THE GEOLOGY OF THE MUSTANG MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

by

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Approved:  

Director of Thesis  

Date
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CHAPTER I - INTRODUCTION

LOCATION

The Mustang Mountains consist of two ranges of hills in the extreme northeastern corner of Santa Cruz County, Arizona (Fig. 1). The western range, which trends northwest-southeast, is separated from the nearly circular

![Index map of Arizona showing location of Mustang Mountains.](image-url)
eastern range by a narrow valley. This mountain group is a southern outlier of the Whetstone Mountains. Arizona State Highway 82 from Nogales to Tombstone runs through the low pass which divides the Mustang from the Whetstone Mountains (Fig. 2).

Discussion in this paper is limited to the western range and statements concerning the Mustang Mountains refer to this range only. An area about five miles long by two miles wide, which includes all of this range except some outlying hills to the southwest, has been studied and mapped (Fig. 2 and Pl. 1).

![Fig. 2. Sketch map of northeastern Santa Cruz County showing location of Mustang Mountains.](image-url)
ACKNOWLEDGEMENTS

The writer gratefully acknowledges the assistance of Dr. A. A. Stoyanow, Dr. M. N. Short and Professor E. D. McKee of the Geology Department and of Dr. J. H. Feth of the U. S. Geological Survey. Mr. George Olin photographed the fossils and prepared most of the photographic plates. Mr. A. S. Piccoli compiled and drafted the geologic map, largely from aerial photographs. The Tucson office of the Soil Conservation Service permitted the writer to reproduce copies of their aerial photographs for his field maps. Mr. Charles H. Grantham and Mr. Ralph Tellez graciously allowed the writer complete access to all parts of the properties which they manage in the Mustang Mountains.

PURPOSE OF STUDY

The purpose of this study is to obtain detailed information on lithologic and faunal zones of the Permian rocks of the Mustang Mountains. It is planned later to expand and continue this type of study in order to correlate the Permian of southeastern Arizona in much greater detail than is now possible.
None of the topographic features of the Mustang Mountains are named on existing maps. A few features have names in local use, notably The Biscuit and Rain Valley but most of the prominent peaks, cliffs, ridges and valleys are merely assigned names for ease of reference. These names are tentative and have not been approved by the Geographic Board.

The Mustang Mountains are bounded on three sides by a broad open valley and on the fourth side by a pass through which the highway runs. The area is drained by tributaries of Babocomari Creek which flows into the San Pedro River (Fig. 2). Near the base of the Mustangs this valley has an average elevation of about 5000 feet. Many of the peaks in the northern and central parts of the range are above 6000 feet. The peak of Grantham Mountain, the highest point in the area, reaches 6348 feet (Pl. 1).

Much of the range is characterized by steep slopes which are topped by sheer cliffs, 200 to 500 feet high and from several hundred to several thousand feet long. The cliffs are best developed where the Cave Cliff member of the Permian Snyder Hill formation crops out with dips of 20 degrees or less.

The drainage pattern of the area is dendritic, but many of the washes are controlled by faults and have
remarkably straight sections, in places hundreds of feet long.

Valleys in the mountain area are typically youthful. Washes have narrow bottoms, steep sides, steep gradients and little development of tributaries. In the surrounding valleys, however, streams show characteristics of maturity to old age — gentle gradients, low sloping banks, meanders and braiding.
The rocks of the Mustang Mountains include: (1) sedimentary rocks of Permian age, dominantly marine limestones, in places magnesian, with some sandstones; (2) Cretaceous (?) non-marine sandstones, siltstones and conglomerates; (3) Tertiary (?) lavas; (4) a Tertiary (?) rhyolite porphyry sill and (5) Quaternary alluvium (Pl. 1 and Pl. 4).

The Permian rocks form blocks that have been thrust over Cretaceous (?) strata. They have a maximum exposed thickness of about 1600 feet. Some basal beds have been cut out by overthrust, and some beds at the top of the section have been removed by erosion. Thus the total amount of Permian strata deposited in the area is not known.

Cretaceous (?) strata are found unconformably overlying the Permian rocks, as well as being present below the overthrust block. The maximum exposed thickness of Cretaceous (?) rocks, measured in a section below the thrust sole, is 315 feet. Overlying the Permian rocks on Quail Peak is a minimum of 16 feet. Rocks of this age exposed in the valley west of Grantham Mountain are 395 feet thick.
intrudes the Cretaceous (?) strata is 150 feet thick. Tertiary (?) lavas unconformably overlie the Creta- ceous (?) rocks, attaining a thickness of 260 feet on Lava Ridge and probably more than 500 feet on Grantham Mountain. About 50 feet of lava rest unconformably on the Permian strata just north of Pointed Peak.

Quaternary alluvium forms a thin veneer on the flanks of the mountains and is progressively thicker with distance out in the valleys. In washes within the range this allu- vium reaches a maximum of about 25 feet.

PERMIAN STRATA - THE SNYDER HILL FORMATION

Definition

The Permian rocks of the Mustang Mountains are as- signed to the Snyder Hill formation. They comprise about 900 feet of limestone overlying 600 feet of strata which consist of two sandstone units separated by one of lime- stone. In the upper middle part of the thick limestones are beds which are equivalent to those at Snyder Hill, type locality of the Snyder Hill formation designated by Stoyanow (1936, p. 531).

No name other than Snyder Hill formation has been used in published descriptions of Permian rocks in southern Arizona. Feth (1948, p. 83) in the Canelo Hills expanded
the original definition of the Snyder Hill formation to include not only the massive limestones in the upper part of the 2200-foot sequence of Permian strata, but also the interbedded sandstones and limestones in the lower part.

The addition of sandstones and limestones of different character to the original massive limestone unit known as the Snyder Hill formation is not in keeping with usual stratigraphic procedure. However, it is believed to be justified in this study pending further regional investigations. Gilluly (1949, letter to E. D. McKee) and Cooper (1949, letter to E. D. McKee) of the United States Geological Survey have given new formation names to the Permian strata in the Dragoon and Little Dragoon Mountains. Further regional studies will be necessary to determine the equivalence of these formations to the strata in the Mustang Mountains. For the present, mappable units in the Mustang Mountains will be designated as members of the Snyder Hill formation. Future work should determine the status of these units, either as new formations, as members of one or more formations or as equivalents of formations being described by Gilluly or by Cooper.

Subdivisions

Five major subdivisions of the Snyder Hill formation are recognized in the Mustang Mountains. They are
designated in ascending order as follows: 1) White sandstone member, 2) Tellez Wash limestone member, 3) Pink sandstone member, 4) Cave Cliff limestone member and 5) Quail Peak limestone member.

Location of sections

Nine partial sections of Permian strata have been measured in the Mustang Mountains. No single one includes both the top and the bottom of the sequence. Sections A and B were chosen as the key sections because they are the thickest and most complete, and were measured in greater detail than other sections. Section A, northwest of Tellez Wash up Cave Cliff, includes the White sandstone, the Tellez Wash limestone, and the Pink sandstone members and all but the top 33 feet of the Cave Cliff limestone member. The uppermost 33 feet of Cave Cliff strata are present in Section B which is northwest of Tank Wash up to the lava which caps Quail Peak. Section B begins about 200 feet above the base of, and includes the complete upper part of the Cave Cliff limestone member, together with the Quail Peak limestone member.

Detailed descriptions of measured sections are given in Appendix A. Correlations of the sections are shown on Plate 3. From these descriptions and correlations, it can be seen that each of the other sections of Permian rocks
measured in the Mustang Mountains is equivalent to a part of the composite column of Sections A and B (Pl. 4).

WHITE SANDSTONE MEMBER

The White sandstone member is the lowest unit of the Snyder Hill formation represented in the Mustang Mountains. It has a maximum thickness of about 320 feet.

Bedding in the White sandstone member is generally flat. A few beds are cross-laminated. The color of the beds ranges from white and light gray to dark reddish brown, with the darker colors confined to limestones near the base of the member. Various shades of brown and gray, dominantly light, characterize weathered surfaces.

The White sandstone member is fine-grained in general. A few beds are very fine-grained; medium- to coarse-grained beds are uncommon. In most places the beds are composed of grains that are well sorted, rounded to sub-angular and sub-spherical. Cementing material is dominantly calcium carbonate, with minor amounts of iron oxide. A few beds have siliceous cement, forming ortho quartzites.

Outcrops and thicknesses

The White sandstone member crops out north of Tellez
Wash. Strata of this member also are exposed on both the east and west slopes below The Biscuit, on the slopes south and west of Ravens Bluff and on the slope east of Pointed Peak (Pl. 1).

A maximum thickness of 319 feet was measured in Section A, north of Tellez Wash, but an unknown amount below has been cut out by a thrust fault (Appendix A, Section A, intervals 1 to 13; Pl. 3). Stratigraphically lower beds are believed to be present south of Ravens Bluff, but exposures are poor. Northwest of these poorly exposed beds are 247 feet of strata (Section I, intervals 1 to 21) which are also assigned to the White sandstone member. The outcrops of the White sandstone member on the lower slopes east of Pointed Peak are also poorly exposed and were not measured below the base of Section J.

**Upper and lower limits**

The base of the White sandstone member is not exposed in the area studied. In the Cave Cliff section (Section A) the lowermost 2 feet of the measured section is formed of grayish orange-pink\(^1\) sandstone, but contains much gouge.

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\(^1\) Color descriptions are based on rock-color chart prepared by the Rock-color Chart Committee, distributed by the National Research Council, Wash., D. C. (1948).

It represents a zone of brecciation in which all signs of
bedding are destroyed. Below this are dark red sandstones and conglomerates of Cretaceous (?) age. No other section measured includes beds that are as low stratigraphically. The White sandstone member grades upward into the overlying Tellez Wash limestone member through a transitional zone that is only a few inches thick. The top of this thin, gradational zone was arbitrarily chosen as the boundary between the members. There are no limestone beds immediately below, and only a few thin beds and lenses of cherty purple sandstone above this boundary (Pl. 3 and Appendix A, Section A, intervals 13 and 14). The same relationships are shown at the top of the White sandstone member below Ravens Bluff and east of Pointed Peak (Sections H and J, Appendix A and Pl. 3).

Topographic expression

The White sandstone member is weakly cemented and easily eroded. In many areas it forms rather gentle slopes below the more resistant Tellez Wash limestone member and is covered with debris from higher, more resistant strata (Pl. 17, fig. 1).

Fauna

No identifiable fossils have been found in the White sandstone member or in any section.
sandstone member. In the limestone beds near the base calcite blebs, which simulate brachiopod and pelecypod shell shapes, are common. Fossils probably were once present in these places but have been replaced by coarse-grained calcite which has destroyed all details of shell structure.

Concretions

Concretions of three types are very common in beds of the White sandstone member, particularly in the upper 200 feet. All three types are similar in composition, but differ in size and shape. They are formed by differences in the kind of cementing material, where iron-rich solutions apparently have precipitated iron oxide about favorable nuclei.

One type of concretion consists of small spheres from an eighth of an inch to half an inch in diameter. They are not noticeable in the fresh rock but appear on weathered surfaces as rounded, dark reddish brown protuberences or as round pits of the same color. The protuberences develop where the sandstones have calcitic cement, and the pits are present in the more silicic beds.

Concretions of the second type have a similar dark reddish brown color on weathered surfaces, but they assume irregular shapes with arm-like protrusions. This second type averages about 4 to 6 inches in diameter.
The third type of concretion is of similar color and composition, but occurs in large masses. These concretions are tabular, 3 to 6 inches thick and as much as 4 feet in maximum extent, commonly oriented nearly perpendicular to the bedding.

**TELLEZ WASH LIMESTONE MEMBER**

**Lithology**

The Tellez Wash limestone member is the second or next to lowest unit of the Snyder Hill formation represented in the Mustang Mountains. It has a maximum measured thickness of 156 feet.

Limestones of this member range in color from pale purple to very dusky red purple. Weathered surfaces are mostly brown, and in many places very rough and blocky, having an appearance that has been termed "raspy" by Feth (1948, p. 93, Fig. 4). This surface texture is particularly characteristic of magnesian limestones, which make up a major part of this member. Even the more calcitic beds have a higher MgO content than any of the limestones that have been analyzed from the Cave Cliff member (Table I).
TABLE 1. Chemical analyses of limestones from the Mustang Mountains.

<table>
<thead>
<tr>
<th>Section &amp; Interval</th>
<th>Zone</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>CaO</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-15 8-10'</td>
<td></td>
<td>9.02</td>
<td>2.08</td>
<td>1.00</td>
<td>47.1</td>
<td>1.96</td>
</tr>
<tr>
<td>A-35 1-5'</td>
<td></td>
<td>3.42</td>
<td>0.77</td>
<td>0.43</td>
<td>52.3</td>
<td>0.59</td>
</tr>
<tr>
<td>A-35 9-13'</td>
<td></td>
<td>4.44</td>
<td>0.60</td>
<td>0.58</td>
<td>51.4</td>
<td>0.53</td>
</tr>
<tr>
<td>B-13 4-12'</td>
<td></td>
<td>2.44</td>
<td>0.50</td>
<td>0.30</td>
<td>52.8</td>
<td>0.53</td>
</tr>
<tr>
<td>G-5 0-3'</td>
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<td>12.10</td>
<td>0.56</td>
<td>0.20</td>
<td>48.4</td>
<td>0.36</td>
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<tr>
<td>G-5 8-10'</td>
<td></td>
<td>9.26</td>
<td>0.42</td>
<td>0.30</td>
<td>49.6</td>
<td>0.22</td>
</tr>
</tbody>
</table>

(Analyses by F. G. Hawley)

The Tellez Wash limestone member is fine-grained and in most places appears aphanitic to the unaided eye. In general the grains are uniform, but patches up to a foot in diameter of coarsely crystalline limestone are irregularly distributed throughout the member.

Outcrops and thicknesses

The most complete and best exposed section of the Tellez Wash limestone member was measured on the hillside north of Tellez Wash where the exposures are excellent (Pl. 1). This member crops out in the same localities as the White sandstone member, i.e., below Ravens Bluff, The Biscuit and Pointed Peak.
The Tellez Wash limestone member is 156 feet thick at a locality north of Tellez Wash. East of Pointed Peak it is also 156 feet thick, and southwest of Ravens Bluff it is 131 feet thick (Pl. 3 and Appendix A: Section A, intervals 14 to 18; Section J, intervals 4 to 12; Section H, intervals 2 to 4).

Upper and lower limits

The base of the Tellez Wash limestone member is conformable on, and gradational from, the White sandstone member. An arbitrary boundary was chosen where the White sandstone member begins to grade into purple limestone. The base of the lowermost limestone bed marks this boundary as explained in describing the upper limit of the White sandstone member.

The upper limit of this member also has been arbitrarily chosen. The Tellez Wash member grades upward into the Pink sandstone member through an alternating series of dark gray limestones and pink to red sandstones. The top of the magnesian limestone underlying the lowest pink sandstone bed of the transition zone is designated as the top of the Tellez Wash member (Section A, intervals 18 and 19, Appendix A and Pl. 3).
Topographic expression

The Tellez Wash member is topographically prominent, forming ledges and small cliffs, especially where the dip is low for it lies between two weak arenaceous members, the White sandstone and the Pink sandstone. Where beds dip steeply, this member forms a ridge or hogback. Exposures are generally very good. In places, however, a miniature ridge-and-valley profile develops and some of the weaker beds are covered.

Fauna

The Tellez Wash limestone member has a fauna that is meager both in quantity and variety. It contains, however, recognizable and identifiable fossils of Permian aspect. Near the middle of the member echinoid spines are abundant, and recrystallized calcite blebs with outlines characteristic of large productids of the _bassi-ivesi_ group are present. Toward the top fossils are more common, with several groups represented. These are discussed in the section entitled "Paleontology".
The Pink sandstone member is the third or middle unit of the Snyder Hill formation in the Mustang Mountains. It is the upper of three units, two sandstones separated by limestone, that lie below the massive cliff-forming limestones.

The Pink sandstone member differs little lithologically from the White sandstone member. The color of the sandstone ranges from white to moderate brownish red, mostly pink. Weathered surfaces are brown and red, in most places darker than those of the White sandstone member. Limestones near the base are medium to dark gray.

Grain size in strata of this member is dominantly fine, but a few beds are medium-grained. The bedding is thin to moderately thick, and cross-lamination is more prevalent than flat bedding.

Concretions, apparently identical in appearance and composition to those in the White sandstone member, are present in the Pink sandstone member and they occur in approximately the same quantities.

The Pink sandstone member is a slope-forming unit. No fossils were found in the sandstone beds. In limestones near the base, calcite blebs like those in the underlying
Tellez Wash member, are believed to have developed in fossil molds.

Outcrops and thicknesses

A representative section of the Pink sandstone member of the Snyder Hill formation was measured north of Tellez Wash where it overlies the Tellez Wash limestone member. The Pink sandstone member also crops out east and west of The Biscuit, in the saddle between The Biscuit and Quail Peak, below Ravens Bluff and east of Pointed Peak (Pl. 1).

The thickness of the Pink sandstone member varies widely. The maximum measured thickness of this member, 152 feet, is in the Tellez Wash section (Section A, intervals 19 to 25). Half a mile east of this locality the thickness is less than 100 feet, and east of Pointed Peak (Section J, intervals 13 and 14) it is only 73 feet. The variation is due to removal of the upper part by low-angle bedding plane faults related to the major overthrust. This is discussed under "Structure."

Upper and lower limits

The boundary between the Pink sandstone and the underlying Tellez Wash limestone member is described in the paragraph discussing the upper limit of the Tellez Wash member. In the Tellez Wash locality there are 43 feet of
alternating sandstones and limestones above the contact (Section A, intervals 20 to 24). Above this boundary in the section below Pointed Peak, there are 21 feet of limestone without intercalated sandstone beds (Section J, interval 13). As the correlation of the underlying Tellez Wash limestone member in the two localities is excellent, it is believed that the sandstone beds in the Tellez Wash locality are lenses which did not extend as far south as Pointed Peak.

Overlying the Pink sandstone member is the Cave Cliff limestone member. In all areas in the Mustang Mountains where the contact between these members was examined, a faulted zone consisting of angular limestone fragments and considerable gouge in the upper part of the sandstone was found to occur. Both the sandstone and the overlying limestone are stained red by iron oxide.

CAVE CLIFF LIMESTONE MEMBER

Lithology

The Cave Cliff limestone is the fourth or next to highest unit of the Snyder Hill formation represented in the Mustang Mountains. It is more than 500 feet thick and is the most prominent stratigraphic unit in the area (Pl. 1).
Limestones of this member are remarkably uniform. They are light to dark gray with medium shades most prevalent. The colors of weathered surfaces are various shades of gray, mostly lighter than those of fresh surfaces. The texture of the weathered surfaces is smooth to rough, usually pitted. A few zones show the raspy surface texture described under the lithology of the Tellez Wash member.

The grain size in limestones of the Cave Cliff member is fine to very fine, in some zones appearing aphanitic. Certain of the lighter-colored limestones have larger grains, distributed in narrow zones and patches.

The chert content of the Cave Cliff member is variable. There are units 100 feet or more in thickness in which the chert occurs only as scattered nodules, probably constituting less than 1 per cent of the rock. There are other equally thick units in which 20 to 30 per cent of the rock is chert, with zones up to 10 feet thick containing 75 per cent or more chert.

Outcrops and thicknesses

Strata having a maximum measured thickness of 563 feet are assigned to the Cave Cliff limestone member. North of Tellez Wash a nearly complete section was measured up Cave Cliff to the top of Cave Cliff Ridge. This section includes all but the topmost 33 feet of beds assigned to the
member. The topmost 33 feet are present in the Quail Peak Section underlying the Quail Peak member (Section B, top 33 feet of interval 8).

Other sections which contain strata that are assigned to the Cave Cliff member were measured northwesterly from Raven Canyon (Section C, intervals 1 to 6 and Section D, intervals 1 to 4); from upper Javelina Canyon to the small peak below the summit of Pointed Peak (Section F, intervals 1 to 7); and on Rainbow Ridge east of Grantham Mountain (Section G, intervals 1 to 6). In none of the sections is the complete vertical extent of the Cave Cliff member shown. In some sections (A, C, D and F) the top is eroded, and in all of them an unknown amount of the basal portion is hidden by alluvium or cut out by faulting.

Upper and lower limits

The Cave Cliff limestone member rests on the Pink sandstone member, as previously described in the paragraph dealing with that member. The attitude of the strata of the two members at their contact is the same, but in all areas where this contact is exposed, a low angle thrust fault occurs. The evidence cited (gouge and breccia zone, iron oxide stain and variation in thickness) was seen at The Biscuit, at the south foot of Ravens Bluff and at the east base of the cliff east of Pointed Peak.
The upper limit of the Cave Cliff limestone member was arbitrarily chosen where thick-bedded to massive gray limestones grade into more thin-bedded, variegated limestones of the Quail Peak member. The boundary was chosen at the base of the lowermost black limestone of the variegated sequence. The black limestones contain numerous brachiopod shell fragments in small pockets scattered along the strike of the beds (Section B, intervals 8 and 9). Below this boundary, gray chert in large irregular masses is abundant. Above the boundary chert is sparse or absent for nearly 200 feet. A faunal change occurs above the contact. Large euomphalids, which are scarce in the Cave Cliff member, are found in abundance in the Quail Peak member. This change is discussed under "Paleontology."

Topographic expression

The Cave Cliff limestone member is very resistant to erosion. It forms the high, steep cliffs which are the dominant topographic feature of the Mustang Mountains (Pl. 17, figs. 1 and 2).

Where the Cave Cliff member has a nearly flat dip (up to 10 degrees), the basal 200 to 400 feet may form nearly vertical cliffs of this height. Where these outcrops are surrounded only by the weaker underlying beds, the cliffs may nearly encircle them, as shown at Ravens Peak and The
Biscuit (Pl. 17, fig. 2).

A cuesta type of topography develops where the beds of the Cave Cliff limestone member have a moderate dip (10 to 30 degrees). Cave Cliff Ridge is such a cuesta, with a steep cliff on the south (up-dip) side and a step-like dip slope to the north.

Steeply dipping beds (greater than 30 degrees) give rise to hogbacks. These are well shown by the spurs in the central part of the range and by Rainbow Ridge east of Grantham Mountain (Pl. 18, fig. 1).

Fauna

The fauna of the Cave Cliff limestone member is rich and diversified. In spite of this abundance and varied character, however, the two most important groups for regional correlation, ammonoids and fusulinids, are lacking or exceedingly scarce. Corals, echinoid spines, brachiopods (especially productids and Composita), bryozoa and crinoid stems are common to abundant from the top to the bottom of the member. Sponges, bellerophontid and euomphalid gastropods, pelecypods and high-spired gastropods are not rare, but are confined to narrow zones, as are Squamularia, Neospirifer and rhynchonelloid brachiopods. Two ammonoid specimens were found which were identified by Stoyanow (1949, p. 1946) as Popanoceras bowmani and
Paragastrioceras serratum. A detailed discussion of the fauna is reserved for the section, "Paleontology."

QUAIL PEAK LIMESTONE MEMBER

Lithology

The Quail Peak limestone is the uppermost unit of the Snyder Hill formation represented in the Mustang Mountains, where it has a maximum measured thickness of nearly 400 feet. It is characterized by well-defined bedding. The beds vary from a few feet to about 10 feet in thickness, in contrast to the thicker, more massive beds of the underly­ing cliff-forming Cave Cliff member. Moreover, these beds show more lithologic variation than do those of the Cave Cliff member. Colors are varied, both on fresh and weather­ed surfaces. A few sandstone beds are present, and many of the limestone beds are arenaceous or argillaceous. Chert is less abundant in the Quail Peak member as a whole than in the Cave Cliff member, and is generally confined to nar­rower zones. Many beds, especially those near the top, have a considerable magnesium content.

The basal 65 feet of the Quail Peak member consists of light gray to medium dark gray, fine-grained limestone beds alternating with thin beds of very dark gray to grayish black, fetid limestone. The very dark limestones contain
abundant calcified brachiopod shell fragments and echinoid spines in small pockets. Large euomphalids are present in abundance in the lower part of the Quail Peak member. Chert is rare.

From 65 to 170 feet above the base of the Quail Peak member are units of gray, brown and red limestone separated by units of thin-bedded white and red sandstone. Near the middle of this division is a very fossiliferous zone with abundant high-spired gastropods and small pelecypods. The chert content is very low.

The next higher 80 feet, from 170 to 250 feet above the base of this member, consists of gray and red limestones. The chert content of this division averages about 15 per cent. Fossils are abundant with brachiopods dominant and euomphalids rare.

The topmost 145 feet of the Quail Peak member is composed of light gray and grayish brown, magnesian limestone. Grain size is generally coarser than in the underlying beds. Fossils are very scarce in this unit but calcite blebs which simulate various shell shapes are common. Chert is abundant in the lower part of this 145-foot division but decreases in amount toward the top.

Outcrops and thicknesses

The Quail Peak limestone member is well exposed on the
south slopes of Quail Peak, from which it was named, and a representative section was measured there. Outcrops assigned to this member are also found near the eastern base of Rainbow Ridge and along the lower slopes on the east side of the range (Pl. 1).

The Quail Peak member is 389 feet thick in the section below Quail Peak (Section B, intervals 9 to 36), and 245 feet thick on Rainbow Ridge (Section G, intervals 7 to 20). In other exposures the thickness is less, as the upper part is either concealed by alluvium or has been removed by erosion.

Lower and upper limits

The Quail Peak thin-bedded limestone member rests conformably on the Cave Cliff massive limestone member. The boundary was arbitrarily chosen at the base of the lowermost, thin, black limestone containing pockets of shell fragments. Above this level, chert diminishes markedly, a faunal change occurs, and bedding is relatively thin and distinct.

The upper limit of the Quail Peak member in the Quail Peak section is an erosion surface overlain by Cretaceous (?) sediments. This section (Section B) includes the youngest Permian rocks exposed in the Mustang Mountains. In all other areas examined pre-Cretaceous erosion has
removed a greater amount of the Quail Peak member, or else the beds of the upper part are buried under alluvium.

Topographic expression

The topography developed on the Quail Peak limestone member is characteristically a series of steps or ledges. The relatively weak sandstone and silty limestone beds are easily eroded and form slopes between more resistant limestone beds. This is especially true where the beds are flat-lying (Pl. 18, fig. 2). In the places where the beds of this member dip at angles above 30 degrees, the ledges are not developed and the strata form more or less uniform slopes.

Fauna

The Quail Peak thin-bedded limestone member contains a fauna quite similar to that of the underlying Cave Cliff member, but there are several striking differences. Large euomphalids are abundant in many zones in the lower 140 feet of the Quail Peak member. Between the two sandstone units just below the middle of the member are several zones which contain numerous genera and species of gastropods. Immediately above this gastropod zone is a narrow bed in which small *Composita* and small pelecypods are abundant. Chert is abundant from 180 to 200 feet above the base
of the member. This 20-foot zone is also very fossiliferous. *Composita* are extremely numerous and small rhynchonelloids and small productids are common. *Squamularia* and *Chonetes* are abundant.

From 200 to 250 feet above the base of the member are numerous fossiliferous zones, including a zone of abundant bryozoa and one of abundant *Meekella*. Near the top of this 50-foot portion is a zone which contains *Hustedia* and small *Chonetes* in abundance.

In addition to these assemblages, which are not common to the Cave Cliff member, many forms which appear in the Cave Cliff continue into the overlying Quail Peak member. Included in this group are large productids, echinoid spines, bryozoa and crinoid stems. Horn corals, which are found throughout the Cave Cliff member are notably scarce in the Quail Peak.

Many other and rarer forms were found in both the Cave Cliff and Quail Peak members. These forms are of little use in field work because of their scarcity. They are noted, however, in the descriptions of the measured sections (Appendix A). A more complete and detailed discussion of the fauna will be found under "Paleontology."
PALEONTOLOGY

General

The Permian faunas of the Mustang Mountains include forms of nearly all of the invertebrate phyla. Two of the most important groups, however, fusilinids and ammonoids, are rare or absent. Brachiopods are most numerous, both in quantity and number of species. The number of species of gastropods approaches that of brachiopods but except for abundant euomphalids, the number of individuals is only a small fraction of the number of brachiopods. Pelecypods are a minor element in the Snyder Hill faunas. Bryozoa and horn corals occur in abundance. Echinoderms are represented principally by Archaeocidaris spines, rarely plates, and by crinoid stems. Sponges are common in some of the more cherty zones.

No detailed systematic paleontological descriptions of the Mustang Mountains faunas will be attempted in this thesis. In lieu of formal descriptions, notes on the various groups are given below. The genera and species names used are those of the forms they most closely resemble as illustrated in the papers of McKee (1938), King (1930), Girty (1908), Lee and Girty (1909), Knight (1941), Shimer and Shrock (1944) and King, Dunbar, Cloud and Miller (1944).

The faunas present in some of the more fossiliferous
zones of the Permian Snyder Hill formation in the Mustang Mountains are illustrated (Pls. 5 to 16). In the explanations of the plates, the specimen numbers are in account number 1385, series 2/G, of the Museum of Northern Arizona, where the specimens will be deposited eventually. The zone number that appears after the specimen number refers to the location in a measured section.

Appendix B consists of a series of tables listing the faunas in various zones of the measured sections. These listings are roughly quantitative and it is expected that they will serve as a basis for more accurate regional correlation than is now possible.

Sponges

Sponges are abundant in several zones in the Cave Cliff member. They were noted in a 6-foot zone about 70 feet above the base of the member and in two narrower zones 236 feet and 250 feet above the base (Section A, intervals 29 and 31). Sponges also occur at approximately the same levels in several other sections (Section C, intervals 1 and 2; Section D, interval 2; Section F, interval 3).

The sponges are found as siliceous networks in the centers of chert nodules. They are commonly 2 inches in diameter but some reach 5 inches. McKee (1938, p. 155) mentions sponges of this undetermined type in the Toroweap
and Kaibab formations and describes their environment and relationship to chert nodules.

Sponges are of little value in regional correlation but locally are of considerable help. In the Mustang Mountains, the three zones containing abundant sponges serve as minor marker beds.

**Corals**

(Pls. 5-13, 15)

Horn corals are common in the Cave Cliff member but in other members are rare or absent. They are found throughout the Cave Cliff member from near the base to the top, but are most abundant in the middle two-thirds.

The presence of horn corals was recorded by Feth (1948, Fig. 3) in the Canelo Hills, at Snyder Hill and in the Empire Mountains. Only one genus (*Lophophyllum*) was identified. It is improbable that the genus *Lophophyllum* occurs in the Snyder Hill formation (Stoyanow, personal communication, April, 1951) and similar forms that have been found in the Mustang Mountains are questionably assigned to the genus *Malonophyllum*. Probably several species of *Malonophyllum* are present. A few specimens that were found have been assigned tentatively to other genera.
Crinoids
(Pl. 5, 8)

Crinoids were very abundant in the Permian seas during the time that the Cave Cliff and Quail Peak members were deposited and to a lesser extent during the deposition of the Tellez Wash member. As only stem joints have been found, no attempt has been made to classify the crinoids. Diameters of the stems vary from 2 to 25 millimeters and small star-shaped joints were found in several zones.

Crinoid stems are of little use in correlation, even locally. It is quite possible, however, that further study and more extensive collecting may show that certain forms are confined to definite zones. This is suggested by the distribution of the small star-shaped stem joints.

Echinoids
(Pl. 5)

Echinoid spines of several different types are found throughout the limestones of the Mustang Mountains. Inter-ambulacral plates are rarely preserved. All types are commonly referred to *Archaeocidaris*. Like the preceding groups, they are of little use in correlation. Diversity of forms, however, suggests that careful zonal and regional collecting and adequate description might prove them to be of considerable stratigraphic value.
Brachiopods comprise the most abundant and diversified group of fossils in the Mustang Mountains. Nearly all of the families and many of the genera that occur in other well-known Permian sequences (West Texas and New Mexico, Kaibab, Phosphoria and Coahuila) of the western United States and northern Mexico are present in the Mustang Mountains.

Composita and large productids of the *Dictyoclostus* group, especially *D. bassi* and *D. occidentalis*, are common to abundant throughout the limestone members of the Snyder Hill formation. Less abundant, but occurring in great numbers in narrow zones, are small rhynchoelloids; *Pugnoides*, *Camarophoria*, *Rhynchopora* and *Leiorhynchus*. *Squamularia* occurs abundantly with *Avonia* in a narrow zone in the Quail Peak member. *Hustedia* is numerous only in the topmost fossiliferous beds of the Quail Peak member, with abundant rhynchoelloids. *Neospirifer pseudocameratus* is found as single individuals at many horizons but is abundant only in a narrow zone above the middle of the Cave Cliff member. *Meekella* is present at many localities; seldom as more than a few specimens except in a zone high in the Quail Peak member where very large forms are common. *Chonetes* is found throughout the limestones of the Snyder Hill formation, usually scarce, but in some places, notably the red chert.
zone, is common to abundant.

Compared to those above, other genera that have been found in the Mustang Mountains are represented by relatively few specimens. Many of these less common forms are illustrated (Pls. 5 to 16) but are not mentioned either in the descriptions of the sections or in the faunal tables. These genera include small productids, Spiriferina, Dielasma, Rhipidomella and Enteletes.

Prorichthofenia and Leptodus, two genera which are characteristic of the Permian strata of West Texas, were not found in the Mustang Mountains.

Bryozoa
(Pls. 5-8)

Bryozoa are abundantly represented in many zones of the Permian limestones in the Mustang Mountains. In some places they are so abundant as to suggest bryozoan reefs or biostromes. Several genera are recognized, including Poly­pora, Fenestella, Septopora, Rhombopora and probably Stenopora. Very little has been published on Permian bryozoa and specific identification is difficult. McKee (1938, Pl. 41) has illustrated several genera of bryozoa from the Kai­bab formation, most of which are similar to forms occurring in the Mustang Mountains.

The abundance of bryozoa, the numerous forms present and their widespread distribution should make them valuable
guide fossils in the future. But extensive regional collecting, and thorough study and description will be necessary before the bryozoa become stratigraphically important fossils in southern Arizona.

Cephalopods (Fls. 15, 16)

Cephalopods are very scarce in the Permian rocks of southern Arizona. Nautiloids have been found in several localities (Snyder Hill, Empire Mountains, Canelo Hills), and a few were collected in the Mustang Mountains. Ammonoids were unreported, however, until a specimen was found in the upper part of the Cave Cliff member which Stoyanow (1949, p. 1946) identified as *Popanoceras bowmani*. Later search in the same zone revealed another ammonoid, identified by Stoyanow (1949, p. 1946) as *Paragastrioceras serratum*. Both species have been found in the Word formation of the Delaware Mountain group (Miller and Furnish, 1940, p. 92, 135). Neither species is represented by more than a very few specimens in the Texas collections and neither is classed as an important guide fossil. However, their presence in the Permian strata of southern Arizona furnishes additional evidence for the more accurate correlation of the Permian of southern Arizona with the American standard Permian section of West Texas.
Pelecypods
(Pls. 7, 10-12, 14, 16)

Pelecypods constitute a rather minor group in the Permian fauna of the Mustang Mountains. Genera represented include *Nucula*, *Astartella*, *Pleuronchorus*, *Allorisma* and several forms of *Pectinacea*. Some of these genera are represented by a single, or at most a few, specimens. Other genera are not so scarce, but none of them are present in quantities that compare with the more common types of brachiopods.

The Permian mollusca of the Kaibab formation in Walnut Canyon have been described by Chronic (1951, in press). Many of the forms from the southern part of the state are identical or closely related to those that she has studied. Work on pelecypods and gastropods should be greatly facilitated by reference to her paper.

Scaphopods
(Pls. 9, 11)

Scaphopods are present but rare in the Mustang Mountains. They have been assigned to two genera and species, *Plagioglypta canna* and *Dentalium mexicanum*. Scaphopods are considered stratigraphically unimportant elements in the Permian faunas.
Gastropods comprise an important part of the Permian faunas of the Mustang Mountains. For purposes of description in this paper the gastropods have been divided into three groups; bellerophontids, euomphalids and high-spired or turritellid gastropods. The low, rounded forms with a visible spire have been included in the high-spired group. This group has been further subdivided into large — greater than one centimeter in length — and small forms. These designations have been used in the appendices and in the text. Euomphalids and bellerophontids are more abundant than high-spired forms. Several genera and species of each group are present. In general, bellerophontids are common in the lower part of the section, but rare above the top of the Cave Cliff member. Euomphalids, on the other hand, are abundant in the Quail Peak member, but in most sections are rather scarce in the underlying beds.

Gastropods of the high-spired group are mostly restricted to narrow zones. Several of these zones are present in the upper part of the Cave Cliff and the lower part of the Quail Peak members. One zone near the top of the Cave Cliff member (A-35, 24-31 feet and its correlatives) contains gastropods in such quantities that it is designated a gastropod zone.
CRETACEOUS (?) STRATA

Age relationships

Numerous exposures of red and brown siltstone, sandstone and conglomerate, the age of which is unknown, occur in the Mustang Mountains. These rocks are designated Cretaceous (?) in this thesis. No fossils have been found in them and evidence of a conformable relationship to rocks of known age, either above or below, has not been located.

The bases for the tentative assignment of these rocks to the Cretaceous are lithology and stratigraphic position. McKee (1951, in press) has reviewed and summarized the information that is available on the character, distribution and thicknesses of Cretaceous deposits of southern Arizona. He notes that continental strata of great thickness in the Huachuca, Empire and Santa Rita Mountains have been assigned to the Lower Cretaceous series, although in all of these places fossil evidence is lacking. In the Huachucha and Empire Mountains Permian strata unconformably underlie the rocks of supposed Lower Cretaceous age.

The lithology and stratigraphic position of Cretaceous (?) rocks in the Mustang Mountains are similar to those in the Huachuca, Empire and Santa Rita Mountains. This suggests that the Mustang Mountains strata also are of lower Cretaceous age. Rocks of Upper Cretaceous age,
including continental types, are known, however, in southern Arizona. They occur in the southeastern part of the Santa Rita Mountains (Stoyanow, 1949, p. 58-60), and in other parts of the region (McKee, 1951, in press). It seems best therefore, to designate the conglomerate, sandstone and siltstone of the Mustang Mountains as Cretaceous (?) until more definite evidence of their exact age is available.

Areal distribution, thickness and lithology

Unconformably overlying the Permian Snyder Hill limestone toward the top of Quail Peak is a thin unit of red and brown conglomerate and coarse-grained sandstone considered Cretaceous (?) in age. The contact between the Permian and Cretaceous (?) strata is poorly exposed on Quail Peak. Cretaceous (?) strata which lie between the Permian limestone and the lava that caps the peak are weakly cemented and easily eroded. They are covered with a mantle of lava fragments washed down from above. The maximum thickness of a single exposure in which the attitude of the beds could be determined with certainty is 16 feet.

The Cretaceous (?) red and brown rocks on Quail Peak lie on the west side of the mountain toward the south. At this same level but approximately 1000 feet to the east, a section of brown pebble conglomerate 12 feet thick is
exposed about 50 feet above the highest outcrop of limestone. This limestone is stratigraphically 110 feet below the top of the limestone at the contact to the west. This indicates that at least 60 feet of limestone beds are missing at the eastern locality and apparently were eroded before the conglomerate was laid down. Thus, pre-Cretaceous (?) erosion developed a surface of considerable relief in this area.

A conglomerate containing sharply angular quartzite fragments in a quartzitic matrix unconformably overlies the Snyder Hill limestone near the top of Pointed Peak (Pl. 1). This conglomerate forms a thin sheet with a possible maximum thickness of 35 feet, but in most places it is closer to 10 feet. On the west slope of the hill the conglomerate is exposed but it is covered by lava to the east. The contact between it and the underlying Snyder Hill formation may be traced, with only minor breaks, for several hundred feet, clearly showing its unconformable nature. The top contact of the conglomerate could not be located as it is concealed by float from the overlying Tertiary (?) lava.

No other outcrops assigned to Cretaceous (?) age in the Mustang Mountains show the character of the basal contact. Conglomerate beds of similar lithology are present but they are either at a considerable distance from outcrops of Permian rocks or they underlie Permian limestone.
In the northernmost wash west of Lava Ridge (Pl. 1; Fig. 3, A) are outcrops of red cherty sandstone, red siltstone, purple rhyolite porphyry, red conglomerate and grayish orange sandstone. Strata at the western end of these outcrops form a small sharp anticline, the west limb of which strikes N 30° W and dips 35° SW. The east limb strikes N 20° W, dips 30° NE. Thirty feet above the bottom

Fig. 3. Sketch map of Rainbow Wash-Lava Ridge area showing locations of outcrops of Cretaceous (?) rocks.
of the wash the fold is truncated by a thrust fault, with beds of the Quail Peak member resting on the Cretaceous (?) rocks.

To the east above the lowest beds exposed at the axis of the anticline are about 400 feet of siltstone, sandstone, conglomerate and purple rhyolite porphyry underlying the yellowish gray rhyolite that caps the ridge. The rocks are poorly exposed, with several gaps in the sequence, and the contact of the sediments with the overlying rhyolite is hidden by alluvium.

A sequence of strata (Appendix A, Section K) similar to that at locality A (Fig. 3) occurs in the wash west of the south end of Lava Ridge (Fig. 3, B). Red and brown sandstones and siltstones, 230 feet thick, are exposed in the banks of the wash below an overthrust block of Snyder Hill limestone. Above the red beds is 150 feet of purple rhyolite porphyry forming a sill; above this is 85 feet of red sandstone, the eroded surface of which underlies the Tertiary (?) rhyolite lava. A pale red sandstone unit below the rhyolite porphyry can be followed along the strike another half mile to the south (Fig. 3, C).

The relation of the rhyolite porphyry to the surrounding rocks is not clear. In this locality (Fig. 3, B) the rhyolite porphyry-sandstone contact is parallel to the bedding of the sandstone. Where the porphyry is exposed a quarter of a mile to the north (Fig. 3, A), it appears to
be a sill with both upper and lower contacts parallel to the bedding of the sandstone. It is, however, about 200 feet stratigraphically higher at B than at A. The relations are discussed more fully in the paragraph describing the purple rhyolite porphyry.

In another gully northwest of Lava Ridge (Fig. 3, D), 165 feet of red and reddish brown siltstone, sandstone and conglomerate and of purple rhyolite porphyry are poorly exposed. These beds strike N 60° W and dip 40° to 55° northeast.

A series similar to that at D crops out in a wash 500 feet to the north at E (Fig. 3). Another folded sequence is poorly exposed in the next wash to the north, at locality F (Fig. 3). Here 18 feet of grayish orange pink sandstone dipping 45° northeast crops out, with both top and base hidden by alluvium. One hundred and fifteen feet to the west is a section, 25 feet thick, of very contorted, yellowish gray sandstone and pale red conglomerate and 106 feet of pale red and grayish orange pink sandstone striking N 30° W and dipping 45° southwest.

Other rocks that are equivalent to parts of the various Cretaceous (?) sequences are exposed in small patches along the northeast flank of the southerly part of the range (Pl. 1). They are present in many of the saddles that divide limestone blocks on the east from the main mass of lava to the west.
Just east of the divide in the valley south of Cave Cliff Ridge (Pl. 1) is another small outcrop of purple and red sandstone and siltstone that probably belongs to the Cretaceous (?) series. Nowhere north of this place, however, do rocks of this type occur.

Cretaceous (?) rocks on the western side of the Mustang Mountains are exposed in 3 localities; 1) toward the top of Javelina Canyon, 2) on the western slope of Grantham Mountain, and 3) in the easterly saddle of an isolated ridge of limestone and rhyolite lying south of Ravens Bluff (Pl. 1).

The section in Javelina Canyon is partially concealed. The base of this section lies toward the head of the canyon. It is very disturbed because it is close to the thrust sole of the Permian limestone. This unit consists of about 280 feet of red, brown and orange sandstone, conglomerate and siltstone which strike roughly northwest and dip 25 to 45 degrees southwest. These strata resemble the Cretaceous (?) rocks on the east side of the range (Section K) and show the same general stratigraphic relations. They are composed of red and purple sandstone, siltstone and conglomerate and are about 180 feet thick. They are overlain by approximately 100 feet of orange, partly cross-laminated, sandstone (Section L). The top of this section is covered by alluvium; brown rhyolite crops out a hundred feet west of the highest exposure of sandstone.
Red and purple rocks of Cretaceous (?) age on the west slope of Grantham Mountain and on the ridge south of Ravens Bluff were not measured. They appear to be in part equivalent to the Javelina Canyon section (Section L).

Rocks designated Cretaceous (?) also crop out in shallow washes on the flats west of Grantham Mountain. Two sections were measured, one in Tellez Wash and the other in the next wash to the south. These exposures are of red and brown siltstone, sandstone and conglomerate which strike northwest and dip steeply southwest. In both washes the base of the section is in fault contact with gray rhyolite, and the top is covered by alluvium (Sections M and N). These red strata are similar in appearance to the red Cretaceous (?) rocks in Rainbow Wash and Javelina Canyon, but contain more feldspar and the conglomerates have gravels of volcanic origin. The volcanic gravels are mostly of andesite but contain pebbles of gray rhyolite, resembling those on Grantham Mountain. It is possible that these red beds are younger than the Tertiary (?) rhyolite, hence they might be of Tertiary age also. Additional study will be necessary to determine their age with certainty.

TERTIARY (?) INTRUSIVE ROCKS

West and southwest of Lava Ridge are outcrops of purple rhyolite prophyry, the only outcrops of intrusive rocks
observed in the Mustang Mountains. The relation of this rock to the enclosing rocks is not clear. In Rainbow Wash, northwest of Lava Ridge, the porphyry crops out in several places but exposures are poor. The contact of rhyolite porphyry with the enclosing rocks parallels the bedding of the sedimentary series. Contacts are not sharp, as the porphyry is intruded into red and purple sandstone and siltstone and seems to have caused little metamorphism other than a narrow zone of baking. In the wash southwest of Lava Ridge the lower contact of rhyolite porphyry and red sandstone is sharper than the lower contact in the washes to the north, but here also little metamorphic effect is shown. In this locality, the upper part of the rhyolite porphyry is not exposed, being hidden under gray rhyolite flows and alluvium.

The purple rhyolite porphyry intrusive body appears to be a sill in that it lies parallel to the structure of the enclosing sedimentary rocks. In the wash southwest of Lava Ridge, however, it is about 200 feet higher stratigraphically than it is in the Rainbow Wash outcrops, therefore it must also transect the bedding locally.

The purple rhyolite porphyry cuts rocks that are designated Cretaceous (?) but is not known to cut the overlying Tertiary (?) lavas. Because the age of neither of these series is established, the intrusive rhyolite is designated Tertiary (?); it is younger than the Cretaceous (?).
sedimentary series on the east side of the Mustang Moun-
tains.

The dark grayish purple rhyolite porphyry is composed
of about 40 percent phenocrysts of orthoclase, quartz and
biotite in an aphanitic groundmass. The phenocrysts of
orthoclase are up to 4 millimeters in size, but average
about 2 millimeters. They are pink, euhedral and largely
altered to kaolin. The quartz and biotite phenocrysts are
smaller, averaging about 1 millimeter. The quartz is in
dull anhedral grains and the biotite is largely altered to
chlorite.

TERTIARY (?) EXTRUSIVE ROCKS

Age relationships

The extrusive rocks of the Mustang Mountains range
from felsite to rhyolite porphyry but are principally rhyo-
lite. They cannot be accurately dated owing to lack of
evidence. These lavas overlie unconformably the Creta-
ceous (?) and Permian rocks and are here designated as Ter-
tiary (?). This method of designation follows the practice
of many geologists who have studied the volcanic rocks of
Arizona. Schrader (1915, p. 71), Darton (1925, p. 165,
277-295), Brown (1939, p. 729) and Feth (1948, p. 83) all
have designated similar volcanic rocks in the same strati-
graphic position as "Tertiary (??)," "Tertiary," or
"Miocene (?) ."

Areal distribution, lithology and thickness

The Tertiary (?) lavas in the Mustang Mountains crop out principally in the central and southern portions of the range (Pl. 1). Grantham Mountain, the highest peak, is made up of lava. Lava Ridge, on the southeast flank; the ridge south of Ravens Bluff; Javelina Ridge; and the ridge south of Javelina Ridge are all composed principally of lava. Along the west and northwest flanks of Grantham Mountain the lava extends well out into the valley. Quail Peak and the ridge northwest of Pointed Peak are both capped by lava and there is a small patch of rhyolite on the ridge north of The Biscuit.

Lava of the Mustang Mountains varies from light gray to dark reddish brown. In the hand specimen it is classed as rhyolite, with phenocrysts of orthoclase up to 2 millimeters, and minute identifiable grains of quartz, in an aphanitic groundmass. The percentage of phenocrysts in some of the lighter colored specimens is less than 5 percent, making it a felsite. Some of the darker varieties grade into rhyolite porphyry with the amount of phenocrysts about 25 percent. The darker varieties commonly show well-defined flow banding. Small orthoclase phenocrysts show a rough alignment. Vesicles up to 2 or 3 centimeters long,
partly or wholly filled with quartz, are elongated and aligned in the direction of flow.

Only one section of rhyolite was measured, that on Lava Ridge, where it is approximately 260 feet thick. The flow lines strike northwest and dip about 45 degrees northeast in this locality. A pacing traverse up the northwest side of Grantham Mountain showed slightly more than 500 feet of rhyolite, which is probably the maximum in the region. This area is considerably faulted, however, and in places exposures are poor, so the figure may be considerably in error, possibly as much as 100 feet, either more or less.
CHAPTER III - STRUCTURE

GENERAL

The outstanding structure of the Mustang Mountains is an overthrust sheet which has been folded into a northwest-trending anticline. Its anticlinal nature is illustrated by comparison of attitudes on the geologic map and sections (Pls. 1 and 2). Overthrusting is clearly shown in several places where Permian limestone blocks rest "without roots" on the underlying rocks of Cretaceous (?) or younger Permian age.

Numerous high angle faults in the Mustang Mountain area fall into two general groups. In one the strike is dominantly east-west, while in the other it trends northwest-southeast. East-west faults appear to have greater displacement and greater influence on the topography. In the few places where their relations are not obscured, they appear to be later than faults of northwest-southeast trend.

Each of the structural elements of the Mustang Mountains exhibits complex and obscure features. Many details of structure could not be worked out because of insufficient time. In discussion of individual structural features many of the interpretations are necessarily based on meager evidence.
THRUST FAULTS

That the Permian limestones and detrital rocks have been thrust over other rocks appears indisputable, but several related points require elaboration. The age of the rocks below the thrust and of the rocks at the base of the overthrust sheet has been determined. Some evidence is available to date the time of thrust faulting and the direction in which the thrust blocks moved.

Related to the thrust problem are gypsum and marl beds present in the lower part of the Permian sequence at various localities in southern Arizona. Several hundred feet of such deposits with intercalated thin limestone units underlie the Snyder Hill formation in the Empire Mountains. Stoyanow (1942, p. 1276) has noted their occurrence below the Snyder Hill formation at Bisbee, in the San Xavier district, in the Santa Rita Mountains and in isolated hills between Tucson and Nogales.

No gypsum or marl beds were found in the Mustang Mountains or in the Canelo Hills, 20 miles to the west (Feth, 1948, p. 90). It appears likely, therefore, that such beds may have been removed by thrusting in these two areas. Beds of marl and gypsum are highly incompetent strata and may have been folded and buckled during the thrusting of the competent beds above, and may have acted as a surface over which thrust blocks moved. Further regional studies
are necessary to prove or disprove this hypothesis.

The rocks above and below the thrust zone are not the same throughout the area. Rather than a single thrust surface, there appear to be numerous fault surfaces along which movement has taken place, and an imbricate pattern has developed by the greater movement of successively higher units. Imbricate structure of this type is well developed in the Huachuca Mountains (Weber, 1950, p. 101-113), and Galbraith (1949, p. 1889) has noted it in the Empire Mountains.

Along the eastern flank of the Mustang Mountains Permian limestone blocks rest on red and brown conglomerate of Cretaceous (?) age. In some places the attitudes of the rocks above and below the thrust fault show no great discordance. Where both are dipping steeply, thrusting is clearly indicated as limestones strike into underlying detrital rocks (Fig. 4).

![Diagram](image-url)
Rainbow Ridge shows clearly this relationship of limestone blocks resting on Cretaceous (?) sandstone and conglomerate. The overthrust contact may be followed, with few interruptions, from the southeast end of the ridge along the west side and around to the northeast side (Pl. 1). The limestone strikes northwest and dips 50 degrees northeast. The underlying Cretaceous (?) rocks strike more toward the north and dip northeast in general. Dips are not uniform, however, and on the northeast side the strata dip southwest.

An overthrust relation is well shown in the wash west of Lava Ridge. The underlying Cretaceous (?) rocks are folded into a small sharp anticline which is truncated by the overthrusting of a limestone mass.

A thrust sole is poorly exposed in Tellez Wash. At the base of the measured section is contorted sandstone containing much gouge. A short distance west of the base of the section and about 50 feet lower is a small outcrop of red sandstone, siltstone and purple rhyolite porphyry that is similar to Cretaceous (?) rocks in Rainbow Wash west and northwest of Lava Ridge. Rocks of similar appearance are also present below the thrust sole of a small klippe of the Cave Cliff member south of Ravens Bluff.

In Tank Wash, rocks below the overthrust sheet are Permian limestones that appear to be identical to those near the top of the Quail Peak member on Quail Peak. In the
overlying block are limestones of the Cave Cliff member; rocks which are about 700 feet lower stratigraphically than those on which they rest.

Many places within the area mapped show faults which are essentially parallel to the bedding. These bedding plane slips are probably related to the major thrusting. They are especially noticeable where sandstone units are present in the section.

The rocks in the contact zone of the Pink sandstone member and the Cave Cliff limestone member are disturbed and brecciated and contain much gouge in all places where they were examined. There is a considerable variation in the thickness of the Pink sandstone member in nearby localities. This variation seems to be due to the cutting out of beds, particularly toward the top, by bedding-plane faults.

Dating of the overthrusting in the Mustang Mountains must remain tentative until the age of the rocks that are designated Cretaceous (?) and Tertiary (?) is established. Feth (1948, p. 99) in the Canelo Hills, 20 miles to the west, noted Permian rocks of the overthrust block resting on Tertiary (?) lavas. In the Tucson Mountains, Brown (1939, p. 748) states that the thrust overrode Cretaceous sediments and volcanic rocks and that the overthrust block was almost completely removed by erosion before the extrusion of Tertiary volcanics. Wilson (1934, p. 429) believes
that the thrusting occurred not earlier than the very close of Cretaceous time. No locality has been found in the Mus­
tang Mountains in which Permian rocks overlie Tertiary (?) rhyolite. In this area the time of thrusting is indicated as post-Cretaceous (?) and pre-Tertiary (?) rhyolite.

The direction of movement of overthrust blocks in southern Arizona has been studied intensively. Weber (1950, Fig. 3) has shown graphically the Laramide fold trends and the direction of overthrusting as deduced by many geologists who have worked in this region.

Evidence was not found that shows clearly the direc­
tion in which the thrust blocks moved in the Mustang Moun­
tains. High-angle faults which trend east-west (discussed below) may be tear faults related to the overthrusting. If these are tear faults, it would indicate a general east-
west direction of movement. The Cretaceous (?) strata be­
low the thrust sheet in Rainbow Wash contain two small anticlines, one of which is slightly overturned toward the southwest. This suggests movement from northeast to south­
west (discussed in more detail under "Folds"). Other than these two points, no additional facts that might bear on the direction of movement of thrust blocks were noted.

HIGH-ANGLE FAULTS

High-angle faults present in the Mustang Mountains do
not show the same pattern in different parts of the range. Most of those that trend east-west have considerably greater displacement than those that trend northwest-southeast.

Most of the high-angle faults in the area near The Biscuit strike east-west. Apparent stratigraphic displacements of several hundred feet are noted, with a maximum of 1200 feet on the fault in the saddle south of The Biscuit. The fault blocks in this northern end of the range appear as horsts and grabens on the geologic map (Pl. 1). It is probable, however, that the movement along these faults has been horizontal rather than vertical — the blocks are slices that have had differential movement along tear faults in the overthrust sheet.

The only fault that trends northwest-southeast in this area extends along the northeast side of, and through the saddle north of, The Biscuit. It is cut by an east-west fault and its northern extension is displaced about 500 feet to the west on the surface. The east side of this fault is down with a stratigraphic displacement of about 300 feet.

On Quail Peak no east-west faults of large displacement were noted. Two northwesterly-trending faults of small displacement were mapped on the south slope. The lower part of the triangular fault block bounded by these faults appears to be a shallow feature and possibly is due to landsliding rather than faulting. The fault on the east
slopes that passes through the saddle between Quail Peak and the hill to the east strikes nearly due north. The east side is about 300 feet stratigraphically below the west side.

Numerous faults of small displacement are present in the Cave Cliff area. Five of the larger ones are shown on the geologic map (Pl. 1) and many others were omitted. All of these faults strike northwest and have the east side down with relative stratigraphic displacements of from 2 to about 50 feet.

Three faults mapped in the Cave Cliff area are not included in the group above. The fault that strikes nearly due north through the middle of Cave Cliff Ridge may be the same fault that cuts the saddle east of Quail Peak, even though the east side is 300 feet higher on Quail Peak and about 20 feet lower stratigraphically on Cave Cliff Ridge.

The fault that trends east-west about 1000 feet south of the east peak of Cave Cliff Ridge may be of landslide nature rather than a true fault. A block of the Cave Cliff limestone member rests on the White sandstone member at least 600 feet lower in the section. The relations shown are analogous to those on the south slope of Quail Peak.

The fault that strikes northwest at the east end of Cave Cliff Ridge differs from the rest of the faults showing this trend. The east side is down relative to the west but the attitude of the beds on either side of the fault is
markedly different. In the west block the beds strike northeast and dip 42 degrees northwest and in the east block they strike northwest and dip 62 degrees northeast. Exposures are generally poor along this eastern slope of Cave Cliff Ridge and it is possible that this may be a thrust rather than a high-angle fault.

Most of the faults in the area south and east of Grantham Mountain trend east-west to northeast-southwest. They do not show as regular a pattern as do those in the blocks to the north, but they have an apparent horst-and-graben structure similar to that in The Biscuit area. Displacements on faults in this southern part are from one hundred to several hundred feet. Apparent relative movements on the faults, however, are in opposite directions on the east and west sides of the ridge. This apparent reversal of upthrown and downthrown blocks at opposite ends of a fault is not explained readily by vertical movements. Horizontal differential movement of adjacent blocks or slices along tear faults related to overthrusting, however, would account for this fault pattern. The fact that these high-angle faults were not found to extend into the underlying Cretaceous (?) rocks in the Rainbow Wash area is additional evidence supporting the hypothesis that these are tear faults.

Dating of the high-angle faulting in the Mustang Mountains was not accomplished in this study. Evidence was
obtained which indicates that faulting occurred along some of the east-west faults during the thrusting. North of The Biscuit a fault that trends northwest may be offset by an east-west fault. If this is true, it is either pre-thrusting or contemporaneous. Southwest of Ravens Bluff a small block of Snyder Hill limestone is in fault contact with Tertiary (?) rhyolite, which shows that this fault is post-lava. No other evidence on which to determine the time of faulting was noted.

FOLDS

The present Mustang Mountains are the faulted and dissected remnants of a northwest-plunging anticline. The axis runs through The Biscuit, Quail Peak, the center of Cave Cliff Ridge, Grantham Mountain, Pointed Peak and Raven Peak (Pl. 1). The axis probably extends down the valley southwest of the long ridge of limestone southeast of Raven Peak. This ridge is the east limb of the anticline and most of the equivalent strata of the west limb have been removed by erosion. The outlying hill of limestone in the extreme southwestern part of the area appears to be part of the west limb.

There are at least four explanations for the origin of the anticline. It may have been formed by: 1) being thrust over an original high; 2) by bowing during the thrusting;
3) by uplift due to igneous activity either before, during or after extrusion of Tertiary (?) rhyolite; or, 4) by more than one of the above events.

Lava overlies the Snyder Hill formation north and west of Pointed Peak, on the southeast slope of Grantham Mountain and on the ridge north of The Biscuit. It overlies Cretaceous (?) strata where the basal contact of the lava is exposed in all other parts of the range. No locality in which the Snyder Hill formation overlies Tertiary (?) rhyolite was found in the Mustang Mountains. The flow lines in the lava on Grantham Mountain are essentially flat along the crest line but are progressively steeper on the flanks. In the outlying hills of rhyolite, the flow lines dip away from the axis of the range at angles of from 35 to 50 degrees.

The facts as noted above do not eliminate any of the proposed explanations for the origin of the anticline. They also indicate the difficulty of arriving at a satisfactory dating for the time of its formation. Until further study of the region is undertaken, it seems best to consider the problem of origin and dating unsolved.

Cretaceous (?) strata below the overthrust block in Rainbow Wash have been folded. Two small, sharp anticlines with axes striking northwest were noted (at A and F, Fig. 3). The crest is not exposed in the anticline to the north but the limbs are parallel and dip to either side at equal
angles, indicating that the fold is upright. In that to
the south the axial plane is slightly inclined to the
northeast. The limbs are nearly parallel and the south­
west limb is 5 degrees steeper than the northeast.

The size and the position of these small anticlines
indicates that they are crumpled strata caused by the over­
thrusting. The southern one is slightly overturned to the
southwest. If they are drag folds, this evidence supports
the idea that the thrusting was from the northeast toward
the southwest. Exposures are poor and outcrops are in the
banks of small washes, therefore it is not deemed justifi­
able to more than tentatively suggest the direction of
movement.
APPENDIX A

DESCRIPTIONS OF MEASURED SECTIONS

Nine measured stratigraphic sections of Permian and four of Cretaceous (?) rocks in the Mustang Mountains are described on the following pages. No single section includes the complete Snyder Hill formation or more than a limited portion of the Cretaceous (?) rocks believed to be present in this area.

Sections A and B together comprise a nearly complete sequence of Permian strata. The White sandstone member of the Snyder Hill formation, however, is known to be thicker than the maximum that was measured, and an unconformity is present at the top of the Quail Peak limestone member. The bases of the sections of Cretaceous (?) rocks are either hidden or faulted and the tops are eroded or covered by aluvium.

The generalized stratigraphic column (Pl. 4) is compiled from Permian sections A and B; Cretaceous (?) section K (which includes the Tertiary (?) rhyolite porphyry sill) plus 16 feet of Cretaceous (?) rocks at the top of section B; and the thickness of Tertiary (?) rhyolite on Lava Ridge. The total thickness is about 2350 feet; 1600 feet of Snyder Hill formation, 330 feet of Cretaceous (?) rocks, 150 feet
of Tertiary (?) rhyolite porphyry sill and 260 feet of Tertiary (?) rhyolite.

Color names were chosen by comparing rock samples with the standard rock-color chart (1948 edition). Grain sizes were determined by matching the grains with standards prepared of seived material cemented on glass slides.

The sections were measured using a "Jacob's staff" on which a small chalk-line level and a protractor were mounted. Measurements were recorded to the nearest foot. Attitudes of the strata were recorded as often as they could be determined. The beds below each recorded observation were assumed to have that attitude until a change in dip or strike was noted lower in the section; in the descriptions of sections the same practice is followed.

The fossils mentioned in the descriptions include only forms that establish recognizable zones, that are present in greater than average abundance, or forms that are rare or unusual. A more comprehensive faunal record is given in tabular form in Appendix B and the faunas in some of the more fossiliferous zones are illustrated on Plates 5 to 16.
SECTION A

Measured northwest from Tellez Wash up Cave Cliff to the top of Cave Cliff Ridge.

Erosion surface: long dip slope.

Permian:

Snyder Hill formation:

Cave Cliff limestone member:

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Limestone: medium gray, fine-grained; bedding indistinct; weathers medium gray, smooth to rough; forms ledges. Chert content 15%, 60% in top 4 feet; light gray to white, ovoid and irregular nodules, 3 inches to 15 inches; weathers light to moderate brown. Gastropod zone at top. From 9-13 feet, with turritellid gastropods common, is equivalent to zone where ammonoids were found in Section G, interval 5.</td>
<td>31</td>
</tr>
<tr>
<td>34</td>
<td>Limestone: medium light gray, fine- to coarse-grained; bedding indistinct; weathers light gray, rough and pitted; forms series of ledges. Chert content 5% with a 3-foot zone near base to 25%; light gray, ovoid and irregular nodules, size 3 inches to 18 inches; weathers white or light to moderate brown. Scattered nodules of black chert at base.</td>
<td>26</td>
</tr>
<tr>
<td>33</td>
<td>Limestone: medium gray, fine-grained; bedding indistinct; weathers light gray, rough surface; forms ledges and cliffs. Chert content 25%; light gray ovoid and irregular nodules, 3 inches to 12 inches, light brown-weathering most common, but has zones of up to 60% of black, and black and white chert in 2- to 4-foot bands throughout the interval. Also has zones of paper-thin, light brown-weathering chert in veins and seams near middle. Fossils include Meekella and star-shaped crinoid stems 100 feet above base; zone of abundant Composita and horn corals 85 feet above base; Spirifer zone at 25 feet above base.</td>
<td>112</td>
</tr>
<tr>
<td>32</td>
<td>Limestone (red chert zone): light gray to grayish purple, aphanitic; 1- to 3-foot beds; weathers light gray to dark reddish brown,</td>
<td></td>
</tr>
</tbody>
</table>
31. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray, rough and pitted surface; forms (with underlying interval 30) sheer cliff of Cave Cliff. Chert content less than 5% except for 10 foot zone at base with 30%; light gray, moderate brown-weathering; ovoid and irregular, 3- to 12-inch nodules of chert with a prominent 15-inch bed of pale red, grayish orange-weathering chert 5 feet above base. Lower 10 feet very fossiliferous with rhynchonelloids, Meekella, turritellids and large horn corals at top; sponges and gastropods in more cherty zone 30 to 45 feet above base. .......................... 124

30. Limestone: medium gray with pale red patches, fine-grained; bedding obscure; weathers blotchy grayish red and medium light gray, rough and pitted surface; forms cliff. Chert content less than 5% except for 10 foot zone at base with 30%; light gray, moderate brown-weathering; ovoid and irregular, 3- to 12-inch nodules of chert to 75% with sponges. .............................. 42

(Strike, N 10° W; dip, 21° SW)

29. Limestone: light gray, fine- to coarse-grained; bedding obscure; weathers medium light gray, rough surface; forms cliff. Chert content 50%; light gray ovoid and irregular nodules average about 1 foot in diameter up to 3 feet in largest dimension; weathers moderate brown to brownish black. Near base chert to 75% with sponges. .............................. 81

28. Limestone: medium gray, fine- to coarse-grained; bedding obscure; weathers blotchy medium gray and medium dark gray; rough surface; forms ledge. Chert content 25%; light gray and moderate red, ovoid to irregular light brown-weathering nodules up to 18 inches; nearly continuous 2-foot zone of red chert 5 feet above base. .............................. 69
27. Limestone: grayish purple, fine-grained; bedding obscure; weathers brownish gray; raspy surface; forms slope. Chert content less than 5%; in thin light brown seams and stringers weathering moderate brown to brownish black. ... 11

26. Limestone: light gray, fine-grained; bedding obscure; weathers light brownish gray; raspy surface; forms ledge. Chert content 20%; white, ovoid, 6-inch, white-weathering nodules. ... 5

Total thickness Cave Cliff limestone member... 529

Pink sandstone member:

(Strike, N 10° E; dip, 22° NW)

25. Sandstone: moderate pink to dark reddish brown, in places white; bedding from a few inches to several feet thick, dominantly cross-laminated; generally firmly cemented; cement silica, calcite in a few beds; weathers pale red to dark reddish brown, small blocky and platy fragments; forms slopes and ledges; numerous grayish purple sandstone concretions toward top. Prominent 2-foot, firmly cemented, grayish orange, calcareous sandstone bed 63 feet above base. ................. 109

24. Limestone (arenaceous): pale reddish brown, single cross-laminated bed; weathers banded moderate and dark reddish brown with pitted surface. ......................... 2


22. Limestone: dark gray, fine-grained; single bed; weathers dusky brown; raspy surface; top 6 inches coarser, darker and very fetid. Calcite blebs and seams to 10%; blebs ½ to 2 inches in diameter, seams to 1 inch thick. ............... 4


20. Limestone: grayish black, fine-grained; beds 8 inches to 2 feet; weathers brownish black; surface raspy; forms ledge. Calcite blebs and seams to 20%; blebs ½ to 2 inches in diameter, seams to 2 inches thick. .......... 11
19. Sandstone: moderate red, fine- to coarse-grained; weakly cemented with calcite; thin, flat-bedded, beds ¼ inches to 1 foot, minor cross-lamination; weathers moderate reddish orange, generally smooth surface; forms slope. Basal portion disturbed with gouge and breccia, probably bedding-plane fault. ........................................ 7

Total thickness Pink sandstone member. ........... 152

Tellez Wash limestone member:

18. Limestone (magnesian): pale red purple, fine-grained; bedding obscure; weathers pale reddish brown; surface rough; forms ledge. Chert content 40%; parallel bands of ovoid to irregular light gray and grayish purple, brownish gray-weathering nodules; size from 2 to 20 inches with prominent dark yellowish orange-weathering band about 8 inches thick at top. Calcite blebs, ½ to 3 inches, common throughout interval. ........... 21

17. Limestone (magnesian): grayish red purple, fine-grained; bedding obscure; weathers pale brown with small moderate brown spots; smooth surface; forms ledge. Chert content 40%; grayish purple nodules to 18 inches in parallel bands; weathers moderate to dusky brown. Calcite blebs, ½ to 2 inches, common throughout interval. ................... 9

(Strike, N 10° E; dip, 23° NW)

16. Limestone (magnesian): medium gray, fine-grained; bedding obscure; weathers medium dark gray; surface rough and pitted; forms ledge. Chert content 45%, white and light gray to grayish purple, moderate to grayish brown-weathering nodules up to ¾ feet in diameter in roughly parallel bands. Abundant bryozoa and small star-shaped crinoid stems and turritellid gastropods common. ................... 11

15. Limestone: grayish purple, fine-grained; bedding obscure; weathers grayish blue; surface smooth to pitted; forms ledge. Chert content less than 5% in pale brown networks and thin seams that weathers moderate brown. Euomphalids and bellerophontids common, many Archaeocidaris plates. ................................. 24

(Strike, N 20° E; dip, 19° NW)

14. Limestone (magnesian): dusky purple, fine-grained to aphanitic; bedding obscure; weathers grayish
brown; surface raspy. Chert content 10%, medium gray and grayish purple mottled nodules; size up to 15 inches; weather moderate to grayish brown. Three thin bands white chert nodules near middle. Two 3-inch beds of cherty grayish red sandstone at 35 and 51 feet above base. Lowest zone of recognizable fossils, Dictyoclostus bassi and Archaeocidarls spines 70 feet above base. .......... 91

Total thickness of Tellez Wash limestone member. 156

White sandstone member:

(Strike, N 8° W; dip, 18° SW)

13. Sandstone: pinkish gray, fine- to coarse-grained; generally flat, thick-bedded, beds to 6 feet, very minor cross-laminations; firmly to weakly cemented with silica, minor calcite; weathers moderate brown; surface pitted and bumpy; forms series of slopes and ledges. Grayish purple sandstone concretions to 18 inches common. Moderate reddish brown sandstone beds, 2 to 4 feet thick at 30, 50 and 60 feet above base. Abundant large grayish purple sandstone concretions reaching 3 inches by 3 feet with greater dimension transverse to bedding. .......... 113

12. Limestone: grayish red; fine-grained; beds 6 inches to 2 feet; weathers pale brown; smooth to rough surface; forms ledge. Has grayish purple cherty sandy streaks that weather dusky purple ½ to 3 inches thick. Calcite blebs up to 2 inches in minor amounts. .......... 6

11. Sandstone: grayish orange pink, coarse-grained; bedding thin and cross-laminated; weakly cemented with calcite, friable; weathers pale yellowish brown; surface bumpy and pitted; small grayish purple sandstone concretions minor; forms ledge. .......... 13

10. Sandstone: moderate red, fine-grained; bedding thin and cross-laminated; weakly cemented with iron oxide; weathers grayish red; surface blocky; small grayish purple sandstone concretions minor; forms slope. .......... 10

(Strike; N 3° W; dip, 22° SW)

9. Sandstone (orthoquartzite): grayish orange pink, very fine-grained; bedding thin, flat; firmly
cemented with silica; weathers grayish orange; surface platy; small grayish purple sandstone concretions common; forms ledge.

8. Sandstone: pale red purple, coarse-grained, bedding thin, flat; firmly cemented with silica; weathers moderate reddish orange; surface pitted and bumpy; small grayish purple sandstone concretions abundant; forms ledge.

7. Sandstone: white to pinkish gray, fine-grained; bedding thin, cross-laminated; firmly cemented with silica; weathers moderate yellowish orange and light gray banded; surface pitted; small grayish purple sandstone concretions abundant; forms ledge.

6. Sandstone (orthoquartzite): pinkish gray to very pale orange, fine-grained; bedding thin, flat with few cross-laminated units, especially toward top; firmly to weakly cemented with silica; weathers grayish orange to pale red; surface bumpy and pitted; grayish purple sandstone concretions common, in places to 4 inches in diameter, more abundant toward top; forms series of slopes and ledges.

5. Sandstone: pale reddish brown, fine-grained; bedding thin, flat; weakly cemented with calcite; weathers pale reddish brown; surface flaky to smooth; forms slope.

4. Limestone (arenaceous): dark yellowish brown, fine-grained; bedding obscure; weathers moderate reddish brown; surface smooth to pitted; forms ledge; numerous 1/4 to 2-inch calcite blebs in top 4 feet.

3. Limestone: grayish red purple, fine-grained; bedding obscure; weathers brownish gray; surface raspy; forms ledge; small calcite blebs present; thin networks of calcite seams throughout interval.

2. Limestone: dark reddish brown, fine-grained; beds 1 to 4 feet thick; weathers dark reddish brown; surface raspy; forms ledge; numerous calcite seams forming white networks throughout interval.
1. Sandstone: grayish orange pink, fine-grained; bedding disturbed, gouge and breccia present.

Total thickness White sandstone member. . . . . 319

Total thickness Snyder Hill formation. . . . . 1156

Thrust sole
Below thrust sole are small outcrops of limestone and sandstone. About 50 feet below and several hundred feet west of interval 1 is a small exposure of red siltstone and red rhyolite.
SECTION B

Measured north up Quail Peak from the lowest exposures on the north side of Tank Wash.

Tertiary (?):
Rhyolitic volcanics

Unconformity

Cretaceous (?):
Conglomerate: gray and purple

Unconformity

Permian:
Snyder Hill formation:
Quail Peak limestone member:

(Strike, N 5° W; dip, 3° SW)

36. Limestone: grayish pink, coarse-grained; beds 2 to 6 feet; weathers pinkish gray; surface smooth; forms slope. Chert content less than 2%; light brownish gray nodules up to 2 inches by 2 feet elongated parallel to bedding; pseudo bed 6 inches thick 4 feet above base; weathers light brown to dark reddish brown and black...

35. Limestone: pinkish gray, fine-grained; single bed; weathers grayish orange; surface smooth; forms slope. Has networks of thin (½- to 2-inch) light brown and white calcite seams...

34. Limestone: pinkish gray, coarse-grained; bedding obscure; weathers pale red; has large masses (3 to 5 feet) of pale yellowish brown, pale brown-weathering limestone to 20% of volume; surface pitted and rough; forms slope. Chert content 10%; large (to 6 feet) moderate pink irregular nodules; weathers moderate reddish orange, very rough and flaky surface; discontinuous bed of moderate reddish brown, dark reddish brown-weathering chert 6 to 12 inches thick 15 feet above base. Calcite blebs (1 to 3 inches) 5% of rock...

33. Limestone: pinkish gray, coarse-grained; bedding obscure; weathers grayish orange pink; surface pitted and rough; forms slope. Chert content 40%; large (to 5 feet) pink irregular nodules; weathers grayish orange; surface rough
and flaky; top 5 feet of interval about 80% chert; zone 10 to 14 feet above base about 60% chert; grayish pink to moderate reddish brown nodules to 2 feet; weathers dusky red. White calcite blebs, ½ to 3 inches, 10% of rock. 21

32. Limestone: pale brown, coarse-grained; bedding 1 to 3 feet thick; weathers brownish gray; surface rough and pitted; forms slope. Chert content 5%; pink to dark red ovoid and irregular nodules to 12 inches; weathers dark brown. White calcite blebs, ½ to 2 inches, 10% of rock. 10

(Strike, N 2° E; dip, 8° NW)

31. Limestone: dark yellowish brown, fine-grained; bedding 2 to 4 feet thick; weathers pale yellowish brown; surface bumpy and pitted; forms slope. Chert content 20%; white to light gray nodules up to 12 inches, in bands 1 to 2 feet thick at 3 to 6 feet apart; weathers light to dark yellowish brown. Calcite blebs to 3 inches make up 20% of rock. 25

30. Limestone (magnesian): pale brown, fine-grained; bedding obscure; weathers pale yellowish brown; surface bumpy and pitted; forms slope. Chert content 5%; light gray nodules to 8 inches; weathers moderate brown. Calcite blebs to 20%, white, ½ to 2 inches. 19

29. Limestone: medium dark gray, fine-grained; bedding obscure; weathers medium light and medium gray blotches; surface very rough and pitted; forms ledge. Chert content 10%; very irregular light gray nodules from 3 to 12 inches; weathers moderate yellowish brown with dusky brown and black patches. Highest zone with identifiable fossils 2 to 6 feet above base, contains abundant small rhynchonellids. 15

28. Limestone: dusky red, fine-grained; single bed, cross-laminated; weathers banded pale and grayish red; surface smooth; forms slope. Chert content 10%; grayish red irregular nodules to 15 inches; weathers moderate brown to black. 1

27. Limestone: dusky red, fine-grained; bedding thin and cross-laminated; weathers banded pale and grayish red; surface smooth; forms slope. Chert content 10%; grayish purple pseudo beds 4 to 6 inches thick, of elongated nodules
(½x3 to 2x12 inches) at 2, 3 and 4 feet above base; weathers grayish red purple.  ............................................. 4

26. Limestone: very dark gray, fine-grained; bedding thin and cross-laminated; weathers banded medium dark and dark gray; surface smooth; forms slope. Chert content 10%; grayish purple pseudo beds 3 inches thick of elongated, pale brown-weathering nodules (½x3 to 2x12 inches) at 2½ and 3½ feet above base; moderate red pseudo beds 6 inches thick of elongated, moderate brown and dusky red-weathering nodules (½x2 to 2x20 inches) at 2 and 3 feet above base.  ............................................ 4

25. Limestone: medium gray, fine-grained with patches of grayish orange pink coarse-grained limestone; bedding obscure; weathers medium gray with pale red blotches; surface rough and raspy; forms ledge. Chert content 5%; band of ovoid, 3- to 8-inch grayish purple nodules at 33 feet above base; several 2- to 4-inch bands of ovoid, 2- to 6- inch pale red, moderate red-weathering nodules at 22 feet above base and a 1-foot band of ovoid 2- to 12-inch white to very light gray ovoid nodules that weather light to moderate brown 4 feet above base. Very large Meekella common 22 feet above base; abundant rhynchonelloids 15 feet above base; and abundant bryozoa 10 feet above base.  .......................................................... 37

24. Limestone: dusky red, fine-grained; single bed; weathers grayish red; surface rough; forms ledge. Chert content 20%; moderate red, ovoid nodules to 4 inches with pseudo bed 3 inches thick at top; weathers dark brownish red. Avonia and Squamularia common.  ............................................. 3

23. Chert: light gray, aphanitic; single bed; weathers light to grayish brown; surface very rough; forms slope. Green and yellow lichens prominent on this bed. D. bassi abundant. Thickness varies along strike, minimum 1 foot to maximum of 4 feet.  ............................................. 4

22. Limestone: medium gray to dusky red, coarse-grained; single bed; weathers grayish red; surface rough; forms ledge. Chert content 30%; moderate red ovoid nodules to 6 inches; weathers dark reddish brown. Composita so abundant it is designated the Composita zone. Rhynchonelloids also abundant.  ............................................. 5
21. Limestone: medium light gray, coarse-grained; bedding obscure; weathers light gray; surface rough and pitted; forms ledge. Chert content 30%; white to light gray, ovoid and irregular, 3- to 18-inch nodules which weather pale brown; nearly continuous 1-foot band of light gray chert at top.

20. Limestone: grayish red purple, coarse-grained; bedding obscure; weathers dark yellowish brown, rough and platy surface; forms ledge. Chert content less than 5%; moderate red small (to 6 inch) ovoid nodules that form thin discontinuous bands at 2 and 5 feet above base.

19. Limestone: grayish red to dusky red, fine-grained; single bed; weathers grayish red with pale yellowish brown blotches; surface very rough; forms ledge. Chert content less than 5% dusky red small (to 4-inch) ovoid nodules that form a 6-inch discontinuous band 4 feet above base.

18. Limestone: very light gray, coarse-grained; single bed; weathers light gray with light brown blotches; surface rough and raspy; forms ledge. Chert content 5%; light gray, 2- to 6-inch, ovoid and irregular nodules; weather moderate to light brown.

17. Limestone: grayish red, fine-grained; single bed; weathers pale red; rough to smooth surface; forms ledge. Highest zone with abundant euomphalids.

16. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms cliff. Chert content less than 5%; occurs as thin (3/4- to 2-inch) discontinuous beds of grayish purple elongated nodules that weather pale to moderate brown, at 7, 14, 23 and 30 feet above base. Zone from 15 to 23 feet above base poorly exposed, may be pink sandstone. Euomphalids common to abundant throughout interval.

15. Sandstone: white and red, medium-grained; weakly cemented with calcite; bedding flat, thin, minor cross-laminations; weathers white to brownish red; surface smooth; forms slope.

(Strike, N 3° W; dip, 11° SW)
14. Limestone: moderate reddish brown, aphanitic; single bed; weathers light brown; surface smooth; forms ledge. .............. 4

13. Limestone: medium gray, fine- to coarse-grained; bedding obscure; weathers medium gray; surface raspy and pitted; forms ledge. Chert content less than 5%; single discontinuous band of small white, pale brown-weathering nodules about 3 inches thick 14 feet above base. Small Composita and pelecypods abundant at top; euomphalids and turritellids common to abundant from base to 15 feet above base. ....................... 20

12. Limestone and sandstone:

12j. Limestone: very light gray, coarse-grained; single bed; weathers grayish orange; surface rough; forms slope. Has 10% calcite blebs, 1 to 3 inches. ............... 1

12i. Sandstone: moderate reddish brown, coarse-grained; bedding obscure; weakly cemented with calcite cement; weathers dark reddish brown; surface smooth; forms slope. ........... 2

12h. Limestone: grayish black, aphanitic; single bed; weathers dark yellowish orange; surface rough and raspy; forms ledge. Has networks of \( \frac{1}{2} \)- to 1-inch calcite seams. ...... 1

12g. Sandstone: moderate red, very fine-grained; bedding obscure; weakly cemented with calcite; weathers moderate reddish brown; surface smooth and raspy; forms slope. .................... 1

12f. Limestone: grayish brown, coarse-grained; single bed; weathers pale yellowish brown with light gray streaks; surface rough and platy; forms ledge. ...................... 1

12e. Limestone: pale yellowish brown, fine-grained; single bed; weathers yellowish gray; surface smooth; forms ledge. ............ 1

12d. Sandstone: light red, medium-grained; bedding obscure; weakly cemented with calcite; weathers mottled pale red and grayish pink; surface smooth; forms slope. .............. 2

12c. Limestone: moderate pink, fine- to coarse-grained; bedding obscure; weathers pale pink; surface smooth to raspy; forms ledge. ................. 3

12b. Limestone: very light gray, fine- to coarse-grained; single bed; weathers pinkish gray; surface smooth to raspy; forms slope. ................. 2

12a. Limestone: dark yellowish brown, coarse-grained; bedding obscure; weathers pale
yellowish brown; surface smooth to pit­
ted; forms slope. Chert content less
than 5%; discontinuous 2- to 4-inch thick
beds moderate brown, dark gray weathering
at 3 and 4 feet above base; replete with
tiny white shell fragments. Calcite blebs
from 1/2 to 2 inches especially common at 7
and 11 feet above base. .............. 12
Total thickness interval 12 .............. 26

11. Limestone: dark gray, fine-grained; 1 to 4 foot
beds; weathers medium dark to dark gray; sur­
face raspy and pitted; forms slope. Calcite 20%
as blebs (1/2 to 3 inches) and networks of seams.
Two 2-foot beds of grayish black limestone with
pockets of shell fragments at 2 and 5 feet
above base. A 2-foot bed of moderate red lime­
stone with dark gray fragments of euomphalids
and Archaeocidaris spines 12 feet above base.
Euomphalids common throughout interval. .......... 28

10. Limestone: grayish red, fine-grained; beds 1 to
3 feet thick; weathers grayish orange pink;
surface raspy; forms slopes and ledges. Calcite
blesbs to 10%; round, 1/2 to 3 inches. Euomphalids
common. ......................... 6

9. Limestone: very light to medium light gray with
pale red patches, fine- to coarse-grained; beds
1 to 5 feet; weathers medium to medium dark gray
with dark yellowish brown wavy bands standing
out along strike; surface smooth to rough; forms
slope. Chert content less than 5%; white and
light gray, light brown-weathering small (2- to
6-inch) nodules. Beds 1 to 2 feet thick of very
dark gray limestone with pockets of small unid­
entified shell fragments at 5, 15 and 26 feet
above base. Lowest zone of euomphalids from 20
to 30 feet above base. ................... 30

Total thickness Quail Peak limestone member. ... 390

Cave Cliff limestone member:

8. Limestone: medium light gray, fine- to coarse­
grained; bedding obscure; weathers light gray;
surface rough and pitted; forms slope. Chert
content 30%; colors variable; irregular white
to light gray, pale to moderate brown-weather­
ing, 6- to 24-inch nodules throughout interval;
large masses, 10 to 24 inches thick, extending
6 to 8 feet along strike near top of interval; mottled light red and white nodules to 8 inches, 10 feet above base; bottom 10 feet of interval has light brown chert in networks of seams, and nodules of black, and black and white chert to 12 inches. .......................... 40

(Strike, N 5° E; dip, 9° NW)

7. Limestone: medium light gray, fine- to coarse-grained; bedding obscure; weathers medium gray; surface rough and pitted; forms ledges. Chert content 5%; white to light gray, ovoid to irregular, 2- to 6-inch nodules weathering light to moderate brown. Gastropod zone at 30 feet above base; zone at 10 feet above base, with turritellid gastropods common, equivalent to zone where ammonoids were found in Section G, interval 5. .......................... 32

6. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough; forms series of slopes and ledges. Chert content 30%; colors variable; zones of black, and black and white nodules to 18 inches at 90, 82, 75, 63, 50, 43, 35, 22 and 14 feet above base; white to light gray chert, weathering white to grayish brown, nodules to 12 inches throughout interval, prominent at 106, 95, 55, 38 and 15 feet above base, with zones at 38 and 15 feet having some pale red chert. Spirifer zone 21 feet above base. .......................... 130

5. Limestone (red chert zone): medium gray to dusky red, fine-grained; beds 1 to 4 feet thick; weathers medium light gray to moderate reddish brown; surface rough to raspy; forms slope. Chert content 50%, with beds to 2 feet nearly 100% chert; both beds and nodules light gray and mottled moderate red and light gray, weathering light brown to moderate reddish brown; a few black nodules in upper part. Small pelecypods common in chert beds. .......................... 27

4. Limestone: medium gray, fine- to coarse-grained; bedding obscure; weathers medium light gray, rough surface; forms series of ledges. Chert content less than 5%; small (2- to 4-inch) light gray, pale brown-weathering nodules. Networks of calcite seams, 1/8 to 1/2 inches wide, throughout interval. .......................... 55
3. Limestone: medium gray, fine-grained; bedding obscure; weathers medium gray, surface smooth to raspy; forms series of ledges. Chert content 10%; zone 15 to 20 feet above base has 30% white and light gray, white to moderate brown-weathering nodules to 15 inches containing sponges. .......................... 61

2. Limestone: medium dark gray, fine- to coarse-grained; bedding obscure; weathers medium gray; surface rough; forms ledge. Chert content less than 5%; light gray, pale brown-weathering nodules to 6 inches. Calcite to 10% in networks of 1/8- to 1/2-inch seams. .................. 12

(Strike, N 10° E; dip, 27° NW)

1. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface raspy and pitted; series of ledges. Chert content 25%; white to light gray, pale brown-weathering nodules to 18 inches. This interval is faulted and disturbed, and with interval 2 is probably equivalent in part to intervals 8 and 9. .......................... 52

Total thickness Cave Cliff limestone member. . . 409

Total thickness Snyder Hill formation. . . . . . 799

Thrust sole

Limestone similar to interval 36, maximum of 20 feet, poorly exposed below thrust sole.
SECTION C

Measured north up ridge toward Pointed Peak from lowest exposed limestone on the north side of Raven Canyon.

Tertiary (?) :
Rhyolitic volcanics

Unconformity

Cretaceous (?) :
Angular quartzite conglomerate

Unconformity

Permian:
Snyder Hill formation:
Cave Cliff limestone member:

6. Limestone: medium gray, fine-grained; bedding obscure; weathers medium gray; surface rough and pitted; forms long dip slope. Chert content 40%; white to light gray, ovoid to irregular nodules, 6 to 15 inches; weathers white to dusky brown. Gastropod zone 25 feet above base. ............................................ 58

(Strike, N 30° W; dip, 28° SW)

5. Limestone: medium gray, fine- to coarse-grained; bedding obscure; weathers medium light gray; surface rough; forms series of ledges. Chert content 10%; various colors and types, white, light gray, pale brown, moderate red, black and white, and black, mostly ovoid and irregular nodules, averaging 6 to 10 inches thick, up to 4 feet along strike; mostly weathering light brown to dusky brown. Turritellid gastropods common at top. .................. 106

4. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms cliff. Chert content 25%; white to light gray, ovoid to irregular nodules, 6 to 18 inches, weathering light to dusky brown; also black, and black and white nodules becoming common in upper half of interval. Spirifer zone at 30 feet above base. . . . 55

(Strike, N 30° W; dip, 32° SW)

3. Limestone (red chert zone): light gray to grayish purple, aphanitic; beds 1 to 4 feet thick;
weathers light gray to moderate reddish brown; surface rough; forms slope. Chert content 35%, with beds up to 2 feet nearly 100% chert; light gray and mottled moderate red and white; weathers light brown to moderate reddish brown. Contains abundant small shell fragments in chert beds. .......... 22

(Strike, N 26° W; dip, 30° SW)

2. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms cliff. Chert content less than 5%; white to light gray, ovoid and irregular nodules, 2 to 10 inches, weathering pale to moderate brown; zone 100 to 120 feet above base up to 20% chert with sponges and gastropods. Fossiliferous zone at base with rhynchonellids, horn corals and turritellids common. Large horn corals common in zone at top of interval. ............... 172

(Strike, N 20° U; dip, 30° SW)

1. Limestone: medium light gray, fine-grained; bedding obscure; weathers medium gray, surface rough; forms cliff. Chert content 35%; white to light gray ovoid nodules from 3 to 18 inches; weathers light gray to moderate brown. Sponge zone 15 feet above base. .... 106

Total thickness Cave Cliff limestone member. ... 519

Total thickness Snyder Hill formation. .... 519

Alluvium
Small, poorly exposed and discontinuous outcrops of pink sandstone.
SECTION D

Measured north up ridge southwest of Pointed Peak from thrust fault in Raven Canyon. Brecciated sandstone with limestone fragments and much gouge and disturbed bedding exposed for a few feet at base of section.

Erosion surface

Permian:

Snyder Hill formation:

Cave Cliff limestone member:  Feet

4. Limestone: medium dark gray, fine-grained; bedding obscure; weathers medium gray; surface rough and raspy; forms cliff. Chert content less than 5%, except zone near top to 20%, white, pale brown-weathering, irregular 1- to 4-inch nodules with sponges. ....................... 38

(Strike, N 44° W; dip, 45° SW)

3. Limestone: medium dark gray with grayish red patches; bedding obscure; weathers medium gray with pale red blotches; surface rough; forms cliff. Chert content 5%; white and mottled moderate red, 2- to 8-inch, ovoid to irregular moderate brown-weathering nodules. Zone 15 feet above base containing turritellid gastropods and horn corals. ....................... 86

(Strike, N 47° W; dip, 44° SW)

2. Limestone: pale brown, fine-grained; bedding obscure; weathers light brownish gray; surface rough; forms cliff. Chert content 40%; color varied; white, mottled pale red and white, light gray; weathers pale to moderate brown, irregular masses 6 inches to 6 feet. A 3-foot zone 30 feet above base about 80% medium dark gray, dark gray-weathering nodules to 18 inches. A 2-foot zone 18 feet above base about 50% grayish red, dark reddish brown-weathering chert in nodules to 12 inches with abundant sponges. ....................... 73

1. Limestone: pale red, fine-grained; bedding obscure; weathers light brownish gray; surface rough to raspy; forms series of ledges. Chert content 20%; white to light gray, ovoid to
irregular, 3- to 18-inch nodules weathering pale to moderate brown. . . . . . . . . . . . . 45

Total thickness Cave Cliff limestone member. . . 242

Thrust sole

Pink sandstone member:
Pink sandstone
SECTION F

Measured southwest up the northwest slope of Pointed Peak from Javelina Canyon to small peak northwest of the summit. Below the measured section are red sandstone and siltstone, brecciated and disturbed, marking the thrust sole.

Erosion surface:

Permian:
Snyder Hill formation:
Cave Cliff limestone member:

Feet

7. Limestone: medium light gray, fine- to coarse-grained; bedding obscure; weathers light gray; surface very rough; forms series of ledges. Chert content 15%; white to light gray, ovoid and irregular nodules to 8 inches; weathers white to pale brown. Horn corals common and crinoid stems abundant in zone 15 feet above base; gastropod zone 5 feet above base. ....... 26

(Strike, N 43° W; dip, 33° SW)

6. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; forms cliff. Chert content 5%; mostly white to light gray, 6- to 12-inch, ovoid nodules weathering pale to moderate brown; has zones of black chert nodules to 15 inches at 112, 63 and 25 feet above base. Rhynchonelloids and turritellid gastropods 15 feet above base; Meekella and small star-shaped crinoid stems 73 feet above base. ......... 153

(Strike, N 41° W; dip, 36° SW)

5. Limestone: medium light gray, fine-grained; bedding obscure; weathers light gray; surface rough; forms cliff. Chert content 30%; white, mottled light gray and pale red, black; nodules ovoid and irregular to 18 inches; weathers light to moderate brown, commonly covered with gray and green lichens; black nodules in bands up to 2 feet thick at 20 and 30 feet above base. Spirifer zone at 23 feet above base. ... 38

(Strike, N 40° W; dip, 41° SW)

4. Limestone (red chert zone): medium light gray to grayish purple; beds 1 to 3 feet thick; weathers pale brown; surface rough; forms slope. Chert content 45%; with beds to 2 feet thick
nearly 100% chert; light gray, and mottled pale red and light gray; weathers pale brown to moderate reddish brown. Abundant small shell fragments in bedded chert.

(Strike, N 39° W; dip, 42° SW)

3. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface smooth to rough; forms series of ledges.
   Chert content less than 5%, except for zone 125 feet above base that reaches 20%; light gray, irregular, 3- to 8-inch, dark yellowish brown-weathering nodules. Sponges and gastropods in zone 120 feet above base; horn corals common at top; rhynchonellids and horn corals in zone 35 feet above base.

2. Limestone: medium gray, fine-grained; bedding obscure; weathers light gray; surface rough; forms slope. Chert content 25%; white ovoid, pale brown-weathering nodules to 6 inches.

1. Limestone: medium dark gray, fine-grained; bedding obscure; weathers medium light gray; surface rough; forms ledge. Chert content 15%; white, ovoid and irregular nodules to 8 inches weathering pale to dusky brown; networks of thin stringers of pale yellowish brown chert, weathering moderate yellowish brown to dusky brown.

Total thickness Cave Cliff limestone member... 468
Total thickness Snyder Hill formation... 468

Thrust sole

Cretaceous:
   Red sandstone and siltstone.
**SECTION G**

Measured north from fault zone near crest at southeast end of Rainbow Ridge, down northeast slope to the alluvium which covers the top of the section.

**Recent:**

1. **Alluvium**

**Unconformity**

**Permian:**

15. **Snyder Hill formation:**

- **Quail Peak limestone member:**

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<td>20. Limestone:</td>
<td>moderate reddish brown, fine-grained; single bed; weathers grayish red; forms ledge. Chert content 20%; moderate red, dusky red-weathering, ovoid nodules to 6 inches, and band at top 6 inches thick about 90% chert nodules. Avonia and Squamularia common.</td>
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<td>18. Limestone:</td>
<td>pale red to dark reddish brown; single bed; weathers grayish red; surface rough; forms slope. Chert content 30%; moderate red, dark reddish brown-weathering ovoid nodules to 4 inches. Composita zone, with rhynchonelloids common.</td>
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<td>17. Limestone:</td>
<td>medium gray, fine-grained; beds 1 to 3 feet thick; weathers medium light gray; surface pitted; forms slope. Chert content 30%; white to light gray and pale red mottled, irregular, 2- to 15-inch nodules, weathering pale yellowish to dark yellowish brown.</td>
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<td>16. Limestone:</td>
<td>grayish red, coarse-grained; beds 2 to 4 feet thick; weathers grayish brown; surface rough; forms ledge. Chert content less than 5%; pale reddish brown, small (to 4-inch) nodules, weathering pale brown, forming well-defined bands.</td>
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<td>15. Limestone:</td>
<td>grayish red, fine- to coarse-grained; beds 2 to 4 feet thick; weathers light brownish gray to dark reddish brown; surface</td>
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rough and raspy; forms ledges and slopes. Chert content \( \frac{5}{8} \); light gray and moderate red ovoid nodules to 4 inches, weathering pale red to dusky brown. Euomphalids common toward base. 17

14. Limestone: medium gray, fine-grained; bedding obscure; weathers light gray; surface rough and pitted; forms series of ledges. Chert content less than \( \frac{5}{8} \); grayish purple pseudo beds up to 3 inches thick that weather moderate brown. Euomphalids common throughout interval, especially toward top. 24

(Strike, N 55° W; dip, 48° NE)

13. Sandstone: pinkish gray, fine-grained; weakly cemented with calcite; bedding flat, thin; weathers grayish orange pink, surface smooth; forms slope. 10

12. Limestone: medium gray, aphanitic; bedding 2 to 4 feet; weathers medium light gray; has 2-foot bed moderate red, grayish red-weathering limestone near top; surface smooth; forms slope. 9

11. Limestone: medium dark gray, coarse-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms slope. Chert content less than \( \frac{5}{8} \); white, small (to 3 inch), pale brown-weathering, ovoid nodules. Small Composita abundant toward top; large euomphalids and turritellid gastropods common 8 feet above base. 21

10. Limestone: varicolored (light gray, pale brown, moderate pink and moderate yellowish brown), fine- to coarse-grained; beds 1 to 6 feet thick, thinner toward top; usually weathers lighter shades than fresh surfaces; surface smooth; forms slope. Has 3-foot bed of light red sandstone, fine-grained, flat-bedded, weakly cemented with calcite, 10 feet above base. 17

9. Limestone: medium dark gray, fine-grained, becoming moderate yellowish brown, coarse-grained, toward top; beds 2 to 5 feet thick; weathers medium gray to dark yellowish brown; surface raspy and pitted; forms slope. Calcite blebs, \( \frac{1}{2} \) to 2 inches, about \( \frac{5}{8} \). A 3-foot bed of moderate red limestone with dark gray Archaeocidaris spines 2 feet above base. 25
8. **Limestone**: medium gray, fine-grained; beds 6 inches to 4 feet thick; weathers medium light gray; surface rough; forms slope. Chert content less than 5%; light gray, pale brown-weathering, small (to 4-inches) ovoid nodules. Beds 6 inches to 2 feet thick of grayish black limestone with small shell fragments concentrated in pockets at 5, 9, 18 and 21 feet above base. Large euomphalids abundant 10 to 14 feet above base.

7. **Limestone**: medium light gray, fine-grained, with pale red, coarse-grained patches, 1 to 4 feet in diameter; beds 1 to 6 feet thick; surface rough; forms slope. Chert content less than 5%; mottled white and moderate red, light brown-weathering, 2- to 5-inch, ovoid and irregular nodules. Beds 6 inches to 2 feet thick of grayish black limestone with pockets of shell fragments (as in interval 8) at 8 and 17 feet above base. Lowest zone of abundant euomphalids from 17 to 25 feet above base.

Total thickness Quail Peak limestone member... 213

Cave Cliff limestone member:

(Strike, N 60° W; dip, 50° NE)

6. **Limestone**: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms series of ledges. Chert content 25%; 3 types prominent; white, moderate brown-weathering, ovoid and irregular nodules throughout interval becoming very large (1 to 2 feet thick extending up to 8 feet along strike) near top; mottled pale red and white nodules to 8 inches in 4-foot zone 15 feet above base; black and white, and black nodules to 15 inches in bottom 10 feet.

5. **Limestone**: medium gray, fine- to coarse-grained; bedding obscure; weathers medium light gray; surface pitted; forms series of ledges. Chert content 20%; light gray, 3- to 6-inch ovoid, moderate brown-weathering nodules. Also nodules of black, and black and white chert similar to that in interval 6. Gastropod zone 28 feet above base. Ammonoids found in zone 12 feet above base, with turritellid gastropods, bellerophontids and abundant large crinoid stems.
4. Limestone: medium gray, fine-grained; bedding obscure; weathers medium light gray; surface rough and pitted; forms ledges and slopes. Chert content 25%; light gray, 3- to 6-inch, ovoid to irregular, moderate brown-weathering nodules, with black and white nodules to 30% in zone near base. ............................................... 24

3. Limestone: medium light gray, fine-grained; bedding obscure; weathers light gray; surface rough; forms series of ledges. Chert content 20%; black and white, and black nodules to 24 inches throughout interval with prominent zones at 65, 50 and 25 feet above base; white to light gray, moderate brown-weathering, ovoid nodules to 12 inches especially abundant at 80, 50, 35 and 20 feet above base, with zones at 35 and 20 feet containing small, pale red chert nodules in well-defined bands. Spirifer zone 25 feet above base. ........................................ 106

2. Limestone (red chert zone): pale red to dusky red, fine-grained; beds 1 to 4 feet thick; weathers moderate reddish brown; surface rough; forms slope. Chert content 40% with beds to 3 feet nearly 100% chert; beds and nodules pale red to moderate red mottled with light gray; weathers light brown to moderate reddish brown. Small pelecypods common in chert beds. .................................................. 25

1. Limestone: medium gray, fine-grained; bedding obscure; weathers light gray; surface rough and pitted; forms slope. Chert content less than 5%; light gray, 2- to 4-inch, moderate brown-weathering, ovoid nodules. Calcite seams up to ½ inch forming networks. Large horn corals common at top. .................................................. 20

Total thickness Cave Cliff limestone member. . . . . . . 247

Total thickness Snyder Hill formation. . . . . . . . . . 460

Fault

Cave Cliff limestone member:
Limestone: medium dark gray
SECTION H

Measured west up across small outlying ridge on the western slope below Ravens Bluff. Both top and bottom are covered by alluvium.

Recent:
Alluvium

Unconformity

Permian:
Snyder Hill formation:

Pink sandstone member:

5. Limestone (magnesian): dark gray, fine-grained; beds to 4 feet thick; weathers grayish brown; surface raspy; forms ledges. Has pink sandstone float but not found in place. Calcite blebs ½ to 2 inches, especially common toward top. .................. 21

Total thickness Pink sandstone member. ........ 21

Tellez Wash limestone member:

4. Limestone (magnesian): very dusky purple, fine-grained; bedding obscure; weathers brownish gay; surface raspy; forms series of ledges. Top 2 feet of interval dark yellowish brown. Chert content 40%; grayish purple and white mottled, ovoid and irregular nodules to 2 feet; weathers dark reddish brown. Calcite blebs to 3 inches common throughout interval. ........ 21

3. Limestone (magnesian): grayish red, fine-grained; bedding obscure; weathers grayish brown; surface very raspy; forms small cliffs and ledges. Chert content less than 5%; mottled white and purple nodules as in interval 4, especially at 50, 20 and 15 feet above base. Zones of very dark gray limestone with abundant small crinoid stems and very large (½x5 inches) Archaeocidaris spines at 35 feet above base and abundant small Archaeocidaris spines 70 feet above base. ........... 74

2. Limestone (magnesian): dusky blue, fine-grained; bedding obscure; weathers medium
bluish gray; surface rough and raspy; forms cliff. Chert content less than 5%; mainly purple and white nodules as in interval 4; lower 10 feet has lenses (1/2 to 3 inches thick up to 30 feet along strike) of siliceous grayish purple sandstone. Bryozoa and very large crinoid stems at 25 feet, and abundant crinoid stems and Archaeocidaris spines at 32 feet above base.

Total thickness Tellez Wash limestone member... 131

White sandstone member:

(Strike, N 41° W; dip, 35° SW)

1. Sandstone: pinkish gray, fine- to coarse-grained; flat beds to 2 feet thick with minor cross-laminations; weakly cemented with calcite; weathers pale yellowish brown; surface bumpy and pitted; forms slope. Contains large (to 12 inches) grayish purple sandstone concretions, often with largest dimension transverse to bedding. .................. 21

Total thickness White sandstone member...... 21

Total thickness Snyder Hill formation....... 168

Alluvium
**SECTION I**

Measured west down slope from saddle south of Ravens Bluff. Top covered by alluvium, lower beds present below base of measured section but exposures very poor.

Recent:

Alluvium

Unconformity

Permian:

Snyder Hill formation:

<table>
<thead>
<tr>
<th>Member</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.</td>
<td>Sandstone: pale pink, fine-grained; bedding indistinct, disturbed, much gouge; surface smooth; forms slope.</td>
<td>3</td>
</tr>
<tr>
<td>20.</td>
<td>Sandstone: pale reddish brown, fine-grained; flat, thick-beded (to 5 feet), minor cross-laminated zones at 10 and 30 feet above base; weakly cemented with calcite; weathers moderate reddish brown; surface smooth; forms slope, few ledges. Grayish purple sandstone concretions to 8 inches in zone 35 feet above base.</td>
<td>38</td>
</tr>
<tr>
<td>19.</td>
<td>Concealed.</td>
<td>6</td>
</tr>
<tr>
<td>18.</td>
<td>Limestone: pale reddish brown, fine-grained; beds 1 to 4 feet; weathers moderate reddish brown; surface rough; forms cliff.</td>
<td>11</td>
</tr>
<tr>
<td>17.</td>
<td>Concealed.</td>
<td>4</td>
</tr>
<tr>
<td>16.</td>
<td>Sandstone: pale purple, fine-grained; beds 4 inches to 1 foot; cross-laminated; weakly cemented with calcite, friable; weathers light brownish gray; surface smooth; forms ledge.</td>
<td>4</td>
</tr>
<tr>
<td>15.</td>
<td>Sandstone: grayish pink, fine-grained; beds 6 inches to 1 foot; cross-laminated; firmly cemented with calcite; weathers moderate orange pink; surface smooth; forms ledge.</td>
<td>4</td>
</tr>
<tr>
<td>14.</td>
<td>Concealed.</td>
<td>7</td>
</tr>
<tr>
<td>13.</td>
<td>Sandstone: moderate orange pink; fine-grained; beds thin (2 to 6 inches), cross-laminated;</td>
<td></td>
</tr>
</tbody>
</table>
weakly cemented with iron oxide; weathers moderate reddish brown; surface rough and blocky; forms ledge.

12. Sandstone: pinkish gray, fine-grained; beds thin (2 to 6 inches), cross-laminated; firmly cemented with silica; weathers grayish orange; surface pitted and bumpy; forms ledge. Has rounded grayish red sandstone concretions up to 18 inches.

11. Sandstone: very light gray, coarse-grained; beds 1 to 2 feet thick, flat; weakly cemented with iron oxide; weathers light brown with abundant small moderate brown pits; surface pitted; forms slope.

10. Sandstone: pinkish gray, fine- to coarse-grained; bedding thin (1/2 inch to 2 feet), cross-laminated; firmly cemented with silica; weathers moderate orange pink; surface pitted and bumpy; forms ledge; small (to 1/2 inch) grayish purple sandstone concretions abundant.


8. Sandstone (orthoquartzite): pinkish gray, fine- to coarse-grained; bedding thin (3 inches to 1 foot), notably cross-laminated; firmly cemented with silica; weathers grayish orange; surface smooth; forms ledge. Grayish purple sandstone concretions to 3 inches.

7. Sandstone: pale pink, fine-grained; bedding 8 inches to 3 feet, flat; weathers pale orange; firmly to weakly cemented with calcite; surface pitted, pits weather grayish orange; forms slope.

6. Concealed.

5. Sandstone: pinkish gray, fine-grained; bedding 6 inches to 3 feet, flat; weathers very pale orange; weakly cemented with calcite; surface pitted; forms slope.


3. Sandstone (orthoquartzite): grayish orange pink, fine-grained; beds 1 inch to 1 foot, cross-laminated; firmly cemented with silica; weathers grayish orange; surface smooth; forms ledge.
2. Concealed.

1. Limestone: light red, fine-grained; beds 1 to 4 feet; weathers pale red; surface rough to raspy; forms ledges. Not exposed from 3 to 8, and 10 to 16 feet above base, probably inter-bedded sandstone.

Total thickness White sandstone member: 224
Total thickness Snyder Hill formation: 224

Alluvium largely conceals lower sandstones and limestones of White sandstone member.
SECTION J

Measured west up ridge below high cliff directly east of Pointed Peak. Top of section is base of cliff, lower beds present below base but poorly exposed and considerably disturbed.

Permian:
Snyder Hill formation:
Cave Cliff limestone member:
Limestone: gray, massive cherty; forms high cliff

Permian:
Snyder Hill formation:
Cave Cliff limestone member:
Limestone: gray, massive cherty; forms high cliff

Thrust zone: limestone and sandstone breccia

<table>
<thead>
<tr>
<th>Pink sandstone member</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feet</strong></td>
</tr>
<tr>
<td>14. Sandstone: moderate pink, fine-grained; weakly cemented with calcite; flat-bedded, beds 1 inch to 1 foot, minor cross-laminations; weathers moderate orange pink; surface smooth; forms slope.</td>
</tr>
<tr>
<td>13. Limestone: medium gray to dark reddish brown toward top, aphanitic; bedding obscure; weathers olive gray to grayish brown; surface rough and raspy; forms ledge. Has abundant irregular, short calcite seams to 2 inches.</td>
</tr>
</tbody>
</table>

Total thickness Pink sandstone member...

<table>
<thead>
<tr>
<th>Tellez Wash limestone member</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feet</strong></td>
</tr>
<tr>
<td>12. Limestone (magnesian): grayish red purple, fine-grained; bedding obscure; weathers grayish red; surface raspy; forms ledge. Chert content 30%; bands of irregular, grayish purple, brownish gray-weathering nodules to 18 inches, pseudo bed 4 inches thick of light brown, moderate yellow-weathering chert near top.</td>
</tr>
<tr>
<td>11. Limestone: pale reddish brown, fine-grained; bedding obscure; weathers pale red; surface rough; forms ledge. Chert content 15%; moderate red and white mottled nodules to 15 inches; weather moderate brown.</td>
</tr>
<tr>
<td>10. Limestone (magnesian): pale red purple, aphanitic; bedding obscure; weathers brownish gray; surface raspy; forms ledge. Chert content 10%;</td>
</tr>
</tbody>
</table>
white to pale yellowish brown nodules, irregular, up to 10 inches; weathers pale brown.

Limestone: grayish red purple, aphanitic; bedding obscure; weathers pale red; surface rough, with calcite blebs; forms ledge. Chert content 50%; mottled pale red and white nodules to 18 inches, pseudo beds to 8 inches thick, 50 to 75 feet long; weathers moderate brown. Pale brown and white calcite blebs up to 2 inches diameter, 10% of rock.

Limestone (magnesian): pale red purple, aphanitic; bedding obscure; weathers pale red; surface raspy; forms ledge. Chert content 10%; in bands 4 inches thick, 30 to 50 feet along strike and in nodules to 3 inches, white to yellowish brown; weather moderate brown.

Limestone (magnesian): grayish red purple, aphanitic; bedding obscure; weathers pale red; surface rough, with calcite blebs; forms ledge. Chert content 15%; mottled pale red and white nodules to 12 inches, pseudo beds 4 inches thick, 20 feet long; weather moderate brown.

Limestone (magnesian): pale red purple, fine-grained; bedding obscure; weathers brownish gray; forms ledge. Chert content 20%; in white and moderate brown nodules to 5 inches forming bands up to 50 feet along strike; weathers dusky brown. Abundant large Archaeocidaris plates and spines in 10-foot zone near middle.

Sandstone: grayish orange pink, fine-grained; bedding thin and flat with minor cross-laminated beds to 8 inches thick; firmly cemented with calcite; weathers pale red; surface pitted. Contains 10% grayish purple sandstone concretions to ½ inch.

Limestone (magnesian): light gray, aphanitic; bedding obscure; weathers brownish gray; raspy surface; forms ledge. Chert content 5%; white to moderate brown nodules to 6 inches, weathers moderate brown.

Total thickness Tellez Wash limestone member.
White sandstone member:

3. Sandstone: grayish orange pink to pale red toward top, fine-grained; firmly cemented with calcite; bedding thin and flat, minor cross-laminations; weathers pale yellowish brown; surface rough and pitted; forms ledge. Contains 15% pale red purple sandstone concretions to ½ inch. .................................... 36

2. Limestone: dark reddish brown, aphanitic; bedding obscure; weathers moderate reddish brown; surface raspy; forms ledge. ................. 14

(Horizontal)

1. Sandstone: grayish orange pink, fine-grained; firmly cemented with calcite; bedding thin and flat, minor cross-laminations; weathers pale brown; surface rough and pitted; forms ledge. Contains 10% grayish purple sandstone concretions to ½ inch. .................................... 76

Total thickness White sandstone member. ........ 126

Total thickness Snyder Hill formation. ........ 345

Alluvium

Outcrops of sandstone and limestone; small, poorly exposed and not continuous.
SECTION K

Measured northeast from lowest exposure below overthrust limestone in wash southwest of Lava Ridge to unconformity below Tertiary (?) rhyolite on west side of Lava Ridge.

Tertiary (?):

Rhyolite

Unconformity

Cretaceous (?):

<table>
<thead>
<tr>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Sandstone: pale red to moderate reddish brown, coarse-grained; flat, thick-bedded, minor cross-laminated zones; calcite cement; weathers moderate reddish brown; surface smooth; forms slope, partly covered by rhyolite float.</td>
</tr>
<tr>
<td>(Strike, N 50° W; dip, 48° NE)</td>
</tr>
<tr>
<td>9. Tertiary (?) rhyolite porphyry sill: grayish purple; aphanitic groundmass with about 40% phenocrysts of orthoclase (20%), quartz (15%), and biotite (5%).</td>
</tr>
<tr>
<td>(Strike, N 48° W; dip, 48° NE)</td>
</tr>
<tr>
<td>8. Sandstone: pale red, coarse-grained; flat, thick-bedded, grading into thinner beds with some cross-lamination toward top; calcite cement; weathers pale red; surface smooth; forms slope.</td>
</tr>
<tr>
<td>7. Sandstone: moderate reddish brown, medium-grained; flat, thick-bedded; calcite cement; weathers moderate reddish brown; surface smooth; forms series of ledges and slopes.</td>
</tr>
<tr>
<td>(Strike, N 50° W; dip, 45° NE)</td>
</tr>
<tr>
<td>6. Sandstone: pale red, medium- to coarse-grained with grayish red pebble conglomerate beds to 18 inches thick forming 30% of unit. Sandstones are flat, thin-bedded; weakly cemented with calcite. Conglomerates have fine-grained sandstone matrix, clay bond. Pebbles to 3 inches, quartz, quartzite, minor limestone.</td>
</tr>
<tr>
<td>(Strike, N 50° W; dip, 45° NE)</td>
</tr>
<tr>
<td>5. Siltstone: moderate red; thin-bedded; calcite cement; weathers moderate red; surface blocky and platy; forms slope.</td>
</tr>
</tbody>
</table>
4. Sandstone: light gray, fine-grained; flat, thin-bedded; calcite cement; weathers light gray; surface smooth; forms ledge.  8

3. Sandstone: pale red, fine-grained; bedding obscure; clay bond; weathers pale red; surface pitted; forms slope.  18

2. Siltstone: moderate reddish brown; bedding obscure; calcite cement; weathers mottled pale red and medium gray; surface blocky; forms slope.  2

1. Sandstone: moderate red, fine-grained; bedding obscure; calcite cement; weathers moderate red; surface rough; forms ledge.  14

Total thickness of Cretaceous (?) beds ... 315
Thickness of Tertiary (?) rhyolite porphyry sill.  150
Total thickness of Section K. ... 465

Base concealed below thrust sole of Snyder Hill limestone.
SECTION L

Measured west down Javelina Canyon from lowest outcrop of conglomerate below overthrust block of Permian limestone. Top covered by alluvium.

Recent:

Alluvium

Unconformity

Cretaceous (?):   Feet

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Sandstone: moderate orange pink, medium-grained; flat, thick-bedded with minor cross-laminated zones; friable, weakly cemented with calcite; weathers moderate orange pink; surface smooth; forms slope.</td>
<td>93</td>
</tr>
<tr>
<td>13</td>
<td>Sandstone and conglomerate (pebble): pale red to moderate reddish brown, thin-bedded; weathers grayish red, forms slope. Sandstone in beds to 18 inches; medium- to coarse-grained; matrix argillaceous. Conglomerate, pebble; beds to 12 inches; matrix, medium sandstone; pebbles, quartz, quartzite, feldspar and muscovite; clay bond.</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>Siltstone (siliceous): moderate red; thin-bedded; strongly cemented with silica; weathers moderate red; surface blocky; forms ledge.</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Conglomerate (pebble): grayish red; single bed; matrix siltstone; clay bond; weathers grayish red; surface rough; forms slope. Pebbles chert and quartz.</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Siltstone: moderate reddish brown; thin-bedded; matrix clay; weathers reddish brown; surface smooth; forms slope.</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Concealed.</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>Siltstone: grayish red; thin-bedded; strongly cemented with calcite; weathers grayish red; surface very rough and blocky; forms cliff. Has seams of calcite and nodules of chert.</td>
<td>5</td>
</tr>
</tbody>
</table>
7. Poorly exposed: small outcrops of pale-red, fine-grained sandstone and moderate reddish brown siltstone.

6. Sandstone: moderate red, fine-grained; flat, thin-bedded; clay bond; weathers moderate red; surface blocky; forms slope.

5. Siltstone: pale red; flat, thin-bedded; clay bond; weathers pale red; surface bumpy; forms slope.

4. Conglomerate (granule): pale red; single bed; matrix siltstone; clay bond; weathers pale red; surface rough; forms slope. Granules chert and quartz.

3. Concealed.

2. Conglomerate (pebble): pale red; single bed; matrix siltstone; calcite cement; weathers pale red; surface rough; forms ledge. Pebbles chert and limestone.

1. Conglomerate (pebble) and sandstone: poorly exposed; moderate orange pink, medium- to coarse-grained sandstone and pale red conglomerate with pebbles of chert and limestone. Bottom 2 feet brecciated, with angular sandstone and limestone fragments in gouge matrix.

Total thickness of Cretaceous (?) rocks.

Thrust sole

Snyder Hill limestone.
SECTION M

Measured west from rhyolite-red beds contact in Tellez Wash northwest of Grantham Mountain. Base in fault contact with rhyolite. Top covered by alluvium.

Recent:

Alluvium

Unconformity

Cretaceous (?):

(Strike, N 35° W; dip, 340 SW)

13. Sandstone (arkosic): pale reddish brown, coarse-grained; flat, thin-bedded; clay bond; weathers reddish brown; surface smooth; forms slope. Has granule lenses with chert, quartzite and volcanic granules.

12. Fault zone: bedding plane fault with gouge and brecciated fragments of brown sandstone.

11. Sandstone (arkosic): moderate reddish orange, medium-grained; flat, thin-bedded; weakly cemented with calcite; weathers pale reddish orange; surface blocky; forms slope.

10. Conglomerate (pebble): grayish red; single bed; matrix siltstone; clay bond; weathers grayish red; surface bumpy; forms ledge. Pebbles quartzite, feldspar, limestone and volcanics.

9. Sandstone (arkosic): moderate reddish orange, coarse-grained; thin-bedded, minor cross-laminations; clay bond; weathers reddish orange; surface platy; forms slope.

8. Conglomerate (pebble): grayish red; single bed; matrix siltstone; weakly cemented with calcite; weathers grayish red; surface rough; forms ledge. Pebbles quartz, limestone, feldspar.

7. Sandstone (arkosic): moderate reddish orange, medium grained; thick-bedded, cross-laminated; clay bond; weathers reddish orange; surface blocky; forms slope.

6. Conglomerate (granule): grayish red; single bed; matrix siltstone; calcite cement; weathers
<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sandstone (arkosic): grayish red, fine-grained; flat, thin-bedded; clay bond; surface platy; forms slope.</td>
</tr>
<tr>
<td></td>
<td>Gouge and breccia zone 6 inches thick at base. ................................</td>
</tr>
<tr>
<td></td>
<td>Total thickness of Cretaceous (?) rocks. ........................................</td>
</tr>
<tr>
<td></td>
<td>86</td>
</tr>
<tr>
<td>2.</td>
<td>Conglomerate (pebble): grayish red; single bed; matrix siltstone; clay bond; weathers grayish red; surface rough; forms ledge. Pebbles quartz, feldspar, limestone, volcanics, some to 5 inches in diameter.</td>
</tr>
<tr>
<td></td>
<td>Fault</td>
</tr>
<tr>
<td></td>
<td>Tertiary (?): Gray rhyolite.</td>
</tr>
</tbody>
</table>
SECTION N

Measured west from rhyolite-red beds contact in wash south of Tellez Wash. Base in fault contact with rhyolite. Top covered by alluvium.

Recent:

Alluvium

Unconformity

Cretaceous (?):

<table>
<thead>
<tr>
<th>Feet</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Sandstone (arkosic): pale red, medium-grained; flat, thick-bedded; clay matrix; weathers moderate reddish brown; surface blocky; forms slope.</td>
</tr>
<tr>
<td>11</td>
<td>Siltstone: pale red with 50% of thin (to 12 inches) beds of pale red, fine-grained arkosic sandstone; weathers moderate reddish orange; surface blocky, with small flat chips; forms slope.</td>
</tr>
<tr>
<td>65</td>
<td>Sandstone (arkosic): pale red, fine-grained; thin, flat-bedded; has 20% of thin (to 12 inches) beds of pale red siltstone; calcite cement; weathers grayish orange pink; surface platy and blocky; forms series of slopes and ledges.</td>
</tr>
<tr>
<td>35</td>
<td>Sandstone and siltstone: like 16 but exposed only in small patches in creek bed.</td>
</tr>
<tr>
<td>47</td>
<td>Sandstone (arkosic): moderate red, fine- to medium-grained; thin, flat-bedded; has 10% of thin (to 12 inches) beds of pale red siltstone; calcite cement; weathers pale red; surface platy and blocky; forms series of slopes and ledges.</td>
</tr>
<tr>
<td>5</td>
<td>Concealed.</td>
</tr>
<tr>
<td></td>
<td>Sandstone (arkosic): pale reddish brown,</td>
</tr>
</tbody>
</table>
medium-grained; thin beds, many cross-laminated; clay matrix; weathers pale reddish brown; surface platy; forms slope. 20

11. Sandstone (arkosic): moderate reddish brown, fine-grained; beds thin, flat with minor cross-laminated zones; clay matrix; weathers pale reddish brown; surface blocky; forms slope. 30

10. Sandstone (arkosic): moderate reddish brown, medium-grained; has 20% of thin (to 8 inches) conglomerate beds like 9; thin-bedded, mostly cross-laminated; clay matrix, weathers pale reddish brown; surface platy; forms slope. 18

(Strike, N 46° W, dip, 47° SW)

9. Conglomerate (pebble): pale red to moderate red; single bed; matrix fine-grained sandstone with lenses of coarse-grained sandstone; weathers pale red; surface pebbly; forms ledge. Pebbles quartz, quartzite, feldspar, minor amounts of limestone and volcanics. 2

8. Sandstone (arkosic): moderate red, coarse-grained; thin, flat-bedded, with 30% of lenses of conglomerate like 9; matrix clay; weathers moderate red; surface smooth to rough and blocky; forms slope. 8

7. Concealed. 5

6. Sandstone (arkosic): moderate red, coarse-grained; like 8, but conglomerate lenses to 50%. 4

5. Sandstone (arkosic): moderate reddish orange, medium-grained; flat, thin-bedded; weakly cemented with calcite; weathers pale reddish orange; surface blocky; forms slope. 3

4. Concealed. 39

(Strike, N 53° W; dip, 48° SW)

3. Sandstone (arkosic): exposed only in patches in creek bed; pale reddish brown, fine-grained; flat, thin-bedded with minor cross-laminations; weakly cemented with calcite; weathers pale reddish brown; surface platy; forms slope. 35

2. Concealed. 20
1. Conglomerate (pebble): grayish red, single bed; matrix siltstone; clay bond; weathers grayish red; surface pebbly; forms ledge. Pebbles quartz, feldspar, quartzite, minor amounts of limestone and volcanics.

Total thickness of Cretaceous (?) beds. . . . . 399

Fault

Tertiary (?):

Gray rhyolite.
APPENDIX B

TABULATION OF FAUNAS

The following tables contain a generalized list of the faunas present in various zones of the measured sections in the Mustang Mountains. Collections were made as the sections were measured, usually confined to about 50 feet on either side of the line of the section. A roughly quantitative estimate of the abundance of forms is given. If only a single individual was found, it is designated rare (r). If two to five similar forms were found, they are considered uncommon (u). Five to twenty specimens in a zone are designated medial (m). Twenty to fifty are common (c) and more than fifty are abundant (a).

Later detailed study of these faunas will undoubtedly show that many of the forms included under one heading, such as bellerophontids, euomphalids, rhynchonelloids, etc., are of several genera and most of the genera listed include several species. Some groups are listed simply by phylum or class, such as Bryozoa, sponges, Crinoid stems and high-spired gastropods.

The tables are arranged in the same sequence as the descriptions of measured sections. In the tables, the
first column on the left gives the interval in the section; the second column indicates the location of the zone in feet above the base of the interval; the third column shows the distance of the zone above the base of the member; the fourth column shows the correlation of the zone to zones in Sections A or B; and the succeeding columns list the forms present and their abundance. The last column includes forms not listed in the tables and indicates the plate on which the forms from certain zones are illustrated.

Twelve plates have been prepared to illustrate the assemblages of forms found in some of the richer or more noteworthy zones in Sections A, B and G (Pis. 5 through 16).
<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>ZONE</th>
<th>ABOVE BASE OF MEMBER</th>
<th>EQUIVALENT TO ZONE OF SEC. A OR SEC. B</th>
<th>horn</th>
<th>corals</th>
<th>crinoid</th>
<th>stems</th>
<th>Archaeo-cidarids</th>
<th>bryozoa</th>
<th>D. bassi</th>
<th>D. occidentalis</th>
<th>Composite</th>
<th>Chonetes</th>
<th>rhynchonellids</th>
<th>euomphalids</th>
<th>beilerophontids</th>
<th>large gastropods</th>
<th>small gastropods</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>23-31'</td>
<td>521</td>
<td>B-7 20-25'</td>
<td>u</td>
<td>a</td>
<td>u</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>Pl.11,fig.14-36</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>16-19'</td>
<td>514'</td>
<td>m a u</td>
<td>u m</td>
<td>c</td>
<td>m</td>
<td>m</td>
<td>u</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>Pl.11,fig.1-13</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>9-13'</td>
<td>507'</td>
<td>B-7 6-14'</td>
<td>m</td>
<td>a</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>u</td>
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Table 2. Section A, Cave Cliff member.
Table 2. Section A, Cave Cliff member (continued).

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<th>bryozoa</th>
<th>D. bassi</th>
<th>D. occidentalis</th>
<th>Composita</th>
<th>Changites</th>
<th>rhyncho-</th>
<th>mollusces</th>
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Table 2. Section A, Tellez Wash member.

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REMARKS

Pl. 14, fig. 64-74
Pl. 15, fig. 1-11

Pl. 14, fig. 60-63
Meekella (c)

Pl. 14, fig. 50-59
Pl. 14, fig. 42-49
pecten (u)

Pl. 14, fig. 35
Avonia (c)

Pl. 14, fig. 28-34
36-41
Squamularia (c)

Pl. 13, fig. 29-35
Pl. 14, fig. 1-27
Composita zone

Pl. 14, fig. 35
Avonia (c)

Pl. 14, fig. 28-34
36-41
Squamularia (c)

Pl. 13, fig. 29-35
Pl. 14, fig. 1-27
Composita zone
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- Spirifer zone
- Neospirifer (u)
- Derbya (r)
- Avonia (u)
- Red chert zone
- Avonia (m)
- Pelecypods (c)
- Neospirifer (r)
- Avonia (m)
- Pelecypods (m)
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Gastropod zone

* star-shaped Meekella (m)

Spirifer zone

Red chert zone

sponges (c)
Table 6. Section F, Cave Cliff member (continued).

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<td>A-35 23-31'</td>
<td>m c m m m m c u u r m m m</td>
<td>Gastropod zone Pl. 16 Ammonoids (u) Pl. 16</td>
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<td>10-15'</td>
<td>A-35 9-13'</td>
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<td>3</td>
<td>25-31'</td>
<td>A-33 25-32'</td>
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**Table 7. Section G, Cave Cliff member.**
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<td>99'</td>
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<td>A-17</td>
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<td>2-7'</td>
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<td>bryozoa</td>
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<td>312-19'</td>
<td>64'</td>
<td>D. occidentalis</td>
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<td>2-10'</td>
<td>2-7'</td>
<td>Composite</td>
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<td>Chonetes</td>
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<td>24-27'</td>
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<td>12-19'</td>
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<td>small gastropods</td>
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Table 8. Section H, Tellez Wash member.
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<th>INTERVAL</th>
<th>ZONE</th>
<th>ABOVE BASE OF MEMBER</th>
<th>EQUIVALENT TO ZONE OF SEC. A OR SEC. B</th>
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<th>crinoid stems</th>
<th>Archaeocidaris</th>
<th>bryozoans</th>
<th>D. bassi</th>
<th>D. occidentalis</th>
<th>Composite</th>
<th>Chonetes</th>
<th>thyphchomelloids</th>
<th>euomphalids</th>
<th>bellierophontids</th>
<th>large gastropods</th>
<th>small gastropods</th>
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<tr>
<td>8</td>
<td>3-11'</td>
<td>70'</td>
<td>A-16 2-10'</td>
<td>m</td>
<td>m</td>
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REFERENCES CITED


(Tellez Wash limestone member: A-16, 2-3 feet, 7-10 feet; A-17, 0-9 feet)

Figure 1-2. *Avonia subhorrida* nevberri McKee (1938, Pl. 46, fig. 11). No. 3664; A-16, 2-3 feet.

3-4. *Lindstroemia cylindrica* Girty, fide Girty (1908, Pl. 17, fig. 16). No. 3665; A-16, 2-3 feet.

5. *Archaeocidaris* spine. No. 3670; A-16, 7-10 feet.


8. Crinoid stem (star-shaped). No. 3667; A-16, 2-3 feet.


11-12. *Productus (Dictyoclostus)* bassi McKee, fide McKee (1938; Pl. 45, figs. 1-2). No. 6027; A-16, 2-3 feet.


15. Rock fragment with *Archaeocidaris* spine and *Productus (Dictyoclostus)* bassi McKee. No. 3674; A-17, 0-9 feet.

16. *Fenestella hilli* Girty, fide Girty (1908, Pl. 19, fig. 3). No. 3669; A-16, 7-10 feet.
<table>
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<tr>
<th>Figure</th>
<th>Specimen</th>
<th>Location</th>
<th>Description</th>
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<tr>
<td>1-2</td>
<td>Composita subtilita (Hall), fide McKee</td>
<td>A-29, 50-52 feet</td>
<td>No. 3733, (1938, Pl. 48, fig. 20)</td>
</tr>
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<td>3-5</td>
<td>Spiriferina hilli Girty, fide King</td>
<td>A-29, 50-52 feet</td>
<td>No. 4750, (1930, Pl. 42, figs. 1-6)</td>
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<tr>
<td>6-7</td>
<td>Productus (Dictyoclostus) paraindicus McKee</td>
<td>A-29, 50-52 feet</td>
<td>No. 3717, (1938, Pl. 46, fig. 5)</td>
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<td>8-9</td>
<td>Productus (Dictyoclostus) occidentalis Newberry</td>
<td>A-29, 50-52 feet</td>
<td>No. 3728, (1930, Pl. 14, figs. 10-14)</td>
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<td>10</td>
<td>Derbva buchi (d'Orbigny), fide King</td>
<td>A-29, 50-52 feet</td>
<td>No. 3727, (1930, Pl. 8, figs. 4-6)</td>
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<td>11</td>
<td>Polypora mexicana Prout?, fide Girty</td>
<td>A-29, 50-52 feet</td>
<td>No. 3732, (1908, Pl. 19, figs. 11-12)</td>
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<td>12</td>
<td>Virgula neptunia Girty, fide Girty</td>
<td>A-29, 28-30 feet</td>
<td>No. 3718, (1908, Pl. 7, figs. 11-12)</td>
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<td>13</td>
<td>Malonophyllum? sp. Okulitch and Albritton</td>
<td>A-29, 28-30 feet</td>
<td>Shimer and Shrock, (1944, p. 87, Pl. 24, figs. 28-31)</td>
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<td>14</td>
<td>Productus (Dictyoclostus) bassi McKee</td>
<td>A-29, 28-30 feet</td>
<td>No. 3716, (1938, Pl. 45, fig. 1)</td>
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<td>15-18</td>
<td>Avonia dorsoconcava McKee</td>
<td>A-29, 50-52 feet</td>
<td>No. 3735, (1938, Pl. 46, fig. 9)</td>
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<td>19-20</td>
<td>Meekella grandis King</td>
<td>A-29, 50-52 feet</td>
<td>No. 3751, (1930, Pl. 6, fig. 7)</td>
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PLATE 7

(Cave Cliff limestone member: A-30, 7-12 feet, 35-42 feet; A-31, 16-20 feet, 28-36 feet)

Figure 1-2. Orthonema sp. No. 3819; A-30, 7-12 feet.

3-6. Phanerotrema manzanicum Girty, fide Girty (1909, Lee and Girty Pl. 11, figs. 3-4). Figs. 3-4, No. 3810; figs. 5-6, No. 3820; A-30, 7-12 feet.


8-10. Spiriferina hilli Girty, fide King (1930, Pl. 42, figs. 1-6). No. 3812; A-30, 7-12 feet.

11-12. Astartella sp. No. 3816; A-30, 7-12 feet.


14-16. Composita mexicana (Hall), fide King (1930, Pl. 43, figs. 1-11). No. 3814; A-30, 7-12 feet.

17-18. Dielasma spatulatum Girty, fide King (1930, Pl. 44, figs. 17-20). No. 3823; A-30, 7-12 feet.

19-21. Malonophyllum? sp. Figs. 19-20, No. 3815; fig. 21, No. 3835; A-30, 7-12 feet.


26-27. Baylea sp., fide Shimer and Shrock (1944, Pl. 184, figs. 10-12). No. 4852; A-31, 28-36 feet.


29. Straparolus (Euomphalus) pernodosus Meek and Worthen, fide Shimer and Shrock (1944, Pl. 188, figs. 20-22). No. 3779; A-31, 16-20 feet.


34-36. *Composita mexicana* (Hall), fide King (1930, Pl. 43, figs. 1-11). No. 3786; A-31, 28-36 feet.
(Cave Cliff limestone member: A-31, 74–82 feet, 119–124 feet; A-33, 36–40 feet, 90–94 feet)

Figure

1-2. **Bucanopsis? sp.** No. 3807; A-31, 74–82 feet.

3. **Straparolus (Amphiscanha) reedsi** Knight, fide Shimer and Shrock (1944, Pl. 188, figs. 26–28). No. 3589; A-31, 74–82 feet.

4-6. **Baylea? sp.** Fig. 4, No. 3805; figs. 5-6, No. 3798; A-31, 74–82 feet.

7. **Straparolus (Amphiscanha) reedsi** Knight, fide Shimer and Shrock (1944, Pl. 188, figs. 26–28). No. 3441; A-31, 74–82 feet.

8-11. **Malonophyllum? sp.** Figs. 8-9, No. 3701; figs. 10-11, No. 3806; A-31, 119–124 feet.

12-13. **Spiriferina hilli** Girty, fide Girty (1908, Pl. 30, Fig. 15). No. 3427; A-31, 74–82 feet.

14. **Dekayella? sp.,** fide Shimer and Shrock (1944, Pl. 97, fig. 28-29). No. 3809; A-31, 74–82 feet.

15. **Composita arizonica** McKee, fide McKee (1938, Pl. 48, fig. 11). No. 3808; A-31, 74–82 feet.


17-18. **Productus graciosus occidentalis** Schellwien, fide King (1930, Pl. 14, fig. 3). No. 3443; A-31, 74–82 feet.

19. **Productus (Dictyoclostus) paraindicus** McKee, fide McKee (1938, Pl. 46, fig. 5). No. 3804; A-31, 74–82 feet.


22-23. **Waagenoconcha montpeliorënsis** (Girty), fide King (1930, Pl. 19, figs. 5–6). No. 3336; A-33, 36–40 feet.

24-25. **Composita arizonica** McKee, fide McKee (1938, Pl. 48, fig. 10). No. 3757; A-33, 90–94 feet.

27-29. Meekella hessensis King, fide King (1930, Pl. 5, figs. 8-9). No. 3335; A-33, 36-40 feet.

30-31. Malonophyllum? sp. No. 3761; A-33, 36-40 feet.
PLATE 9

(Cave Cliff limestone member: A-33, 25-32 feet; 36-40 feet, 63-68 feet, 90-94 feet; A-34, 0-6 feet, 15-22 feet)

Figure
1-5. **Spirifer** (Neospirifer) pseudocameratus Girty, fide King (1930, Pl. 39, fig. 3). Fig. 1, No. 3706; fig. 2, No. 6104; fig. 3, No. 6105; figs. 4-5, No. 3706a; all from A-33, 25-32 feet.

6-7. **Meekella attenuata** Girty, fide King (1930, Pl. 5, fig. 4). No. 3755; A-33, 90-94 feet.

8-9. **Pugnoides pinguis** (Girty), fide King (1930, Pl. 34, fig. 15). No. 3763; A-33, 63-68 feet.

10-11. **Euomphalus sulcifer** Girty, fide Girty (1908, Pl. 16, fig. 24). No. 3423; A-33, 36-40 feet.

12. **Plagioglypta canna** White, fide Girty (Lee and Girty, 1909, Pl. 11, Fig. 11). No. 3840; A-34, 0-6 feet.


15-17. **Pugnoides pinguis** (Girty), fide King (1930, Pl. 34, fig. 15). No. 3839; A-34, 0-6 feet.

18-19. **Meekella attenuata** Girty, fide King (1930, Pl. 5, fig. 7). No. 3842; A-34, 0-6 feet.

20. **Productus** (Dictyoclostus) occidentalis Newberry, fide King (1930, Pl. 14, figs. 12,14). No. 3681; A-34, 15-22 feet.


23-24. **Composita subtilita** (Hall), fide King (1930, Pl. 44, figs. 1-8). No. 3843; A-34, 0-6 feet.

PLATE 10

(Cave Cliff limestone member: A-35, 1-5 feet)

1. Euomphalus sulcifer Girty, fide Girty (1908, Pl. 16, fig. 24). No. 4647.

2. Bucanopsis modesta Girty, fide Girty (1909, Lee and Girty, Pl. 11, fig. 1). No. 4875.

3-4. Trepospira sp., fide Shimer and Shrock (1944, Pl. 183, figs. 21-23). No. 4873b.


7-9. Pseudozygopleura sp., fide Shimer and Shrock (1944, Pl. 187, fig. 8). Fig. 7, No. 4657; fig. 8, No. 4651; fig. 9, No. 4872a.


13. Foordella? sp. Compare Knight (1941, Pl. 23, fig. 2). No. 4874.

14-16. Trepospira sp., fide Shimer and Shrock (1944, Pl. 183, figs. 21-23). Figs. 4-5, No. 4884a; fig. 16, No. 4858.

17. Composita subtilita (Hall), fide King (1930, Pl. 44, fig. 1). No. 4646.


19-21. Pugnoides swallowianus (Shumard), fide King (1930, Pl. 34, figs. 10-12). No. 4655.


31-33. *Allorisma terminale* Hall, fide Shimer and Shrock (1944, Pl. 165, figs. 10-11). No. 4661.
PLATE II

(Cave Cliff limestone member: A-35, 9-13 feet, 24-31 feet)

Figure

1. **Productus leonardensis** King, fide King (1930, Pl. 14, fig. 6). No. 4613; A-35, 9-13 feet.

2. **Productus (Dictyoclostus) occidentalis** Newberry, fide McKee (1938, Pl. 46, fig. 1). No. 4603; A-35, 9-13 feet.

3. **Derbya arizonensis**? McKee, fide McKee (1938, Pl. 44, figs. 3-4). No. 4602; A-35, 9-13 feet.

4-5. **Composita subtilita** (Hall), fide Girty (1909, Lee and Girty, Pl. 11, fig. 11). No. 4607; A-35, 9-13 feet.


7-9. **Pugnoides pinguis** (Girty), fide King (1930, Pl. 34, fig. 15). No. 4611; A-35, 9-13 feet.

10-11. **Squamularia** sp. Compare Girty (1908, Pl. 14, fig. 7). No. 4609; A-35, 9-13 feet.

12-13. **Squamularia guadalupensis** (Shumard), fide McKee (1938, Pl. 48, fig. 1). No. 4608; A-35, 9-13 feet.

14. **Bellerophon crassus** Meek and Worthen, fide Shimer and Shrock (1944, Pl. 178, figs. 21-22). No. 4881; A-35, 24-31 feet.


17-18. **Productus (Dictyoclostus) occidentalis** Newberry, fide McKee (1938, Pl. 46, fig. 1). No. 4629; A-35, 24-31 feet.

19-21. **Trepospira cf. T. sphaerulata** (Conrad), fide Shimer and Shrock (1944, Pl. 183, figs. 19-20). Fig. 19, No. 4878b; figs. 20-21, No. 4878; A-35, 24-31 feet.

22-23. **Malonophyllum**? sp. No. 4630; A-35, 24-31 feet.

24-25. **Composita subtilita** (Hall), fide McKee (1938, Pl. 48, fig. 20). No. 4627; A-35, 24-31 feet.

29-30. _Soleniscus_ sp. Compare Girty (1909, Lee and Girty, Pl. 11, fig. 6). No. 4878a; A-35, 24-31 feet.

31. _Helicospira_? sp. Compare Knight (1941, Pl. 43, fig. 3). No. 4882; A-35, 24-31 feet.

32-34. _Pleurophorus mexicanus_ Girty, _fide_ Girty (1909, Lee and Girty, Pl. 10, fig. 1). No. 4618; A-35, 24-31 feet.

PLATE 12

(Cave Cliff limestone member: A-35, 24-31 feet; B-7, 6-14 feet)

Figure 1-2. Orthonema soconensense Girty (1909, Lee and Girty, Pl. 11, fig. 13). Fig. 1, No. 4624; fig. 2, No. 4625; A-35, 24-31 feet.

3-5. Worthenia sp. Fig. 3, No. 4624a; fig. 4, No. 4632; fig. 5, No. 4624b; A-35, 24-31 feet.

6-7. Hustedia meekana (Shumard), fide King (1930, Pl. 42, figs. 34, 37). No. 4622; A-35, 24-31 feet.

8-9. Composita mira (Girty), fide King (1930, Pl. 44, fig. 5). No. 4634; A-35, 24-31 feet.

10-11. Pugnoides swallovianus (Shumard), fide King (1930, Pl. 34, fig. 11). No. 4615; A-35, 24-31 feet.


14-15. Malonophyllum sp. No. 4919; B-7, 6-14 feet.

16-20. Pleurophorus mexicanus Girty, fide Girty (1909, Lee and Girty, Pl. 10, fig. 1). Fig. 16, No. 6057; fig. 17-18, No. 6067; fig. 19-20, No. 6055; B-7, 6-14 feet.

21. Euomphalus sulcifer var. angulatus Girty (1908, Pl. 16, fig. 25). No. 4754; B-7, 6-14 feet.

22. Aviculopecten? sp. No. 4923; B-7, 6-14 feet.


25-26. Composita subtilita (Hall), fide McKee (1938, Pl. 48, fig. 20). No. 4751; B-7, 20-26 feet.

27-28. Squamularia guadalupensis (Shumard), fide McKee (1938, Pl. 48, fig. 1). No. 4763; B-7, 6-14 feet.

29-34. Nucula levatiformis Walcott, fide Girty (1909, Lee and Girty, Pl. 10, fig. 7). Fig. 29-31, No. 4921; fig. 32-34, No. 4752a; B-7, 6-14 feet.
35. **Aviculopecten** sp. Compare Shimer and Shrock (1944, PI. 159, fig. 20). No. 3352; B-7, 6-14 feet.

36. **Astartella subquadrata** Girty, fide Girty (1909, Lee and Girty, PI. 10, figs. 10-12). No. 4922; B-7, 6-14 feet.

37-38. **Shansiella planicostata** (Girty), fide Shimer and Shrock (1944, PI. 185, figs. 9-10). No. 4762a; B-7, 6-14 feet.

39-42. **Baylea** sp. Compare Shimer and Shrock (1944, PI. 184, figs. 11-12). Fig. 39-41; No. 4756a; fig. 42, No. 4759a; B-7, 6-14 feet.

43-44. **Glabrocingulum** sp. Compare Shimer and Shrock (1944, PI. 184, fig. 21). No. 4760; B-7, 6-14 feet.

45-46. **Naticopsis** sp. No. 4756b; B-7, 6-14 feet.

47. **Pseudozygopleura** sp. fide Shimer and Shrock (1944, PI. 187, fig. 8). No. 4769b; B-7, 6-14 feet.

48-49. **Shansiella planicostata** (Girty), fide Shimer and Shrock (1944, PI. 185, figs. 9-10). No. 4757; B-7, 6-14 feet.

50. **Trepspira** cf. **T. sphaerulata** (Conrad), fide Shimer and Shrock (1944, PI. 183, figs. 19-20). No. 4916; B-7, 6-14 feet.
(Cave Cliff limestone member: B-6, 87-91 feet; B-7, 20-26 feet. Quail Peak limestone member: B-22, 0-5 feet)

Figure

1-2. Marginifera popei (Shumard), fide McKee (1938, Pl. 47, fig. 6). No. 3302; B-7, 20-26 feet.

3-6. Derbya? sp. No. 3578; B-7, 20-26 feet.

7-9. Composita mira (Girty) fide King (1930, Pl. 44, fig. 6). No. 3579; B-7, 20-26 feet.

10. Derbya? sp. No. 3573a; B-7, 20-26 feet.

11-12. Dielasma spatulatum Girty, fide King (1930, Pl. 44, fig. 15). No. 4931; B-7, 20-26 feet.

13-14. Composita arizonica var. McKee, fide King (1938, Pl. 48, fig. 17). No. 4751; B-7, 20-26 feet.

15-17. Goniasma sp. Compare Knight (1941, Pl. 42, fig. 6). Fig. 15-16, No. 3575a; fig. 17, No. 3575c; B-7, 20-26 feet.

18-19. Omphalotrochus? sp. Compare Knight (1941, Pl. 77, figs. 3-5). No. 4855; B-7, 20-26 feet.

20. Soleniscus sp. Compare Girty (1909, Lee and Girty, Pl. 11, fig. 6). No. 4864; B-7, 20-26 feet.


24. Foordella? sp. Compare Knight (1941, Pl. 23, fig. 3). No. 4928; B-7, 20-26 feet.

25. Goniasma sp. No. 3575b; B-7, 20-26 feet.

26-27. Meekella grandis King, fide King (1930, Pl. 6, fig. 7). No. 3467; B-6, 87-91 feet.

28,36. Meekella globosa King, fide King (1930, Pl. 5, fig. 12). No. 3439; B-6, 87-91 feet.

29-31. Productus (Dictyoclostus) occidentalis Newberry, fide McKee (1938, Pl. 46, figs. 1-4). No. 3491; B-22, 0-5 feet.
32-33. *Avonia costata* R. E. King, fide Cloud (1944, King, Dunbar, Cloud and Miller, Pl. 17, figs. 11-12). No. 4797; B-22, 0-5 feet.

34-35. *Chonetes kaibabensis* McKee, fide McKee (1938, Pl. 44, fig. 5). No. 3605; B-22, 0-5 feet.
PLATE 14

(Quail Peak limestone member: B-22, 0-5 feet; B-24, 0-3 feet; B-25, 2-24 feet; B-29, 2-6 feet)

Figure

2-6. **Composita subtilita** (Hall), fide King (1930, Pl. 44, fig. 6). Fig. 2, No. 4802; fig. 3-4, No. 4798; fig. 5-6, No. 4801a; B-22, 0-5 feet.

7-9. **Composita arizonica var.** McKee, fide McKee (1938, Pl. 48, figs. 17-18). No. 4801; B-22, 0-5 feet.

10. **Squamularia guadalupensis** (Shumard), fide McKee (1938, Pl. 48, fig. 2). No. 4800; B-22, 0-5 feet.

11-15. **Camarophoria deloi** King, fide King (1930, Pl. 34, fig. 27). Fig. 11-13, No. 6017; fig. 14-15, No. 6012; B-22, 0-5 feet.

16-24. **Pugnoides swallovianus** (Shumard), fide King (1930, Pl. 34, fig. 12). Fig. 16-17, No. 6014; fig. 18-21, No. 6016; fig. 22-24, No. 6011; B-22, 0-5 feet.

25-27. **Squamularia guadalupensis** (Shumard), fide Girty (1908, Pl. 14, fig. 7). No. 3485; B-22, 0-5 feet.

28. **Acanthopecten carboniferus** (Stevens), fide Shimer and Shrock (1944, Pl. 159, fig. 27). No. 4776; B-24, 0-3 feet.

29. **Aviculopecten** sp. No. 4775; B-24, 0-3 feet.

30-31. Pattelloid gastropod. No. 4853; B-24, 0-3 feet.

32-34. **Squamularia guadalupensis** (Shumard), fide McKee (1938, Pl. 48, fig. 1). No. 3566; B-24, 0-3 feet.

35. **Aviculopecten** sp. No. 4785; B-25, 2-6 feet.

36-37. **Marginifera cristobalensis** Girty, fide King (1930, Pl. 21, fig. 20). No. 4824a; B-24, 0-3 feet.
38-39. Marginifera popei (Shumard), fide McKee (1938, Pl. 47, fig. 6). No. 4824; B-24, 0-3 feet.

40-41. Composita arizonensis var. McKee, fide McKee (1938, Pl. 48, fig. 17). No. 4772; B-24, 0-3 feet.

42-43. Spiriferina hilli Girty, fide Girty (1908, Pl. 30, fig. 15). No. 4815; B-25, 8-12 feet.

44-46. Camarophoria deloi King, fide King (1930, Pl. 34, fig. 25). No. 4814; B-25, 8-12 feet.

47-49. Composita arizonica var. McKee, fide McKee (1938, Pl. 48, fig. 17). No. 4816; B-25, 8-12 feet.

50-52. Spiriferina hilli Girty (1908, Pl. 30, fig. 15). No. 3505; B-25, 14-18 feet.

53-54. Marginifera cristobalensis Girty, fide King (1930, Pl. 21, fig. 20). No. 3503a; B-25, 14-18 feet.

55-58. Dileasma spatulatum Girty, fide Girty (1908, Pl. 17, fig. 16). No. 3503; B-25, 14-18 feet.

59. Lindstroemia cylindrica Girty, fide Girty (1908, Pl. 17, fig. 16). No. 3503; B-25, 14-18 feet.

60. Acanthopecten coloradoensis (Newberry), fide Shimer and Shrock (1944, Pl. 159, fig. 25). No. 3475; B-25, 20-24 feet.

61-63. Composita arizonica McKee, fide McKee (1938, Pl. 48, fig. 11). No. 4931; B-25, 20-24 feet.

64-66. Pugnoides pinguis (Girty), fide King (1930, Pl. 34, fig. 15). No. 4933; B-29, 2-6 feet.

67-70. Camarophoria deloi King, fide King (1930, Pl. 34, fig. 25). Fig. 67-68, No. 4935; fig. 69-70, No. 4936; B-29, 2-6 feet.

71-74. Pugnoides pinguis (Girty), fide King (1930, Pl. 34, fig. 15). No. 4937; B-29, 2-6 feet.
PLATE 15

(Quail Peak limestone member: B-13, 4-12; B-29, 2-6 feet)

Figure

1-3. Composita arizonica var. McKee, fide McKee (1938, Pl. 48, figs. 17-18). No. 3415; B-29, 2-6 feet.

4-9. Hustedia pusilla (Girty), fide King (1930, Pl. 42, fig. 21). Fig. 4-6, No. 4932a; fig. 7-9, No. 4932; B-29, 2-6 feet.


12. Nautiloid. No. 6120; B-13, 4-12 feet.
PLATE 16

(Cave Cliff limestone member: G-5, 10-28 feet)

Figure


3-4. Bellerophon sp. No. 6076.


11-12. Bellerophon sp. Compare Knight (1941, Pl. 11, fig. 3d). No. 6103.


15-20. *Pleurophorus mexicanus* Girty, fide Girty (1909, Lee and Girty, Pl. 10, fig. 1). Fig. 15-17, No. 6058; fig. 18-20, No. 6090.

21. Rock fragment with *Goniasma* sp., *Pseudozygopleura* sp., *Trepospira* sp. and *Baylea* sp. No. 6078.

22. *Pseudozygopleura* sp. No. 6088.


26-31. *Sauamularia* sp. Compare Girty (1908, Pl. 14, fig. 7). Fig. 26-28, No. 6079a; fig. 29-31, No. 6079.

32. *Aviculopecten* sp. No. 6109.

33-35. *Goniasma* sp. Compare Knight (1941, Pl. 42, fig. 6d). No. 6102.

36-38. Shansiella? sp. Compare Shimer and Shrock (1944, Pl. 185, figs. 9-10). No. 6086.

Figure 1.

Cave Cliff from the south across Tellez Wash.

Four members of the Snyder Hill formation shown where Section A was measured: White sandstone (Csw), Tellez Wash limestone (Cstw), Pink sandstone (Csp) and Cave Cliff limestone (Cscc) members.

Figure 2.

Raven Peak and Pointed Peak from the east across Rainbow Wash.

Shows the high, steep cliffs developed in the Cave Cliff limestone member of the Snyder Hill formation. Raven Peak to the south (left) and Pointed Peak to the north (right). North slope of Lava Ridge in the left foreground.
Figure 1.

Figure 2.
Figure 1.
Rainbow Ridge from the southeast.

**Strata of the Cave Cliff limestone member of the Snyder Hill formation dip 50 degrees northeast forming a hogback.**

Figure 2.
Quail Peak from the southeast across Tank Wash.

Flat-lying beds of the Quail Peak limestone member of the Snyder Hill formation are eroded into a series of steps. Shows the Quail Peak limestone (Csqp) and Cave Cliff limestone (Cscc) members where Section B was measured. Tertiary (?) rhyolite (Tr) caps Quail Peak.
Figure 1.

Figure 2
PLATE 1

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY

Unconformity

CRETACEOUS

Unconformity

PERMIAN

ALLUVIUM

CLASTIC ROCKS

Sandstone, siltstone, conglomerate, mostly red

QUAIL PEAK LIMESTONE MEMBER

Thin-bedded limestone variegated, mostly gray

CAVE CLIFF LIMESTONE MEMBER

Massive gray, very cherty in lower portion

PINK SANDSTONE MEMBER

TELLEZ WASH LIMESTONE MEMBER

Massive gray limestone, cherty, in part magnesian

WHITE SANDSTONE MEMBER

QUARTZITE, LIMESTONE, Siltstone

IGNEOUS ROCKS

TERTIARY (?)

RHYOLITE VOLCANICS

RHYOLITE PORPHYRY

intrusive

STRIKE AND DIP

CONTACT

OVER-THRUST FAULT

Over-riding block indicated

FAULT

LINE OF MEASURED SECTION

AREAL GEOLOGY

OF THE

MUSTANG MOUNTAINS

SANTA CRUZ COUNTY, ARIZONA

SCALE: 1:10,000

CONTOUR INTERVAL 100 FEET
PLATE 2

GEOLOGIC SECTIONS OF THE MUSTANG MOUNTAINS

(TO ACCOMPANY GEOLOGIC MAP)

D.L.B. April 1950
EXPLANATION

- Quaternary alluvium
- Tertiary (?) volcanics, mainly brown & pink rhyolite
- Cretaceous (?) brown & red sandstone
- Tertiary (?) purple rhyolite porphyry sill
- Cretaceous (?) purple & red siltstone & sandstone, conglomeratic toward top
- Cretaceous (?) purple & gray conglomerate
- Permian variegated, thin-beded limestone; magnesian in part
- Permian thick-beded to massive gray limestone; magnesian in part
- Permian variegated & nodular chert; relative percentage of chert indicated; each nodule symbol shows approximately 5% chert
- Permian white to red sandstone; cross-laminated in part as indicated

GENERALIZED GEOLOGIC COLUMN OF THE ROCKS OF THE MUSTANG MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

D.L.B. 1951
STRATIGRAPHIC SECTIONS OF THE PERMIAN ROCKS OF THE MUSTANG MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

Donald L. Bryant - July 1950