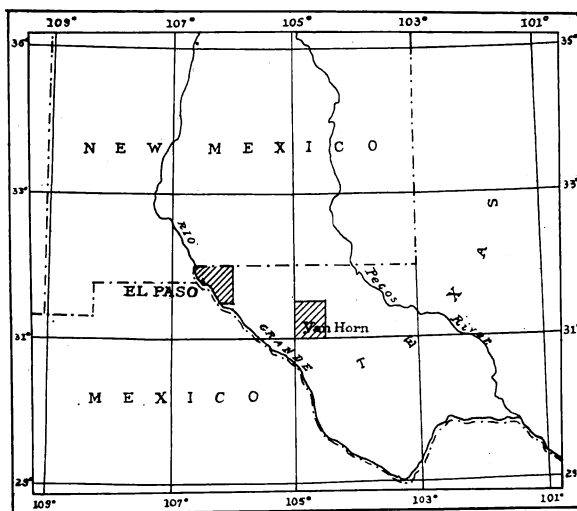


ART. XLIX.—*Paleozoic Formations in Trans-Pecos Texas ;*
by G. B. RICHARDSON.*

THE presence of Paleozoic rocks in trans-Pecos Texas has been known since the middle of the last century, when fossils were collected by the surveying parties engaged in exploring routes for a Pacific railway and in establishing the boundary between the United States and Mexico.† In 1874 W. P. Jenney‡ measured a section of the rocks in the Franklin Mountains, north of El Paso, and called attention to the long Paleozoic sequence there exposed, which in 1896 was also examined by C. D. Walcott. W. H. von Streeruwitz and E. T. Dumble made a number of references to the Paleozoic rocks



in the vicinity of Van Horn, in the reports of the Geological Survey of Texas, 1890-93, but that organization was discontinued before correlations and maps were published.

An important result of the early surveys was the determination by the Shumard brothers§ of the presence of a Permian

* Published by permission of the Director of the U. S. Geological Survey.

† Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, vol. ii, Washington, 1855. Report of the United States and Mexican Boundary Survey, by Wm. H. Emory, vol. i, part 2, Washington, 1857.

‡ This Journal (3), vii, p. 25, 1874.

§ Transactions St. Louis Academy of Science, vols. i and ii, 1860, 1868.

fauna in the Guadalupe Mountains, near the Texas-New Mexico boundary about 60 miles west of Pecos River. R. S. Tarr disagreed with this conclusion,* but G. H. Girty in 1901 confirmed the early work,† and he has described the unique fauna in an elaborate report which is now in press.‡ And in 1904, J. A. Udden reported the presence of Carboniferous rocks in the Chinati Mountains in Presidio County.§

The present writer in 1903 made a reconnaissance of that portion of trans-Pecos Texas in which the greater part of the Paleozoic rocks are exposed,|| and later, in connection with the survey of the El Paso and Van Horn quadrangles, had an opportunity to map the formations in detail and to collect fossils. These have been examined by Messrs. C. D. Walcott, E. O. Ulrich and G. H. Girty, and the writer is particularly indebted to Dr. Girty, who accompanied him in the field both in the El Paso and Van Horn regions.

The formations which are the subject of this paper outcrop in the Franklin and Hueco Mountains in the El Paso quadrangle, and in the Sierra Diablo, Delaware Mountains and associated groups of hills in the Van Horn quadrangle. These two quadrangles, which have recently been mapped by the U. S. Geological Survey, are situated about 60 miles apart and they include practically all of the known occurrences of lower Paleozoic rocks in trans-Pecos Texas. The following table summarizes the Paleozoic formations in the El Paso and Van Horn quadrangles:

CAMBRIAN.

Bliss Sandstone.

The main occurrence of the Bliss sandstone is along the eastern slopes of the Franklin Mountains, but the considerable faulting to which the range has been subjected causes its distribution to be very irregular. The Bliss is a massive, fine-textured, brownish sandstone that varies from a few feet to slightly more than 300 feet in thickness. The lower beds are indurated and are practically quartzites and at the base of the formation the strata are coarser textured, locally are conglomeritic and contain pebbles of the underlying rocks. The sandstone is composed of small grains of quartz imbedded in a matrix of sericite and kaolin. In places the Bliss sandstone

* Reconnaissance of the Guadalupe Mountains, Bull. No. 3, Geol. Survey of Texas, 1892.

† This Journal (4), xiv, p. 363.

‡ The Guadalupian fauna, U. S. Geol. Sur., Prof. Paper No. 58.

§ The Geology of the Shafter Silver Mine District, Bull. No. 8, University of Texas Mineral Survey, 1904.

|| Report of a reconnaissance in trans-Pecos Texas north of the Texas and Pacific Railway, Bull. No. 9, University of Texas Mineral Survey, 1904.

Table of Paleozoic formations in the El Paso and Van Horn Quadrangles, Texas.

El Paso quadrangle	Thick-ness	Sys-tem	Series	Thick-ness	Van Horn quadrangle
Absent		Carboniferous	Permian ?	500 +	Capitan limestone
Absent			(Guadalupian)	2000 +	Delaware Mountain formation
Hueco limestone	3000		Pennsylvanian	2500 +	Hueco limestone
Absent			Mississippian		Absent
Absent		Devonian			Absent
Fusselman limestone	1000	Silurian	(Niagara)		Absent
Montoya limestone	250	Ordovician	Upper and Middle Ordovician	250	Montoya limestone
El Paso limestone	1000		Lower Ordovician	750	El Paso limestone
Bliss sandstone	0 to 300	Cambrian	Saratogan or Acadian	0 to 700	Van Horn sandstone

is in contact with granite of post-Carboniferous age and elsewhere it rests on rhyolite porphyry, of which it contains rounded pebbles in the basal beds. In the central part of the Franklin Mountains the sandstone thins out and locally disappears, and the overlying limestone, containing a basal conglomerate, lies directly on the rhyolite porphyry.

Annelid borings both perpendicular and parallel to the bedding occur abundantly in the Bliss sandstone. Other fossils are rare, but in places in the lower strata some brachiopod shells have been found. Of these Mr. Walcott has identified *Lingulepis acuminata*, *Obolus matinalis* (?) and fragments of *Lingulella* which determine the Cambrian age of the rocks and indicate that either the upper or middle division of the system is here represented.

Van Horn Sandstone.

The Van Horn is a medium to coarse-textured cross-bedded sandstone that is banded with thin lenses of conglomerate. The formation is of a prevailing brick-red color in its lower part, which becomes paler towards the top, where the color fades away and the sandstone is white. The conglomerate lenses vary from a few inches to about a foot in thickness and are irregularly distributed throughout the formation. At the base the pebbles are composed of fragments of the underlying rocks and consist of quartz schist, fine-textured red sandstone, cherty limestone, porphyry and quartz, while the conglomerate in the upper part of the formation consists chiefly of well rounded quartz pebbles. The sandstone likewise varies in composition; its lower part being composed of quartz and decomposed feldspar grains while the upper portion is prevailingly quartzose. The formation varies from a few feet to 700 feet in thickness and averages about 400 feet.

The Van Horn sandstone unconformably overlies highly tilted metamorphosed rocks and is overlain in places by the El Paso limestone (Ordovician), and elsewhere by the Hueco limestone (Carboniferous). The upper part of the formation contains numerous annelid borings and fucoid-like remains, but no characteristic fossils have been found in the sandstone and its age therefore is undetermined.

The presence of sandstone at the base of the Paleozoic section in southwestern United States has been noted wherever observations have been made, and it is suggested that the Bliss and Van Horn sandstones are the probable equivalent of the Tonto sandstone of the Grand Canyon, the Bolsa quartzite of Bisbee, the Coronado quartzite of Clifton, the Reagan sandstone of Oklahoma and the Cambrian sandstone of the Central Texas Paleozoic area.

ORDOVICIAN.

El Paso Limestone.

The El Paso limestone outcrops in the Franklin and Hueco Mountains in the El Paso quadrangle and in Beach and Baylor Mountains in the Van Horn quadrangle. The formation is

typically a massive gray magnesian limestone which contains the same fauna in both regions. In the El Paso area the formation is about 1000 feet thick, the lower 100 feet of which is characteristically arenaceous and weathers brownish. A distinctive feature of the middle portion of the formation is the presence of thin connected nodules of brown chert arranged in irregular streaks parallel to the bedding. This limestone lies apparently conformably on the Bliss sandstone, but, as already stated, in the central part of the Franklin Mountains the Bliss sandstone is locally absent and the El Paso limestone rests directly on pre-Cambrian (?) rocks with a basal conglomerate varying up to 20 feet thick composed of rounded pebbles of rhyolite porphyry in a calcareous matrix. In the Van Horn quadrangle the El Paso limestone does not contain the cherty layers that are characteristic of the middle parts of the formation in the Franklin Mountains, and 50 feet above the base of the formation a thin bed of white sandstone is present. In this region there are indications of an unconformity at the base of the limestone marked by a slight undulatory contact between the El Paso and Van Horn formations.

Mr. Ulrich reports that the fossils obtained from the El Paso limestone in both the El Paso and Van Horn quadrangles represent essentially the same Beekmantown fauna. Most of the species are undescribed, but all are of unmistakable types. The more characteristic forms are the following:

Calathium, sp. nov. (coral-like sponge), *Maclurea* ? sp. nov. The small horn-like opercula are very common. The shell itself is of the type of *M. oceana* Billings. Solid siphuncles of endoceratoid cephalopod, evidently a close ally of *Camero-ceras brainardi*. Besides these there are a number of less easily recognized small gastropods.

Montoya Limestone.

The Montoya limestone also has been recognized by its stratigraphic position and fossils in both of the quadrangles. This limestone contains two distinct Ordovician faunas, the Richmond and Galena, and on paleontologic grounds it is desirable to separate the two, but the small thickness of the formation, only about 250 feet, and the scale of the maps will not admit of it.

Fossils characteristic of the Galena occur in the lower part of the Montoya limestone, the zone being commonly marked in the El Paso quadrangle by massive dark-colored limestone containing little or no chert. The upper part of the limestone is prevailingly gray, but some of the beds are almost white

while others are dark, and the two parts of the formation can not always be distinguished lithologically. The zone which carries the most abundant Richmond fossils in places is seamed with conspicuous bands of chert a few inches in thickness. In the Van Horn quadrangle the base of the Montoya limestone is commonly marked by the presence of thin-bedded earthy yellow and reddish limestone, but otherwise in both quadrangles the contact is apparently conformable. Like the El Paso limestone, the Montoya is characteristically magnesian. Mr. Ulrich has identified the following fossils from the Montoya limestone:

Fossils from the Galena beds.

<i>Receptaculites oweni.</i>	<i>Hormotoma major.</i>
<i>Machurina manitobensis.</i>	<i>Ormoceras</i> sp. undet.
<i>Machurina acuminata.</i>	

Fossils from the Richmond beds.

<i>Streptelasma rusticum.</i>	<i>Dinorthis proavita.</i>
<i>Hemiphragma imperfectum.</i>	<i>Platistrophia acutilaterata.</i>
<i>Monotryprella quadrata.</i>	<i>Rhynchotrema capax.</i>
<i>Strophomena flexuosa.</i>	<i>Orthis whitfieldi.</i>
<i>Leptaena unicastata.</i>	<i>Parastrophia divergens.</i>
<i>Dinorthis subquadrata.</i>	

In southwestern United States outside of the areas here considered few Ordovician rocks are known. The system apparently is not represented by sediments in either the Grand Canyon or Bisbee districts. The Longfellow formation in the Clifton quadrangle, Arizona, probably should be correlated with the El Paso limestone as well as a part of the Ordovician limestone in the central Texas region. Recently several small areas of Ordovician rocks have been reported in central New Mexico by Gordon and Graton.* Mr. Ulrich reports that the Beekmantown fauna of the El Paso limestone is of the type prevailing in the Wichita Mountains, Oklahoma, in the upper 1,000 feet or so of the Arbuckle limestone; and that the Galena and Richmond fauna of trans-Pecos, Texas, are similar to those in the Mississippi valley, Oklahoma, the Black Hills, the Big Horn Mountains, and elsewhere.

SILURIAN.

Fusselman Limestone.

The Silurian system in trans-Pecos Texas is represented only in the El Paso region, where the Fusselman limestone outcrops in the Franklin and Hueco Mountains. This is a massive

* This Journal (4), xxi, p. 190, 1906.

whitish magnesian limestone approximately 1000 feet thick. It overlies the Montoya limestone apparently conformably, although in one locality fragments of the underlying limestone included in the Fusselman is evidence of an unconformity. Throughout the greater part of the formation fossils are scarce, but at a few horizons they are very abundant. The commonest form is a species of radially plicated pentameroid shell which, with *Amplexus* and *Favosites*, determined by Mr. Ulrich, proves that the upper Niagaran stage of the Silurian is here represented. Gordon and Graton* have recently found Silurian fossils in the Silver City region and at Lake Valley, New Mexico; and Taff's Hutton formation in Oklahoma† also contains a Silurian fauna. But with these exceptions the Fusselman limestone is the only known occurrence of rocks of Silurian age in southwestern United States.‡

CARBONIFEROUS.

Hueco Limestone.

Neither the Devonian nor the Lower Carboniferous, so far as known, is represented by sediments in trans-Pecos Texas, and the Silurian, where present, is overlain by the Upper Carboniferous. The Hueco limestone outcrops in an area of several hundred square miles in trans-Pecos Texas. It underlies the Diablo Plateau, a large area between the El Paso and Van Horn quadrangles, and outcrops in the Sierra Diablo, Finlay, Hueco and Franklin Mountains. The Hueco is a rather homogeneous gray limestone, generally massive, though in places it is thin-bedded. It is comparatively free from chert and differs from the limestones of Silurian and Ordovician age in that it contains little or no magnesia. Although the limestone is pre-vailingly gray, there are local variations in color from light gray to almost black.

In the Franklin and Hueco Mountains the Hueco limestone immediately overlies the Fusselman limestone apparently conformably in spite of the fact of the great hiatus indicated by their ages. But in the Van Horn region a well developed basal conglomerate averaging approximately one hundred feet in thickness and composed of pebbles of all of the pre-Carboniferous formations is present at the base of the limestone, which rests with marked irregularity on the underlying formation. The Hueco limestone generally is overlain by Pleistocene debris, but in a few areas, notably in the Finlay Mountains, and also eight miles northwest of Van Horn, it is directly overlain by Cretaceous strata. The total thickness of

* Quoted above.

† Tishomingo Folio, U. S. Geological Survey, 1903.

‡ Kindle, E. M., this Journal (4), xxv, pp. 125-129, 1908.

the Hueco limestone has not yet been determined, but it is more than 3000 feet.

The Hueco limestone carries an abundant fauna of Pennsylvanian age, of which the following, identified by G. H. Girty, is a partial list. According to Dr. Girty, this fauna with some modifications is similar to that found over much of the Cordilleran region, and the Hueco limestone is tentatively correlated with the Aubrey formation and the Weber quartzite.*

List of fossils from the Hueco limestone.

- Fusulina*, several sp.
- Archæocidaris* cf. *A. biangulata* Shum.
- Azophyllum* sp.
- Fistulipora* sp.
- Septopora* sp.
- Schizophoria* sp.
- Enteletes* cf. *E. hemiplicatus* Hall.
- Orthotetes* sp.
- Productus* cf. *P. inflatus* Tsch., non McChesney.
- Productus* cf. *pustulatus* Keys.
- Productus* cf. *P. longus* Tsch., non Meek, and *P. porrectus* Kut.
- Productus*, cf. *P. irginae* Stuck.
- Productus*, several sp. type of *P. semireticulatus* Martin.
- Marginifera*, cf. *M. wabashensis* Nor. and Pratt.
- Spirifer*, cf. *S. marcoui* Waagen.
- Spirifer*, cf. *S. cameratus* Morton.
- Squamularia* (?) sp.
- Spiriferina* cf. *S. cristata* Schlot.
- Seminula*, cf. *S. subtilita* Hall.
- Hustedia*, cf. *H. Mormoni* Marcou.
- Camarophoria* cf. *C. mutabilis* Tsch.
- Pugnax*, cf. *P. utah* Marcou.
- Dielasma*, cf. *D. truncatum* Waagen.
- Myalina* sp.
- Naticopsis* sp.
- Euomphalus* sp. (large.)
- Omphalotrochus obtusispira* Shumard.
- Bellerophon* sp.
- Patellostium*, cf. *P. Montfortainum* Nor. and Pratt.
- Phillipsia* sp.

GUADALUPIAN.

In the Van Horn quadrangle and north of it the bolson plain known as Salt Flat, which is occupied by an unknown depth of unconsolidated Quaternary deposits, lies between the Sierra Diablo on the west and the Guadalupe-Delaware Mountains on the east and completely conceals the relations of

* Proceedings Washington Academy of Sciences, vol. vii, p. 14, 1905.

the rocks in the two mountains. As has been stated, the Sierra Diablo is made up of the Hueco limestone, the stratigraphic top of which has not been observed. And the Guadalupe-Delaware Mountains are composed of Paleozoic strata, younger than the Pennsylvanian, which contain a fauna not elsewhere known in North America, that Girty has named Guadalupian. This fauna, which has Permian affiliations, is described by Dr. Girty in a paper now in press, and it is intended here only to outline the stratigraphy of these rocks, which complete the long Paleozoic sequence of trans-Pecos Texas.

Delaware Mountain Formation.

The Delaware Mountain formation includes a varying mass of sandstone and limestone having a maximum thickness of at least 2300 feet, but the base of the formation is not exposed in Texas and has not been determined. In the northern part of the Guadalupe-Delaware Mountain uplift, the formation is prevailingly sandy and contains only thin beds and lenses of limestone. Southward the sandstone decreases and the limestone increases in amount until, in the southern part of the main Delaware Mountains, the formation consists of gray limestone with only subordinate beds and lenses of sandstone. The sandstone is a massive to thin-bedded buff to brownish quartzose rock and the limestone likewise is both thick and thin-bedded, of a prevailing gray color, and contains little chert. The following fossils, determined by Dr. Girty, are characteristic of the Delaware Mountain formation:

List of fossils from the Delaware Mountain formation.

<i>Fusulina elongata.</i>	<i>Astartella nasuto.</i>
<i>Productus Guadalupensis.</i>	<i>Pleurophorous Delawarensis.</i>
<i>Productus Meekanus.</i>	<i>Pleurotomaria englyphia.</i>
<i>Productus Walcottianus.</i>	<i>Pleurotomaria arenaria.</i>
<i>Richthofenia Permiana.</i>	<i>Warthia Americana.</i>
<i>Myoconcha costulata</i> var.	<i>Gastrioceras serratum.</i>

Capitan Limestone.

In the Guadalupe Mountains, 60 miles north of Van Horn, about 2200 feet of the Delaware Mountain formation is conformably overlain, in a magnificently exposed section, by 1800 feet of limestone named the Capitan limestone. The name is taken from El Capitan Peak, which, having an elevation of 8690 feet,* is the highest point in Texas. The Capitan is a light colored, usually white limestone which, although possessing minor variations, is homogeneous in general appearance. Bedding planes in many places are not appa-

* Recently determined by Arthur Stiles.

rent and the rock is characteristically massive. Chemically it is of variable composition, some analyses showing the presence of considerable magnesium while others indicate its almost complete absence. Besides its main occurrence in the Guadalupe Mountains the Capitan limestone was determined in 1907 to be present in the southern end of the Delaware Mountains, where it has been faulted down and adjoins the limestone of the Delaware Mountain formation. R. S. Tarr reports, in the paper cited above, the presence of 1000 feet or more of sandstone lying above the Capitan formation, but these rocks have not been studied, so that neither the base nor the top of the strata bearing the Guadalupian fauna has yet been determined. It is expected that these relations can be determined in the northward continuation of the formations in the Sacramento Mountains of New Mexico. The following is a short list of fossils typical of the Capitan limestone determined by Dr. Girty:

List of fossils from the Capitan limestone.

<i>Fusulina elongata</i>	<i>Squamularia Guadalupensis</i>
<i>Orthotetes Guadalupensis</i>	<i>Spiriferina pyramidalis</i>
<i>Chonetes Hillanus</i>	<i>Composita emarginata</i>
<i>Productus latidorsatus</i>	<i>Pugnax Swallowiana</i>
<i>Productus pinniformis</i>	<i>Dielasma spatulatum</i>
<i>Richthofenia Permiana</i>	<i>Heterelasma Shumardianum</i>
<i>Spirifer Mexicanus</i>	<i>Leptodus Guadalupensis</i>

Résumé.

In both the El Paso and Van Horn quadrangles the basal Paleozoic strata are sandstones which lie unconformably on pre-Cambrian rocks. These conditions are in accord with observations elsewhere in southwestern United States, where part of late Cambrian time was characterized by the deposition of coarse arenaceous sediments in a sea which was advancing on an old land surface. The succeeding record is of subsidence, interrupted by probable emergences, and of the accumulation in Ordovician, Silurian, and Upper Carboniferous time of a great mass of limestone exceeding 5000 feet in thickness. The presence in this limestone of five distinct faunas representing the Beekmantown, Galena, Richmond, Niagara, and Pennsylvanian stages, and the absence of the intervening faunas which are present in the complete Paleozoic section, imply a number of unconformities to account for the hiatuses, yet these are not lithologically well marked and their exact stratigraphic positions generally are unrecognizable. It is especially noteworthy that in the Franklin Mountains Upper Carboniferous

(Hueco) limestone lies with apparent conformity on Silurian (Fusselman) limestone. The absence of the intermediate series between the Cambrian and Pennsylvanian in the two quadrangles points to several uplifts which in general did not appreciably deform the rocks, and apparently the emergences were so slight that there is little record of erosion. But in the Van Horn region there is abundant evidence of profound pre-Pennsylvanian erosion, for the Hueco limestone with a well-developed basal conglomerate rests indifferently on all of the underlying formations. The deposition of the sandstone members of the Guadalupian series indicates changed conditions during late Paleozoic time in contrast to those prevailing during the accumulation of the great mass of limestone in the earlier periods, but the extent and relationships of these Permian? strata have not yet been determined.

The close of the Paleozoic era in the trans-Pecos Texas region apparently was accompanied by general uplift, but there is little record of immediately succeeding events. Early Mesozoic rocks are known in only a few areas, such as the marine Jurassic beds in the Malone Mountains,* 65 miles southeast of El Paso. East of the Van Horn quadrangle the Delaware Mountain formation is unconformably overlain by several hundred feet of gypsum of undetermined age. There is abundant evidence of considerable post-Carboniferous, pre-Cretaceous erosion in this region and in several places the Hueco limestone is immediately overlain by Lower Cretaceous strata.

U. S. Geological Survey, Washington, D. C.

* Bulletin No. 266, U. S. Geological Survey, 1905.