Geology of the Eagle Mountains, Hudspeth County, Texas

James R. Underwood Jr., 1980, pp. 183-193

in:

Trans Pecos Region (West Texas), Dickerson, P. W.; Hoffer, J. M.; Callender, J. F.; [eds.], New Mexico Geological Society 31st Annual Fall Field Conference Guidebook, 308 p.

This page is intentionally left blank to maintain order of facing pages.

GEOLOGY OF THE EAGLE MOUNTAINS, HUDSPETH COUNTY, TEXAS*

JAMES R. UNDERWOOD, JR.
Department of Geology
Kansas State University
Manhattan, Kansas 66506

INTRODUCTION

Eagle Mountains and the associated highlands, Devil Ridge and Indio Mountains, trending generally northwest to north-northwest, are surrounded by "bolsons" or intermontane basins partly filled with alluvium and are an extension into southeastern Hudspeth County of the eastern part of a long, narrow, mountainous, structural belt that begins some 240 km southeast near Ojinaga, Chihuahua, Mexico. The summit of Eagle Peak, 27 km southwest of Van Horn, Culberson County, 38 km southeast of Sierra Blanca, Hudspeth County, and 2,285 m above sea level, is the highest point in Hudspeth County. Lowest point in the map area, the southeastern corner along the Rio Grande, is 960 m above sea level; the maximum difference in elevation is about 1,325 m.

In the highlands, well-exposed rocks ranging in age from Precambrian to Recent include about 1,525 m of metamorphosed Precambrian sedimentary rocks, at least 300 m of Permian limestone, and about 2,135 m of marine Cretaceous strata, much of which is covered by an early Tertiary volcanic rock sequence of flow breccia and fine-grained flow and pyroclastic rocks. Small intrusive bodies, mainly sills and dikes, crop out throughout the area; the highest part of the Eagles is a small, roughly semicircular stock. The range is flanked by well-defined alluvial fans and terraces.

The stratigraphy of the Cretaceous rocks was controlled by a fluctuating shoreline during the general advance of the Cretaceous sea north and eastward from the Chihuahua Trough onto the Diablo Platform and the continental margin; structurally, the spatial relationships of the Cretaceous rocks were controlled by their location (1) on the southwest flank of the Van Horn uplift, (2) near the northwest end of the Laramide Chihuahua tectonic belt, and (3) near the eastern margin of the Basin and Range Province.

The area is in the Mexican Highlands section of the Basin and Range Province; the highlands of the Eagle Mountains and vicinity are horsts flanked by intermontane basins or grabens, all of which were created by mid- to late Tertiary block faulting that followed the volcanic activity. This deformation was superimposed on earlier Laramide folds, thrust faults, and strike-slip faults characteristic of the Chihuahua tectonic belt.

The thickness of the alluvial fill in the fault-created intermontane basins is not certainly known, but several deep water wells are believed to have bottomed in the alluvium; at the head of Green River, the fill is at least 335 m thick; at Hot Wells, at least 300 m thick; and near Red Light windmills, at least 200 m thick. In the closed basins, the drainage systems are responding to a rising base level, whereas the open drainage systems are operating under a regime in which base level is dropping. Basin integration is advanced.

STRATIGRAPHY

Rocks exposed in the Eagle Mountains range in age from Precambrian to Recent. Igneous intrusive and extrusive rocks as well as basin fill, terrace gravel, alluvium, and windblown sand constitute the rocks of Tertiary and Quaternary age. Pre-Cenozoic rocks exposed in the map area are of Precambrian, Permian, and Cretaceous age, but the subsurface pre-Cenozoic stratigraphic record is probably more nearly complete.

Precambrian Rocks: Carrizo Mountain Formation

The Carrizo Mountain Formation includes the oldest exposed rock in the region and is best exposed about eight kilometers northeast of the Eagle Mountains in the Carrizo Mountains. The small exposure in the Eagle Mountains lies on the northeast flank and is the southwesternmost exposure of basement rocks on the Van Horn uplift.

According to Flawn (1953, pp. 45-50), the Carrizo Mountain Formation is a body of low-grade metamorphic rocks about 5,000 feet thick that includes meta-arkose, metaquartzite, schist, phyllite, and limestone. Retrogressive cataclastic metamorphism superimposed on an earlier progressive metamorphism failed to obliterate many of the sedimentary structures. Foliation is commonly parallel to bedding. Strike averages N. 70° E. and dip, 60° to 65° SE. Flawn mapped five unnamed rock units in the Carrizo Mountain Formation exposed in the Eagle Mountains; they are, beginning with the lowest and oldest: feldspathic metaquartzite; meta-arkose; two mixed units of schist, slate, phyllite, metaquartzite, and limestone; and amphibolite. Quartz tourmaline veins occur throughout the area.

Permian Rocks: Hueco Limestone

Erosion of Tertiary and Cretaceous rocks has exposed at least a thousand feet of Permian rocks in relatively small outcrops along the north flank of the Eagles. The basal Powwow Conglomerate Member and the overlying Hueco Limestone record the transgression of the Permian sea onto the Diablo Platform during the Wolfcamp Epoch. The fusulinids of the Hueco Limestone appear to belong to the upper part of the Wolfcampian; most of them are intermediate between *Triticites* and *Pseudoschwagerina* and are closely related to forms such as *Pseudofusulina? moranensis* Thompson and *Pseudoschwagerina convexa* Thompson (Garner Wilde, personal communication). *Triticites* s.s. was also tentatively identified in the samples. The age of the Permian limestone of the Eagle Mountains is thus almost certainly Wolfcamp, and the formation is correlative, totally or in part, with the Hueco Limestone of the Hueco Mountains.

Cretaceous Rocks

Marine Cretaceous rocks, which average about 2,135 m in thickness and range in age from late Aptian to perhaps as young as

*In part modified and abstracted from Underwood (1963). The author appreciates the kind permission of The University of Texas Bureau of Economic Geology to modify, and abstract from, Geologic Quadrangle Map 26 and text.

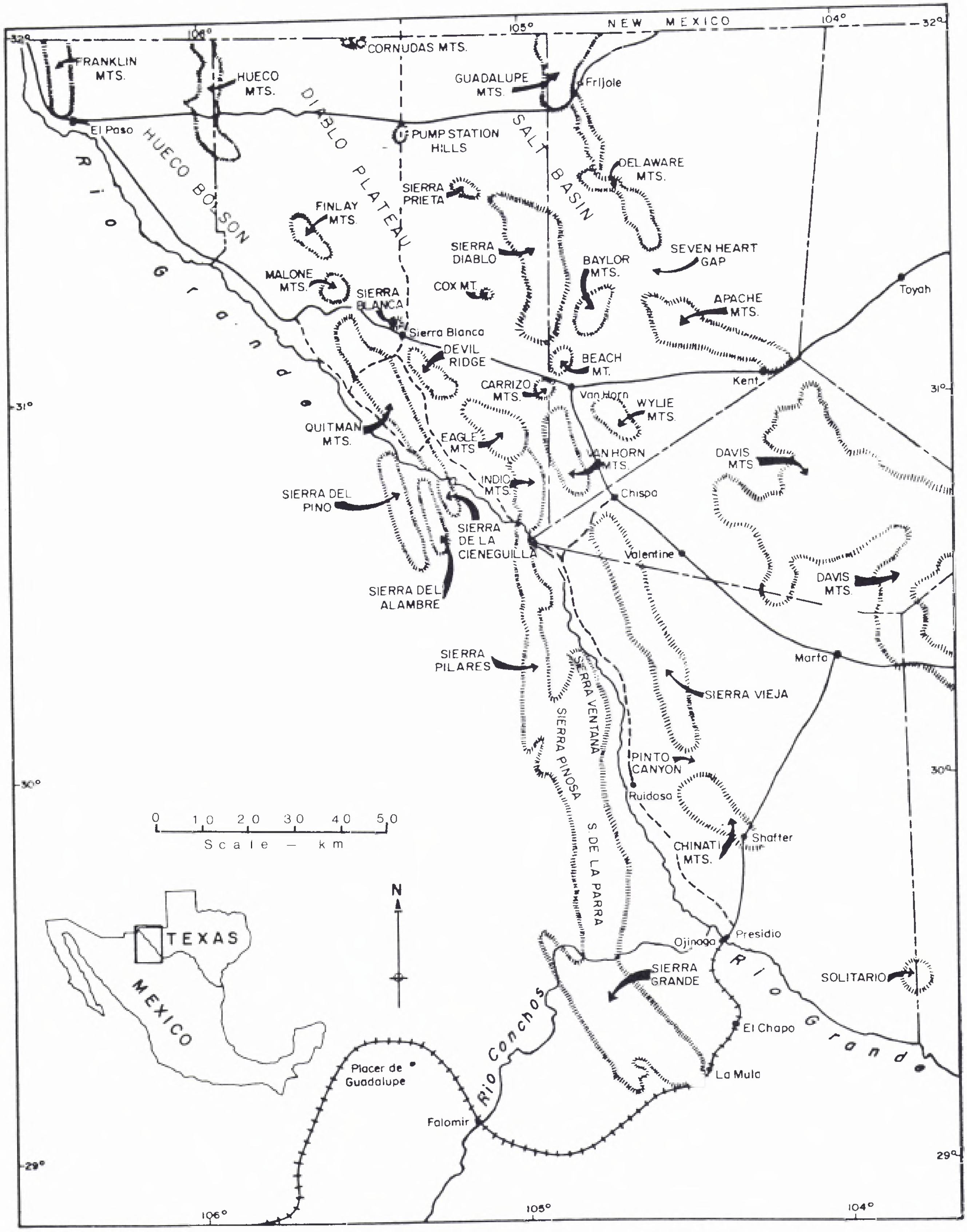


Figure 1. Physiographic features of western Trans-Pecos Texas and adjacent Chihuahua, Mexico.

late Turonian, were deposited along the eastern margin of the Chihuahua Trough; they constitute most of the pre-Cenozoic rocks exposed in the Eagle Mountains and vicinity. The Comanche and Gulf Series, together comprising nine lithologically distinct formations, have been recognized. An unconformity separates the Comanche and Gulf Series in many places in Trans–Pecos Texas and elsewhere but was not observed in the map area. Within the Cretaceous section, there is evidence only for two short periods of erosion: one at the Cox-Finlay contact and the other within the sandstone member of the Benevides Formation. All other formation contacts within the Cretaceous are conformable.

The Cretaceous section shows cyclic lithologic alternation of carbonate and siliciclastic rock. Within the rocks of the Comanche Series four lithologic couplets are represented, each of which consists of red-brown siliciclastic rock overlain by grey carbonate rock. Each unit of a couplet was mapped as a formation.

In the course of the advance of the Cretaceous sea onto the platform and foreland, the Comanchean formations overlapped each other and overstepped older formations; thus the basal siliciclastic or marginal facies is younger toward the north and east. The age of the basal siliciclastic facies of the Cretaceous System in the Eagle Mountains and vicinity is Aptian; at the Cornudas Mountains about 80 km north of Sierra Blanca, the age is late Albian.

For Cretaceous formations (discussed in ascending order below), typical color, lithology, key fossils, thickness, and weathering habit are summarized in Figure 2. Regional correlation of Cretaceous formations is shown in Figure 3.

Yucca Formation

The Yucca Formation includes the oldest Cretaceous rocks exposed in the Eagle Mountains (see also Campbell, this guidebook).

Taff (1891, p. 725) named the Yucca Formation for its excellent exposures on the north face of Yucca Mesa, the northwesternmost promontory of Devil Ridge, where about 365 m of the formation is exposed.

Exposures of Yucca in the Eagle Mountains are few: near Eagle Spring and just south of the Precambrian inlier. The Yucca disconformably overlies the Permian, contains more siliceous conglomerate and less limestone than does the Yucca at Yucca Mesa, and the formation is much thinner. The thickness of the Yucca near Eagle Spring is 180 to 215 m; included at the top is a colorful sequence of sandstone, shale, sandy limestone, and limestone-pebble conglomerate that some earlier workers considered to be a basal part of the Bluff.

Just north of the Precambrian inlier on the northeast flank of the Eagles, the Bluff Formation rests on Permian Hueco Limestone. The absence of the Yucca may be the result of nondeposition over a high, or of faulting.

The age of the Yucca is based mainly on the well-documented "Glen Rose" or early Albian age of the overlying Bluff Formation. By inference, the age of the upper part of the Yucca is late Aptian to early Albian.

Bluff Formation

Bluff Mesa, on the east flank of the northern Quitman Mountains, is the source of the name "Bluff beds" used by Taff (1891, pp. 726-727). Smith (1940, pp. 609-611, 621-623) applied the name "Bluff Formation" to the beds of sandstone and *Orbitolina*-bearing limestone in the Devil Ridge area that are bounded stratigraphically by the colorful limestone and shale of the conformably underlying Yucca Formation and by the light-colored sandstone of the conformably overlying Cox.

The most diagnostic fossil of the Bluff is the large foraminifer *Orbitolina* d'Orbigny, which is found about 24 m above the base and at intervals throughout the upper 180 m of the formation.

On the northeast flank of the Eagle Mountains, the Bluff is less easily distinguished from the underlying Yucca and the overlying Cox, because there the Bluff contains more sandstone and shale than elsewhere, e.g., in the Devil Ridge area. This is to be expected because the Bluff in the Devil Ridge area is part of a thrust sheet that moved northeast out of the Chihuahua Trough. The Bluff exposed along the northeast flank of the Eagles is beneath the thrust fault and is presumably a nearer-shore facies than most of that in the Devil Ridge area.

At Eagle Spring, limestone of the Bluff caps an east-facing scarp just west and northwest of the Eagle Spring ranchhouse. The Yucca–Bluff boundary was placed at the base of the thick *Orbitolina*-bearing limestone that caps the ridge above and west of the adit at the Eagle Spring fluorspar prospect. About midway in the Bluff section there, *Arctica roemeri* (Cragin), *Tylostoma* sp., and *Anatina* sp. were found, and near the base, *Trigonia* sp.

Limestone of the Bluff Formation is sparsely exposed low on the northwest flank of Lone Hill, just east of Eagle Spring, and an anomalously thin section is exposed to the southeast where the Bluff overlies the Permian with little, if any, discordance. This may be the result of faulting, or it may be that the Bluff is thinner there than to the northwest or to the south.

The Bluff Formation of the Eagle Mountains and vicinity contains *Orbitolina* sp. and is therefore paleontologically correlative with the Glen Rose Limestone of central Texas, the age of which is early Albian.

Cox Sandstone

The white, brown, orange or pink Cox Sandstone is an excellent stratigraphic marker because of its lithologic and color contrast with the gray limestone of both the underlying Bluff Formation and the overlying Finlay Limestone. Richardson (1904, p. 47) named this unit the "Cox formation," taking the name from Cox Mountain (Tabernacle Mountain), about 25 km northeast of Sierra Blanca.

The Cox is widely exposed in the Eagle Mountains. From just west of Eagle Spring the Cox outcrop extends in a broken but broad band along the northeast flank of the mountains. The beds dip generally southwestward and have been intruded by rhyolite sills.

A complete section of Cox is not exposed in the Eagles, but well over 300 m crops out in the Spar Valley area. As in the Devil Ridge area, the Cox is a well-indurated fine- to medium-grained sandstone but with more conglomeratic lenses scattered throughout. Ripple marks, burrows and trails, and cross-beds are common features. Sandstone of the Cox is characteristically desert-varnished.

Platy, angular fragments of the sandstone predominate in the colluvium of the Cox and mask less resistant rock. This gives the erroneous impression that the Cox is 100 percent sandstone, whereas shale and limestone interbeds are common.

The upper part of the Cox is paleontologically correlative with the Fredericksburg Group of central Texas; the lower part may be correlative with the upper Trinity. The age of the Cox is Albian.

Finlay Limestone

The massive, gray beds of limestone that form the outer rim of the Finlay Mountains, about 32 km northwest of Sierra Blanca, Texas, were named the Finlay Formation by Richardson (1904, p. 47).

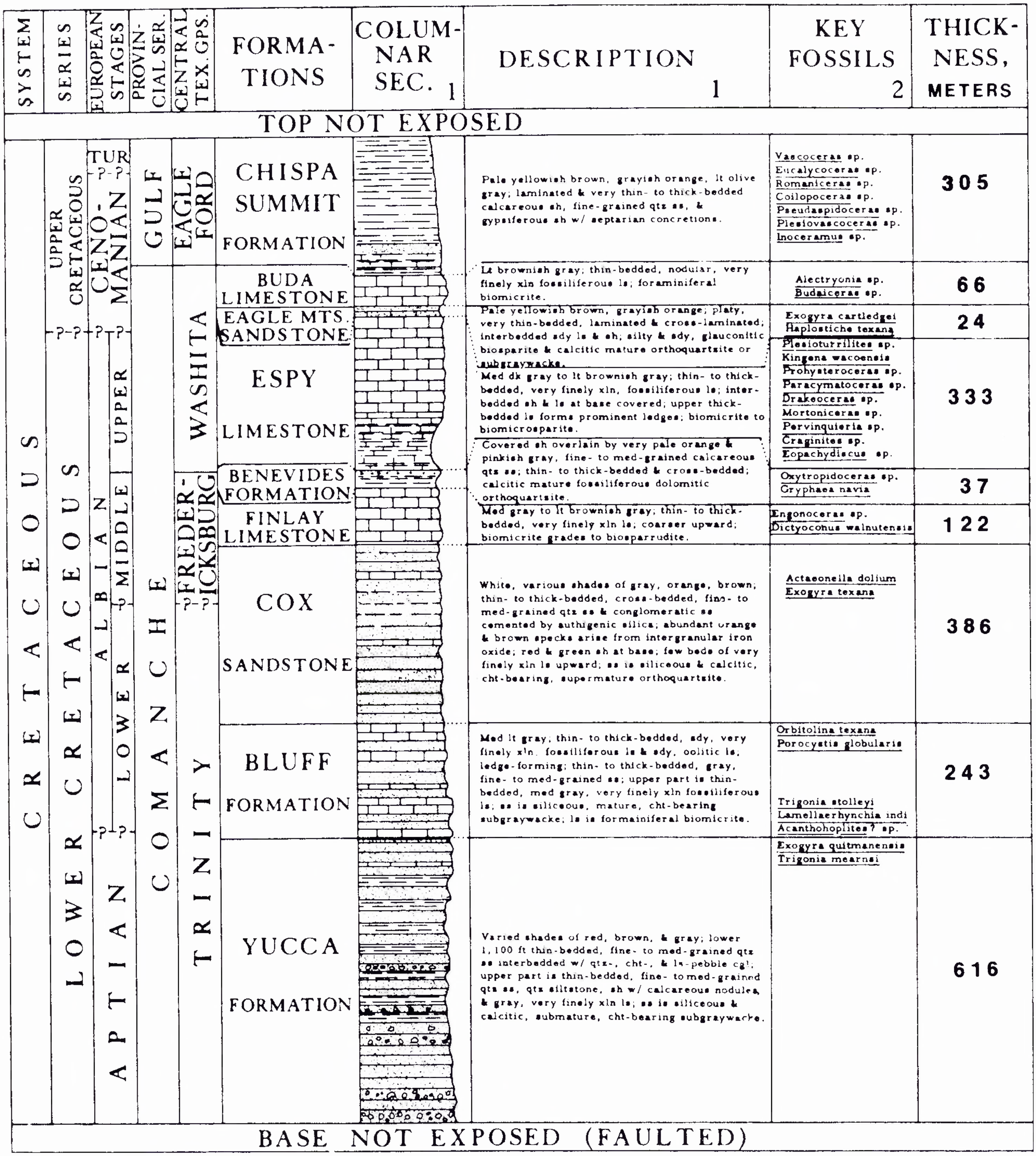


Figure 2. Stratigraphic section of Cretaceous rocks in Eagle Mountains and vicinity. 1—Based on Cretaceous section in Indio Mountains. 2—Representative of entire study area.

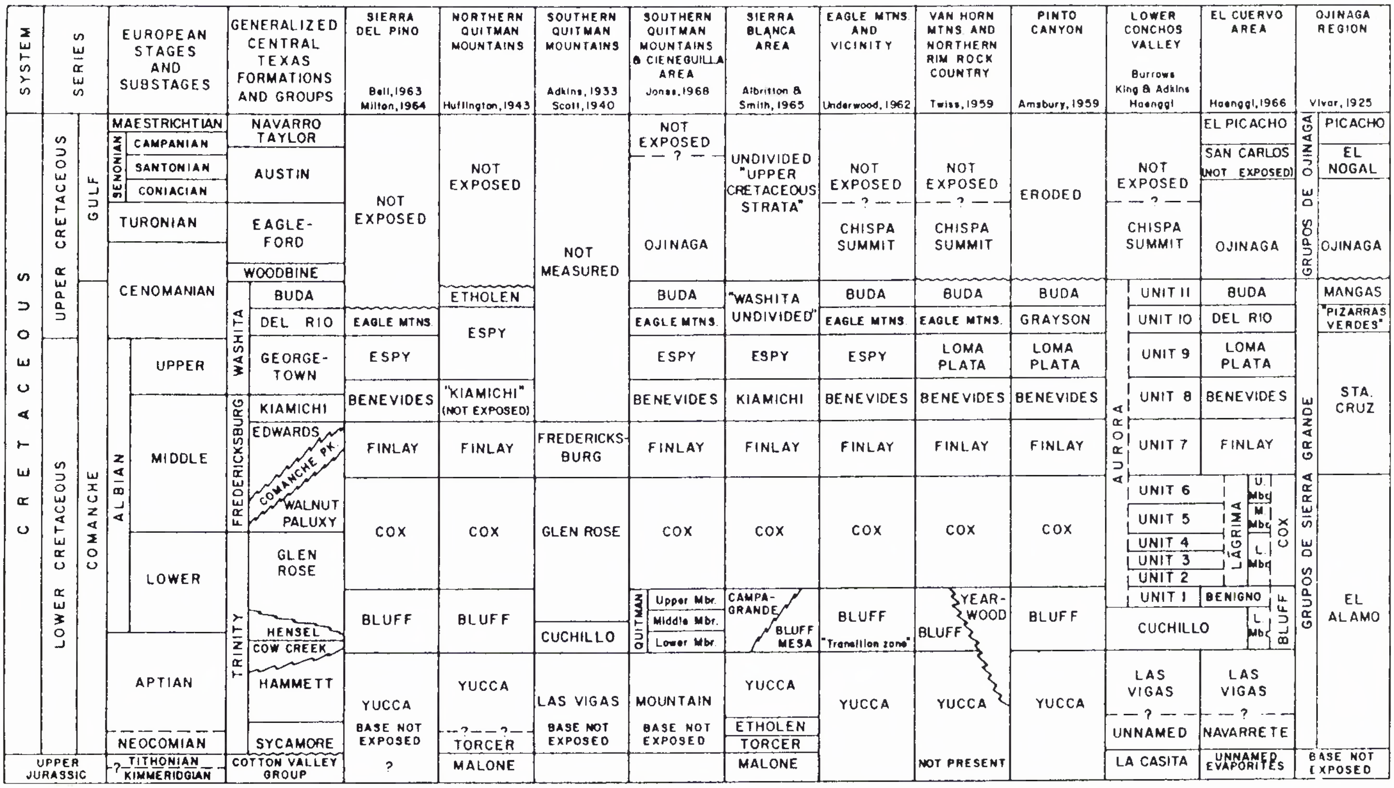


Figure 3. Correlation of Cretaceous and Upper Jurassic rocks, Trans-Pecos Texas and northern Chihuahua, Mexico.

The most diagnostic fossil of the Finlay is the foraminifer *Dictyoconus walnutensis* (Carsey). *Exogyra texana* Roemer occurs throughout the Finlay.

The lithology, fauna, and weathering habit of the Finlay in the Eagle Mountains are much like those in Devil Ridge, but a complete section is not exposed. In the Eagles, the Finlay is exposed in the northwest-trending valleys that contain the fluorspar mine and prospects. The Finlay is everywhere faulted against younger rock.

Gillerman (1953, p. 24) reported the occurrence of corals in the zone of *Toucasia texana* (Roemer) 32 m above the base of his measured section 4. *Requienia* sp., presumably from this zone, were collected by Gillerman (1953, p. 23), who also reported the presence locally of oolitic limestone in the interval above the "*Toucasia* reef beds."

The age of the Finlay Limestone is middle Albian, and it is paleontologically correlative with the Fredericksburg Group of Central Texas—that is, the Walnut, Comanche Peak, and Edwards Formations. Because the upper part of the Cox may be synchronous with the lower part of the Fredericksburg of central Texas, the Finlay of Trans-Pecos Texas may be synchronous with all but the lowest part of the Fredericksburg Group of central Texas.

Benevides Formation

The Benevides Formation, a thin sequence of non-resistant siltstone and overlying ledge-forming sandstone, is one of several siliciclastic units in the area that separates carbonate units of the Comanche Series.

On the east flank of the Eagles, 17 m of Benevides was measured. Olive-gray and black sandy quartz siltstone is interbedded with sandy very finely crystalline nodular limestone. This is overlain by 8.5 m of fine- to coarse-grained calcareous quartz sandstone. Near the top, calcareous cement is replaced by silica and iron-oxide cement; the sandstone appears to be "case hardened" and is widely stained by iron oxide. The sandstone has been intruded by a sill of "lower rhyolite" 7.5 m thick, above which more of the sandstone of the upper member is sparsely exposed. Fossils collected from this locality are: *Craginites* sp., *Pecten (Neithea)* sp., *Pervinquieria* sp., and *Pervinquieria?* sp.

The Benevides is paleontologically correlative with the Kiamichi of north-central Texas and possibly with lower part of the Duck Creek Formation as well. The age is upper Albian.

Espy Limestone

Huffington (1943, p. 1005) proposed the name "Espy Formation" for the Washita beds mapped by Smith (1940, pl. 1) in the Devil Ridge area. Because of the distinctive, brown-weathering sandstone (the Eagle Mountains Sandstone) in the upper part of Huffington's Espy and Smith's Washita, the section is easily divisible into three units. It has been proposed to restrict the term "Espy Limestone" to that body of rock between the Benevides Formation and the Eagle Mountains Sandstone (Underwood, 1963).

The occurrence of *Kingena wacoensis* (Roemer), *Gryphaea* aff. *G. graysonana* Stanton, *Pecten (Neithea) georgetownensis* Kniker, and *Pedinopsis* sp. in the gently dipping limestone beds that crop out in the cliffs that form the west flank of the Eagles identifies those beds as Espy.

In the northwest-trending valleys in which the fluorspar mine and prospects are concentrated, the Espy has been repeated by faulting; to the southeast, the Espy has been intruded by sills of lower rhyolite as well as by dikes of a dark green rock. In the Eagle Mountains, the thickness of the Espy stratigraphic interval is about 290 m. The lower 245 m of the section is interbedded gray shale and black limestone, the lower half of which yielded *Kingena* sp., *Ostrea (Arctostrea) carinata* (Lamarck), *Gryphaea washitaensis* Hill, *Pecten (Neithea) subalpinus* (Böse), *Pecten (Neithea) texanus* (Roemer), *Pervinquieria* cf. *P. kiliani* (Lasswitz), *Pervinquieria* cf. *P.*

trinodosa (Böse), *Pervinquieria* sp., *Eopachydiscus* cf. *E. brazoense* (Shumard), and many others (Gillerman, 1953, pp. 25-26). The succeeding 27 m of nodular, thin-bedded, black limestone (Gillerman's Carpenter Limestone Member of the Grayson Formation) is very fossiliferous: *Kingena* sp., *Exogyra arietina* Roemer, and *Exogyra drakei* Cragin were collected by Gillerman (1953, pp. 24-30). This is overlain by about 18 m of massive, gray, rough-weathering limestone (Gillerman's "reef-limestone member" of the Grayson Formation) which is characterized by abundant caprinids and rudistids. Elsewhere in the Eagles, the Espy yielded *Beudanticeras* sp., *Eopachydiscus* sp., and *Mortoniceras* sp.

The age of the Espy is late Albian to early Cenomanian; it is paleontologically correlative with the Georgetown Limestone of central Texas and is approximately paleontologically correlative with part of the Duck Creek, as well as the Fort Worth, Denton, Weno, Pawpaw, and Main Street Formations of northeast Texas.

Eagle Mountains Sandstone

The platy, orange- and brown-weathering, calcareous Eagle Mountains Sandstone is in color, lithologic, and faunal contrast to the conformably underlying (Espy) and overlying (Buda) gray limestone. Gillerman (1953, p. 27) divided his Grayson Formation in the Eagle Mountains into three members on "lithological and faunal bases." From oldest to youngest they are the "Carpenter limestone member," the "reef-limestone member," and the "Eagle Mountains sandstone member." He described the youngest as follows (1953, p. 31): ". . . a distinct and persistent member . . . found throughout the mapped area adjacent to the reef-limestone member except where rhyolite intervenes. About 20 m of interbedded brown sandstone (some of which is quartzitic), brown shales, siltstone, and sandy limestones make up the member. The characteristic brown color of the beds contrasts strongly with the dominant blue-gray color of the other formations of late Comanchean age. *Exogyra cartledgi* [sic] Böse is characteristic of the Eagle Mountains member and is abundant in the beds immediately overlying the reef-limestone member. Other fossils identified are *Protocardia* sp. and *Trigonia*? sp.

The Eagle Mountains Sandstone comprises that sequence of orange- and brown-weathering interbedded sandy limestone, calcareous sandstone, and shale that rests on the gray limestone of the Espy and that is overlain by the nodular gray limestone of the Buda.

The Eagle Mountains Sandstone is paleontologically correlative with the Del Rio Clay of southwest Texas, but proof of lateral continuity between the Del Rio Clay and the Eagle Mountains Sandstone is lacking. The age of the Eagle Mountains Sandstone is early Cenomanian.

Buda Limestone

The top of the Buda Limestone coincides with the top of the Comanche Series in the map area. The gray, nodular limestone of the Buda, where it is exposed along with the underlying Eagle Mountains Sandstone and overlying Chispa Summit Shale, stands out in marked contrast to those orange- and brown-weathering siliciclastic units. Lithologically, the Buda and Espy Limestones are not easily distinguished.

The Buda is a characteristically light brownish-gray, very finely crystalline, nodular, thin-bedded limestone that weathers very pale orange to pale yellowish brown. Microscopic shell fragments, largely gastropods and pelecypods, and foraminifers occur in varied abundance throughout the Buda.

From the Buda in the Eagle Mountains, Gillerman (1953, p. 31) reported *Lima shumardi* Shattuck, *Pholadomya shattucki* Böse, *Isocardia* sp., *Exogyra* sp., *Turritella* sp., *Nerinea* sp., *Tylostoma* cf. *T. harrisi* Whitney, and *Enallaster texanus* (Roemer). In addition, he cited the occurrence of a persistent bed of *Turritella* and *Nerinea* at the base of the formation immediately above the Eagle Mountains Sandstone. In places, the uppermost Buda contains abundant turritelid gastropods.

Buda is the only central Texas name that has been used in the map area. The formation can be traced from central Texas into western Trans-Pecos Texas and very likely was once a continuous body of rock. The age of the Buda is Cenomanian; its top in Trans-Pecos Texas, northern Chihuahua, and in central Texas coincides with the top of the Comanche Series.

Chispa Summit Formation

The Chispa Summit Formation includes the youngest Cretaceous rock exposed in the Eagle Mountains and vicinity. The base of the Chispa Summit coincides with the base of the Gulf Series; it is generally covered. Adkins (1933, p. 437) proposed the name for the approximately 245 m of yellow and brown interbedded, flaggy limestone, marl, and clay that crop out near Chispa Summit about 32 km south-southeast of Eagle Peak.

In the Eagle Mountains, the Chispa Summit Formation crops out in the Eagle Spring area and from place to place to the southeast. Near Eagle Spring, more than 425 m is exposed (Smith, 1941, p. 74), including coal seams in black shale. The Chispa Summit is well exposed in the area of Carpenter Spring, about 4 km south-southeast of Eagle Spring, where Taff (1891, pp. 734-735) measured 340 m of brown, fissile, calcareous shale and sandy shale, calcareous flaggy sandstone, and black, fissile shale and sandy shale containing *Inoceramus* sp. Gillerman (1953, p. 33) collected *Coilopoceras* sp., *Romaniceras*? sp., *Ostrea soleniscus* Meek, and *Inoceramus* sp. near Carpenter Spring. Fish teeth and fish scales have also been collected from the shale within a few meters of Carpenter Spring.

The Chispa Summit is paleontologically correlative with the Eagle Ford of central Texas, the Ojinaga of northern Chihuahua, and the Boquillas in the Big Bend Area. Its age is late Cenomanian and Turonian. It is possible that the upper part of the Chispa Summit in the Sierra Vieja region may be as young as Campanian (Twiss, 1959b, p. 50).

Tertiary Rocks

The eruptive rocks of the Eagle Mountains are sodium-rich rhyolitic and trachytic rocks (see also Hoffer, Leggett and Verrillo, this guidebook). The light-colored, fine-grained, microporphyritic intrusive rhyolite of the Devil Ridge area resembles that of the northern Indio Mountains, and both are similar to the rhyolite of the Eagle Mountains.

Basin fill of both Tertiary and Quaternary age and terrace gravel, alluvium, and windblown sand almost encircle the Eagle Mountains.

Igneous Rocks

The eruptive rocks of the Eagle Mountains compose the interior, highest part of the mountains. The texture of each of the three major mapped units—from oldest to youngest, lower rhyolite, trachyte porphyry, and upper rhyolite—is both horizontally and vertically variable.

The intrusive rocks include rhyolite, microgranite, quartz syenite, basalt and diabase. The small stock is Eagle Peak Syenite.

Although the age of the eruptive rocks of the Eagle Mountains may be inferred from regional geology to be Oligocene (DeFord, 1958), no vertebrate fossils have been recovered.

Lower rhyolite.—The "lower rhyolite" is a sequence of sedimentary rock, extrusive and intrusive rhyolite, volcanic breccia, flow breccia, and tuff that ranges in thickness from several hundred to more than a thousand feet. This sequence was deposited on an uneven surface of Cretaceous rock where relief was as much as 150 m. Formations of Comanchean and Gulfian age are overlain unconformably by the lower rhyolite.

Trachyte porphyry.—The outcrop of "trachyte porphyry" along the east flank of the Eagles is narrow, and this rock is missing or hidden by younger rock along the south flank of the mountains. It thickens to the west, however, as does the lower rhyolite; at the west flank of the mountains there is 266 m of trachyte porphyry.

The lower rhyolite and the upper rhyolite are in contact from place to place along the southwest margin of the mountains. The trachyte porphyry may have been eroded or it may never have been present in the area. To the east the lower rhyolite and trachyte porphyry grade vertically into one another; the gradation suggests continuous eruption.

Along the west flank of the Eagles, the lower rhyolite-trachyte porphyry boundary is very distinct. The light-colored, rounded weathered surface of the lower rhyolite is in sharp contrast with the dark-colored angular blocks of the trachyte porphyry. Gillerman (1953, pp. 36-37) suggested that some of the outliers of trachyte porphyry in the Eagle Spring area may be intrusive.

Upper rhyolite.—The precipitous, bare, light-colored slopes of Eagle Bluff rise nearly 600 m above the basin fill on the east flank of the Eagle Mountains. Eagle Bluff and much of the higher parts of the Eagles are composed of varied rhyolitic volcanic rocks shown on the map as "upper rhyolite."

This formation is composed of rhyolite volcanic breccia, and flow breccia and includes the areally restricted basal conglomerate of Gillerman's "upper rhyolitic series." The roughly circular outcrop of upper rhyolite surrounds the stock of Eagle Peak Syenite. At Eagle Bluff, the upper rhyolite is 450 to 600 m thick; it thins northward and westward.

The highest and steepest part of Eagle Bluff has a dike-like form. Rock near the base of this highest part of the bluff, however, has pronounced horizontal flow structure. Within the upper rhyolite on the flanks of Eagle Bluff, there are outcrops that have been identified as Bluff Formation, Cox Sandstone, and Espy Limestone. Neither the identity of these rocks nor their mode of emplacement within the upper rhyolite is certain. The smaller blocks may be xenoliths.

Lower rhyolite sills.—On the north and east flank of the mountains near the contact of the lower rhyolite volcanic rock sequence and the Cretaceous and Permian sedimentary rocks, sills of orange-weathering lower rhyolite have intruded the Cretaceous formations in a number of places. These sills range in thickness from a meter to 100 m or more; they show well-developed liesegang bands.

Clearly all these intrusive bodies of lower rhyolite were emplaced at about the time the lower rhyolite lava was extruded. Perhaps the localization of the intrusive rhyolite along the north and east flank of the Eagles is an indication that the magma gained access to the surface in this area through one or more vents or fissures. No vents were identified, but the Eagle Peak Syenite stock may be emplaced within a major vent. Although locally varied, the rhyolite is characteristically light colored (white, gray, very pale orange), fine grained, and in places is microporphyritic and spherulitic. Patinas of iron oxide are common on weathered surfaces; irregular patches of iron oxide scattered throughout give the rock a spotted appearance on a fresh surface. Some of the rhyolite is distinctly laminated.

Eagle Peak Syenite.—Gillerman (1953, p. 38) proposed the name "Eagle Peak Syenite" for the compact rock of a small stock that makes up the interior and highest part of the Eagle Mountains. Small apophyses of the Eagle Peak Syenite crop out east of the stock. North of the main stock, small intrusive bodies of the syenite crop out within the lower rhyolite, the trachyte porphyry, and the upper rhyolite. Vertical contact between the Eagle Peak Syenite and the upper rhyolite is well established at the east of the crescent-shaped stock, but in places toward the west end the syenite appears to be concordant with and underlain by extrusive upper rhyolite (Gillerman, 1953, p. 38). The syenite may be a sill between the extruded layers of upper rhyolite.

The color of most of the Eagle Peak syenite is pale brown to pale yellowish brown; at the east end of the stock near the contact with the upper rhyolite, it is medium dark gray. Samples from this area invariably have a discolored zone extending as much as one centimeter inward from the weathered surface. Weathered surfaces are various subdued shades of brown and orange. Erosion has carved V-shaped valleys and ridges with relatively steep, unbroken slopes in the syenite, but the effects of erosion on the upper rhyolite and the Eagle Peak Syenite are not different enough to distinguish these formations.

The syenite is composed of phenocrysts of subhedral alkalic feldspar and minor amounts of anhedral iron olivine and subhedral plagioclase in a fine-grained orthophyric matrix of quartz, alkalic feldspar, and an unidentified mafic mineral. Apatite and zircon are accessory minerals. Much of the olivine has been altered to iron oxide—hematite, limonite, and magnetite. The few grains of plagioclase are commonly armored with alkalic feldspar; the phenocrysts of alkalic feldspar are commonly armored or patchily zoned with alkalic feldspar of lower index of refraction. The rock has a granophyric texture. Locally, the Eagle Peak Syenite is a microgranite; quartz constitutes as much as 15 to 20 percent of the rock. The terms "porphyritic" and "porphyry" are also applicable because phenocrysts of alkalic feldspar are up to 6 mm long and constitute as much as 25 percent of the rock.

Diabase dikes.—In several areas within the Eagle Mountains, near-vertical or vertical dikes composed of a dark greenish-gray, fine-grained rock are in sharp contrast to light-colored sedimentary and igneous country rock. These dark rocks do not have everywhere the same composition or texture, but they are classified generally as diabase.

Bolson Fill

Fluvial, lacustrine, and aeolian deposits, the results of erosion in response to the difference in elevation created by late Tertiary normal faulting, almost completely surround the Eagle Mountains and their subsidiary ranges. Probably the "older gravel" and some of the oldest part of the "bolson fill" are contemporaneous and intergradational, although in general, the two formations are related to two different episodes of faulting.

These deposits, which filled the troughs (grabens) created by late Tertiary faulting, vary widely in grain size and composition. They are generally coarse near the margins of the intermontane basins and fine toward the center. The composition of the coarse material is directly related to the rock that was available for erosion in the nearby mountains. Probably much of the fine material came down the ancestral Rio Grande. Thickness of the bolson deposits, based on the known depths of deep water wells that bottom in the fill, is as great as 335 m in places.

South of the Eagles in Red Light bolson, a locality produced bones of the following animals from the youngest part of the bolson fill beneath the capping terrace gravel: *Equus* sp., *Nannippus?* sp., *Lepus* sp., *Eurecyon* sp., *Geomys bursarius*, *Camelops* sp., *Platygonus* sp., *Glyptotherium texanus*, *Testudo* sp. (large), and *Proboscidean* (mastodont). This fauna indicates an early Pleistocene (pre-Illinoian) age for the bolson deposits in which they were found. The deposits may be as old as Nebraskan or as young as Kansan.

Terrace Gravel

There are three principal terrace gravels along the Rio Grande and its major tributaries in the area; these represent successively lower base levels of the Rio Grande drainage system. They are not identified by lithology but by relative position above the present drainage system. Within a mile of the Rio Grande, the upper surfaces of the terrace gravels are at the following elevations above the adjacent flood plain: lowest, 6 m; intermediate, 23 m; and highest, 45 m. Like the bolson fill, the terrace gravels range widely in grain size and composition. They are loose to well-indurated mixtures of particles ranging from the finest silt to boulders. Because the composition depends upon the rock types available for weathering in the mountains, it may vary more widely geographically within one terrace gravel than it does stratigraphically within one gravel or between successive terrace gravels. Near the Rio Grande, the broad, prominent gravel terrace is the second terrace gravel. The highest terrace gravel is patchily preserved near the margins of the bolsons only. Along the arroyos, the lowest terrace gravel, is also sparsely preserved.

The correlation of the terrace gravels of the Rio Grande drainage system with those of the Salt Basin drainage system on the other side of the Eagles is based primarily on the assumption that the same conditions that produced the great alluvial fans on the southwest flanks of the mountains, produced those on the northeast flanks.

Alluvium

The flood plains and stream beds of the present streams other than the Rio Grande are alluvium. The flood plain of the Rio Grande is cut some 3 to 4 m below the flood plain of many of the tributary streams. The stream bed of the Rio Grande and that of the tributaries are substantially at grade. Widespread undifferentiated alluvium covers much of the lower parts of the Devil Ridge area and the lower areas along the northeast and east flanks of the Eagle Mountains.

The material that composes the Quaternary alluvium ranges from the finest silt in the valley flats and the large flood plains to large boulders in stream channels within the mountains. The range in composition is just as great and includes the many types of rocks that crop out in the map area.

Fissures in the alluvium about 4 km southeast of Hot Wells, immediately west of Red Light hills and near the head of Green River, appeared almost overnight, although in different years. The fissures range up to 3 km in length, are a meter or so wide at the surface, and extend downward an unknown depth. The trend of the fissures is generally north, and they are characterized by short branches that are nearly perpendicular to the main fractures. In places their pattern is polygonal. The origin of the fractures seems to be related to earthquake tremors or to erosive action of water. Their grossly polygonal pattern in places suggests that they may be large desiccation cracks (*see also* Goetz, this guidebook).

STRUCTURAL GEOLOGY

The volcanic pile of the central Eagle Mountains obscures the kinds of structural details and features that are so much better exposed in the Devil Ridge area to the northwest or in the Indio Mountains to the south. In the Devil Ridge area the thrust faults and the axes of the folds strike northwest, indicating that the maximum principal compressive stress in the area during the Laramide orogeny was northeast-southwest.

A complex of parallel to subparallel northwest-trending thrust and normal faults cuts pre-Tertiary rocks on the northeast flank of the Eagles. Several conspicuous east-west near-vertical to vertical faults transect the Eagle Mountains, cutting the Tertiary extrusive rocks. These faults may represent older strike-slip faults (conjugate shear fractures) that developed during the Laramide orogeny, then experienced vertical displacement during the post-volcanic mid- to late Tertiary episode of block faulting.

It is along this complex of fractures and juxtaposed blocks of Cretaceous limestone and Tertiary rhyolite that the replacement and vein deposits of fluorspar occur. These deposits, discovered in 1919, were mined during World War II years and then intermittently until the small flotation mill was dismantled in 1950. U.S. Bureau of Mines records show that a total of 13,377 metric tons of fluorspar had been shipped by that date.

The dip of Cretaceous rocks peripheral to the Eagle Mountains and of the overlying volcanic rock is generally centroclinal. In describing the structure, which trends northwest, Gillerman (1953, p. 40) proposed the name Eagle Mountain syncline; it is shown in the structure section Figure 4. Because the Cretaceous rocks were tilted during the Laramide orogeny, there is a disparity in most places between their dip and that of the overlying volcanic rock.

The Eagle Mountains are probably bounded on the northeast and the southwest by normal faults whose displacement can only be estimated by the depth of the bolson fill as determined from deep water wells. Late movement along or at least parallel to these boundary faults is indicated by the northwest-trending faults in the terrace gravel on the southwest flank of the mountain.

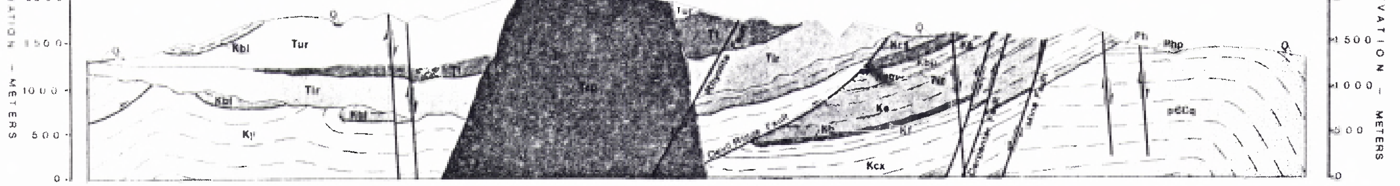


Figure 4. Structural cross-section through Eagle Mountains.

GEOLOGIC HISTORY

Precambrian

The earliest geologic event recorded in rocks exposed in the Eagle Mountains as well as in Trans–Pecos Texas is the deposition of the sediments of the Carrizo Mountain Formation in a geosyncline within the largely granitic and granodioritic Texas Craton (Flawn, 1956). Flawn believed that the overall homogeneity of the metasedimentary rock of the Carrizo Mountain Formation indicates that it is a single sedimentary series. Because the outcrop area of the Carrizo Mountain Formation is relatively small and because subsurface control on the basement in the region is scanty, the shape, orientation, and areal extent of this geosyncline are unknown.

The geosynclinal deposits were subjected to folding and regional progressive metamorphism of low to medium grade; intrusion by rhyolite and then by diorite followed (Flawn, 1956). The grade of metamorphism increases from northwest to southeast. In the Carrizo Mountains and Eagle Mountains, low-grade metamorphism is indicated by the greenschist facies in which many sedimentary structures are preserved, whereas in the Van Horn Mountains to the southeast, medium-grade metamorphism is indicated by the amphibolite facies in which most sedimentary structures have been obliterated.

The sills of diorite that intruded the Carrizo Mountain Formation of the Eagle Mountains and elsewhere were converted to amphibolite by a second period of deformation. During this second orogeny, the geosynclinal deposits of the Carrizo Mountain Formation were cataclastically and retrogressively metamorphosed and overthrust northward.

A younger red, unfossiliferous, arkosic, cross-bedded, coarse-grained local continental deposit—the Van Horn Sandstone—has been designated Precambrian(?) by King (1953, p. 90).

Paleozoic

Pre-Permian

During the Cambrian Period, most of Texas, including the Van Horn uplift, was undergoing erosion. Rock of latest Cambrian age is known in the Llano uplift as well as in the El Paso area.

The thin-bedded, quartzose Bliss(?) Sandstone of Early Ordovician age, about 35 m thick and well exposed on Beach Mountain just north of Van Horn, records the transgression of an epicontinental sea. The Van Horn region was not a site of continuous deposition throughout the Ordovician, however, for the El Paso Limestone, a 340-m sequence of thick-bedded dolomitic limestone and dolomitic sandstone, lies disconformably on the Bliss(?) at Beach Mountain. The El Paso, in turn, is overlain by the dolomitic and cherty Montoya Limestone of Late Ordovician age. Silurian, Devonian, Mississippian, and Pennsylvanian rocks crop out in the Trans–Pecos region, and an even more nearly complete section is present in the subsurface. The map area and surrounding region were no doubt receiving sedimentation during much of the pre-Permian part of the Paleozoic Era.

A series of Pennsylvanian orogenies, the last of which extended into earliest Permian time in Trans–Pecos Texas, deformed the sediments of the Marathon geosyncline and uplifted and gently folded the Van Horn region to the northwest. Subsequent erosion removed much of the earlier Paleozoic rock; at least, on the northeast side of the map area, erosion was sufficient to expose and probably partly remove rock of Precambrian age.

The major structural elements that were created late in the Pennsylvanian Period and early in the Permian Period controlled sedimentation in the region throughout the Permian. The Eagle Mountains are on the southwest flank of the Van Horn uplift, a generally domical high on the larger Diablo Platform

Permian

The Early Permian sea that covered western Trans–Pecos Texas transgressed over an uneven erosional surface; the Powwow Conglomerate, a basal siliciclastic unit, filled topographic lows on this irregular pre-Permian surface. Recorded within the Powwow is the transition from a continental fluvial environment to an epineritic environment of deposition. The very finely crystalline fossiliferous limestone or micrite of the Hueco records the gradual advance of the neritic Wolfcampian sea onto the Diablo Platform.

More than a thousand meters of rock of Leonardian and Guadalupian age probably were deposited on the Hueco Limestone in the map area concomitant with the development of the Permian reefs to the north, east, and southeast, and with the development of the accompanying basin, reef, and marginal shelf facies. During the Ochoan Epoch, the map area, together with marginal shelf areas, rose above water as the Permian sea regressed toward Mexico.

Mesozoic

Early Mesozoic

Erosion that followed the disappearance of the Permian sea from Trans–Pecos Texas eventually reduced the land to a low, irregular surface which R. T. Hill called the "Wichita paleoplain." The transgression of the Mexican sea over this vast, low-lying erosional surface began in Aptian time and continued uninterruptedly into the Early Cretaceous (Albritton, 1938, p. 1754; Huffington, 1943, p. 997).

Cretaceous

The Diablo Platform and the differentially subsiding Chihuahua Trough to the southwest, which was inundated by the Mexican sea, were the tectonic elements that controlled sedimentation in the map area during the Cretaceous Period.

Comanche Epoch—The Yucca Formation, a siliciclastic and calciclastic nearshore deposit probably both marine and continental, includes the oldest Cretaceous rock exposed in the map area. During the advance of the Mexican sea, the regolith of the pre-Cretaceous surface was incorporated in the heterogeneous material that composes the Yucca. Transgression of the sea was so rapid that the sediments were poorly sorted.

Continued transgression created a neritic environment in the map area for the first time since the Permian Period, within which the limestone of the Bluff Formation was deposited. Conditions were somewhat unstable, however, as indicated by the sandy, oolitic, reef character of the lower part of the Bluff compared to the homogeneous, very finely crystalline *Orbitolina*-bearing limestone of the upper part of the formation. During a slow regression of the sea, marked perhaps by minor regressive and transgressive movements, the map area was for a long time the locus of a shore or near-shore environment in which reworked material was brought in and further reworked. These environmental conditions accompanied by little or no tectonism were widespread throughout Trans–Pecos Texas, and the Cox Sandstone that resulted is characteristically a supermature orthoquartzite. The Cox Sandstone is the youngest Cretaceous formation that rests on Paleozoic and older rocks; thus, it marks the culmination of the transgression of the Mexican sea over the Diablo Platform.

The Finlay Limestone represents the most extensive transgression of the Mexican sea into Trans-Pecos Texas up to this time—a transgression that brought into the map area a marginal neritic sea in which rudistid and caprinid reefs or banks developed.

The increasingly brief interruptions of carbonate deposition, represented by thin Benevides and Eagle Mountains formations, as well as the homogeneity of the very finely crystalline (micrite) limestone of the Espy and Buda formations, reflect increasing tectonic stability during the Comanche Epoch.

Once the Diablo Platform was inundated, the Mexican sea invading Trans-Pecos Texas merged with the Cretaceous sea advancing onto the continental shelf to the east. Westward, however, there is no certainty that the Mexican sea and the Pacific Cretaceous sea ever merged.

Gulf Epoch.—The lithologically varied rock that constitutes the Chispa Summit Formation was deposited in a changeable neritic sea as well as along the shore in stagnant lagoons. There may or may not have been a brief period of subaerial erosion between Comanchean and the Gulfian deposition.

In the map area, erosion has removed that part of the Gulfian section younger than late Turonian, but sedimentation may have continued there even into Tertiary time. As the sea retreated, well before the end of the Cretaceous Period, nearshore marine deposition gave way to fluvial and deltaic deposition, and this to continental deposition.

Laramide Orogeny

The thrust faults and folds of the Eagle Mountains and vicinity record a part of the intense deformation that accompanied the Laramide orogeny. In the map area, the Chispa Summit Formation is the youngest formation now exposed that was certainly involved in the deformation. The time of culmination of the Laramide orogeny was later than the youngest Cretaceous rock and earlier than the oldest volcanic rock of the Rim Rock country. This places it as post-Campanian (probably Maestrichtian or later) and pre-Oligocene.

Cenozoic Era

Although the early part of the Cenozoic Era was a time of intense structural deformation, erosion was probably sufficient to maintain a relief of less than 300 m. By the time the first volcanic rocks were laid down in the map area, the maximum relief was about 150 m. The irregular distribution of the volcanic rock units of the Eagle Mountains in part reflects the uneven surface over which the lava flowed.

The north-northwest to northwest trend of Laramide structural features that is so evident today probably controlled the topography of the erosional surface on which the volcanic rock was deposited.

Volcanism

Widespread volcanism in the region during Oligocene time, probably centered in the Davis Mountains area, spread a blanket of extrusive igneous rock over much of Trans-Pecos Texas. Few vents through which the volcanic rocks reached the surface have been identified, perhaps because these rocks still cover large areas. The volcanic outbursts that spread tuff, welded tuff, trachyte, and basalt over the Indio Mountains area were cyclic. Because the igneous rock section so closely resembles that of the Van Horn Mountains, and because the Pantera Trachyte thins westward, the source of the volcanic material was probably to the east. The thick section of volcanic breccia and flow breccia in the Eagle Mountains must have had a local source, although no vents have been positively identified.

Intrusive Igneous Activity

During the eruption of the material that now forms the lower rhyolite of the Eagle Mountains, the country rock was intruded by numerous sills and dikes of the rhyolite. Some time later, after the emplacement of the trachyte porphyry and the upper rhyolite and perhaps additional rock that has since been eroded, the rocks of the Eagle Mountains were intruded by the Eagle Peak Syenite.

The relative ages of the Eagle Peak Syenite, the diabase, and the rhyolite that generally intruded along east-west faults are uncertain, as is the relationship of the intrusion of those rocks to the time of normal faulting. Much of the normal faulting may have preceded the intrusion of the igneous rock. It certainly seems, for example, that the rhyolite and diabase intrusive bodies in the Eagle Spring area are intruded along pre-existing fractures. The same may well be true of all the dikes as well as of the stock of Eagle Peak Syenite. Whether these fractures, joints, or faults, were formed during the episode of Tertiary block-faulting is not known. It is entirely possible that the diabase dikes and the late rhyolite dikes antedated the emplacement of the Eagle Peak Syenite.

Folding

In a few places in the region, folds in volcanic rocks indicate that there was late or post-volcanism compressive tectonism. Perhaps the strongest evidence for this late period of folding is the Colquitt syncline in the northern part of the Rim Rock country. In this fold, rock of Oligocene age is folded concordantly with the Cox and Finlay Formations of Cretaceous age (Twiss, 1959b, p. 149).

In the Eagle Mountains, perhaps the strongest evidence for post-volcanic compression is the change in attitude of the lower part of the upper rhyolite in a north-trending canyon cut into the south flank of the mountains. This and several gentler warps in the volcanic rock of the map area may, however, have resulted from subsidence that accompanied the extrusion of vast quantities of igneous rocks.

Block Faulting

During the Laramide orogeny, western Trans-Pecos Texas and northern Chihuahua were near sea level, but in about mid-Oligocene time, the region was uplifted many hundreds of meters and block-faulted (DeFord and Bridges, 1959, pp. 292-293). Some of the intrusive rocks of the Eagle Mountains and vicinity may have been emplaced along normal faults that date from mid-Tertiary time, but their emplacement could have been earlier.

The differences in elevation caused by mid- to late Tertiary block-faulting in the Eagle Mountains and vicinity led to the formation of an old gravel that is probably correlative with the Tarantula Gravel of the northern Rim Rock country. In the map area, the old gravel was recognized only in the Indio Mountains, where it probably resulted from erosion of the scarp created by the Indio fault.

Although the normal faults have a thousand meters or so of separation, movement along the faults was probably intermittent and slow enough to allow erosion to maintain differences in elevation of a hundred to several hundred meters. The faults that have displaced the bolson fill and later terrace gravel show that the normal faulting was long-lived; it may still be active.

From the time of the earliest block-faulting, the topographic depressions or grabens were filled by debris eroded from the adjacent highlands. Within the closed basins, such as Eagle Flat and Salt Basin, this process continues today; within the open basins, material eroded from the highlands is sporadically being transported to the Gulf of Mexico.

Evolution of Drainage and Terrace Development

Following the Laramide orogeny the region probably had a trellis drainage pattern with a prominent northwest trend parallel to the fold axes, as well as to the hogbacks and ridges created by thrust faults. With the creation of the intermontane lowlands by block-faulting, drainage basins became closed, and as the fill buried the mountains the drainage developed a radial pattern. When the intermontane lowlands were breached and open drainage systems were again established, degradation began and has continued to the present day. As the streams cut downward through the fill, they were superposed on the older rocks. Much of the drainage, therefore, crosses structure at a high angle. Following the breaching of Red Light Bolson and the establishment of an open drainage system, removal of the bolson fill and exhumation of adjacent highlands began. This probably antedated the beginning of degradation in the Hueco Bolson, dated by Strain (1959, p. 377) as between late Kansan and medial Illinoian time.

The three principal terraces and several intermediate ones that are present from place to place are a record of changes in climate or base level or both, which in turn changed conditions of erosion and deposition. The smooth, gravel-capped upper surfaces of the terraces were developed when the controlling factors (climate, tectonic activity, lithology) were so adjusted as to allow the formation of a broad surface on which aggradation and degradation were approximately in balance. A change in one or more of the controlling factors caused the streams to seek a grade at a lower level, and the older surfaces are preserved as gravel-capped terraces.

REFERENCES

Adkins, W. S., 1933, The Mesozoic systems of Texas, *in* Sellards, E. H., and others, The geology of Texas; Volume 1, Stratigraphy: University of Texas Bulletin 3232, p. 239-518.

Albritton, C. C., Jr., 1938, Stratigraphy and structure of the Malone Mountains, Texas: Geological Society of America Bulletin, v. 49, p. 1747-1806.

Baker, C. L., 1927, Exploratory geology of a part of southwestern Trans-Pecos Texas: University of Texas Bulletin 2745, 70 p.

DeFord, R. K., 1958, Tertiary formations of Rim Rock Country, Presidio County, Trans-Pecos Texas: Texas Journal of Science, v. 10, p. 1-37. Reprinted as Texas Bureau of Economic Geology Report of Investigations No. 36.

DeFord, R. K., and Bridges, L. W., II, 1959, Tarantula Gravel, northern Rim Rock country, Trans-Pecos Texas: Texas Journal of Science, v. 11, no. 3, p. 286-295.

Flawn, P. T., 1953, *in* King, P. B. and Flawn, P. T., Geology and mineral desposits of Precambrian rocks of the Van Horn area, Texas: University of Texas Publication 5301, p. 27-69, 133-147, 177.

Gallick, C. M., editor, 1975, Geology of the Eagle Mountains and vicinity, Trans-Pecos Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Field Trip Guidebook 75-15, 204 p.

Gillerman, Elliot, 1953, Fluorspar deposits of the Eagle Mountains, Trans-Pecos Texas: U.S. Geological Survey Bulletin 987, 98 p.

Huffington, R. M., 1943, Geology of the northern Quitman Mountains, Trans-Pecos Texas: Geological Society of America Bulletin, v. 54, p. 978-1048.

King, P. B., 1953, *in* King, P. B. and Flawn, P. T., Geology and mineral deposits of Precambrian rocks of the Van Horn area, Texas: University of Texas Publication 5301, p. 71-121, 125-133.

Richardson, G. B., 1904, Report of a reconnaissance of Trans-Pecos Texas north of the Texas and Pacific Railway: University of Texas Bulletin 23 (Minerals Survey Series 9), 119 p.

Smith, J. R., Jr., 1940, Stratigraphy and structure of the Devil Ridge area, Texas: Geological Society of America Bulletin, v. 51, p. 597-638.

———, 1941, Geology of the Eagle Spring area, Eagle Mountains, Hudspeth County, Texas: Field and Laboratory, v. 9, no. 2, p. 70-79.

Strain, W. S., 1959, Blancan mammalian fauna from Rio Grande valley, Hudspeth County, Texas: Geological Society of America Bulletin, v. 70, p. 376-378.

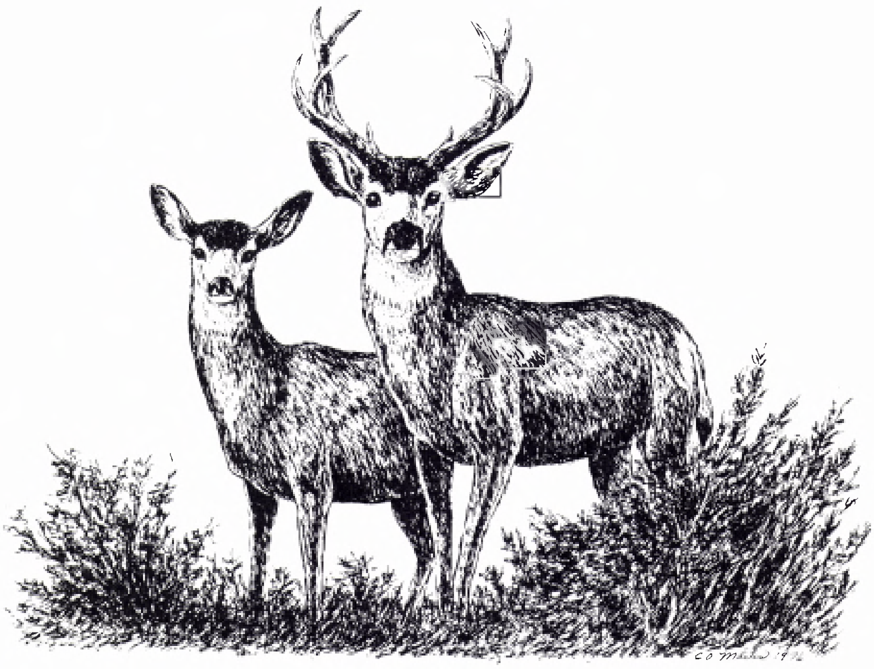
Taff, J. A., 1891, The Cretaceous deposits of El Paso County: Texas Geological Survey Second Annual Report, 1890, p. 714-738.

Twiss, P. C., 1959a, Geology of Van Horn Mountains, Texas: Texas Bureau of Economic Geology, Geologic Quadrangle Map No. 23.

———, 1959b, Geology of Van Horn Mountains, Texas (Ph.D. dissertation): University of Texas, Austin, 234 p.

Underwood, J. R., Jr., 1962, Geology of Eagle Mountains and vicinity, Trans-Pecos Texas (Ph.D. dissertation): University of Texas, Austin, 560 p.

———, 1963, Geology of Eagle Mountains and vicinity, Hudspeth County, Texas: Texas Bureau of Economic Geology, Geologic Quadrangle Map 26, 32 p. text.



Mule deer, *Odocoileus hemionus.*