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PERMIAN STRATIGRAPHY IN THE JARILLA MOUNTAINS, OTERO COUNTY, NEW MEXICO

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ABSTRACT.—We assign the limestone-dominated section of upper Paleozoic strata exposed in the northern Jarilla Mountains of Otero County, New Mexico, to the Pennsylvanian-Permian Panther Seep Formation and the Lower Permian Shalem Colony and Community Pit formations of the Hueco Group. Panther Seep strata (formerly referred to the Laborcita Formation by some workers) are mostly shale and thin beds of algal limestone that are extensively intruded by Cenozoic plutons and faulted, so previous thickness estimates of ~500 m cannot be verified. Similarly, Hueco Group thicknesses of ~ 275 m in the Jarilla Mountains are overestimates, as the Hueco section here is only about 135 m thick. The Shalem Colony Formation is 68 m thick and consists of relatively thick beds of cherty, coarse-grained limestones and interbedded slopes of shale. The Community Pit Formation is at least 66 m thick (a complete section of the formation is not preserved in the Jarilla Mountains) and is composed of thin beds of lime wackestone and mudstone and intercalated shale slopes. Fusulinacean fossils indicate that the upper part of the Panther Seep Formation is earliest Wolfcampian in age, whereas the Shalem Colony Formation is of middle Wolfcampian age. Lithostratigraphic and biostratigraphic data support correlation of the Permian strata in the Jarilla Mountains to the much thicker Panther Seep-middle Hueco section in the southern San Andres Mountains, ~ 50 km to the northwest.

INTRODUCTION

The Jarilla Mountains in Otero County, New Mexico (Fig. 1) are a structural dome of upper Paleozoic limestones intruded by Cenozoic igneous stocks, dikes and sills. Most of these limestones are of Permian age, and are exposed in the northern part of the Jarilla Mountains. Almost all that is known of these strata is based on the report of Schmidt and Craddock (1964). Here, we present new data on the lithostratigraphy and correlation of Permian strata exposed in the Jarilla Mountains. In this paper, NMMNH = New Mexico Museum of Natural History and Science, Albuquerque.

PREVIOUS STUDIES

The earliest published observations on the geology of the Jarilla Mountains (e.g., Lindgren et al., 1910; Meinzer and Hare, 1915) identified "Carboniferous limestone" in the range, but Darton (1921, 1928a, b) mapped these rocks as "Chupadera Formation," which was composed elsewhere of the Permian Yeso and San Andres formations.

Needham (1937) documented Wolfcampian fusulinaceans from the Jarilla Mountains. His locality is described as "the eastern foothills of the Jarilla Mountains, 3 to 4 miles north of Oro Grande [sic]" (Needham, 1937, p. 13). Needham documented the following taxa from this locality: *Pseudoschwagerina morsei* Needham, *Schwagerina emaciata* (Beede) and *S. emaciata* var. *jarillaensis* Needham. In describing *P. morsei*, Needham (1937, p. 56) stated it is "rather abundant in limestones of Hueco age Lower Permian" in the Jarilla Mountains.

Nothing new on the geology of the Jarilla Mountains appeared in print until Reynolds and Craddock (1959) published a reconnaissance geologic map and reviewed the geology of the range. However, they only briefly described the succession of sedimentary rocks in the range, mostly limestones, stating that they are of Pennsylvanian and Early Permian age, and made no lithostratigraphic assignments.

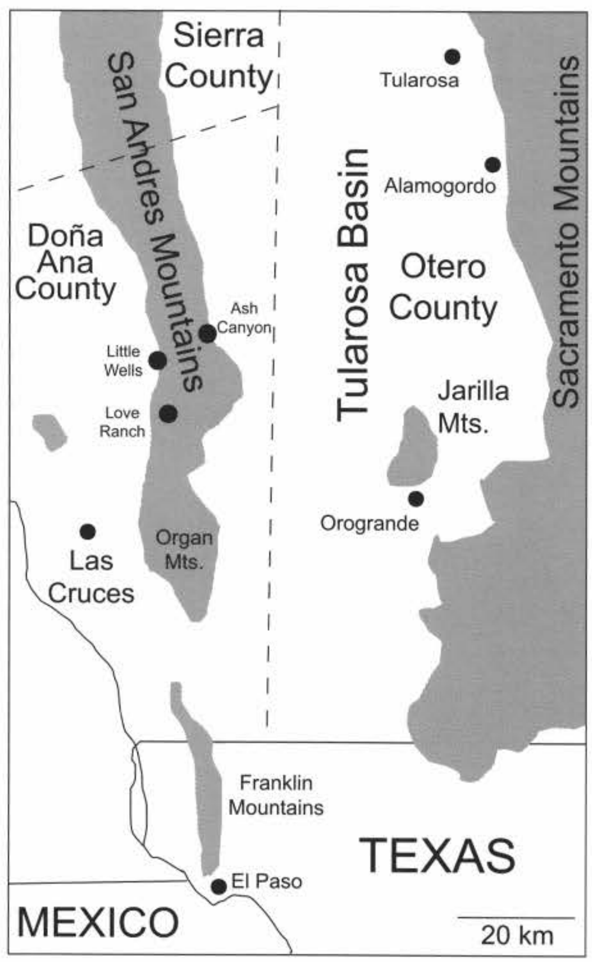

FIGURE 1. Map of part of the Tularosa Basin and adjacent areas in southern New Mexico showing location of the Jarilla Mountains.

Kottlowski (1963), in a review of Paleozoic strata in southern New Mexico, made no specific reference to Permian strata in the Jarilla Mountains, which well reflects how few data were available at that time. Soon thereafter, Schmidt and Craddock (1964) published a detailed study and geologic map of the Jarilla Mountains. They identified Pennsylvanian strata in the southern part of the range and assigned them to the Gobbler Formation (Bug Scuffle Member). Schmidt and Craddock (1964), in the northern part of the Jarilla Mountains, assigned the limestone-dominated strata to the Laborcita and Hueco formations. They provided a detailed description of lithotypes (including description of a 765-m thick measured section: Fig. 2) and lists of fusulinaceans and macrofossils (principally brachiopods and gastropods) of biostratigraphic significance.

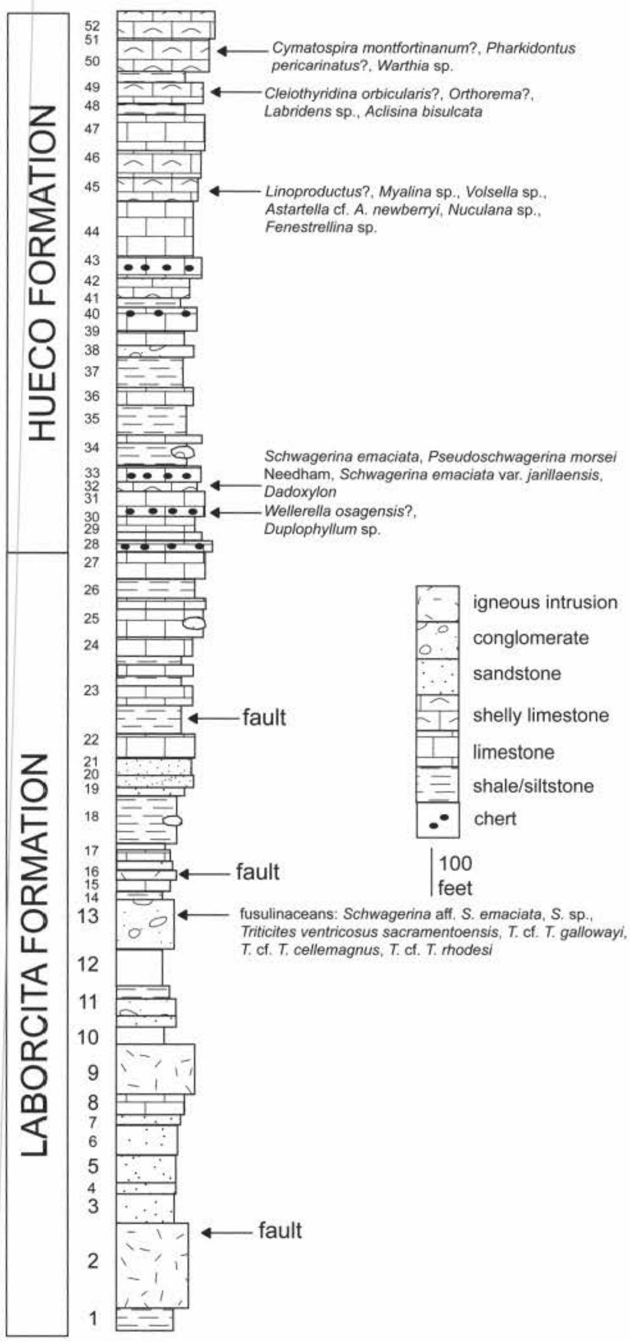

FIGURE 2. Measured section of Permian strata in the Jarilla Mountains, drawn from the description of Schmidt and Craddock (1964, p. 18-21), showing fossil taxa they list and stratigraphic nomenclature they advocated.

Today, Schmidt and Craddock (1964) remains the primary source of data on the Permian strata in the Jarilla Mountains. Indeed, Jordan's (1971, 1975) description of the Permian section in the Jarilla Mountains is based primarily on their data. The only more recently published geologic information is the map of Seager et al. (1987), who identified as Panther Seep Formation the strata Schmidt and Craddock assigned to the Laborcita Formation. However, they also mapped as Panther Seep Formation some of the strata that Schmidt and Craddock (1964) and we assign to the Hueco Group, especially in secs. 9-10, T21S, R8E. Seager et al. (1987) stated that Panther Seep strata are ~2400 ft (731 m) thick in the vicinity of the Jarilla Mountains (also see Kottlowski, 1960).

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

Panther Seep Formation

Schmidt and Craddock (1964) and Jordan (1975) recognized the strata below the Hueco Group in the Jarilla Mountains as Laborcita Formation, with a maximum thickness of 465 m (Fig. 2). Jordan (1975) reported that most of the section is metamorphically overprinted due to Tertiary intrusions (cf. Fig. 3), and that the uppermost 46 m are not metamorphosed, consisting of limestone (mudstone or wackestone), with minor amounts of siltstone. Limestones contain a sparse fauna, mostly ostracods. Seager et al. (1987) mapped these strata as Panther Seep Formation, an assignment endorsed by us.

At the base of our section A (Figs. 4-5), we measured ~ 60 m of Panther Seep strata that are not faulted or extensively metamorphosed. These strata are a slope-forming unit dominated by mostly covered shale slopes (78% of the section). Where shale is exposed, it is light gray or pale orange and calcareous. Intercalated limestone beds are thin (< 1 m thick) and mostly wackestones (12% of the section), many of which are algal laminates (Fig. 6B). Minor rock types are lime mudstone, grainstone, sandstone and limestone-pebble conglomerate.

We identify these stata below the Hueco Group as Panther Seep Formation, particularly because the limestones differ significantly from those of the Laborcita Formation in the northern Sacramento Mountains, which are characterized by a highly diverse fauna and algal flora (Otté, 1959; Pray, 1961). Furthermore, Laborcita strata include siliciclastic conglomerates and red beds, lithotypes absent in the Jarilla Mountains. Dark gray mudstones and laminated mudstones (local algal stromatolites), which are the dominant carbonate lithologies in the uppermost Panther Seep Formation of the Jarilla Mountains, are almost absent in the Laborcita Formation (Otté, 1959; Pray, 1961).

Indeed, in the Jarilla Mountains the lithotypes of the strata below the Hueco are very similar to those of the Panther Seep Formation as described by Kottlowski et al. (1956) in the San Andres Moun-

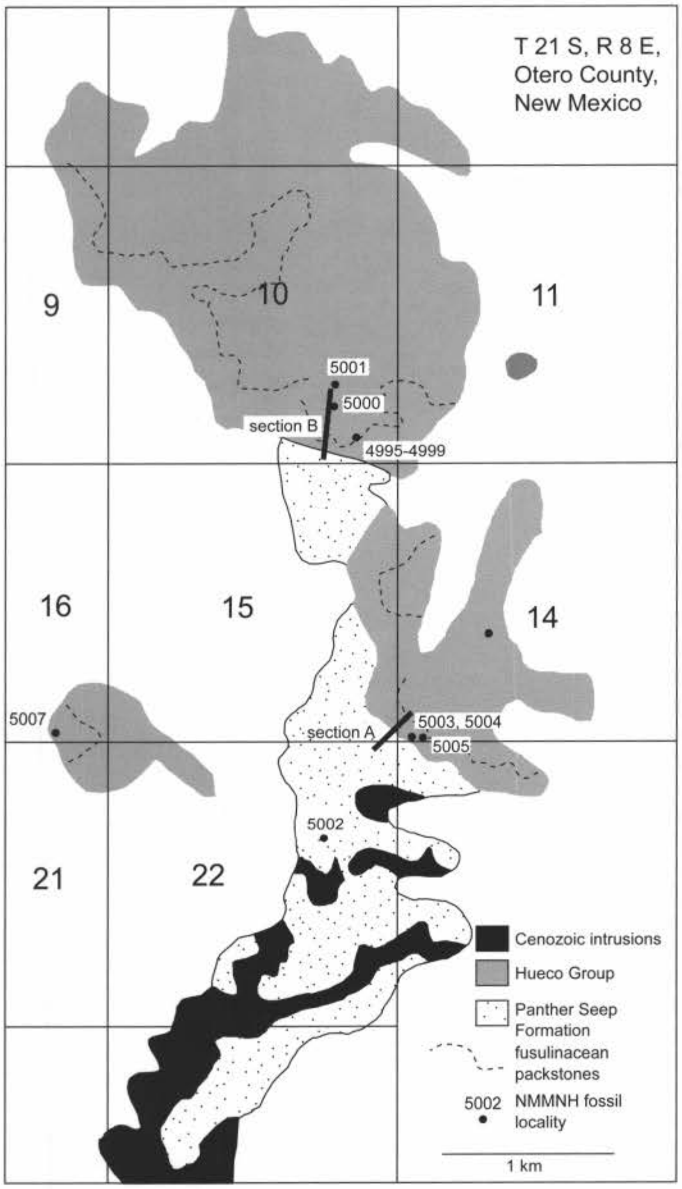

FIGURE 3. Geologic map of Permian strata in the northern Jarilla Mountains showing measured sections and fossil localities of our study. Geology modified from Schmidt and Craddock (1964).

tains. The Panther Seep Formation has been mapped from Mockingbird Gap to the southern end of the San Andres Mountains, and in the northern end of the Franklin Mountains (Kottlowski et al., 1956; Kues, 2001). Its recognition in the Jarilla Mountains thus only extends the formation's distribution about 40 km to the east.

In our section A (Figs. 4-5), the uppermost 50 m of the Panther Seep Formation consist of the following ledge-forming lithotypes: (1) bioturbated gray mudstone containing a sparse fauna (ostracods, rarely brachiopods, crinoids); (2) laminated gray lime mudstone (stromatolitic); (3) thin-bedded lime mudstone (near the top); (4) thin layers of intraformational conglomerate with limestone intraclasts up to about 2 cm in diameter; (5) sandy limestone, massive or indistinctly laminated; (6) massive and trough-crossbedded calcarenite with minor amounts of siliciclastic grains; and (7) siltstone and fine-grained calcarenite with small-scale current ripples. Similar lithotypes form the uppermost 6 m of the Panther Seep Formation in section B (Figs 4-5): (1) sandy limestone with a few pebbles up to 1 cm; (2) fine-grained calcarenite with small scale current ripples; (3) conglomerate; and (4) limestone-pebble conglomerate/sedimentary breccia composed of angular, dark gray limestone clasts up to several cm in diameter, floating in lime mudstone matrix.

Depositional Environments

In the Jarilla Mountains, Panther Seep lithotypes are typical of a peritidal depositional environment. The bioturbated gray mudstones and thin-bedded lime mudstone with a sparse and low diversity fauna were deposited in a subtidal, low energy environment. The laminated limestones represent algal mats, mostly flat laminated forms, rarely of laterally linked hemispherical shapes, and are characteristic of the upper intertidal and lower supratidal environment. Intraformational conglomerates most probably were reworked during storm events and deposited in tidal channels or on supratidal flats. Carbonate conglomerate, sandstones and siltstones, all containing small amounts of siliciclastic grains, indicate deposition in a high-energy environment, i.e., in tidal channels or in a nearshore environment. Terrestrial deposits or evidence of subaerial exposure have not been recognized in Panther Seep strata in the Jarilla Mountains.

Schoderbek (1994) described similar lithologies of a peritidal environment in the Panther Seep Formation of the southern San Andres Mountains. There, the lithologies represent different types of cycles, both transgressive and regressive. Cycles are probably also represented in Panther Seep strata in the Jarilla Mountains, particularly in the middle part of section B, but as the sequence is not completely exposed and shows many gaps between the ledge forming lithologies, recognition of cycles is difficult.

Hueco Group

In the Jarilla Mountains, we assign strata formerly termed Hueco Formation or Hueco Limestone (Schmidt and Craddock, 1964; Jordan, 1971, 1975) to the Shalem Colony and Community Pit formations of the Hueco Group, terminology introduced by Lucas et al. (1998) and further explained and developed by Lucas et al. (2002). According to Schmidt and Craddock (1964) and Jordan (1975), the base of the Hueco Group in the Jarilla Mountains is formed by a 10-m thick unit of platy algal packstone (Figs. 2, 5B, 6C). In both of our measured sections (Figs. 4-5), the boundary between the Panther Seep Formation and overlying strata of the Hueco Group is relatively sharp. In section A, the base of the Hueco Group is formed by a carbonate mound with a maximum thickness of 6 m, which laterally thins over a distance of several tens of meters, grading into gray fossiliferous lime mudstone with large nodules and thin lenses of chert (Fig. 6C). These cherty limestones mark the base of the Hueco in section B (Fig. 4).

In section B, the exposed thickness of the Hueco Group is 135 m, and the succession may be divided into three lithostratigraphic units, which we assign to the Shalem Colony and Community Pit formations.

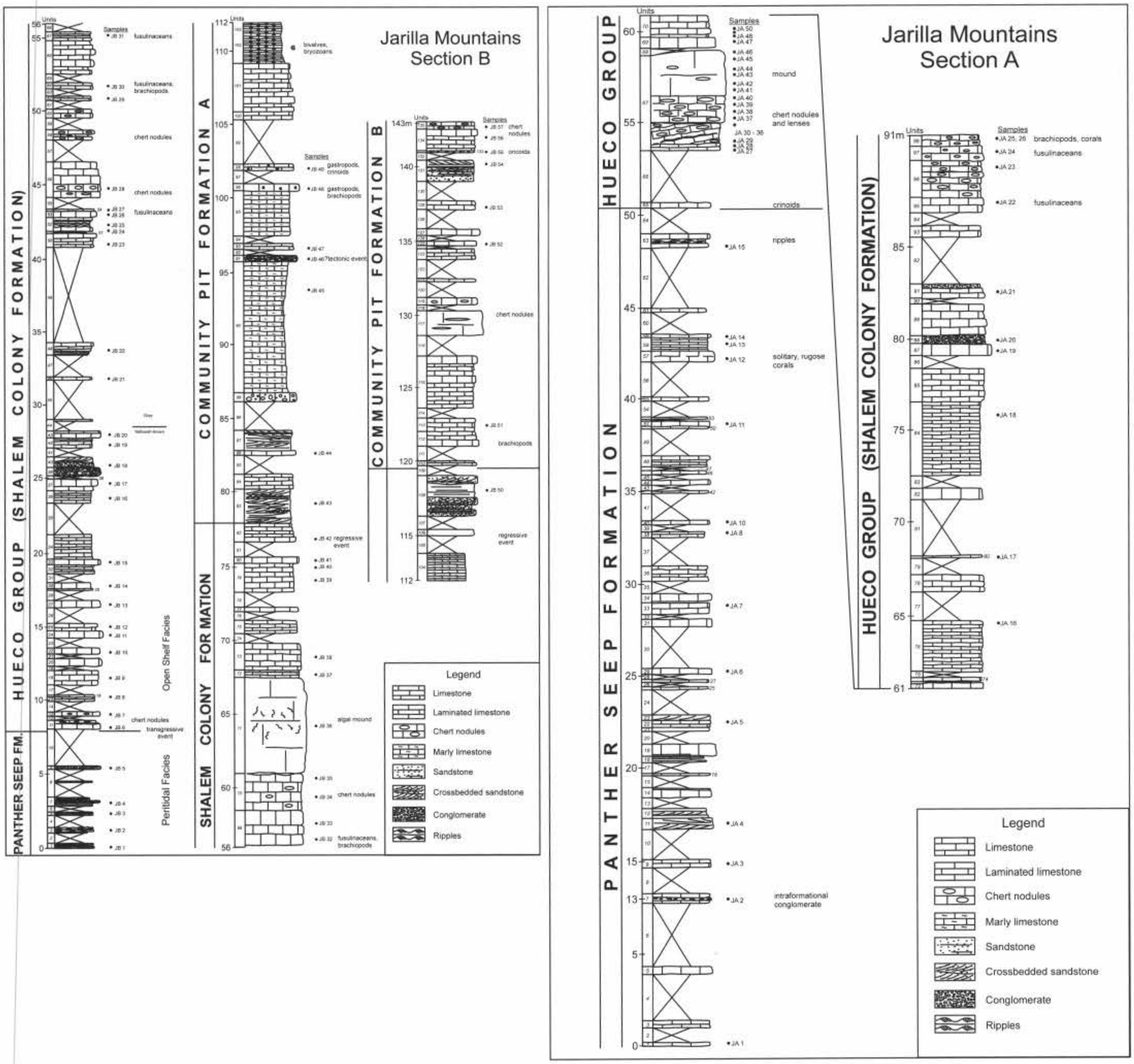

FIGURE 4. Measured sections A and B of Permian strata in the Jarilla Mountains. See Figure 3 for location of sections and the Appendix for description of numbered lithologic units.

Shalem Colony Formation

The lowermost 68 m of section B (units 11 – 82) are composed of the following lithotypes: (1) gray lime mudstone, fossiliferous limestone containing large chert nodules and lenses at the base (1.2 m); (2) dark gray to gray lime mudstone containing a few fossils, slightly wavy bedding, individual beds 10-50 cm thick; (3) laminated lime mudstone beds; (4) fossiliferous lime mudstone beds; (5) fusulinacean limestones (in the middle part: beds 54, 55, 66, 69 and 71); (6) nodular limestone containing algae and a few oncoids (rare; bed 53); (7) thick bedded to massive limestone (phylloid algal limestone, bioclastic limestone) with a thickness of 6.5 m (mound; bed 73)—this bed is the "upper bioherm 160 to 180 ft above the base of the Hueco" mentioned by Jordan (1975); (8) thick bedded bioclastic and algal limestones, containing silicified brachiopods and locally large chert nodules and lenses; and (9) polymict carbonate-clast conglomerate (bed 39) with carbonate clasts up to 3 cm in diameter, overlain by coarse-grained sandstone, which grades into crossbedded sandstone on top (bed 40). We assign these strata to the Shalem Colony Formation and it can be readily correlated to section A, where the lowermost 41 m of the Hueco Group have been measured (Fig. 4).

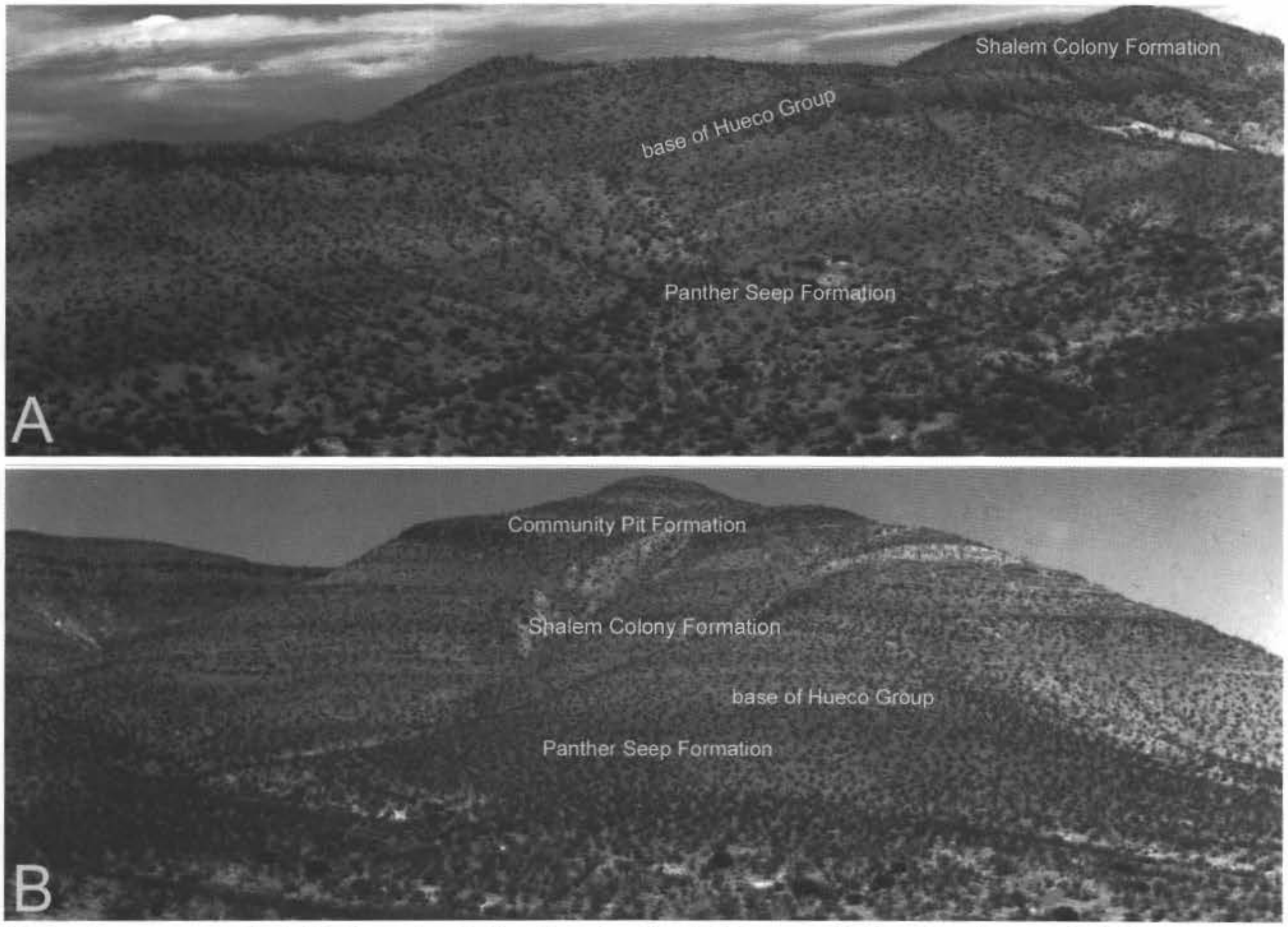

FIGURE 5. Permian outcrops in the Jarilla Mountains. A, Overview of section A of this paper. B, Overview of section B of this paper.

In section A, the Hueco Group has a mound at the base, which in the lower part contains abundant chert nodules and lenses (Fig. 6C). The mound shows the following lithotypes from base to top:

1. Two dark gray limestone beds are exposed at the base, both 0.4 m thick. The lower bed contains abundant calcareous algae, and the overlying limestone bed is a bioclastic wackestone containing abundant crinoid fragments and large chert nodules. Both limestone beds display wavy bedding and are separated by a 1-cm thick, reddish shale.

2. Above a 0.5-m thick covered interval there follows a 1.3-m thick sequence of thin (10-20 cm), wavy bedded, dark gray lime mudstone with abundant dark chert nodules and chert lenses. The limestone beds of this sequence are inclined towards the west (inclination ca. 10°), and overlain by:

3. A 1.3 m thick, indistinctly wavy bedded, dark gray lime mudstone containing abundant chert nodules and chert lenses. Chert nodules are up to 20 cm thick, and chert lenses are up to several cm thick and as much as more than a meter long. This limestone interval rests on the inclined limestones with an angular unconformity, separated by a thin reddish mudstone/siltstone layer.

4. The uppermost part of the mound is composed of massive to indistinctly bedded gray lime mudstone (2.5 m thick), containing only a few smaller chert nodules in the lower part.

The mound can be traced laterally over a distance of >50 m, thins out and grades into bedded cherty limestones. Except in the the two limestone beds at the base, fossils, particularly calcareous algae, were not recognized in the field. Absence of algae and an abundance of chert nodules and lenses indicates that this mound may have been formed by bryozoans and siliceous sponges, the latter providing the silica for the chert nodules and lenses. The dipping beds of interval 2 probably represent the "flank bed facies" of the mound core. We anticipate that thin section analysis of rock samples from this mound will provide more information about the mound-forming organisms. A 10 m thick platy algal packstone, which according to Jordan (1975) marks the base of the Hueco in the Jarilla Mountains, has not been observed in section A nor in section B.

The mound is overlain by lime mudstone, rarely laminated, and bedded gray limestones similar to those in section B. The conglomerate (bed 88) corresponds to the polymictic conglomerate (bed 39) of section B. The cherty limestones on top of section A (beds 96 – 98), containing fusulinaceans, silicified brachiopods, and solitary rugose corals (Fig. 6D), correspond to the cherty limestone of beds 57 – 62 of section B.

Thus, in the Jarilla Mountains, the complete section of the Shalem Colony Formation is 68 m thick. More than one third of the formation (40% of the measured section) is covered shale slopes; where shale crops out, it is yellowish gray, grayish orange and calcareous. The remainder of the section is almost totally limestones, which are mostly wackestones (26% of the section), and lesser amounts of grainstone (19%) and lime mudstone

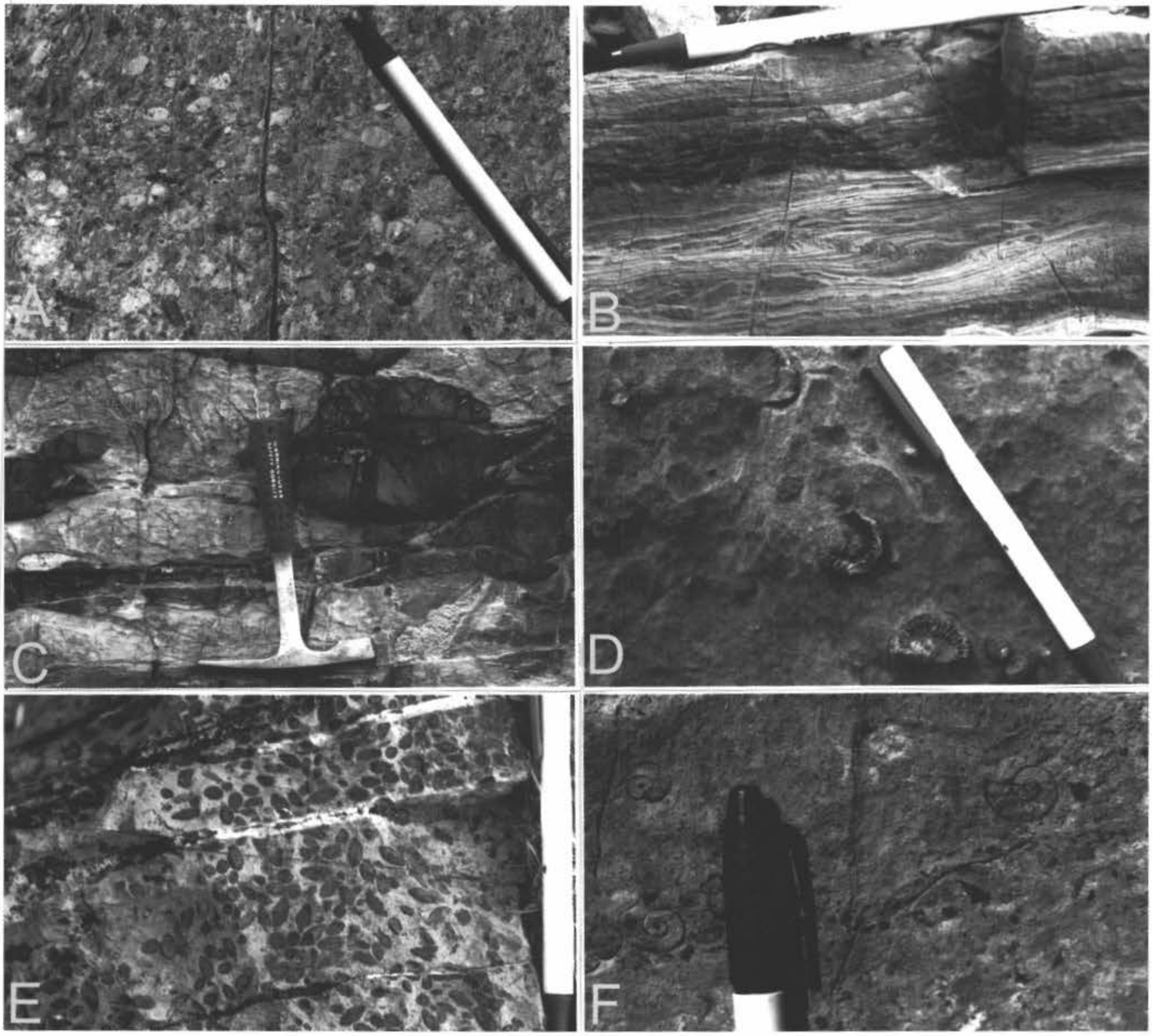

FIGURE 6. Photographs of selected beds in the Panther Seep Formation and Hueco Group in the Jarilla Mountains. A, Conglomerate bed with earliest Wolfcampian fusulinaceans of the Panther Seep Formation, NMMNH locality 5002. B, Algal laminated limestone of uppermost Panther Seep Formation, section A, bed 37. C, Basal cherty limestone of Shalem Colony Formation, section A, bed 67. D, Silicified rugose corals and brachiopods (*Wellerella*) in the Shalem Colony Formation, section A, bed 97. E, Fusulinacean packstone in the Shalem Colony Formation, section B, bed 64. F, Gastropods in limestone of upper part of Shalem Colony Formation, section B, bed 80.

(14%). Minor rock types are calcarenite and limestone-pebble conglomerate. Thick, cliff-forming limestones, cherty limestones, grainstones and ostracodal/fusulinacean packstones are characteristic of the Shalem Colony Formation in the Jarilla Mountains, as they are elsewhere (Lucas et al., 1998, 2002).

Community Pit Formation

Only an incomplete section of the Community Pit Formation is exposed in the Jarilla Mountains, and our section B includes 66 m of this unit. As in sections to the west, the Community Pit Formation is interbedded covered shale slopes and thin (< 1 m thick) beds of limestone. Limestones are mostly lime mudstones (29% of the section) and wackestones (25% of the section); grainstones, onchoidal limestones and calcarenites are rare. Covered shale slopes comprise 33% of the section, and there are two beds of limestone-pebble conglomerate. Colors are characteristically pale orange, grayish orange and yellowish brown, and chert is rare.

We can subdivide the Community Pit Formation in the Jarilla Mountains into two units that may deserve member status. The lower unit (section B, beds 84 to 108) is 42 m thick and characterized by the following lithotypes: (1) a sandy interval at the base, composed of an arenaceous bioclastic bed at the base, overlain by laminated lime mudstone (bed 84), and carbonate sandstones with horizontal bedding, trough crossbedding and synsedimentary deformation structures (beds 85, 89) intercalated with gray muddy, wavy bedded fossiliferous limestones (beds 86, 88); (2) dark gray marly limestones (mudstones), with 30-50 cm thick beds in the lower part (beds 92, 97), thin bedding in the upper part, containing bivalves and bryozoans (bed 104); (3) gray to dark gray lime mudstone (beds 95, 102, 103); (4) fossiliferous dark gray lime mudstone beds containing gastropods, brachiopods and crinoids (beds 98, 100); (5) a dark gray limestone bed composed of cm-size limestone clasts floating in a lime mudstone matrix (bed 91); (6) gray, clast-supported limestone conglomerate containing clasts up to several cm in diameter (mostly 0.5 – 1 cm); some siliciclastic grains are also present (bed 93); and (7) a clastic interval on top of this unit composed of carbonate sandstone, pebbly sandstone and fine-grained carbonate conglomerate with horizontal bedding and trough crossbedding.

The upper unit includes the uppermost 24 m of the section (section B, beds 110 to 135) and is composed predominantly of: (1) gray lime mudstone (beds 113, 115, 121, 125, 134), which in the middle part contain chert nodules and lenses (beds 117, 119); (2) individual beds of fossiliferous limestone (silicified brachiopods) (beds 110, 112, 123); (3) a gray, laminated lime mudstone (bed 129); (4) a thin oncoidal limestone bed in the upper part (bed 133); (5) a carbonate sandstone horizon, pebbly in the lower part and crossbedded in the upper part (bed 131); and (6) cherty limestone on top (bed 135).

Depositional Environments

Interpretation of depositional environment is based on field observations, so we can present only a preliminary and general outline. In all three units of the Hueco Group in the Jarilla Mountains, lime mudstones of exceptionally dark gray color dominate, and in the field relatively few limestone beds were observed to contain fossils, including calcareous algae, fusulinaceans (particularly in unit A), brachiopods, gastropods, crinoids, and rugose corals. Dominance of lime mudstone textures, irregular and wavy bedding, rarity of grainstone facies as well as the fossil assemblages indicate deposition in a low-energy shelf environment below the wave base with normal marine salinity and possibly restricted circulation.

The mounds present in the Shalem Colony Formation probably formed on a gently dipping carbonate shelf platform (ramp). The lower mound at the base of the Hueco Group, in which calcareous algae seem to be absent, may have even formed below the base of the photic zone (water depth some tens of meters), whereas the mound in the upper part of this unit, which locally contains abundant phylloid algae and thus represents a "phylloid algal mound," accumulated in the photic zone.

The covered intervals that frequently occur in the Shalem Colony Formation and in the upper part of the Community Pit Formation, most likely represent shaley or marly sediments. They indicate that accumulation of limestone was frequently interrupted due to increased terrigenous (clay) influx. But, during these periods water depth seems to have not changed significantly. The coarse-grained clastic intervals (sandstone, conglomerate) are interpreted to represent tectonically induced, regressive events.

Within the Hueco Group, relative sea-level highstands are marked by cherty limestones, whereas relative sea-level lowstands are represented by coarse-grained clastic intervals. The base of the Hueco is marked by a distinct lithologic change from deposits of a peritidal environment to cherty limestones of a shelf environment. This lithologic change indicates a significant deepening of the depositional environment at the onset of Hueco deposition, perhaps by a few tens of meters.

PALEONTOLOGY AND AGE

Needham (1937) first reported fossils from the Hueco Group in the Jarilla Mountains (see above). Schmidt and Craddock (1964) also listed fusulinaceans (some identifications by Grant Steele), macroinvertebrate fossils and fossil wood from the Panther Seep Formation and Hueco Group in the Jarilla Mountains. We have also collected fusulinaceans and macroinvertebrate fossils in the Jarilla Mountains, but these will be described elsewhere.

The stratigraphically lowest fossils reported by Schmidt and Craddock (1964, p. 21) are fusulinaceans from bed 13 of their section in strata they assigned to the Laborcita Formation (Fig. 2). We have relocated this bed and assigned it to NMMNH locality 5002 (UTM zone 13, 395897E, 3592643N, NAD 27), and it is a limestone-pebble conglomerate in which the fusulinaceans appear to be reworked clasts. This bed is part of an apparent fault block of the Panther Seep Formation, so we are not able to determine its position in the Panther Seep section. The fusulinaceans listed by Schmidt and Craddock (1964) appear to be of early Wolfcampian age (Zone PW-1 of Wilde, 1990).

In the lower part of their Hueco Formation, in limestone/shale beds ~ 40 m above its base, Schmidt and Craddock (1964, p. 14-15, fig. 6) identified fossil logs as *Dadoxylon*. These must be logs of terrestrial gymnospermous trees that floated into and were buried in a marine environment. Indeed, similar occurrences are known elsewhere in the Hueco Group of New Mexico (Tidwell and Munzing, 1995) and in the Upper Pennsylvanian of central New Mexico (Tidwell et al., 2000). We could not locate the logs documented by Schmidt and Craddock (1964), but we did find fragments of fossil logs at the top of our section A, which must be the same occurrence they reported.

Fusulinaceans are abundant in six packstone beds in the middle part of the Shalem Colony Formation (beds 53, 62, 64, 67 and 69 of our section B: Fig. 4). The assemblages are dominated by *Pseudoschwagerina* and *Schwagerina*, and must be the source of the fusulinaceans reported by Needham (1937) and by Schmidt and Craddock (1964). The taxa they list indicate a middle Wolfcampian age (Zone PW-2 of Wilde, 1990).

Schmidt and Craddock (1964) reported bryozoans, corals, brachiopods, bivalves and gastropods from various beds in the Hueco Group in the Jarilla Mountains (Fig. 2). We have collected similar fossils, including bivalve-dominated assemblages from the Community Pit Formation at NMMNH localities 5000 and 5001. These fossils are under study by Barry Kues (University of New Mexico) and will be reported elsewhere.

CORRELATION

Seager et al. (1987) identified as Panther Seep Formation the strata Schmidt and Craddock (1964) assigned to the Laborcita Formation, and we concur with Seager et al. (see above). Given the faulting and intrusion of the Panther Seep Formation in the Jarilla Mountains (Fig. 2), we were unwilling to construct a single, thick (~ 500 m) section of the unit in the range, as did Schmidt and Craddock (1964). Fusulinaceans from a Panther Seep Formation conglomerate bed on a fault block of uncertain stratigraphic position are of earliest Wolfcampian age. Fusulinaceans and macroinvertebrate fossils from the Panther Seep Formation in the San Andres Mountains indicate it is of Virgilian-early Wolfcampian age (e.g., Kottlowski et al., 1956; Soreghan and Giles, 1999; Lucas and Kues, 2001; Kues, 2002). Therefore, correlation of at least some of the Panther Seep Formation in the Jarilla Mountains to the upper part of the Panther Seep in the San Andres Mountains is justified biostratigraphically and on lithostratigraphic grounds.

Jordan (1971, 1975) correlated the Hueco Group section in the Jarilla Mountains to other Hueco sections in and around the Orogrande basin, and we concur with his correlation. Thus, Jordan recognized a lower and a middle Hueco Limestone in the Jarilla Mountains, which clearly correspond to the units we term Shalem Colony and Community Pit formations. However, we are unable to verify the thicknesses Jordan reported for the Hueco Group (~300 m) and Shalem Colony (~ 150 m) and Community Pit (~ 120 m) formations in the Jarilla Mountains.

As indicated by Jordan (1971, 1975), the Shalem Colony and Community Pit formations can be readily correlated to the same units in the southern San Andres Mountains (also see Lucas et al., 2002). Lithotypes and biostratigraphy support this correlation to the thicker (260 m, vs. 135 m in the Jarillas) lower-middle Hueco Group section in the San Andres Mountains.

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APPENDIX-MEASURED SECTIONS

Jarilla B

Measured in the SE ¼ sec. 10, T21S, R8E. Base of section at UTM zone 13, 396123E, 3594911N, and top at 395955E, 3595357N, NAD27. Strata dip 6° to N30° W.

unit	lithology	thickness (m)
	Hueco Group:	
	Community Pit Formation:	
132	Limestone; medium gray (N5) cherty wackestone.	0.5
131	Limestone; light gray (N7); grainstone; ledgy.	1.6
130	Limestone; light gray (N7); onchoidal.	0.1
129	Covered slope.	0.5
128	Limestone; medium light gray (N6); grainstone.	1.5
127	Covered slope.	1.3
126	Limestone; medium gray (N5), weathers light brown (5YR6/4); wackestone; thin bedded; *Aviculopecten.*	0.6
125	Covered slope.	1.3
124	Limestone; medium dark gray (N4); weathers grayish orange (10YR7/4); mudstone.	0.4
123	Covered slope.	0.4
122	Limestone; medium dark gray (N4); bioclastic wackestone.	0.3
121	Covered slope.	0.2
120	Limestone; medium gray (N5); weathers grayish orange (10YR7/4); mudstone.	0.7
119	Covered slope.	1.3
118	Limestone; medium dark gray (N4); weathers very pale orange (10YR8/2); wackestone.	0.2
117	Covered slope.	1.1
116	Limestone; same as unit 114.	0.5
115	Covered slope.	0.4
114	Limestone; medium light gray (N6) with bands of pale yellowish brown (10YR6/2); a cherty wackestone; thin bedded.	0.7
113	Covered slope.	1.5
112	Limestone; medium gray (N5); wackestone; ledgy, with shale interbeds.	3.5
111	Covered slope.	0.7
110	Limestone; medium light gray (N6); wackestone; same silicified fossil assemblage as unit 109, but fewer shells.	0.9
109	Limestone; medium light gray (N6); silicified shells (brachiopods and gastropods) are brownish gray (5YR4/1); wackestone.	1.0
108	Covered slope.	1.0
107	Limestone; medium light gray (N6), weathers grayish orange (10YR7/4); wackestone; NMMNH locality 5001 *(Aviculopecten, Derbyia, Composita,* bryozoans, crinoids).	0.3
106	Covered slope.	0.7
105	Conglomerate; medium dark gray (N4) and grayish orange (10YR7/4); limestone pebbles and chert; thick bedded.	2.7
104	Covered slope.	1.9
103	Calcarenite; light olive gray (5Y6/1), weathers pale yellowish brown (10YR6/2); trough crossbedded.	0.4
102	Covered slope.	1.2
101	Limestone; pale yellowish brown (10YR6/2); wackestone; thin bedded; NMMNH locality 5000 *(Aviculopecten).*	4.6
100	Limestone; medium light gray (N6), weathers pale yellowish brown (10YR6/2); mudstone; thin bedded.	3.3
99	Covered slope.	3.0
98	Limestone; medium gray (N5); wackestone; gastropods and brachiopods.	0.4
97	Covered slope.	0.9
96	Limestone; medium dark gray (N4); wackestone; gastropods, brachiopods.	0.5
95	Limestone; medium dark gray (N4), weathers pale yellowish brown (10YR6/2); sandy mudstone; thin bedded.	3.0
94	Covered slope.	0.5
93	Limestone; medium light gray (N6); bioclastic wackestone; two ledges.	0.4
92	Covered slope.	0.4
91	Conglomerate; light gray (N7) and medium gray (N5) limestone pebbles and moderate yellowish brown (10YR5/4) chert pebbles.	0.4
90	Limestone; medium dark gray (N4), weathers moderate yellowish brown (10YR5/4); mudstone; thick bedded with some thin shale interbeds.	9.0
89	Limestone; medium gray (N5); mudstone; units 84-89 form a prominent black cliff.	0.6
88	Covered slope.	2.0
87	Limestone; same as unit 83.	1.5
86	Limestone; medium gray (N5); mudstone.	0.3
85	Covered slope.	1.3
84	Limestone; light gray (N7); grainstone.	1.0
83	Limestone; light olive gray (5Y6/1); sandy grainstone; crossbedded and some soft sediment deformation; thin shale breaks.	2.3
	Shalem Colony Formation:	
82	Limestone; medium gray (N5); sandy grainstone; thin wavy bedding.	1.2
81	Covered slope.	1.0
80	Limestone; medium dark gray (N4); gastropod packstone.	0.4
79	Limestone; medium light gray (N5); sandy ostracodal wackestone; thin bedded.	2.0
78	Covered slope.	1.0
77	Limestone, medium light gray (N5) and grayish orange (10YR7/4); lime mudstone; thin wavy bedding.	0.3
76	Covered slope.	0.6
75	Limestone; same as unit 77.	0.9
74	Covered slope.	0.7
73	Limestone; medium light gray (N5); grainstone; thick bedded.	1.8
72	Limestone; same as unit 77.	0.5
71	Limestone; light gray (N7); sandy grainstone; cherty; units 69-71 form a "black" cliff.	6.5
70	Limestone; light gray (N7); algal wackestone; some chert.	2.5
69	Limestone; medium gray (N5); fusulinacean packstone; NMMNH locality 4999.	2.3
68	Covered slope.	0.8
67	Limestone; medium light gray (N6); fusulinacean packstone; NMMNH locality 4998.	0.4
66	Limestone; medium gray (N5), weathers pale yellowish brown (10YR6/6); mudstone; ledgy.	2.5
65	Covered slope.	0.6
64	Limestone; medium dark gray (N4); fusulinacean packstone;	

Wellerella; NMMNH locality 4997. **0.4**

63 Covered slope. **0.5**

62 Limestone; medium dark gray (N4); fusulinacean packstone; NMMNH locality 4996. **0.3**

61 Covered slope. **0.6**

60 Limestone; medium gray (N5); nodular wackestone; cherty; chert is moderate brown (5YR4/4). **0.6**

59 Covered slope. **0.8**

58 Limestone; medium gray (N5); nodular wackestone; cherty; chert is moderate brown (5YR4/4). **0.7**

57 Covered slope. **1.5**

56 Limestone; same as unit 58. **2.4**

55 Covered slope. **0.8**

54 Limestone; medium gray (N5); nodular fusulinacean packstone. **0.1**

53 Limestone; medium light gray (N6); algal and fusulinacean packstone; NMMNH locality 4995 (= Schmidt and Craddock [1964] bed 32). **0.6**

52 Limestone; medium light gray (N6); nodular wackestone. **0.5**

51 Limestone; medium gray (N5); wackestone; gastropods, bryozoans. **0.7**

50 Limestone; medium gray (N5); mudstone. **0.6**

49 Covered slope. **6.6**

48 Limestone; medium dark gray (N4); ostracodal wackestone; thinly laminated. **0.8**

47 Covered slope. **1.5**

46 Limestone; medium dark gray (N4); wackestone. **0.2**

45 Covered slope. **2.7**

44 Covered slope with a couple of thinly laminated limestone ledges; limestone is medium gray (N5) grainstone. **0.7**

43 Limestone; medium gray (N5), weathers very pale orange (10YR8/2); mudstone. **0.5**

42 Limestone; medium gray (N5); ostracodal wackestone; thin bedded. **0.7**

41 Shale; grayish orange (10YR7/4); calcareous. **0.6**

40 Calcarenite; medium gray (N5); cross bedded and laminar. **0.7**

39 Conglomerate; mottled medium gray (N5) and grayish orange (10YR7/4); clast supported limestone pebbles. **0.6**

38 Covered slope. **0.2**

37 Limestone; medium gray (N5); weathers grayish orange (10YR7/4); mudstone. **0.8**

36 Limestone; medium gray (N5); algal wackestone. **0.8**

35 Covered slope. **2.1**

34 Limestone; medium gray (N5); mudstone; thin bedded. **1.6**

33 Limestone; medium gray (N5); algal wackestone. **0.4**

32 Limestone; medium light gray (N6) and very pale orange (10YR8/2); algal wackestone. **0.6**

31 Shale; yellowish gray (5Y7/2); calcareous. **0.6**

30 Limestone; medium gray (N5); algal wackestone. **0.4**

29 Limestone; medium gray (N5); mudstone. **0.1**

28 Covered slope. **0.7**

27 Limestone; medium gray (N5); weathers dark yellowish orange (10YR6/6); mudstone. **0.5**

26 Covered slope. **1.1**

25 Limestone; medium dark gray (N4); sandy mudstone. **0.5**

24 Limestone; medium gray (N5); mudstone. **0.5**

23 Covered slope. **0.7**

22 Limestone; medium gray (N5); wackestone. **0.4**

21 Covered slope. **0.3**

20 Limestone; medium light gray (N6); weathers very pale orange (10YR8/2); wackestone. **0.5**

19 Covered slope. **0.3**

18 Limestone; medium gray (N5); mudstone; thin bedded. **1.0**

17 Covered slope. **0.7**

16 Limestone; medium light gray (N6); algal wackestone. **0.2**

15 Limestone; medium gray (N5); medium bedded; wackestone. **0.4**

14 Covered slope. **0.7**

13 Limestone; medium light gray (N6); wackestone. **0.3**

12 Covered slope. **0.3**

11 Limestone; medium gray (N5); cherty wackestone. **0.6**

Madera Group:

Panther Seep Formation:

10 Covered slope. **2.5**

9 Conglomerate; medium gray (N5); limestone pebbles. **0.2**

8 Shale; same as unit 2. **1.9**

7 Calcarenite; same as unit 3. **0.6**

6 Shale; same as unit 2. **0.4**

5 Calcarenite; same as unit 3. **0.2**

4 Shale; same as unit 2. **0.8**

3 Calcarenite; medium light gray (N6); ripple laminated. **0.4**

2 Shale with lenses of calcarenite; yellowish gray (5Y8/1) **0.7**

1 Conglomerate; medium gray (N5); limestone and chert pebbles. **0.3**

Jarilla A

Measured in the SW ¼ sec. 14, T 21S, R8E. Section base is at UTM zone 13, 396140E, 3593157N and top is at 396433E, 3593172N, NAD27. Strata dip 17° to N40° E.

unit lithology **thickness (m)**

Hueco Group:

Shalem Colony Formation:

99 Limestone; medium light gray (N6); fusulinacean wackestone; NMMNH locality 5005. **not measured**

98 Limestone; same as unit 96. **0.6**

97 Limestone; medium gray (N5) and medium light gray (N6); fusulinacean wackestone; NMMNH locality 5004. **0.8**

96 Limestone; medium light gray (N6); cherty wackestone; chert is light brown (5YR5/6 to 5YR6/4). **2.0**

95 Limestone; medium dark gray (N4); fusulinacean wackestone; NMMNH locality 5003. **0.8**

94 Covered slope. **0.7**

93 Limestone; medium dark gray (N4); wackestone. **0.6**

92 Covered slope. **2.5**

91 Limestone; medium gray (N5); wackestone; thin bedded; top 0.1 m is limestone pellet conglomerate. **0.7**

90 Covered slope. **0.3**

89 Limestone; dark yellowish orange (10YR6/6) and medium gray (N5); grainstone; cherty. **1.7**

88 Conglomerate; medium gray (N5), weathers pale yellowish brown (10YR6/2); limestone pebbles. **0.5**

87 Limestone; medium gray (N5), weathers light olive gray (5Y6/1); algal wackestone. **0.7**

86	Covered slope.	**0.7**
85	Limestone; medium dark gray (N4), weathers medium gray (N5); grainstone; thick bedded.	**1.8**
84	Limestone; medium gray (N5), weathers light olive gray (5Y6/1); grainstone; thin bedded.	**4.0**
83	Covered slope.	**0.7**
82	Limestone; medium dark gray (N4); grainstone; thin bedded.	**0.6**
81	Covered slope.	**3.0**
80	Limestone; same as unit 82.	**0.1**
79	Covered slope.	**0.9**
78	Limestone; medium gray (N5); weathers pale yellowish brown (10YR6/2); algal wackestone; thinly bedded with thin shale breaks.	**0.9**
77	Covered slope.	**1.6**
76	Limestone; same as unit 78.	**2.8**
75	Covered slope.	**0.3**
74	Limestone; medium light gray (N6); sandy cherty wackystone; chert is dark yellowish orange (10YR6/6).	**0.2**
73	Covered slope.	**0.1**
72	Limestone; same as unit 74.	**1.1**
71	Limestone; medium gray (N5); weathers grayish orange (10YR7/4); mudstone.	**0.3**
70	Limestone; medium gray (N5); weathers grayish orange (10YR7/4); crinoidal conglomerate.	**0.2**
69	Limestone; medium light gray (N6); wackestone; gastropods.	**0.6**
68	Covered slope.	**0.2**
67	Limestone; medium gray (N5); cherty algal wackestone; chert is moderate brown (5YR4/4 and 5YR5/4); unit forms a cliff that thins and thickens on strike; algal bioherm.	**5.0**

Madera Group:

Panther Seep Formation:

66	Covered slope.	**2.8**
65	Limestone; medium gray (N5), weathers grayish orange (10YR7/4); mudstone; thinly laminated.	**0.3**
64	Covered slope.	**1.4**
63	Limestone; pale yellowish brown (10YR6/2); rudite; thin bedded.	**0.7**
62	Shale; light gray (N7); calcareous.	**3.3**
61	Limestone; medium light gray (N6); algal wackestone; thinly laminated.	**0.2**
60	Covered slope with a few thin limestone lenses like unit 59.	**7.2**
59	Limestone; medium dark gray (N5); algal wackestone.	**0.2**
58	Limestone; medium light gray (N5); algal wackestone; thinly laminated.	**0.8**
57	Limestone; medium gray (N5); wackestone; rugose corals.	**0.6**
56	Covered slope.	**1.9**
55	Limestone; medium dark gray (N4); algal wackestone; laminated.	**0.2**
54	Covered slope.	**0.9**
53	Limestone; medium gray (N5); algal wackestone.	**0.1**
52	Covered slope.	**0.1**
51	Conglomerate; medium gray (N5); limestone pebbles.	**0.3**
50	Covered slope.	**0.3**
49	Limestone; thinly color banded medium light gray (N6) and grayish orange (10YR7/4); algal wackestone.	**0.1**
48	Covered slope with some thin limestone lenses like unit 47.	**1.5**
47	Limestone; medium gray (N5); weathers grayish orange (10YR7/4); ooidal wackestone; thin bedded.	**0.6**
46	Covered slope.	**0.2**
45	Limestone; medium gray (N5); wackestone; thinly bedded.	**0.2**
44	Covered slope.	**0.3**
43	Limestone; medium dark gray (N4); wackestone.	**0.3**
42	Covered slope.	**0.3**
41	Limestone; medium dark gray (N4); algal wackestone; thinly laminated.	**0.1**
40	Covered slope.	**1.5**
39	Limestone; medium dark gray (N4), weathers pale yellowish brown (10YR6/2); mudstone.	**0.2**
38	Covered slope.	**0.4**
37	Limestone; banded medium dark gray (N4) and grayish orange (10YR7/4); algal wackestone; laminated.	**0.3**
36	Covered slope.	**1.5**
35	Limestone; medium dark gray (N4); wackestone.	**0.8**
34	Covered slope.	**0.7**
33	Limestone; medium dark gray (N5); mudstone.	**0.5**
32	Limestone; medium light gray (N6); weathers grayish orange (10YR7/4); wackestone; crinoids and brachiopods.	**0.6**
31	Covered slope.	**0.3**
30	Limestone; medium dark gray (N4); mudstone; fetid.	**0.4**
29	Covered slope.	**2.3**
28	Limestone; medium dark gray (N4); mudstone; thinly laminated.	**0.3**
27	Covered slope.	**0.3**
26	Limestone; medium gray (N5); weathers grayish orange (10YR7/4); algal wackestone.	**0.1**
25	Covered slope.	**0.3**
24	Limestone; medium dark gray (N4); pelloidal rudite.	**0.1**
23	Covered slope.	**1.4**
22	Sandstone; medium gray (N5), weathers moderate brown (5YR3/4); fine to medium grained; quartzose; calcareous; trough crossbeds; locally pebbly.	**0.3**
21	Limestone; medium gray (N5); wackestone; thinly bedded.	**0.4**
20	Limestone; medium gray (N5); grainstone.	**0.2**
19	Covered slope.	**0.7**
18	Limestone; banded medium gray (N5) and dark yellowish orange (10YR6/6); algal wackestone; wavy laminae.	**0.7**
17	Limestone; medium light gray (N6); wackestone; thinly bedded.	**0.3**
16	Covered slope.	**0.6**
15	Limestone; medium gray (N5); weathers pale yellowish brown (10YR6/2); grainstone; thinly laminated.	**0.1**
14	Covered slope.	**0.7**
13	Limestone; medium dark gray (N4); grainstone.	**0.5**
12	Covered slope.	**0.6**
11	Sandstone; medium gray (N5) and pale yellowish brown (10YR6/2); fine to very coarse grained; quartzose; poorly sorted; calcareous; pebbly.	**1.1**
10	Covered slope.	**1.6**
9	Limestone; medium dark gray (N4); mudstone; fetid.	**0.4**
8	Covered slope.	**1.4**
7	Conglomerate; medium gray (N5); limestone pellets; thin tabular beds.	**0.5**

6	Shale; very pale orange (10YR8/2); calcareous.	**8.5**
5	Limestone; color banded pale yellowish brown (10YR6/2) and dark yellowish orange (10YR6/6); algal wackestone; wavy laminations.	**0.1**
4	Covered slope.	**2.5**
3	Limestone; same as unit 5.	**0.4**
2	Covered slope.	**0.8**
1	Limestone; same as unit 5.	**0.2**