at 800°C and absorbed on charcoal at liquid nitrogen temperature in a break seal. A typical blank is about 10^{-11} moles of atmospheric argon; the best are about 4 x 10^{-12} moles.

The constants used to compute the ages are

$$\mathrm{Rb}^{87}\ \lambda_{\beta} = 1.47 \times 10^{-11}/\mathrm{yrs}$$

$$\mathrm{Rb}^{87} = 0.283\ \mathrm{gm/gm\ Rb}$$

$$\mathrm{K}^{40}\ \lambda_{\delta} = 0.585 \times 10^{-10}/\mathrm{yrs}$$

$$\lambda_{\beta} = 4.72 \times 10^{-10}/\mathrm{yrs}$$

$$\mathrm{K}^{40} = 1.22 \times 10^{-4}\ \mathrm{gm/gm\ K.}$$

Sample date obtained from the mass spectrometers were processed by computer using an original program to calculate ratios, quantities, ages, and the standard errors associated with these measurements. Our results compare favorably with published standards (see Lanphere and Dalrymple, 1967).

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Tertiary Formations of Rim Rock Country, Presidio County, Trans-Pecos Texas

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ABSTRACT

The rim rock of the Vieja Rim, the quartz pantellerite of Lord, is named the Bracks Rhyolite. Beneath the Bracks, the "Vieja series" of Vaughn (1900), which is newly subdivided into five formations named, in descending order, the Chambers Tuff, Buckshot Ignimbrite, Colmena Tuff, Gill Breccia, and Jeff Conglomerate, rests unconformably on Upper Cretaceous formations. The Vieja Group is expanded to include also the Bracks and three overlying formations, named, in ascending order, the Capote Mountain Tuff, the Brite Ignimbrite, the Petan Basalt. An ancient post-volcanic gravel above the Petan antedates the bolson fill. The minimum hiatus at the base of the Vieja may include part of the Upper Cretaceous, all the Paleocene, and most of the Eocene epochs. The age of major faulting that created the bolsons is pre-Pleistocene, and probably most of the bolson fill was deposited before the end of the Tertiary Period.

INTRODUCTION

In 1922 Charles Laurence Baker (1927, p. 5, fn. 1) completed a manuscript on the geology of the most inaccessible part of Texas, which he had mapped at the rate of 35 square miles per day. His mapping was an exploratory feat of the first order, and his account of the geology is fundamental. All geologic maps (Stose, 1932; Sellards, Adkins, and Plummer, 1933b; Baker, 1935; Sellards, 1936, 1939; Darton, Stephenson, and Gardner, 1937; Longwell, 1944; Sellards and Hendricks, 1946; Stose, 1946) of the Rim Rock country subsequently published are versions of Baker's (1927: Pl. 1), although Stovall's map (Stovall, 1948: 80) of part of it has additional information.

The Texas-Chihuahua border region, which is still a challenge to map makers, was long a veritable terra incognita. The first Europeans (Davenport and Wells, 1919: 248–259 and map) to visit the Rim Rock country were the fabulous Cabeza de Vaca and his companions, Castillo and Dorantes, who traversed it in 1535, traveling on foot up the east bank of the Rio Grande. In 1581, forty-six years later, Rodriquez (Bolton, 1915: 135–145), two other friars, nine soldiers, and sixteen Indian servants traveled the same route, and the Rodriquez party was followed in 1582 by another party led by Espejo (Bolton: 163–175), a wealthy citizen of the City of Mexico. Then almost exactly a hundred years elapsed before the next party, led by Captain Mendoza (Bolton: 316–326) and preceded 15 days by two friars, went down the west side of the river from El Paso to La Junta (Ojinaga) in the last half of December 1683, recording the precipitous topography

> well overgrown with lechuguilla so that it was not possible to travel by night.[1]

Three hundred years after Cabeza de Vaca's 17 *jornadas*, the first authentic map of any kind, geological or otherwise, was yet to be made. Two early summaries (Hitchcock and Blake, 1874: 8; Hitchcock, 1887) of geological maps of the United States record that Maclure's of 1809 and 1817, the first to be published, and James Hall's of 1843 showed only the geology of the eastern states and that the coloring on Sir Charles Lyell's of 1845 did not extend much west of the 95th meridian. The list continues: Marcou, 1853; Edward Hitchcock, 1853; Keith Johnson, 1856; and a second by Marcou in July 1855, republished in March 1856 and in 1858. After the return of the Pacific Railway exploring expeditions in 1854–1855, a map of the region west of the 100th meridian was compiled by C. H. Hitchcock or W. P. Blake and exhibited at the meeting of the American Association in Albany, New York, 1856, but it was never published (Hitchcock and Blake, 1874: 8). Shortly afterward, the map of the country west of the Mississippi compiled by James Hall (1875b) of Albany was published.

The geology of the Rim Rock country as published for the first time on Hall's map was based on Emory's boundary survey. Fifteen years later, Hitchcock and Blake prepared a geological map of the United States dated 1872 and another dated 1874. On these two most of Trans-Pecos Texas is shown as a wide outcrop of Cretaceous rock. Surprisingly, the 1872 version of Trans-Pecos geology is better than the 1874, and Hall's mapping in the Trans-Pecos region is better than either.

I have not seen Hitchcock's large wall map, scale 20 miles to the inch

(Hitchcock, 1887: 482) which was published in 1881. McGee's map (1885: 36–38) of 1884, scale 112.3 miles to the inch, served as the base for Hitchcock's handsomely colored map of 1886, on which the geology of Trans-Pecos Texas was revised once more; but Hall's version of the southwestern part was still the best to date. Hitchcock (1887: 488) justly concluded that

> In the earlier surveys no name stands more prominent than that of James Hall.

Hall's map provides interesting examples of geologic extrapolation. It was based on the work of early explorers, who, by submitting specimens to geologists, had correctly identified Carboniferous rocks, now called Permian, in the Guadalupe-Delaware Mountains on the north and in the Chinati Mountains on the south. Reasonably enough, albeit incorrectly, Hall joined the two outcrops through the Davis Mountains east of the Rim Rock country. He also showed an apocryphal Carboniferous core in the 120-mile range in Chihuahua immediately west of the Rim Rock country. A dozen years later Kimball (1869: 387) remarked that

> The number of Cretaceous fossils collected by myself west of Presidio del Norte, quite disproves the position of Dr. Parry, viz., that the "natural boundaries of this basin (near Presidio del Norte) consist of irregular mountain ranges composed principally of carboniferous limestone similar to that seen above" (near El Paso). But Dr. Parry (1857: 50) in this matter seems to follow Prof. Hall (1857a: 110) who referred the limestone of this section to the carboniferous exclusively on the ground of the lithological analogy with the Carboniferous limestone in numerous western localities of a simple specimen from the rapids of the Rio Grande, in which no fossils could be recognized.

When Streeruwitz (1891b: 685; Geiser, 1957) crossed Vieja Pass in 1886, he made no map but observed with foresight

> that the basaltic and other volcanic rocks predominate in that portion of Trans-Pecos Texas, and that in all probability they are second in value to the Chinatti prospects and the Quitman and the Carrizo Mountains, as far as ore bearing is concerned.

The topography was surveyed in 1892 (Chispa Sheet) and in 1895 (San Carlos Sheet; Vaughn, 1900: Pl. 6). In 1904, B. F. Hill and Udden published a geologic map of the region. Their rough reconnaissance was transferred to the first geologic map of North America (Willis and Stose, 1911) and the first detailed geologic map of Texas (Udden, Baker, and Böse, 1916b). Earlier versions of the geology of

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[1] "... es forzoso parar por ofrecerse el dia siquiente tierra fragosa y poblada de mesquite, y Uña de Gato aunque andable, y luego ofrecerse una Cuesta muy encumbrada y de la parte del Oriente ocinada y muy poblada de Lechuguilla, casi hasta llegar al Rio del Norte, y no poderse andar de noche."

Texas are shown in maps by McGee (1885: 40–41), the Merchants' Association of New York (1901: Chart 8), Simonds (1905: Fig. 2), and Dumble (Merrill, 1920: 492–493). The geology of the adjoining part of Chihuahua is not well known; it is shown on Hall's map, the maps of North America, the tectonic map of the United States, and the recent maps of Mexico (Flores, 1942; King, 1942: Pl. 1; King, 1947: Láminas 1 and 2; Eardley, 1951: Fig. 249, 422; Guzman et al., 1952; Carta Geológica, 1956; Diaz and de Cserna, 1956: Fig. 2). I have not seen "Senor Antonio Castillo's excellent Geological Map of Mexico, Mexico, 1889," which was utilized by R. T. Hill (1893: Fig. 2), or Fleury's map, which was criticized by Kimball (1869: 382 and 383).

In July 1895 (Parker, 1895b: 193; Vaughn, 1900: 75; Bilbrey, 1957), when all Texas west of the hundredth meridian was wild, the Rim Rock country already had a railroad. The Rio Grande Northern, a spur line that extended from Chispa siding on the Galveston, Harrisburg, and San Antonio Railroad (Southern Pacific) over Chispa summit in the pass between the Van Horn Mountains and the Sierra Vieja, was laying track toward the coal deposits at San Carlos, where shafts were being sunk. The railroad reached San Carlos in November, but the shafts did not penetrate commercial coal. Mining by means of adits was begun in January, 1896, but the production was so small that the Galveston, Harrisburg, and San Antonio refused to furnish transportation because it would not be economical. The coal company hired an engine and may have hauled a little coal between January and June 1896, although there is no record of sale. Prior to 1896 the *Mineral Resources* volumes (Ashburner, 1886: 68; Parker, 1895a, 1895b: 193) gave highly optimistic reports of anticipated production, finally in summary (Parker, 1896: 522) of the year 1895, stating that

> The San Carlos mines in Presidio County did not get out any coal, commercially, before the close of the year, the first run over the tipple being made on January 3, 1896.

The authors of subsequent volumes not only failed to report production but simply ignored the subject. (*Cf.*, however, Ries, 1905: 105; Hornaday, 1911; Phillips and Worrell, 1913: 29–31; Phillips, 1915: 201–202; Dumble, 1916: 193; Darton, 1933: 120.) In 1900 the Rio Grande Northern was abandoned. To this day the chief sources of ranch lumber under the rim are the old ties and bridge timbers, and several miles of the old roadbed still serves as the main ranch road, which goes through the railroad tunnel (Vaughn, 1900: Pl. 10) at San Carlos.

The preceding paragraph might be taken as a paraphrase of the futile history, so far, of each mining prospect in the Rim Rock country—

nitrate, silver, manganese, uranium—although none other has entailed quite so elaborate a development as the San Carlos coal district. Exploration for petroleum has also been unsuccessful and unavoidably expensive in this remote country, but at least the wildcatters have drilled their dry holes without erecting tank farms or laying pipe lines to handle the oil they hoped to produce. The outlook for eventual discovery is still favorable.

In 1911, W. B. Phillips (1910, 1911a, 1911b, 1911c; Gale, 1912: 28) inspected a nitrate prospect in the Rim Rock country near Candelaria, where

> nitrate of soda exists as thin crusts on and thin seams in a hard dense trachyte, or lava.

Writing in the third person, Phillips summed up his investigation of nitrate in northern Mexico and western Texas (1911b) in words of disillusionment:

> He has ridden many miles to see white encrustations on the walls of canyons, along arroyos, etc., in the hope that they would prove to be what some enthusiastic prospector had reported they were. Except for the pleasure of the ride and the views of impressive scenery he might have been better employed.

H. M. Robinson (Mansfield and Boardman, 1932: 69–75, Fig. 8) examined the nitrate deposits at a mining camp on Capote Creek 8 miles NE by E of Candelaria in August 1918 and reconnoitred the geology (Robinson, 1918) within 5 or 6 miles of the camp. Mansfield and Vanderwilt examined other nitrate deposits (Mansfield and Boardman, 1932: 77, Figs. 9 and 10, Pls. 9B and 10; Wooton, 1927) in the Candelaria vicinity in June, 1928.

Darton's (1933: Sheet 15) guidebook has a sketch of the geology of the eastern slope of the Sierra Vieja. There is no published record of Sellards' (1933) trip through the Rim Rock country after the Valentine earthquake of 16 August 1931 or of the surveys made by a number of oil company parties in the three decades between 1927 and 1957. Among the early petroleum explorers were V. C. Maley and M. B. Arick; among the later, H. M. Neilson and associates.

In 1932 (Stovall, 1948: 84) Baker discovered bone fragments in the Rim Rock country. Stovall (1948: 85), Savage, McAnulty, and Langston collected fossil mammals in 1938 and 1940; Brown (1941: 103) and Bird collected a few bones and teeth in November 1940. Bryan Patterson (Goldich and Elms, 1949: 1144–1145) and Quinn collected vertebrate fossils in 1946, and Goldich and Patterson made a brief reconnaissance in November 1946; Carlisle, Mankin, and Quinn collected bones in 1954; and J. A. Wilson and Clabaugh, in 1956 and

1957. A field examination has indicated that the X marked "Fossil Locality" on Stovall's map and the corresponding description in the first paragraph of his text must both be wrong; it is probable that his fossils came from Big Cliff two miles farther west, where Patterson and Wilson subsequently collected.

In 1954, 1956, and 1957 graduate students from The University of Texas (DeFord, 1957) mapped the geology of the Rim Rock country in greater detail than has yet been published. The mapping in the summer of 1954 extended from Lat. 30° 06′ to 30° 22′ N. J. E. Peterson mapped part of the eastern slope of the Sierra Vieja east of the high rim. Four parties mapped between the Rio Grande and the high rim, as follows: 06′–10′ N, C. J. Mankin and B. J. McGrew; 10′–14′ N, J. C. Carlisle and C. R. Sewell; 14′–18′ N, B. Buongiorno and J. T. Smith; 18′–22′ N, R. C. Duchin and S. S. Moran.

The mapping in the summers of 1956 and 1957 extended from south of Lat. 30° 22′ to 30° 42′ N. Five parties mapped between the Rio Grande and Vieja Rim, as follows: from south of 22′ to 26′ N, D. G. Bilbrey and J. T. Schulenberg; 26′–30′ N, J. D. Ferguson and W. D. Miller; 30′–34′ N, C. R. Colton and R. G. McKinney; 34′–38′ N, L. W. Bridges and E. J. Dasch; 38′–42′ N, P. Braithwaite and D. R. Frantzen. Robert Allen and J. C. Nichols mapped the Sierra de los Fresnos across the Rio Grande in Chihuahua from 15′ to 23′ N, and D. B. Clutterbuck and A. D. Ferrell, the north end of the Sierra Pilares from 34′ N to the Rio Grande. The mapping in 1957, north of 34′ N, is not shown in the figures in this paper.

As a result of the mapping, the Tertiary sequence may be divided into formations. The purpose of this paper is to present a local classification of the Cenozoic volcanic rocks to serve as a basis for further investigation and publication. It may prove useful to those who undertake to organize the biostratigraphic classification or unravel the tectonic history or find oil.

GEOGRAPHY AND STRUCTURE

The Rim Rock country occupies a deep valley between parallel mountain ranges. The talweg, the south-southeasterly course of the Rio Grande, called Rio Bravo del Norte by the Mexicans, descends about 7 feet per mile through this drouth-stricken country, which has long been dry. In 1535 Cabeza de Vava (Davenport and Wells, 1919: 253) asked the Indians along the river

> why they did not raise maize, and they replied that they were afraid of losing the crops, since for two successive years it had not rained, and the seasons were so dry that the moles had eaten the corn, so

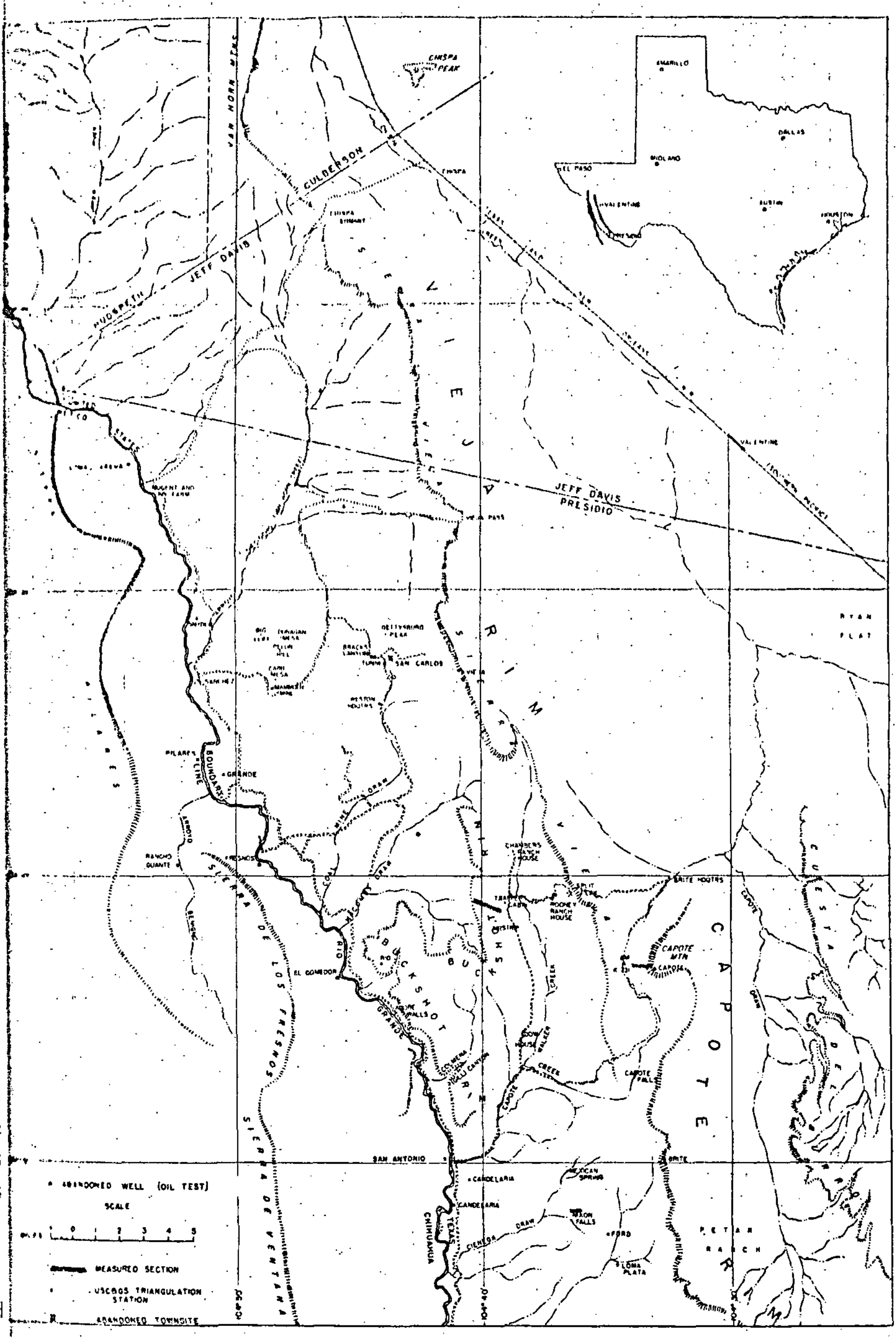

Fig. 1. Map of Rim Rock Country, Trans-Pecos Texas.

> that they did not dare to plant until it rained very hard. And they also begged us to ask Heaven for rain.[2]

All the explorers found the same xerophytes that still grow on the rims above the river.

Emory (1857. Part.1: 50)

> was informed, on good authority, that in the summer of 1851 a man drove a gang of mules along the bed of the river from Presidio del Norte to El Paso. The bed was dry for nearly the whole distance, occasional pools of water standing in places. . . .

Nearly 50 years later Dumble (1898: 491) described the river bed below El Paso as

> a sandy plain which is often entirely dry or with water standing in pools. At other times great floods pour down its channel and spread out in the valley. . . .

The drouth then recurrent has since become chronic: from McNary, about 50 miles southeast of El Paso, through the Rim Rock country to Ojinaga (Presidio del Norte), 140 miles southeast of McNary, the Great River now flows only when flooded by summer cloudbursts. Any upstream water spared by the drouth is claimed for irrigation.

The eastern border of the Rim Rock country, the Sierra Vieja, is about half of a 100 mile mountain range along the Texas border. From the north end of the range seven miles south of Van Horn, Texas, the Van Horn Mountains extend southward 17 miles to Chispa Summit. Thence the Sierra Vieja continues 35 miles southward to Capote Peak (Gannett, 1899: 684, 1906: 947; 1928 Texas Almanac: 45), and thence on southward another 15 miles to the head of Pinto Canyon. The high Chinati Mountains, about 20 miles long, extend from Pinto Canyon to Shafter, Texas. Beyond Shafter the range continues another 10 miles to its southern end in Cienega Mountain.

The Sierra Vieja (San Carlos Sheet, 1896; Hill, 1899; Gannett, 1902: 139; Phillips, 1904: 5; Simonds, 1905: Fig. 133; Bailey, 1905: Pls. 1, 3, 12, and 14; Deussen, 1910: 62, and 1911: 141; Ransome, 1915: 335; Dumble, 1916: 174; Mansfield and Boardman, 1932: Pl. 10; Texas almanacs, maps of Texas, 1936 and 1943; Darton, 1937; Sellards and Hendricks, 1946; Blair and Miller, 1947: 67, 68, 88; Handbook of Texas, 1952, Vol. 2: 609, 780; Texas almanacs, maps of Texas and Presidio County maps, 1941, 1945, 1947, 1949, 1951, 1953, 1955; Hammond and Encyclopedia Britannica atlases) has also been called the Vieja Mountains (Livermore, 1883; Havard, 1886: 482, 492; Vaughn, 1900: 73; Clarke, 1900: 60; Gannett, 1902: 153; Simonds, 1905: 28; Hammond atlas), the Vieja Range (Shipman, 1926: 19), the Tierra Vieja Mountains (Gannett, 1902: 42, 148; Udden, Baker, and Böse, 1916, 1st ed.: 12, 15, 78, 101; Baker and Bowman, 1917: 119, 124, 141; Baker, 1921: 25; Smith and Walker, 1923, Political Map; Texas almanacs, maps of Texas, 1925, 1926, 1927, 1928; Shipman, 1926: 116; Baker, 1927: 37, 49; Texas almanacs, 1927: 57, 1928: 338; Baker, 1928: 343, 348, 354, 355, 371; Adkins, 1931: 35 and Fig. 7; Carter, 1931: 159; Carter and Cory, 1932: 30; Sellards, 1933: 145; Plummer, 1933: 801, 803; Darton, 1933: 99, 101, 102, and Sheet 15; Baker, 1935: 156, 187, 188, Fig. 15 and Pl. 4; Sellards, 1936; Baker, 1941: 82, 88, 89, 90; Goldich and Elms, 1949: 1144–1145, Fig. 2; Eifler, 1951: 342; Handbook of Texas, 1952, Vol. 2: 780; McAnulty, 1955: 558; Rand McNally and Glydendals atlases) the Tierra Vieja Range (Texas almanac, 1929: 347), the Sierra Tierra Vieja (King, 1935: 241, 243, 254, and Fig. 5; Hinckley, 1947: 162, 164, 165, 171, 172, 177), the Sierra de Tierra Vieja (Baker, 1928: 373, Pls. 20, 21, 22; Baker, 1941: Pls. 10 and 11), the Rim Rock Mountains (Dumble, 1895: 385; Dumble, 1898: 485; Baker, 1935: Fig. 15 and Pl. 4), and, redundantly, the Sierra Vieja Mountains (Hill and Udden, 1904; Chispa Sheet as reprinted in 1938; Jameson and Flury, 1949: 54; York, 1949: 59 and Fig. 2; Phillips and Thornton, 1949: 102; Texas almanac, 1939: 447; Cram's and Stieler's atlases), the Sierra Vieja Range (Blair and Miller, 1949: 67; Jameson and Flury; York; Phillips and Thornton; Texas almanac, 1926: 178; Handbook of Texas, Vol. 2: 609, 841), the Sierra Viejas (Dumble, 1916: 176; Blair and Miller; Jameson and Flury; Phillips and Thornton), and the Sierra Tierra Viejas (York), and, mistakenly, the Sierra de Pilares (Humboldt, 1812b; Solm-Braunfels, 1846a and 1936), and the Chanatte Mountains (Roessler, 1874).

The forms *Viega* (Gannett, 1899, p. 706; 1906, p. 972) and *Viego* (Gillett, 1921: 278–280) are due to inaccurate transcription. The form *Viejo* (Streeruwitz, 1891b: 685; 1892: 386, and 1893: 175; Osann,

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[2] "Preguntámosles cómo no sembraban maíz; respondiéronnos que lo hacían por no perdér lo que sembrasen, porque dos años arreo les habían faltado las aguas, y habia sido el tiempo tan seco que a todos les habían perdido los maíces los topos, y que no osarían tornar a sembrar sin que primero hobiese llovido mucho; y rogábamos que dijésemos al cielo que lloviese y se lo rogásemos, y nosotros se lo prometimos de hacerlo ansi . . . dijérronos que el camino era por quel río arriba hacia el Norte, y que en diez y siete jornadas no hallaríamos otra cosa niguna que comer, sino una fruta que llaman chacan, y que la machucan entre unas piedras si aun después de hecha esta diligencia no se puede comer, de áspera y seca . . . y ansi seguimos nuestro camino, y atravesamos toda la tierra hasta salir a la mar del Sur; y no bastó a estorbarnos esto el temor que nos ponían de la mucha hambre que habáiamos de pasar, como a la verdad la pasamos, por todas las diez y siete jornadas que nos habían dicho . . . y ansi pasamos todas las diez y siete jornadas, y al cabo de ellas atravesamos el río. . . ."

1893: 134; Dumble, 1895: 385, and 1898: 485; Shipman, 1926: 95, 156) probably came from Paso Viejo (Gillett, 1925, 200–202, account of 1881; Shipman, 1926: 95 and 199), now called Vieja Pass; indeed, the name of the mountains themselves may have been derived from the name of this old pass. The Sierra Vieja is bounded by two passes and subdivided by two more. From north to south these are Chispa Summit, Vieja Pass, the divide between Capote Creek and Capote Draw near Capote Peak, and the head of Pinto Canyon. Two early maps (Chispa Sheet, 1892; Vaughn, 1900: Pl. 6; cf. Presidio County maps in Texas almanacs, 1941, 1945, 1947, 1949, 1951, 1953, 1955) imply that the name *Tierra Vieja* denoted only that part of the range between Chispa Summit and Vieja Pass. Chispa Summit is mislabeled "Vieja Pass" on Presidio County maps in Texas almanacs, 1945, 1947, 1949, 1951.

The eastern face of the Van Horn Mountains is a scarp related to normal faulting downthrown to the east. The northern and southern parts of the scarp join in a sharp angle. The northern part extends about 9 miles S 10° W to the angle; from it the southern part continues about 5 miles S 45° E to Chispa Summit, beyond which the northern part of the Sierra Vieja shows the same trend for another 3 miles.

Reversing the features of the Van Horns, the western face of the Sierra Vieja, the great rim, is related to normal faulting downthrown to the west. A system of large persistent faults with less persistent smaller faults parallels the rim for 50 miles. The whole Rim Rock country is an intermontane depression due to block faulting. The mean trend of the crest of the sierra is close to SSE, and the local variations from this trend are neither marked nor persistent.

On the eastern slope of the Sierra Vieja the strata dip (Sellards: 1939; Sellards and Hendricks, 1946) eastward under Ryan Flat (Hill, 1900: 9, col. 1), a broad valley of interior drainages, Capote Draw and Chispa Creek, that are not connected with the sea. The altitude of the flat ranges between 4,000 and 4,500 feet above sea level. From it the surface of the ground rises (Vaughn, 1900: Pl. 7) approximately 2,000 feet in 4–8 miles to the crest of the range, terminating in a westward-facing precipice several hundred feet high. Between Chispa Summit and Capote Mountain this precipice (Vaughn: Pl. 8; Baker, 1928: Pls. 21 and 22; Baker, 1941: Pl. 11; Hinckley, 1947: Fig. 1; Keith, 1950: xix) is the Vieja Rim. On the north where its crest is about 12 miles from and 3,000 feet above the Rio Grande, there is a 2,000-foot difference in elevation within a mile and a half of the rim in places; at San Carlos, where the river is 11 miles away, the difference is 2,700 feet (Vaughn: 75, Pl. 6) in 3 miles; the topography of the rest of the country from rim to river is up and down. Farther south the rim is but 10 miles from the river and 3,500 feet above it; this has been described (Shipman, 1926: 117) as

> the highest, wildest looking bluff in the lonesome stretches of the Big Bend. The border bandit could stand on this bluff and look down two thousand feet, then out over miles of broken, uninhabited country to the Rio Grande. In the opposite direction, twenty miles distant he

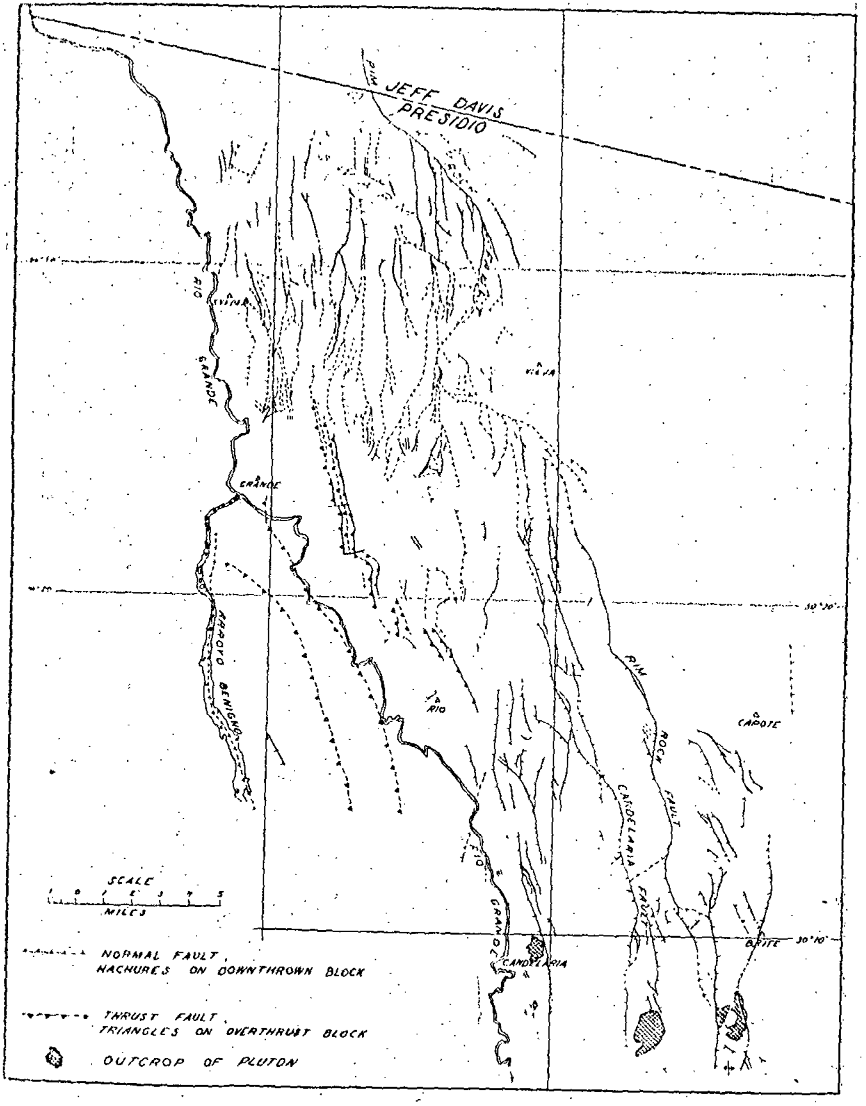

Fig. 2. Fault pattern in Rim Rock country.

> might see the link with the outside world—the Southern Pacific passenger train. . . .

At first look the Vieja Rim appears to extend all the way to Pinto Canyon, but closer inspection shows that the still higher Capote Rim, which caps Capote Mountain, is the chief rim of the southern third of the Sierra Vieja. On Robinson's 1918 map the Capote Rim is mislabelled "*pantellerite*." It was correctly shown above the Vieja Rim by Baker (1928: Pl. 10), by Carter (1931: Fig. 82, mislabelled "Chinati Mts."), and by Baker (1941: Pl. 20; see also Keith, 1950: xix, xxix, and end papers).

The great valley under the Vieja Rim has many local rims that cap tilted blocks bounded by faults. One of the most prominent is the Buckshot Rim (Hinckley, 1947: Fig. 3), which rises many hundred feet directly above the Rio Grande in the southern part of the Rim Rock country (Fig. 1).

The western border of the Rim Rock country formed by the Sierra Pilares and Sierra de Ventana comprises about half of a 120-mile mountain range, most of which is in Chihuahua, Mexico. At the north end of the range, in Texas, is the imposing mass of the Eagle Mountains (Sierra Cola de Aguila of Humboldt, 1812b; Solms-Braunfels, 1846a, 1936; Streeruwitz, 1891a: xci), about 12 miles west of the north end of the Van Horns. The Indio Mountains extend from the Eagle Mountains 15 miles S by E to the Rio Grande, which transects the range in a deep canyon. The dry wash, tributary to the Rio Grande, between the parallel Van Horns and Indios is called Green River. On the Chispa Sheet and most subsequent maps it is named Glenn Creek, but that name is no longer in local use. Streeruwitz's usage (1891a: xci and xcii) seems to indicate that Green River Canyon and Glenn Creek once were names of different places, whereas Baker (1927: 40; see also 1935: 139 and 201) 30 years later wrote about the "head of Green River (Glenn Creek)" as a single locality.

From the Rio Grande the Sierra Pilares extends 30 miles S by E and the Sierra de Ventana continues another 30 miles, whence it swings due S 10 miles to a junction, near Cuchillo Parado, with the Sierra Grande, which continues 25 miles S by E to the southern end of the range at La Mula. The mountains are composed dominantly of Lower Cretaceous limestone, which, in contrast with the rim rocks, is sharply folded and thrust-faulted. The front of the Ventanas rises steeply from the Rim Rock country within three or four miles of the Rio Grande. The steep front of the Pilares is in similar position expect that on the north it joins the river, and on the south the Sierra de los Fresnos stands as a partly distinct frontal element within a mile of the river. The *ventana* from which the Sierra de Ventana probably got its name is actually in the crest of the Fresnos; it was mentioned in Mendoza's narrative[3] of the expedition of December 1683.

LITHOSTRATIGRAPHY

The chief rim rock, the Bracks Rhyolite that caps the Vieja Rim, is the key to the Tertiary stratigraphy of the Rim Rock country. This is the quartz pantellerite of Lord (Vaughn, 1896; Vaughn, 1900: 77, 81, 82, 83, Pls. 8 and 10; Lord, 1900: 88–95). The "Vieja series" as originally defined by Vaughn (1900: 77; p. 81, Resumé of San Carlos section) included all the Tertiary formations below the base of the Bracks, but excluded the Bracks, although Adkins (1933: 513) stated inaccurately that Vaughn's Vieja included the pantellerite. Adkins instinct was right. Vaughn was not aware of the presence of volcanic rocks younger than the pantellerite. Mapping in the northern part of the Rim Rock country where the Bracks key bed is missing has emphasized the practical need for a group of all the volcanic formations. It is therefore proposed to expand the Vieja Group to include also the Bracks, the Capote Mountain, the Brite, and the Petan formations.

The Vieja rests unconformably on Upper Cretaceous rocks; in many places the contract is concordant, but in others the Cretaceous rocks were folded or thrust-faulted prior to Vieja deposition. The minimum unconformity at the base of the Vieja Group under the Vieja Rim near San Carlos probably entails the absence of some of the Upper Cretaceous, all the Paleocene, and most of the Eocene. In some other outcrops in the Rim Rock country most of Upper Cretaceous is also missing.

In descending order the formations of the Vieja Group are:

> Petan Basalt, Brite Ignimbrite, Capote Mountain Tuff, Bracks Rhyolite, Chambers Tuff, Buckshot Ignimbrite, Colmena Tuff, Gill Breccia, Jeff Conglomerate.

All except *Jeff* and *Vieja* are new names proposed in this paper; their descriptions are extracted chiefly from two unpublished theses by Sewell and McGrew. To understand the derivation of the new names let us refer to Figure 1, beginning at Candelaria (8.5–41).[4] The mouth of Capote Creek is two miles upstream from Candelaria. Colmena Canyon, the next considerable tributary to the Rio Grande on

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[3] "En veinte y quatro dias del dho. mes y año salimos de este pasage que por nombre se le puso N. S. de Belen por un Portillo que hace en los alto de una sierra que está de dicho pasage como media legua poco mas ó menos y el dicho Portillo hace como á modo de ventanas." Bolton (1916: 323).

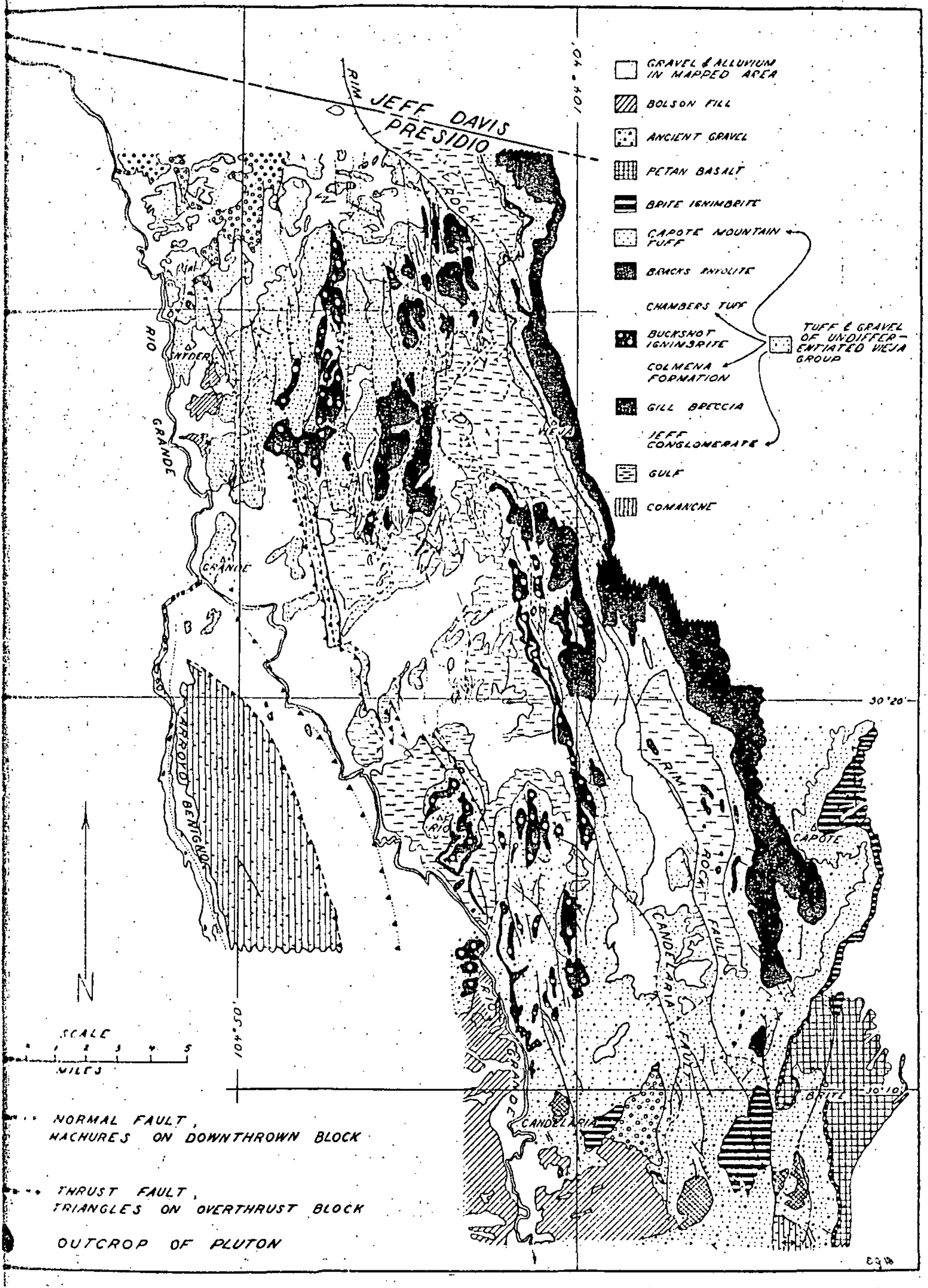
[4] 30°8.5′N, 104°41′W; the geographic coordinates used hereinafter are all in minutes north of Lat. 30°N and west of Long. 104°W.

the Anglo-American side, three miles farther upstream (13–42), called Gill Canyon on the San Carlos Sheet, is a gap in the Buckshot Rim. The Chambers (20.8–38.8) and the Rooney (19–37.2) ranches are N of Candelaria between the river and the Vieja Rim, the Chambers headquarters 15 miles N by E from Candelaria and the Rooney 2½ miles SE of the Chambers. The Rooney ranch is directly beneath Split Peak (Keith. 1950: xxxvii), where a trail over the high rim marks the site of an abandoned road; this is 8 miles N of another trail over the rim that marks the site of the abandoned grade of the old county road from Valentine to Candelaria via the Brite headquarters N of Capote Mountain. The Petan ranch is on the Capote Rim near Pinto Canyon. The name *Jeff* does not belong to the Rim Rock country.

Jeff Conglomerate.—Eifler (1951: 343–344) named the Jeff Conglomerate, the type locality of which is in the Barrilla Mountains about 70 miles from the Rim Rock country, NE of Pinto Canyon (2–28) and E of Chispa Summit (43–47). By mapping outcrops, the Jeff has been traced as a practically continuous body from its type locality to the northern end of the Davis Mountains about 30 miles NE of Chispa Summit. There are no outcrops of Jeff in these intervening 30 miles.

The basal conglomerate (Baker in King, 1935: 243; Goldich and Elms, 1949: 1145) of the Vieja Group is notably similar to the Jeff Conglomerate (Eifler: Pl. 2; McGrew, 1955: 34–36, Figs. 9–11; Sewell, 1955: 17–19, Pl. 9; Peterson, 1955: 20–22). In much of the southern part of the Rim Rock country the Gill Breccia intervenes between the basal conglomerate and the Colmena Tuff. Northward the breccia pinches out and the conglomerate thickens, presumably as the lower part of the Colmena Tuff grades into conglomerate, so that on the north a major part of the interval between the Buckshot Ignimbrite and the base of the Vieja Group is occupied by conglomerate. It is arguable that a new name should be given to the basal conglomerate of the Rim Rock country or that the conglomerate and the tuff should be described as interfingering facies of the Colmena Formation, but it is proposed, nevertheless, to use the name *Jeff Conglomerate*, at least until the detailed mapping on the north is more nearly complete.

Gill Breccia.—In much of the southern part of the Rim Rock country where the outcrops of Jeff Conglomerate are difficult to detect, the obvious basal unit of the Vieja Group is a flow breccia, named herein the Gill Breccia, which attains a maximum thickness of 300 feet in the type section in Colmena Canyon. The Gill may be composed of a series of flow breccias. Sewell (1955: 22–31, Pls. 11–16) recognized three rock types, to-wit: (1) medium gray fragments in a grayish red



Areal geology of Rim Rock country.

matrix; (2) mottled fragments (pink, green, yellow, gray, and brown) in a dark greenish gray to orange pink matrix; and (3) brecciated to massive light olive green to dark greenish gray fine-grained rock. The majority of the fragments are composed of trachybasalt porphyry, although the composition of the rock may be said to range from trachyandesite to basalt. McGrew (1955; 36–43, Figs. 12–16) described and illustrated the petrography in detail.

The Gill Breccia contains blocks (Sewell, 1955: 14, 23–26, Pl. 8; Moran, 1955: 55–60, Figs. 12 and 13; Duchin, 1955: 26) of massive Lower Cretaceous limestone, some of them as large as a three-story building. The locations of nine of these blocks were described by Sewell (1955: 23–24) as follows: (block 1) the most accessible limestone block is on the east bank of the Rio Grande, where it causes a steep hill (10.5–41.4) on the river road about 2½ miles N of Candelaria and a quarter of a mile N of the Capote Creek crossing; (blocks 2 and 3) there are two blocks in Colmena Canyon (13–41.5) about 0.8 mile from the mouth, and (blocks 4 and 5) two more in Colmena Canyon (13.5–41.1) about a mile and a half from the mouth and about 0.1 mile up the eastern fork of the mainstream; (blocks 6 and 7) there are two blocks about a mile (16–34) up a draw from its mouth at Adobe

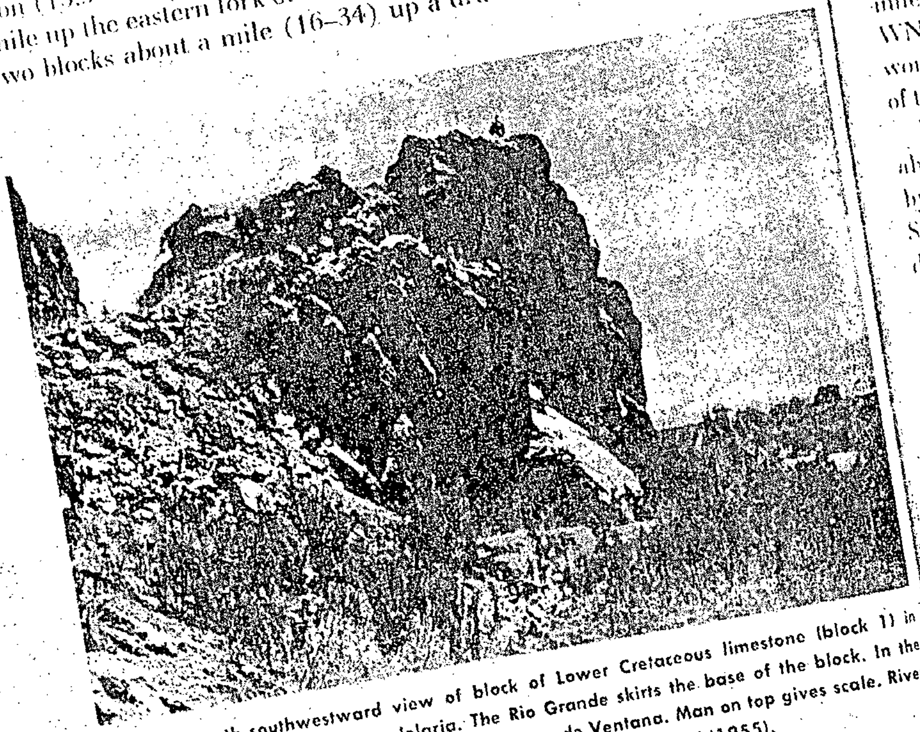


Fig. 4. South-southwestward view of block of Lower Cretaceous limestone (block 1) in Gill Breccia 2½ miles N of Candelaria. The Rio Grande skirts the base of the block. In the distance beyond the Rio Grande valley is the Sierra de Ventana. Man on top gives scale. River road passes through notch at upper left. Photograph by C. R. Sewell (1955).

Walls on the river road about six miles upstre 8) there is a block under the Vieja Rim about a mile N (13.7– the old Candelaria-Brite ranch county road; (block 9) and another along the Rim Rock fault about a mile NW (14–36.3) of block 8. After reviewing the several possibilities that the blocks are klippen, landslide blocks, peaks of buried mountains or eroded crests of anticlines, or the result of sedimentary intrusion, Sewell, Moran, Clabaugh, and DeFord favored the hypothesis that the blocks were brought up by the magma that formed the Gill Breccia. Lonsdale did not concur.

In most of the few good exposures on the south, the base of the Gill Breccia is concordant with the underlying Jeff Conglomerate or Upper Cretaceous formation. Its upper surface appears to form buried hills under the Colmena Tuff.

Measured Section 1.—The type locality (8.3–37.2) of the Colmena and Buckshot formations, which overlie the Gill, is Measured Section 1 (MS 1), four miles due E of Candelaria (8.5–41). It is hard to get to. The trail to Mexican Spring (9.7–36.6) joins Cienega Draw about three miles east of Candelaria and continues thence up the draw the rest of the way, passing the mouth of the tributary from Nixon Falls about half a mile upstream. MS-1 (8.3–37.2) is in a northeastern side canyon about a mile up this tributary from its mouth and about a mile down it from Nixon Falls (8–36.4), which are a mile and a half WNW of Ford ranch (7.5–35). It may prove desirable after further work to propose a more accessible reference locality, although no part of the Rim Rock country is readily accessible.

From bottom to top, MS-1 extends from SW to NE. The beds dip about 8° E. The section was measured and sampled in August, 1954, by C. J. Mankin and B. J. McGrew (McGrew, 1955, MS 4: 100–102; Sewell, 1955, MS 4: 96–98; Peterson, 1955, MS-4: 65–68). Their description follows:

Unit	*Description*	*Thickness in feet*
	BUCKSHOT IGNIMBRITE:	
18	*Rhyolite porphyry*	50
	COLMENA TUFF:	
17	*Tuff conglomerate:* dusky yellow, weathers dark brown; massive; extremely hard; boulders round to subround	32
16	*Tuff conglomerate:* white on fresh exposure, weathers light brown; weathered surface is rough and hackly; contains well-rounded pebbles, cobbles, and boulders of igneous and tuffaceous material; jointing strikes N66°E, dips 75°SE	21

Unit	Description	Thickness in feet
15	*White tuff:* hard; slightly nodular on surface; random jointing probably due in part to weathering	18
14	*Tuff and conglomerate:* pale red purple tuff grading upward into red conglomerate with boulders up to 2 feet in diameter; conglomerate grades upward into pale purple tuff	106
13	*Tuff:* light brown; containing numerous holes due to weathering; locally changes to tuff conglomerate and grades upward into conglomerate	81
12	*Tuff conglomerate:* yellow; massive; boulders and pebbles subangular to subround, diameter 1 inch to 1 foot, average 3 inches; resistant to weathering	48
11	*Tuff:* pale purple; nodular; no evident bedding; locally numerous holes due to weathering; faintly cross-bedded in a few places	49
10	*Tuff:* white; thin-bedded; grading upward into light brown tuff, then upward into pale green tuff; upper 4 feet resistant and thick-bedded; green tuff contains pebbles of purple, white, and dark green tuff	11
9	*Tuff:* dark red; hard; beds 1 foot or more thick; nodular	11
8	*Tuff:* variegated, predominantly pale green with stringers of pale purple	5
7	*Tuff:* pale red purple with white splotches; hard; nodular; some beds are honeycombed	22
6	*Tuff:* very light gray (N8), containing small, greenish yellow, rounded inclusions and random splotches of pale purple; massive	11
5	*Tuff:* variegated, grayish red purple on fresh exposure, weathering to pale purple; nodular; very loose; contains several 6-inch bands of greenish yellow tuff	11
4	*Tuff breccia:* matrix pale red purple on fresh exposure, weathering to light brownish gray; angular fragments pale green, red, brown, and black; massive	22
	Measured thickness of Colmena Tuff	448

UNCONFORMITY.
JEFF CONGLOMERATE:

Unit	Description	Thickness in feet
3	*Conglomerate:* cemented by calcareous reworked material; boulders and pebbles subround to round, chiefly well-polished sedimentary-quartzite pebbles and dark-gray limestone pebbles, diameter ranging from 1 inch to more than 1 foot, with a few boulders of 3 feet, average 4 inches; local sandstone lenses 1–2 feet long, sand is the same as in Unit 2	20

Unit	Description	Thickness in feet
2	*Sandstone:* dusky yellowish gray on fresh surface weathering to dark yellowish gray; medium-grained; calcareous; faint cross-bedding in places; grades upward into conglomerate	2
	Measured thickness of Jeff Conglomerate	22
	Total thickness measured	520

BASE OF VIEJA GROUP.
UPPER CRETACEOUS MARL:

Unit	Description	Thickness in feet
1	*Marl:* dark yellowish orange on weathered surface, medium yellowish orange on fresh exposure; massive; locally contains gypsum and irregular concretions; in places bears shells of *Gryphaea aucella;* shows polygonal jointing on exposed surface	?

Colmena Tuff.—The rough topography created by the emplacement of the Gill Breccia was smoothed by the deposition of the Colmena Tuff. Consequently the Colmena is missing in some places, even though its thickness exceeds 450 feet in others.

The Colmena is composed of beds of rhyolitic tuff and beds of conglomerate with pebbles, cobbles, and boulders of Gill Breccia and some pebbles and cobbles of Lower Cretaceous limestone; near the mouth of Capote Creek it contains beds of tuffaceous non-marine limestone 4 to 10 feet thick; near Loma Plata (6.3–34.5), beds of silty claystone and a layer of a glassy flow-rock. It can be described as a light-brown tuff-conglomerate interbedded with variegated tuff. The principal colors are brown, pink, and red. The lower part of the formation is calcareous. Four random thin sections described by McGrew (1955: 44 and 114) show a fine-grained rhyolitic tuff containing 7–10% quartz with some chert; the remainder is composed of sanidine, orthoclase, plagioclase, and igneous-rock fragments; magnetite or ilmenite is common; biotite, sphene, apatite, and augite are present. The grains are subangular, poorly to well sorted. The usual cement is opal and chalcedony; locally the rock contains as much as 30% calcite. Bone fragments are common in the lower part of the formation.

The available information about the vertebrate fossils collected from the Colmena Tuff in the southern part of the Rim Rock country has been summarized by Mankin (1955: 86–91). The age of the fossils is Duchesnean or Chadronian; that is, latest Eocene or early Oligocene. In most places, but unfortunately not in all, the Colmena is overlain by the Buckshot Ignimbrite; the caprock of the Buckshot Rim is a typical outcrop of the Buckshot.

Buckshot Ignimbrite.—Although the rhyolite prophyry that caps the Buckshot Rim looks like lava rock, its matrix in thin section shows glass shards and other pyroclastic material, and it is proposed to call it the Buckshot Ignimbrite (McGrew, 1955: 25–30, 44–53, Figs. 18–21). It is resistant to erosion and forms a caprock 40 to 75 feet thick in many places. The rock exhibits well-developed vertical jointing and breaks with an even to slightly conchoidal fracture. The color of the fresh rock is grayish red to moderate yellowish brown; the weathered surface, pale to dark reddish brown. A dusky green layer of brittle glassy rock is present locally at the base of the Buckshot. The ignimbrite ranges from non porous at base to vesicular at the top, the length of the amygdules averaging about 1 cm., most of them containing a ferriferous carbonate or chalcedony or both. In many places the rock is characterized by abundant round dark reddish-brown spots of buckshot size, many of which have small centers, grayish red like the matrix, and thick, very dark red to blackish red rims. Most of the phenocrysts, which compose about 20% of the rock are sanidine; some are orthoclase, and some, quartz.

The upper surface of the Buckshot Ignimbrite (Sewell, 1955: 34–38. Pls. 17–20; Peterson, 1955: 27–29) is dotted by circular blister cones (Sewell. Pl. 17) from 1 foot to 5 feet high and 2 to 50 feet in diameter and marked by folds (Sewell, Pl. 18) about 100 feet long, 6 feet high, and 5 feet across. Next above the Buckshot is a thick tuff, which rests directly on the Colmena Tuff where the Buckshot is absent.

Chambers Tuff.—The name *Chambers Tuff* is proposed for a formation that comprises the strata between the top of the Buckshot Ignimbrite and the base of the Bracks Rhyolite. Where the Buckshot is absent the Chambers and Colmena may be differentiated by identifying the horizon of the Buckshot; if its identity proves somewhere to be too problematic for practical use, the lithostratigraphic name *Vieja* will still be applicable to the combined sequence. Similarly where the Bracks Rhyolite is absent as in the southern end of the Rim Rock country and in its northern third west of the Vieja Rim, the undifferentiated Vieja may serve as a map unit. Probably the horizon of the Bracks, that is, the Chambers-Capote Mountain contact, can be practically established in some places, but not everywhere.

The moderately to well bedded Chambers Tuff presents a drab array of colors, mostly pale yellowish brown, and grayish green in the upper 250 feet, and dull somber, pale red to dark reddish brown in the lower 150 feet (Sewell, 1955: 39–40, 100–101, 105–106, Pl. 17). In the southern part of the Rim Rock country it contains a persistent layer of coarse sandstone with lenses of cobble conglomerate about 130 feet above the base.

In two thin sections from the Chambers, McGrew (1955: 53–55, 104–105, 108–109, 113) described a fine- to medium-grained rhyolitic tuff containing 5 to 10% quartz with some chert, sanidine, orthoclase, plagioclase, and fragments of rhyolitic glass and volcanic rock. Magnetite or ilmenite, biotite, and a pyroxene are also present. The grains are subangular. Most of the cement is calcite; some of it is silica.

The vertebrate fossils collected in the northern part of the Rim Rock country by Stovall, Patterson, Wilson, and their associates all came from the Chambers Tuff. Although superposition demonstrates that the Chambers is younger than the Colmena, the first look at the fossils from each seems to indicate the same geologic age. Careful paleontological work may yet show a difference or may fail to show it; the resemblance is close.

Measured Section 2.—The type locality (20–40) of the Chambers Tuff is at Measured Section 2 (MS-2), about 12 miles N of Candelaria (8.5–41). The river road extends about 2 miles N of Candelaria to the mouth of Capote Creek. Thence the road to Chambers, formerly Dan (Robinson, 1918), Ranch (20.8–38.8) extends northeastward up Capote Creek about 5½ miles to the mouth of Walker Creek, up which it extends about 1½ miles N to the Dow house and continues N up Walker Creek 5 miles to an airplane landing strip and thence N another mile to a house on the W side of the road, known as the trapper's cabin. The end of the road is at Chambers Ranch another 2 miles N. The top (18.75–39.1) of MS-2 is 0.3 mile W of the road, half a mile NNW of the airstrip, and 0.4 mile S of the trapper's cabin. The base (19.2–40.4) of MS-2 is about 1.4 miles almost due W of the cabin and 2.5 miles SW of the Chambers headquarters. From bottom to top, MS-2 extends about 1½ miles ESE. The section was measured and sampled by R. C. Duchin and S. S. Moran in the summer of 1954. Their description follows:

Unit	*Description*	*Thickness in feet*
CAPOTE MOUNTAIN TUFF:		
54	*Tuff:* very thin-bedded; above is about 100 feet of tuff that was not measured; section ends on Triangle Hill between the Bracks Rhyolite and the Brite Ignimbrite	9
53	*Tuff:* alternating red and pink beds that weather to rounded ledges; fine-grained	76
52	*Tuff:* pinkish gray; hard; fine-grained; thick-bedded; bottom part is very pitted by weathering	13

Unit	*Description*	*Thickness in feet*
51	*Sandy tuff:* pale reddish brown with mottled patches locally; fine- to coarse-grained; weathers to rounded ledges	77
50	*Tuff:* pale reddish brown; coarse-grained; beds 1–3 feet thick, weather to rounded ledges; surfaces pitted	51
49	*Calcareous tuff:* white at base, grading upward to alternating soft and hard, pale purple layers; weathers into the hill	5.8
48	*Purple tuff*	12
47	*Tuff:* very light gray (N8) at base, beds above are grayish pink (5R8/2) and pale red (5R6/2); beds 1–8 feet thick, weather to rounded ledges	70
46	*Tuffaceous-sandstone key-bed:* brown, weathering to pale red and dark reddish brown, hard, tuffaceous quartz-sandstone, just below which is 3-foot bed of pink, highly calcareous tuff; beds 1–4 feet thick weather to rounded, prominent ledges	16
45	*Tuffaceous quartz-sandstone:* pale red; hard; medium- to coarse grained; beds 1 foot to several feet thick; weathers to well rounded ledges	45
44	*Tuffaceous quartz sandstone and sand:* brown; subrounded fine to medium quartz grains; weathers to form ledges	47
43	*Sand and sandstone:* interbedded, fine- to coarse-grained sandstone and calcareous sand; sand is light yellow green, soft, friable, with subrounded quartz grains; sandstone is brown to pale red purple, hard; together they form a slope with protruding ledges; harder layers are near the top	68
42	*Quartz-sandstone:* light brown to reddish brown; hard; coarse-grained; thick-bedded at base and thin-bedded at top; quartz grains subrounded; weathers to form large rounded masses and ledges	29
41	*Quartz-sandstone:* light gray; fine-grained; calcareous; alternating soft and hard layers; thin-bedded	3.8
40	*Sandstone and tuffaceous sandstone:* medium- to very coarse-grained; some beds well consolidated, light yellow gray, form ledges; interbeds of soft, loose, grayish red sandstone	45
39	*Argillaceous limestone:* soft; thin beds; weathers back into the hill	12
38	*Sandstone and tuff:* pale reddish brown; coarse-grained; a few soft tuff beds and one thin calcareous layer are present	16
37	*Sandy tuff:* red brown; indurated; top 3–5 feet is pale pink, soft	24
36	*Quartz-sandstone:* grayish brown, weathering to dark red brown; coarse-grained; forms rounded ledges	11
35	*Quartz-sandstone key-bed:* moderate brown, weathered surface reddish brown; irregularly bedded to cross bedded; medium-to-coarse subangular quartz grains; weathers to form prominent ledge above the light-colored beds	27
34	*Sandstone:* light pink to grayish pink, (light color distinguishes this bed); very fine-grained; indurated to hard; calcareous at base, tuffaceous at top; thin-bedded, weathers to thin ledges and rounded blocks	6.4
33	*Tuffaceous sandstone:* pale red purple, weathered surface grayish red; coarse-grained with a few pebbles; subrounded quartz grains; weathers to prominent ledges several feet thick	30
32	*Tuff:* pale purple; soft; weathers back into hill	11
31	*Tuff:* pale purple; very fine-grained; hard; thick-bedded; pitted surfaces; weathers to prominent, rounded ledges	8.8
30	*Sandstone and tuff:* purple; soft; medium-grained; thin-bedded; hard, pale purple sandstone forms a prominent ledge in middle of Unit 30	7.6
29	*Sandstone and tuff:* dusky red; coarse, subrounded quartz grains; beds 1–3 feet thick	34
28	*Sandstone:* pale grayish purple to light gray, weathers to give a pink and white streaked appearance, upper part is brown and contains pebbles locally; coarse, subrounded quartz grains; forms a rounded ledge	27
27	*Tuff:* dull red with white spots; hard; fine-grained; slightly sandy; weathers to form block-shaped ledges	1.8
26	*Sandy tuff:* mottled and purple and white; indurated; fine-grained; contains large amount of biotite; weathers to gentle slope	4.3
25	*Tuff:* brownish gray, weathering to rusty gray brown with white patches; very fine-grained; hard; contains key bed 1–4 feet thick that stands out as a massive ledge	22
24	*Tuff:* mottled, light grayish purple; indurated; very fine-grained; thin-bedded	6
	Measured thickness of Capote Mountain Tuff	817

BRACKS RHYOLITE:

23 *Rhyolite:* thickness not measured.

TOP OF VIEJA GROUP.
CHAMBERS TUFF:

22	*Quartz-sandstone:* light gray, weathers to light green; indurated; grains coarse to very coarse, subangular; beds 1–4 feet thick	25
21	*Tuff:* light grayish purple; hard; thin-bedded; weathers to broken, block-shaped ledges	17

Unit	*Description*	*Thickness in feet*
20	*Tuff:* light gray with white specks; slightly sandy; hard; massive; weathers to steep, rounded ledges which form prominent breaks in the slope	18
19	*Tuffaceous quartz-sandstone:* light gray; grains coarse to very coarse, subangular to round; beds 1–2 feet thick	22
18	*Tuffaceous sandstone:* very dull reddish brown; hard; grains subrounded, medium to coarse; thin-bedded; weathers to a ledge with some thin tuff breaks	15
17	*Tuffaceous quartz-sandstone:* light gray; medium-grained; indurated; thin-bedded; weathers to ledges with some soft breaks	15
16	*Tuff:* light gray with green splotches; slightly sandy; alternating soft and hard layers	9.8
15	*Quartz sandstone:* reddish brown; indurated; coarse-grained; beds 1–2 feet thick form subrounded ledges	23
14	*Quartz sandstone:* light gray to dull reddish brown; medium- to coarse-grained; most layers are indurated, some are friable; slightly calcareous; beds 1–2 feet thick weather to rounded ledges	30
13	*Tuff key-bed:* grayish red (10R4/2); very hard; very fine-grained; weathers to sharp, angular blocks that form a ledge	1.8
12	*Tuff:* pale red purple; fine-grained; beds 1 foot to several feet thick; weathers to rounded blocks	139
11	*Tuff:* pale red purple with white specks; beds 1 foot to several feet thick weather to rounded blocks	32
10	*Tuff:* grayish purple; fine-grained; indurated; poorly bedded	37
9	*Tuff:* pale green; fine-grained; indurated; some dark minerals present, but sparse; irregular, nodular bedding with more consistent bedding toward the top	7.2
8	*Tuff:* grayish purple (5P4/2) to dark gray (N4); fine-grained; soft at bottom grading to hard at top; weathers to resistant, block-shaped masses	6.0
7	*Tuff:* light greenish gray to greenish white; fine-grained; thin-bedded; weathers to rounded blocks	13
6	*Tuff:* dark reddish brown with small dark specks; hard; thin-bedded; contains some small pebbles; weathers to small blocks	57
5	*Tuff:* grayish purple; homogeneous, very fine-grained; beds 1–2 feet thick; some beds form ledges	64
4	*Tuff:* pale red purple; fine-grained; massive	11
3	*Sandy tuff:* grayish purple with dark specks; massive; weathers back into hill	6.1
2	*Tuff:* pale red (5R6/2) speckled by muscovite; fine-grained; beds form ledges	4.7
1	*Tuff:* pale red purple; soft; friable; thin-bedded, forms gentle slope	4.8
	Measured thickness of Chambers Tuff	558
	Total thickness of MS–2 (excluding Bracks)	1,375

TOP OF BUCKSHOT IGNIMBRITE.

Bracks Rhyolite.—The preceding section (MS–2) shows more than 800 feet of tuff overlying the Chambers and separated from it by the Bracks Rhyolite, which Lord called pantellerite. This important stratigraphic marker is the chief rim rock of the Rim Rock country. Its place in the stratigraphy was first recognized during the development of the coal deposits at San Carlos. The end of the abandoned railroad grade still marks the site of the coal mining town, but not a building remains. San Carlos was located in a topographic basin (Vaughn, 1900: 75) that is almost completely surrounded by rims of Bracks Rhyolite, and Coal Mine Draw (Fig. 1), Vaughn's San Carlos Arroyo, drains the basin southward. The newly proposed stratigraphic name *Bracks* is taken from the narrow gorge (38–44) called Bracks Canyon (San Carlos Sheet; Vaughn: 82, Pls. 6 and 10), which cuts through the outcrop of Bracks Rhyolite just west of San Carlos. In view of the original description, the proper place for a type locality appears to be in the vicinity of San Carlos, probably the high Vieja Rim (Vaughn: Pl. 8) east of the basin, which is the thickest outcrop of Bracks, although the rim is not readily accessible, and the high cliff face would be difficult to sample foot by foot. The maximum thickness of 300 feet or more decreases northward, southward, and westward, as the Bracks completely peters out on the northwest, north, and south; but its fate due west of San Carlos is not recorded in the outcrops, and eastward it dips underground.

The characteristic color of the Bracks is greenish, ranging from light olive gray to greenish black. In places it is dark reddish brown. The original description by Lord (1900: 90–95), which includes a chemical analysis (also in Clarke, 1900: 60–61), has recently been supplemented by McGrew (1955: 55–60, 113, Figs. 24–26). Sewell (1955: 40–46, Pls. 7 and 10), in restudying its origin, concluded that it was probably emplaced by lava flows. In the few places where the Bracks-Capote Mountain contact (Sewell: 43) is exposed, it appears to be fairly regular with a suggestion of breccia on the surface of the Bracks. The Bracks-Chambers contact also appears to be regular. The following section (MS–3) begins not far above the top of the Bracks.

Measured Section 3.—The type locality (17–34) of the Capote Mountain Tuff is Measured Section 3 (MS–3) on the high west face of Capote Mountain. The base of MS–3 is appoximiately 4 miles from the Brite Ranch headquarters along the abandoned county-road to Candelaria; it is 0.28 mile E of U.S. Coast and Geodetic Survey's bench mark *K731*, 1943, and 30 feet NE of a wooden hitching post at the base of the mountain. The top of MS–3 is 0.1 mile NW of triangulation station *Capote* (16.75–33.0), which is on the summit of Capote Peak, the highest point of Capote Mountain. (The 1928 Texas Almanac: 45, has a striking picture of "Summit of Capote Peak, Presidio County.") Thus, MS–3 extends eastward up the face of the mountain, ascending 1,000 feet in a horizontal distance of about 3,000 feet. Near the top, the beds dip about 9° E. The section was measured and sampled in the summer of 1954 by J. E. Peterson (1955: 97–105; Sewell, 1955: 110–111; McGrew, 1955: 110–111).

Unit	*Description*	*Thickness in feet*
BRITE IGNIMBRITE:		
7	*Rhyolite porphyry:* with aphanitic grayish orange pink (5YR7/2) to light brownish gray (5YR6/1) groundmass; phenocrysts are small angular clear quartz and opalescent tabular sanidine crystals; forms a cliff	Estimated 100
CAPOTE MOUNTAIN TUFF:		
6	*Tuff:* moderate orange pink; indurated	24
5	*Tuff:* very light gray (N8) to white (N9), contains black and orange specks; fine- to coarse-grained; indurated; bottom 15 feet is massive, but most beds are 2 inches or less thick; cross-bedded; forms a slope under the Capote Rim	288
4	*Tuff:* white to pinkish gray, overall appearance is whitish gray with many black specks that give a salt-and-pepper effect; fine- to coarse-grained; indurated; weathered surface is rough and irregular	51
3	*Tuff:* variegated, predominant colors are white, pinkish gray, moderate orange pink, and moderate reddish orange; indurated bottom 20 feet forms cap of ledge with white tuff beneath; upper 75 feet is not so well indurated and forms stair-step ledges; fine- to coarse-grained; weathered surface is rough, uneven, and nodular	123
2	*Tuff:* white to grayish pink, overall appearance is dull pinkish white, salt-and-pepper; indurated; beds are 6 inches to 2 feet thick; most beds are fine- to medium-grained and nodular on the surface, a few beds are very fine-grained and weather into smooth vertical faces; strike N4°W, dip 9°NE; bottom contact is obscured by pebbles, cobbles, and boulders littering the slope	42

Unit	*Description*	*Thickness in feet*
1	*Tuff:* pale red to grayish red, overall appearance is pale red alternating with grayish red; fine- to coarse-grained; indurated; beds 2 inches to 6 feet thick; the beds 2 feet thick to 6 feet thick form most of the ledges, beds less than 2 feet thick form most of the slopes; material from 230 to 280 feet above base of MS–3 exhibits castellated weathering, with alternating light and dark red beds, the lighter beds 1 foot to 3 feet thick, the darker beds 2 to 6 inches thick appearing as plates between the thicker, lighter beds; weathered surface is rough and uneven, and the slopes are littered with pebbles, cobbles, and boulders	1,350
	Measured thickness of Capote Mountain Tuff	1,878
	Total thickness of MS–3	1,978

At this place the basal part of the Capote Mountain Tuff is covered by alluvial and colluvial material, but the top of the Bracks Rhyolite is not far below the base of MS–3.

Capote Mountain Tuff.—At places in the southern part of the Rim Rock country, according to Sewell (1955: 48, Pl. 21), the Capote Mountain Tuff has a characteristically three-fold outcrop that exhibits an upper white-to-pinkish-gray member nearly 1,300 feet thick, a middle red siltstone layer 10–40 feet thick, and a lower variegated tuff member, predominantly dusky brown to grayish red purple, more than 200 feet thick. According to Peterson (1955: 34, Fig. 6) the lower 1,350 feet of the type section shows alternating pale red and grayish red beds above which are white beds and gray beds. Be that as it may, a thick sequence of white tuff characterizes the Capote Mountain, but more work needs to be done assuredly to differentiate the Capote Mountain from the underlying Chambers on the north and south where the Bracks is absent.

The Capote Mountain (Peterson, 1955: 33–36, 90–94, 97–105, Figs. 4 and 6; Sewell, 1955: 47–50, 99–104, 110–111, 115–116, Pls. 6, 7, 21, 22; McGrew, 1955: 60–62, 103–107, 110–111, 113, Figs. 21, 27, 40) has the general composition (McGrew: 61) of a fine- to coarse-grained non-calcareous rhyolitic tuff consisting of 70–80% volcanic glass (n c. 1.50) with 2–5% quartz and 1% biotite and heavy minerals; the remainder is alkalic feldspar with a little plagioclase. The rock is loosely cemented with silica. In places it contains beds of pebble-to-boulder conglomerate. The middle, resistant layer of red siltstone is well-sorted and cemented with calcite and some opal; it has an even to subrounded fracture and is minutely cross-laminated; it is an arkose composed of subangular grains of which 70% are alkalic feldspar and

10% quartz and chert; the rest are volcanic rock, magnetite altering to hematite, pyroxene, and rare plagioclase. Only a few turtle bones have yet been collected from the Capote Mountain. The top of the Capote Mountain Tuff is at the base of the overlying rhyolite, which is called the Brite Ignimbrite.

Brite Ignimbrite. Capote Mountain, which towers above the headquarters of the historic Brite Ranch (Keith, 1950; Shipman, 1926: 115–119; Darton, 1933: 100), is composed of typical Capote Mountain Tuff, capped by typical Brite Ignimbrite about 100 feet thick (Peterson: Fig. 6; Baker, 1928: Pl. 10; Baker, 1944: Pl. 20; 1928 Texas Almanac: 45; Keith, 1950: xix, xxix, and end papers). In other words, the top of Capote Mountain is the type locality of the Brite. The rock (McGrew: 62–71, 103, 110, 112–113, Figs. 21, 28–32, 36; Sewell: 50–52, 99, 102, 110, 114, 115, Pl. 23; Peterson: 36, 69, 73, 97, Fig. 6) resembles a sanidine rhyolite porphyry, but the matrix (McGrew: 62) shows glass shards and other pyroclasitic material in thin section. The sanidine crystals are opalescent. The fresh rock is light-colored ranging from grayish orange pink to light brownish gray. The Brite is overlain by the Petan Basalt.

Petan Basalt.—The first part of the new name *Petan Basalt* is taken from the Petan Ranch, which occupies the Capote Rim and Capote Draw from the south fence of the Brite Ranch to the head of Pinto Canyon. The second part is a field term for a dark-colored fine-grained igneous rock not necessarily used in a strictly petrographic sense. The Petan is exposed in the general vicinity of the U.S. Coast and Geodetic Survey's triangulation station *Brite* (19.1–32.4), where it attains a maximum thickness (Peterson, 1955: 37) of approximately 300 feet. The rock appears to have poor resistance to erosion, for only remnants rest on the Brite Ignimbrite in the form of small hills up to 300 feet high. Both the Brite and the Petan crop out in the Cuesta del Burro, a westward-facing bluff along the east side of Capote Draw about 5 miles east of the Capote Rim. Amsbury plans to describe the Petan in more detail in a forthcoming paper.

The Petan is composed of trachyandesite porphyry (McGrew, 1955: 71–74, 112, Figs. 33, 34; Sewell, 1955: 56, 114–115, Pls. 21, 26). The color of the fresh rock is dark greenish gray to brownish gray. It contains numerous vesicles partly filled with calcite. The texture is merocrystalline, porphyritic with an aphanitic matrix. Andesine (An$_{35}$) and orthoclase phenocrysts compose 25–50% of the rock. Accessory minerals are magnetite or ilmenite, augite, olivine almost completely altered to iddingsite, and apatite. The groundmass consists of laths of plagioclase and orthoclase, the interstices filled with orthoclase and cryptocrystalline material. The formation next above the Petan is an ancient gravel, which, for the time being, will be informally called the post-volcanic gravel.

Post-volcanic gravel.—The post-volcanic gravel lies discordantly on the Petan Basalt, and, in places, on the Brite Ignimbrite. It antedates the mighty faulting that created the rim-rock topography, for it too is faulted down into the southern part of the Rim Rock country. Its deposition was subsequent to most of, and perhaps all, the volcanic outbursts, for no igneous rock has yet been found in or on it. Its subround-to-round pebbles and cobbles are composed chiefly of extrusive igneous rock and Lower Cretaceous limestone. The gravel is cemented with caliche.

Bolson fill.—During the Tertiary Period, subsequent to the widespread volcanism, extensive faulting created deep intermontane basins, which were thereafter partly filled with bolson deposits. The fill tends to be conglomeratic near the mountains and to grade outward into calcareous sandstone and silt. Recent work by W. S. Strain (oral communication, Aug. 1956) near McNary, Texas, indicates that the age of the top of similar bolson fill in the Rio Grande Valley 70 miles upstream from the Rim Rock country is latest Pliocene or earliest Pleistocene.

CONCLUSION AND ACKNOWLEDGMENT

Inasmuch as this preliminary paper aims chiefly to lay a nomenclatural foundation for stratigraphic geology of the Tertiary volcanic deposits of the Rim Rock country, the intrusive igneous rocks in the form of dikes and thick sills are not described. The lithostratigraphic data are taken largely from the work of students, particularly Messrs. Buongiorno, Carlisle, Duchin, Mankin, McGrew, Moran, Peterson, Sewell, and Smith and the petrographic data from Messrs, McGrew and Sewell, whose theses were supervised by Dr. Clabaugh. Drs. J. A. Wilson, S. E. Clabaugh, and J. T. Lonsdale kindly contributed additional information and editorial criticism.

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