STRATIGRAPHY OF THE LOWER PERMIAN HUECO GROUP IN THE ROBLEDO MOUNTAINS, DONA ANA COUNTY, NEW MEXICO

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Abstract

Most of the Paleozoic strata exposed in the Robledo Mountains, Dona Ana County, New Mexico have long been referred to the Hueco Formation divided into four informal members. We re-visit stratigraphy by elevating Hueco to group status in the Robledo Mountains and naming its constituent formations (ascending order) the Shalem Colony, Community Pit, Robledo Mountains, and Apache Da m Formations. The Shalem Colony Formation is about 183 m thick and mostly calcirudites, calcarenites and grainstones. The Community Pit Formation is about 61 m thick and mostly packstones and micrites. The 125-m- thick Robledo Mountains Formation is packstones, marine shale and red-bed sandstones and siltstones. The Apache Da m Formation is about 122 m thick and mostly alga l plate limestones. Biostratigraphically useful fossils from the Robledo Mountains Formation indicate a late Wolfcampian age.

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STRATIGRAPHY OF THE LOWER PERMIAN HUECO GROUP IN THE ROBLEDO MOUNTAINS, DONA ANA COUNTY, NEW MEXICO

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ABSTRACT: Most of the Paleozoic strata exposed in the Robledo Mountains, Dona Ana County, New Mexico have long been referred to the Hueco Formation divided into four informal members. We revise stratigraphy by elevating Hueco to group status in the Robledo Mountains and naming its constituent formations (ascending order) the Shalem Colony, Community Pit, Robledo Mountains, and Apache Dam Formations. The Shalem Colony Formation is about 183 m thick and mostly calcirudites, calcarenites and grainstones. The Community Pit Formation is about 61 m thick and mostly packstones and micrites. The 125-m-thick Robledo Mountains Formation is packstones, marine shale and red-bed sandstones and siltstones. The Apache Dam Formation is about 122 m thick and mostly algal plate limestones. Biostratigraphically useful fossils from the Robledo Mountains Formation indicate a late Wolfcampian age.

INTRODUCTION

The Robledo Mountains are a wedge-shaped horst of Paleozoic rocks tilted southward and located on the western margin of the Rio Grande rift in Dona Ana County, just northwest of Las Cruces (Fig. 1). Most of the Paleozoic strata exposed in the Robledo Mountains have long been referred to the Hueco Formation, divided into four units: lower member, middle member, Abo Tongue (or Member) and upper member (e.g., Kottlowski, 1960a, 1963; Jordan, 1971, 1975). Recently, Lucas et al. (1995a) abandoned the term Abo Tongue (or Member) and replaced it with the term Robledo Mountains Member of the Hueco Formation.

The currently used shatigraphic nomenclature of three informal members and one formal member of the Hueco Formation well reflects the fact that four distinct, mappable Lower Permian lithostratigraphic units are present in the Robledo Mountains. However, this stratigraphic nomenclature is not consistent with the nomenclature of the Hueco Group used in the Hueco and Franklin Mountains to the southeast (cf. Williams, 1963; Jordan and Wilson, 1971). Furthermore, a detailed and comprehensive lithostratigraphy of Hueco strata exposed in the Robledo Mountains has not been published, although much information is available in unpublished form in Jordan (1971). Here, we present such a detailed lithostratigraphy and a formal nomenclature of Hueco strata in the Robledo Mountains consistent with regional stratigraphic nomenclature of the Hueco Group.

PREVIOUS STUDIES

Darton (1928, p. 326) mentioned the Robledo Mountains (as "Roblero Mountain"), but he believed the limestones exposed in the range are mostly "Magdalena Group" and therefore pre-Hueco and of Pennsylvanian age. Indeed, Darton (1928, p. 20) only identified Hueco strata in New Mexico in the northern Franklin and Sacramento Mountains. Dunham (1935, p. 166-167, 247) also identified most of the Paleozoic limestones exposed in the Robledo Mountains as Magdalena "Series" and noted these strata are intertongued with red beds of the Abo "Sandstone."

Thompson (1942, pl. 2) first identified the Hueco Limestone in the Robledo Mountains (also see Thompson, 1954, fig. 8). Thompson (1954) documented a fusulinid fauna from the lowermost Hueco strata in the Robledo Mountains, including species of *Schwngerinn*, *Pseudoschwngerinn* and *Dunbnrinelln*.

Kottlowski (1960a), in his geologic map of the Las Cruces quadrangle, mapped all the Paleozoic strata in the Robledo Mountains south of Robledo Peak as Hueco Formation. He indicated a total Hueco thickness in the Robledo Mountains of 523 m, including in the upper half of the Hueco an "Abo tongue" or "Abo elastic tongue" (Fig. 2); Kottlowski (1960b, fig. 31; 1963) recounted this stratigraphy.

Jordan (1971, 1975) presented the most detailed study of Hueco stratigraphy in the Robledo Mountains to date (Fig. 2). He divided the Hueco into four units: (1) lower member, about 183 m of oolitic grainstone, calcirudite and minor crossbedded sandstone and siltstone interpreted as shoal water deposits; (2) middle member, about 61 m of carbonate mudstone, shale and minor packstone and grainstone interpreted as shallow-water shelf environments; (3) Abo Tongue, 125 m of red-bed elastics, marine limestone and shale interpreted as nearshore to terrestrial facies; and (4) upper member, 122 m of algal-plate limestone, thin biostromes and interbedded siltstones interpreted as very shallow-water shelf facies.

Simpson (1976; also see LeMone et al., 1971, 1975) presented detailed shatigraphic and paleontologic data on the "Abo Tongue" and "upper member" of the Hueco in the Robledo Mountains. He used Jordan's (1971, 1975) stratigraphic framework, as did Seager et al. (1987) in the most recently published geologic map of the Robledo Mountains. Lucas et al. (1995a) presented the only revisions to Jordan's stratigraphy when they abandoned the name Abo Tongue and replaced it with the name Robledo Mountains Member of Hueco Formation.

LITHOSTRATIGRAPHY

Hueco Group

Rationale

We elevate the term Hueco Formation in the Robledo

Mountains to group status, as Hueco Group (Fig. 2). We do so because: (1) Hueco is used as a group-level unit in the Franklin Mountains and at its type area in the Hueco Mountains, sections similar in many features to the Hueco section in the Robledo Mountains (Williams, 1963; Jordan and Wilson, 1971); and (2) the 500+-m-thick Hueco section in the Robledo Mountains is readily divided into four lithostratigraphic units mappable at 1:24,000 scale (e.g., Lucas, et al., 1995a, fig. 2). These units are better termed formations of a Hueco Group, rather than members of a Hueco Formation (Fig. 3).

Shalem Colony Formation

The w1it Jordan (1971, 1975) termed "lower member" of the Hueco Formation here is termed the Shalem Colony Formation of the Hueco Group. However, the lower 53 m of Jordan's (1971) "lower member" are returned by us to the Bursum Formation as previously recognized by Thompson (1954) and Kottlowski (1960b, 1963).

settlement of that name on the eastern flank of the Robledo

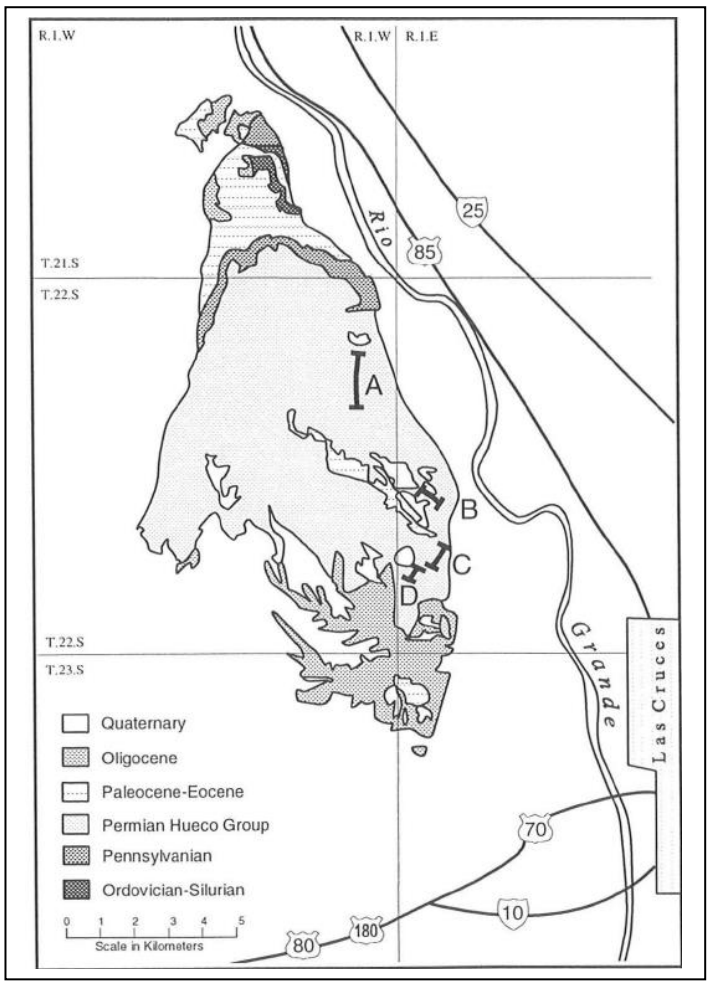

FIGURE 1. Generalized geological map of the Robledo Mountains (after Seager et al., 1987) showing locations of measured sections in Figure 3. A=Shalem Colony Formation type section; B=Community Pit Formation type section; C=Robledo Mountains Formation type section; D=Apache Dam Formation type section.

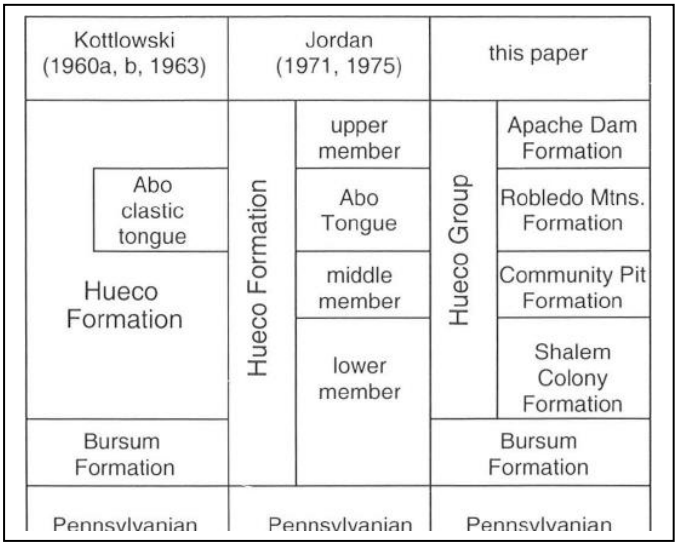

FIGURE 2. Development of lithostratigraphic nomenclature of the Hueco Group in the Robledo Mountains.

Mountains. The type section of the Shalem Colony Formation (Fig. 4) was measured in three north-south segments in the Elh Wlh sec. 12, T22S, RlW about 5 km NW of the Shalem Colony (Fig. 1). The type section of the Shalem Colony Formation is 106 m thick, but this is not a complete section of the unit. Jordan (1971) estimated a complete thickness of the unit of approximately 183 m, and we use that thickness here (Fig. 3).

Approximately 50% of the type section is slope-forming shale or siltstone. The most common ledge-forming beds are calcirudites (13%), calcarenites (11%), and grainstones (9%) (Fig. 5A-C). Less common are packstones (7%), micrites (5%), algal boundstones (4%), and wackestones (< 1%). Typical colors are light brownish gray, pale brown and grayish orange. Some calcarenites are crossbedded. The Shalem Colony Formation thus is recognizable as a generally brownish, coarse-grained succession of interbedded, slope-forming shale and bench-forming limestone dominated by calcirudites, calcarenites and grainstones. Its base is the stratigraphically lowest calcirudite above Bursum packstones, and its top is the highest calcirudite below Community Pit Formation packstones, micrites and shale (Figs. 3-4).

The Shalem Colony Formation is extensively exposed in the Nlh T22S, RlW (Fig. 1). However, due to faulting, no single, complete section is preserved. The type section thus is a relatively thick (about 60% of the total) and representative section of the Shalem Colony Formation.

Community Pit Formation

Jordan's (1971, 1975) "middle member" of the Hueco Formation here is named the Community Pit Formation. The Community Pit is a large building-stone quarry developed in the Hueco Group just southeast of the formation's type section, which is in the SE¼ NW¼ and NW¼ SE¼ sec. 19, T22S, RlW (Fig. 1).

The type section of the Community Pit Formation is 59 m thick (Fig. 4), but it is not quite a complete section of the unit (Fig. 5). Jordan (1971) estimated a total thickness of the Community Pit Formation of 61 m, and that thickness is used here (Fig. 3).

At the type section, nearly half of the unit (42% of the section)

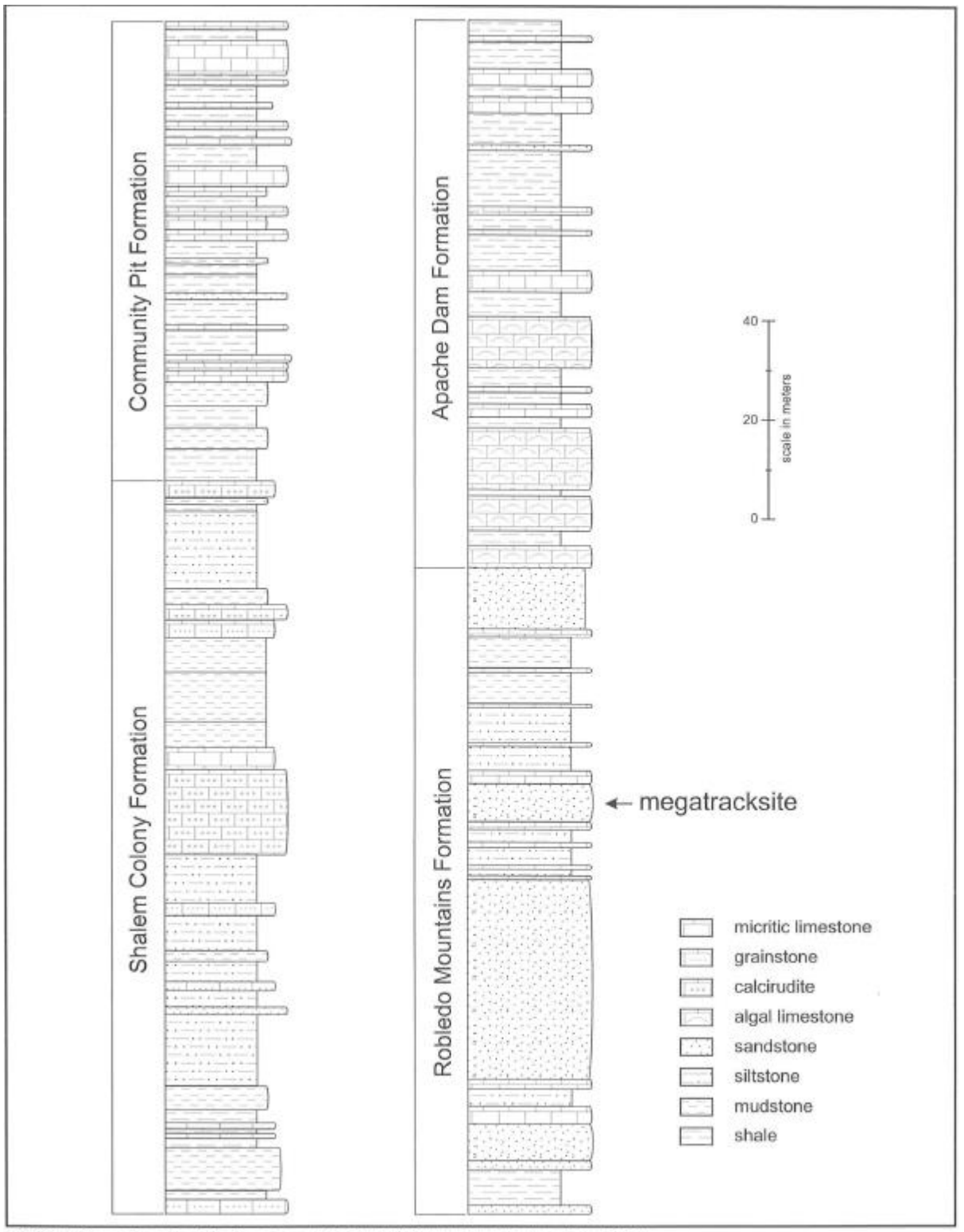

FIGURE 3. Composite section of the Hueco Group in the Robledo Mountains (modified from Jordan, 1971).

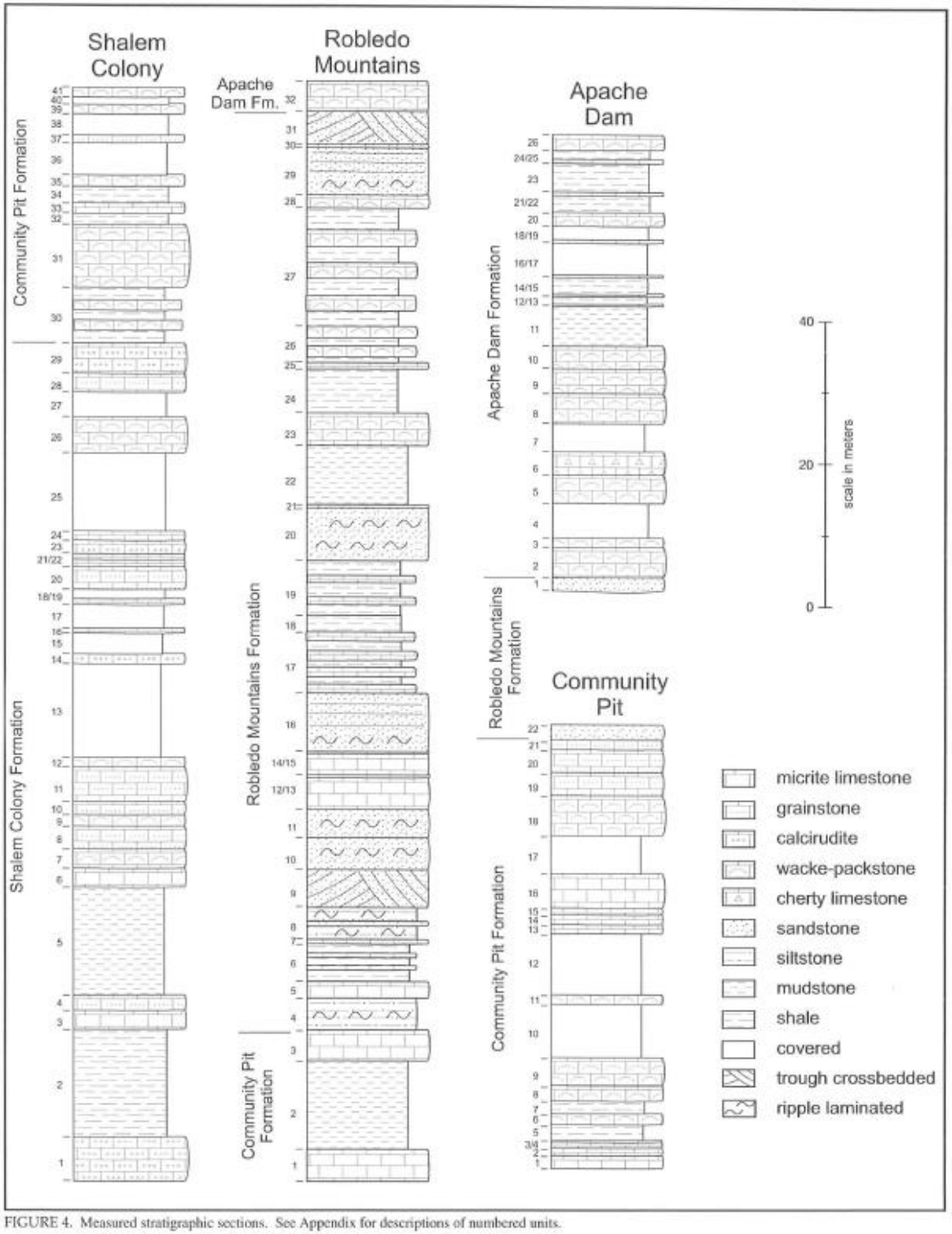

FIGURE 4. Measured stratigraphic sections. See Appendix for descriptions of numbered units.

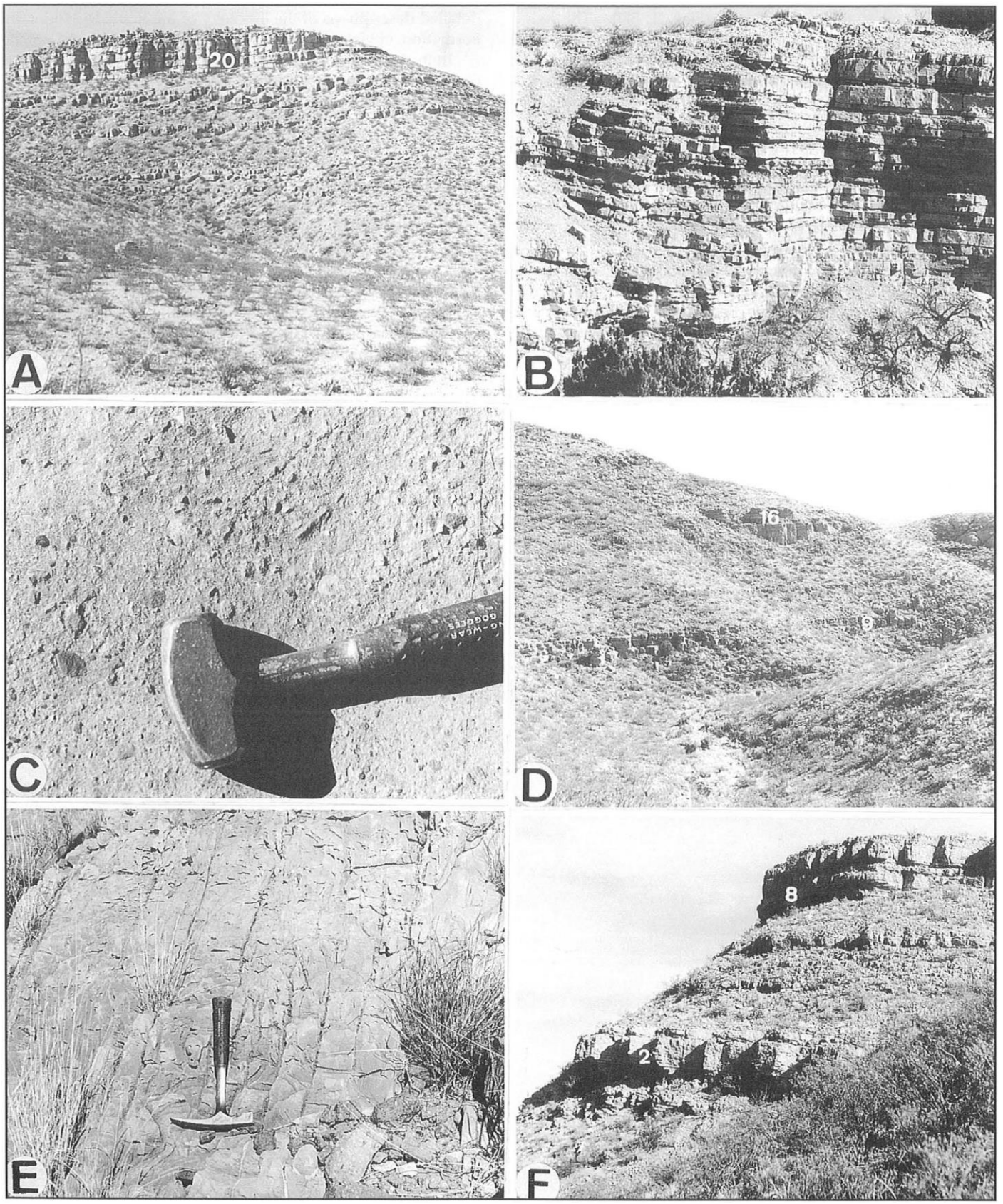

FIGURE 5. Selected photographs of Hueco Group strata in the Robledo Mountains. A, Slope of Shalem Colony Formation in NW¼ NW¼ sec. 18, T22S, R 1W. Unit 20 of the type section of the Shalem Colony Formation forms base of the cliff. B, Medium-bedded, brownish grainstones of Shalem Colony Formation in SE¼ NE¼ sec 13, T22S, R 1W. C, Characteristic calcirudite of Shalem Colony Formation (unit 23 of type section). D, Overview of lower part of type section of Community Pit Formation (units 9 and 16 labelled). E, Characteristic lime mudstone of Community Pit Fomiation (unit 13 of type section). F, Ove1view of type section of Apache Dam Formation (units 2 and 8 labelled).

is slope-forming shale or siltstone (Figs. 4, SD). The ledge-forming units are mostly packstones (26%) and micrites (19%) (Fig. SE). Grainstones (11%) and calcarenites (2%) are only common near the top of the Community Pit Formation, just below its contact with the overlying Robledo Mountains Formation. Typical colors are brownish gray and grayish orange.

The Community Pit Formation thus can be characterized as a brownish-gray to grayish-orange succession of interbedded shale, packstone and micrite. Its basal contact with the Shalem Colony Formation is the top of the highest calcirudite, and its upper contact is the base of the lowest red-bed siliciclastics of the Robledo Mountains Formation.

The Community Pit Formation is widely exposed in the central part of T22S, R1W and the west-central part of T22S, R1E (Fig. 1). Here, nearly complete sections of the formation are common, and the type section of the formation well represents the unit.

Robledo Mountains Formation

We elevate the term Robledo Mountains Member of Lucas et al. (199Sa) to formation status. The type section of the Robledo Mountains Formation (Figs. 4, 6) is in the N1h SE%, sec. 30, T22S, R1W, where the unit is 12S.4 m thick and consists of marine shale and nodular limestone, nonmarine red-bed sandstone, ledgy marine limestone and shale (Lucas et al. 199Sa, fig. 4, appendix). Lucas et al. (199Sa), and Krainer and Lucas (199S) provided detailed descriptions of the lithology of the Robledo Mountains Formation, obviating the need for a description here.

In the Robledo Mountains, the Robledo Mountains Formation is only exposed in the southern part of the range in the S1h T22S, R1W-R1E (Kottlowski, 1960a; Seager et al., 1987; Lucas et al., 199Sa). Here, it is readily identified because of the red-bed elastics it includes (Fig. 6).

The Robledo Mountains Formation has received the most intensive paleontological study of any part of the Hueco section in the Robledo Mountains (see papers in Lucas and Heckert, 199S). It provides the only direct and precise evidence of the age of the Hueco Group in the Robledo Mountains (see below).

Apache Dam Formation

We coin the name Apache Dam Formation for the unit termed "upper member" of the Hueco Formation by Jordan (1971, 197S). The type section of the Apache Dam Formation (Figs. 4, SF, 6) is located in the NE% SW% sec. 30, T22S, R1W, about 1.S km NW of Apache Dam, a stock dam in Apache Canyon on the SE flank of the Robledo Mountains (Fig. 1).

At the type section, the Apache Dam Formation is 61.7 m thick, but this is an incomplete thickness of the unit because nowhere in the Robledo Mountains is a Permian unit younger than the Apache Dam Formation present. Jordan (1971) estimated a maximum (but still incomplete) thickness of the Apache Dam Formation of about 122 m, and that figure is used here (Fig. 3).

FIGURE 6. Low angle aerial photograph of Hueco Group outcrops (principally in sec. 30, T22S, R1W). Type sections of Robledo Mountains Formation (R) and Apache Dam (A) Formations indicated. Note how readily mappable the two formations are here (also see Lucas, et al., 1995, figs. 2, 8). Photograph by Paul L. Sealey.

The Apache Dam Formation at the type section is essentially equal amounts of algal biopackstone (48% of the section) and slope-forming shale/siltstone (48% of the section). Characteristic colors are dark gray and brownish gray. Algal-plate limestones are characteristic of the Apache Dam Formation, and very detailed descriptions of the unit can be found in Simpson (1976). Its basal contact is mapped at the base of the lowest such limestone above Robledo Mountains Formation elastics (Lucas et al., 1995a, fig. 2).

The Apache Dam Formation is widely exposed in the southern third of T22S, RlW and the southwestern part of T22S, RlE, where it generally caps mesas and cuestas (Figs. 1, 6). The type section is a representative, accessible but incomplete section of the formation.

PALEONTOLOGY AND AGE

Thompson (1954) reported some long-ranging fusulinids from the Shalem Colony Formation. No other biostratigraphically useful fossils have been reported from the Shalem Colony or Community Pit Formations. In the Robledo Mountains, fusulinids from the Bursum Formation indicate an early Wolfcampian age (Thompson, 1954), so this is the maximum age of the Hueco Group in this area. In Hueco Group strata in the Robledo Mountains, only the Robledo Mountains Formation has produced biostratigraphically significant fossils (Fig. 7), and they have been discussed and documented by Kietzke and Lucas (1995), Kozur and LeMone (1995), Kues (1995), Lucas (1995) and Lucas et al. (1995a).

The "megatracksite" (numerous tracksites at a single stratigraphic level over an area of 20 km^2: Lucas et al, 1995a) occurs stratigraphically low in the Robledo Mountains Formation (Fig. 3). B. Wardlaw of the U.S. Geological Survey (written commun., 1995) extracted and identified conodonts from limestones collected by Lucas that bracket the principal tracksite, NMMNH locality 846. From limestone below the tracks (unit 2 of Hunt, et al., 1993, fig. 4) he identified *Sweetognatlws expansus* (Perlmutter), and from limestones just above the tracks (units 6 and 8 of Hunt, et al., 1993, fig. 4) he identified *Sweetognatlws expansus* (Perlmutter), *Hindeodus excavatus* (Behnken), *Neostreptognathodus clarki* Kozur, *Diplog11athod11s* sp. and *Sweetina festiva* (Bender and Stoppel). Wardlaw concluded: "these are all shallow-water faunas . . . of about the same age . . . indicating a latest Artinskian age (this is in the Kozur-Wardlaw scheme of things where Artinskian is below Leonardian)."

Kozur and LeMone (1995) described conodonts from the unit they termed "Hueco I" in the Shalem Colony section of the "Abo Member" that they concluded indicate the *Mesogondolella bisselli* - *Sweetog11ath11s merrilli* Zone of Artinskian age. Their "Hueco I" interval is stratigraphically below the megatracksite level (Lucas, 1995, fig. 2 erroneously showed it as above), and thus their age determination is consistent with Wardlaw's age determination. The lower part of the Robledo Mountains Formation is of late Wolfcampian (Artinskian) age.

Fossils from the uppermost Robledo Mountains Formation indicate an age very close to the Wolfcampian-Leonardian boundary. Ostracods described by Kietzke and Lucas (1995) include *Cavellina edmistonae* (Harris and Lalicker), which suggests an age of latest Wolfcampian-earliest Leonardian. Kues (1995) described brachiopods and two ammonoid species *(Properrinites bosei* [Plummer and Scott] and *Metalegocems baylorense* [White]) indicative of a latest Wolfcampian age. The entire Robledo Mountains Formation thus is of well-established late Wolfcampian age (Fig. 7).

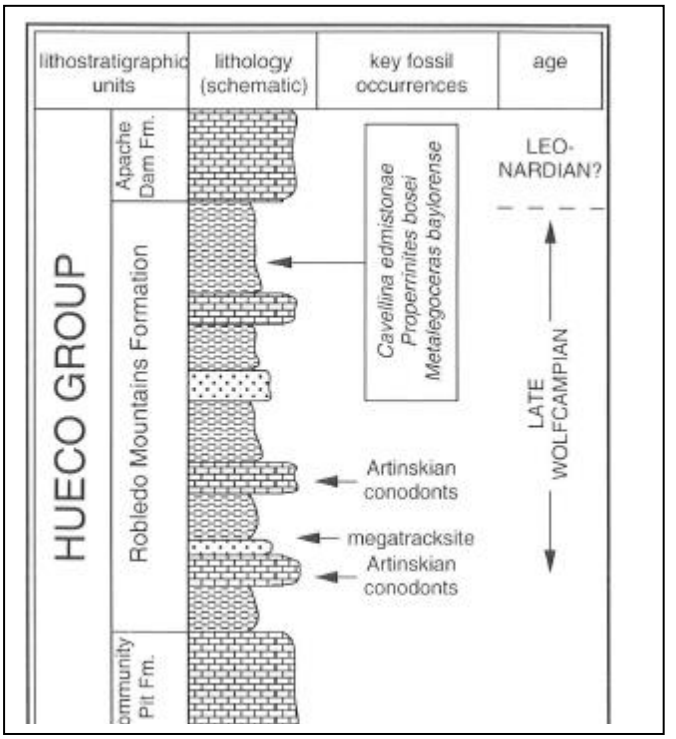

FIGURE 7. Stratigraphic distribution of biostratigraphically useful fossils in the Robledo Mountains Formation.

No age-diagnostic fossils have been reported from the Apache Dam Formation in the Robledo Mountains. It may be of earliest Leonardian age (Fig. 7), but this is not certain.

CORRELATION

The Hueco Group section exposed in the Robledo Mountains can be correlated to Hueco Group sections exposed in other parts of New Mexico and West Texas where sections also deposited in the Paleozoic Orogrande basin are exposed (Fig. 8). In the Dofia Ana Mountains to the northeast just across the Rio Grande, Seager et al. (1976), Mack et al. (1988) and Lucas et al. (1995b) described the Hueco section as: (1) lower Hueco, about 128 m of algal biomicrudite, shaly limestone and micrite; (2) middle Hueco, about 76 m of biomicrite and micrite; (3) gastropod-bearing member, about 122 m of gastropod-rich limestone; and (4) Abo Formation (Seager et al., 1976; Mack et al., 1988) or Robledo Mountains Member (Lucas et al., 1995b), about 81m of calcareous shale, packstone and red-bed sandstone and siltstone. This unit (and the entire Hueco) is incomplete in the Dofia Ana Mountains due to erosion.

Clearly, the term Robledo Mountains Formation can be readily extended into the Dofia Ana Mountains (Lucas et al., 1995b) (Fig. 8). Direct extension of the Shalem Colony and Community Pit Formations into the Dofia Ana Mountains is not so straightforward, as their distinctive lithologies are not reflected in the more basinward facies of the Hueco Group in the Dofia Ana Mountains. As Seager et al. (1976, fig. 6) indicate, the Community

Pit Formation in the Robledo Mountains is probably equivalent to the upper part of the lower-middle Hueco and the gastropod-bearing member in the Dona Ana Mountains, but a more precise correlation requires further information.

To the southeast, in the Franklin Mountains, the Hueco Group section (Fig. 8) is about 640 m thick and has been divided into the Hueco Canyon, Cerro Alto and Alacran Mountain Formations (Williams, 1966; Jordan and Wilson, 1971). This is the same stratigraphic nomenclature used in the Hueco Mountains further east where the type Hueco Group section is about 488 m thick (Williams, 1963; Jordan, 1975), though in the Hueco Mountains the Hueco Canyon Formation contains basal red-bed siliciclastics (Powwow Member) not present in the Franklin Mountains. Key to correlation of these sections to the Robledo Mountains Hueco strata is the fact that the Cerro Alto Formation contains a late Wolfcampian fusulinid assemblage (Williams, 1963), and this supports correlation to the late Wolfcampian Robledo Mountains Formation (Jordan, 1975). The Shalem Colony and Community Pit Formations are thus broadly correlative to the Hueco Canyon Formation, and the Apache Dam Formation can be considered approximately correlative to the Alacran Mountain Formation (Fig. 8). However, the paleontological and lithostratigraphic basis for these latter correlations is not definitive.

In the San Andres Mountains, the Hueco section is about 440 m thick (Kottlowski et al., 1956). It has been divided into a lower Hueco dominated by grainstones, algal-plate limestones and bioherms, followed by the upper Hueco (about two-thirds of the unit) of wackestones, packstones and crossbedded siltstones. The Hueco intertongues with and grades into overlying Abo red beds. Like Jordan (1975), we correlate these Abo red-beds to the Robledo Mountains Formation in the Robledo Mountains. Therefore, the Hueco Limestone in the San Andres Mountains correlates to the Shalem Colony and Community Pit Formations in the Robledo Mountains (Fig. 8).

In the southern Sacramento Mountains, the Hueco Formation is a tongue (Pendejo Tongue of Pray, 1961) about 190 m thick between two red-bed tongues of Abo Formation (Bachman and Hayes, 1958; Otte, 1959; Pray, 1961). The lower Abo Tongue is the Danley Ranch Tongue, whereas the upper Abo Tongue is the Lee Ranch Tongue, both units named by Bachman and Hayes (1958). Otte (1959), Pray (1961) and Williams (1963) demonstrated biostratigraphically that the Pendejo Tongue in the southern Sacramento Mountains correlates to the Hueco Canyon, Cerro Alto and Alacran Mountain (lower part) Formations in the Hueco Mountains. This indicates that the Pendejo Tongue correlates to the Shalem Colony, Community Pit, and Robledo Mountains Formations in the Robledo Mountains (Fig. 8).

Bachman and Hayes (1958) correlated the Lee Ranch Tongue of the Abo Formation with the lower part of the Yeso Formation. They did so because the Lee Ranch Tongue contains an assemblage of the *Supaia* paleoflora ("Zone"), which Read and Mamay (1964) identified as a Leonardian paleoflora. However, as Hunt (1983) demonstrated, some localities of the *Supaia* paleoflora are of Wolfcampian age; the distribution of the paleoflora is more facies- and taphofacies-controlled than temporally significant. Therefore, the correlation of Williams (1963) and Jordan (1975) of the Lee Ranch Tongue and the redbeds of the Alacran Mountain Formation in the Hueco Mountains is plausible. This means the Lee Ranch Tongue is correlative to at least part of the Apache Dam Formation in the Robledo Mountains (Fig. 8).

Correlation of Hueco Group strata in the Robledo Mountains emphasizes the relatively unique Hueco section preserved in the range. These strata were deposited on the western side of the Orogrande basin (Jordan, 1975) and begin with shoal deposits (Shalem Colony Formation) overlain by more normal marine shelf deposits (Community Pit Formation). Mixed tidal flat and shallow marine deposits (Robledo Mountains Formation) follow and are capped by bioherm and shelf deposits (Apache Dam Formation). Correlation of these Hueco Group strata in the Robledo Mountains to more basinward facies in the Franklin, Dona Ana and San Andres Mountains is not very precise. Perhaps the most similar section is that deposited on the eastern margin of the Orogrande basin, in the Hueco Mountains. But

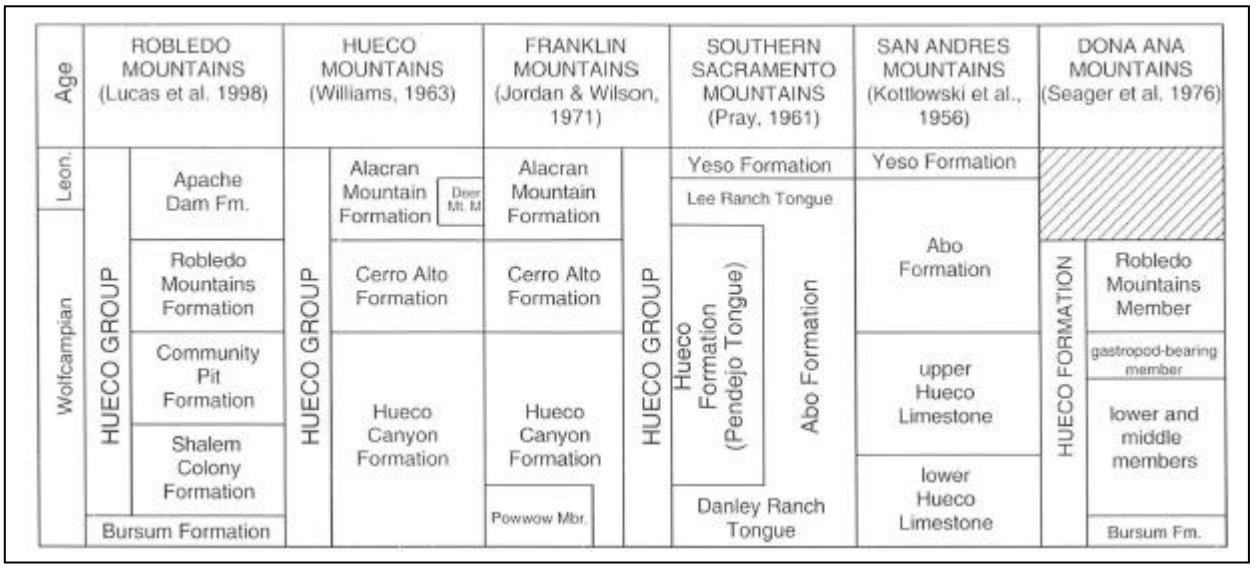

FIGURE 8. Correlation of Hueco Group strata in the Robledo Mountains with other Hueco sections in the Orogrande basin.

even this section is fundamentally different in parts from the Robledo Mountains Hueco Group (note, for example the dissimilarity of the shelf/biohermal deposits of the Cerro Alto Formation and the apparently correlative Robledo Mountains Formation). These dissimilarities must reflect local differences in tectonics and subsidence during Wolfcampian sedimentation in the Orogrande basin. A more robust biostratigraphy and lithostratigraphy of these Wolfcampian strata is needed to further delineate these differences.

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APPENDIX

Shalem Colony Formation Type Section

Section measured in 3 segments in the E1/2 of the W1/2 section 12, T22S, R1W. Section begins at UTM Zone 13, 321S64N, 3S87839E, near (1971) RH section and ends at UTM Zone 13, 322208E, 3S8699N. Strata dip S°E, striking N7°E.

unit	lithology	thickness (m)
Hueco Group:		
Community Pit Formation:		
41	Biopackstone; yellowish gray (SY7/2) to pinkish gray (SYR8/1); forms a ledge along ridge crest.	1.0
40	Covered slope.	1.3
39	Packstone and bioclastic micrite; light brownish gray (SYR6/1) fresh; weathers pale yellowish brown (10YR6/2) to moderate orange pink (SYR8/4); some rugose corals; forms a ledge.	1.2
38	Covered slope.	2.9
37	Bioclastic grainstone; grayish orange pink (SYR7/2) to pale brown (SYRS/2) fresh; weathering rinds of moderate orange pink (SYR8/4) and light brown (SYR6/4); cherty; forms a ledge.	1.1
36	Covered slope.	4.6
3S	Wackestone; moderate light gray (N6) with numerous light brownish gray (SYR6/l) chert nodules; weathers to light gray (N7) and moderate reddish orange (10R6/6); forms a ledge.	1.6
34	Shale; forms a mostly covered slope.	2.1
33	Bioclastic micrite; light brownish gray (SYR6/l) fresh; weathers pale yellowish brown (10YR6/2); some chert as in unit 22; some crinoid debris; top of segment at 3212164E, 3S87330N; offset to SE to 322234E, 3S87069N.	l.S
32	Shale; forms a mostly covered slope.	1.4
31	Biopackstone; medium dark gray (N4) fresh; weathers medium gray (NS) to medium light gray (N6) and light brown (SYR6/4); some chert that is brownish gray (SYR4/l) fresh, weathering pinkish gray (SYR8/1); bedded in 0.3 to 0.5-m-thick-ledges.	8.8
30	Interbedded wackestone and shale; wackestone is medium dark gray (N4) fresh, weathers light brownish gray; forms thin ledges; shale forms mostly covered slopes.	7.8
Shalem Colony Formation:		
29	Calcirudite; matrix is medium light gray (N6), clasts are dark gray (N3) fresh; weathers to light brown (SYRS/6) with rinds of very pale orange (10YR8/2); clasts predominantly 2-S mm diameter limestone pebbles; ledgy; beds are 0.3 to O.S-m-thick.	4.2
28	Calcarenite; pale brown (SYRS/2) fresh; weathers dusky brown (SYR3/2); fine- to medium-grained, subangular, well-sorted, graded beds and crossbeds.	2.7
27	Covered slope.	3.3
26	Biopackstone to calcirudite; packstone is medium light gray (N6) fresh; weathers to crusts of brownish gray (SYR4/1) and light brownish gray (SYR6/l); calcirudite is medium gray (NS) fresh; weathers moderate orange pink (10R7/4); much algal debris; forms a cliff. At top of this unit offset approximately 200 m to southeast to 322072E, 3S87394N.	S.2
2S	Covered slope.	10.8
24	Calcarenite; medium dark gray (N4) fresh; weathers pale yellowish brown (10YR6/2); very fine-grained, subangular, well-sorted quartzose calcarenite; forms a ledge.	1.3
23	Calcirudite; matrix is light brownish gray (SYR6/1), clasts are medium dark gray (N4) fresh; weathers grayish orange pink (SYR7/2); well-rounded limestone clasts up to lS mm in diameter; poorly sorted; forms a ledge.	1.8
22	Calcirudite; medium gray (NS) fresh; weathers medium dark gray (N4); subrounded limestone and chert pebbles up to 3S mm diameter.	0.7
21	Calcarenite; light brownish gray (SYR6/l) fresh; weathers pale brown (SYRS/2); fine-grained, subrounded, very well sorted calcarenite.	1.2
20	Calcarenite; pale red purple (SRP6/2) fresh; weathers moderate brown (SYR4/4); fine- to coarse-grained, subangular, moderately poorly sorted quartz- and lithic-rich calcarenite; Jordan's locally pebbly; some crossbeds; graded beds.	3.3
19	Covered slope.	1.3
18	Biowackestone; medium dark gray (N4) fresh; weathers moderate reddish orange (10R6/6) to grayish orange pink (SYR7/2); pitted weathering; forms a ledge.	0.7
17	Covered slope.	3.0
16	Calcirudite; medium light gray (N6) fresh; weathers grayish orange pink (SYR7/2); limestone clasts up to S mm in diameter; moderately well-sorted; forms a ledge.	1.0
lS	Covered slope.	2.8
14	Calcarenite to calcirudite; calcirudite is pale brown (SYRS/2) fresh, weathers white (N9), dark yellowish brown (10YR4/2) and light brown (SYR6/4); clasts up to 8 mm in diameter; calcarenite is pale red (10R6/2) fresh; weathers light brown (SYR6/4); very fine- to fine-grained quartz-rich, well-sorted quartzarenite; some crossbeds.	1.4
13	Covered slope.	13.0
12	Algal boundstone; medium light gray (N6) fresh; weathers grayish orange pink (10R8/2); wavy stromatolitic texture; ledge.	1.4
11	Grainstone to pebbly calcarenite; light brownish gray (SYR6/1) fresh; weathers light gray (N7); clasts are fine-grained to pebbly limestone; some yellow shale partings.	4.5
10	Grainstone to pebbly calcarenite; grainstone is light brownish gray (SYR6/l) fresh; weathers light brown (SYR6/4); calcarenite is light brownish gray (SYR6/l) to brownish gray (SYR4/l); fine-grained to pebbly; unit tops out at 32162SE, 3S8768SN. Offset on top of unit 10 to SE to 321864E, 3S87440N.	1.9
9	Packstone; brownish gray (SYR4/l) fresh; weathering to very pale orange (10YR8/2), grayish red (10R4/2) and moderate reddish brown (10R4/6) crusts; much algal matting that is moderate brown (SYR4/4) fresh; weathers to variegated dark yellowish orange (10YR6/6); very pale orange (10YR8/2), and brownish black (SYR2/1); some hematitic blobs; cherty; forms a cliff.	1.8
8	Grainstone; light brownish gray (SYR6/1) fresh; weathers to grayish pink (SR8/2) rinds; cherty; some gastropods; hummocky bedded; forms a cliff.	2.9
7	Algal boundstone; same colors as unit 7; hummocky lamination; much shell debris; forms a cliff.	2.8
6	Bioclastic micrite; medium dark gray (N4); grayish orange pink (SYR7/2); much crinoid, gastropod, and brachiopod debris; unit forms base of large cliff.	2.6
S	Muddy siltstone and silty shale; grayish orange pink (SYR7/2); some ledges of wackestone that is pale yellowish brown (10YR6/2) fresh; weathers to grayish orange (10YR7/4).	lS.l
4	Calcarenite; pale reddish brown (10RS/4) fresh; weathers grayish orange (10YR7/4); fine grained, subrounded, well-sorted, quartz-rid1 calcarenite; forms a ledge.	2.2
3	Micrite, with minor calcirudite; micrite is medium gray (NS) fresh; calcirudite is medium dark gray (N4) fresh; both weather to very light gray (NB) and medium light gray (N6), with pale yellowish orange (10YR8/6) crusts; micrite is thick bedded in sets 0.3 to 0.5-m-thick; locally bioclastic; forms a ledge.	2.7
2	Shale; grayish orange (10YR7/4); slightly silty; some ledges of calcarenite to calcirudite which are moderate red (SRS/4) to light brownish gray (SYR6/l) fresh; weathering to grayish orange (10YR7/4) with grayish orange pink (10R8/2) crusts.	lS.O

Interbedded calcirudite and calcarenite; limestone is moderate reddish orange (10R6/6) fresh; weathers grayish orange (10YR7/4); calcarenite is pale reddish brown (10R5/4) fresh; weathers dark gray (N3); fine- to medium-grained, subangular, moderately well-sorted calcarenite; ledgy; thin-bedded. 6.1+

Community Pit Formation Type Section

Section measured in two segments, the lower portion in the SE1/4 NW1/4 and the upper in the NW1/4 SE1/4 of section 19, T22S, R1W. Section begins at UTM zone 13, 322963E, 3584008N. Strata dip 11° to S50°E in the lower segment (units 1-17) and 10° to S50°E in the upper segment (units 18-22).

unit	lithology	thickness (m)
Hueco Group:		
Robledo Mountains Formation:		
22	Sandstone; pale reddish brown (10R5/4) to dark reddish brown (10R3/4); very fine- to fine-grained, subangular, moderately well-sorted quartzarenite to sublitharnite; ripple laminated; calcareous.	not measured
disconformity?		
Community Pit Formation:		
21	Calcarenite; light brown (5YR5/6) fresh; weathers dark yellowish orange (10YR6/6); very fine- to fine-grained, well-sorted.	1.4
20	Grainstone; grayish orange (10YR7/4) fresh; weathers light brown (5YR5/6); heavily recrystallized.	3.0
19	Grainstone; olive gray (5Y4/1) fresh; weathers grayish orange (10YR7/4) with pinkish gray (5YR8/1) to very pale orange (10YR8/2) rinds; forms a cuesta.	3.3
18	Biopackstone; brownish gray (5YR4/1) to light brownish gray (5YR6/1) fresh; weathers grayish orange (10YR7/4); some laminar sections are dark yellowish orange (10YR6/1) to pale red (10R6/2) fresh; weathering to variegated moderate orange pink (5YR8/4) and moderate red (5R5/4); forms a series of 0.7-m-thick ledges.	5.4
17	Covered slope.	5.3
16	Micrite; medium dark gray (N4) fresh; weathers light brownish gray (5YR6/1); mud mound; forms a cliff; offset at top of this unit to 323154E, 3583487N	4.8
15	Bioclastic micrite; brownish gray (5YR6/1) to brownish gray (5YR4/1) fresh; weathers medium light gray (N6) to moderate orange (10R7/4).	1.0
14	Micrite; light brownish gray (5YR6/1) fresh; weathers grayish orange (10YR7/4); some very finely comminuted shell debris; forms a mud mound.	1.3
13	Bioclastic micrite; light brownish gray (5YR6/1) fresh; weathers to grayish orange pink (10R8/2); mud mound; forms a cliff.	1.5
12	Slope; much covered with some micrite ledges that are light brownish gray (5YR6/1) to brownish gray (5Y4/1) fresh; weathering to grayish orange (10YR7/4).	8.3
11	Biopackstone; light brownish gray (5YR6/1) to brownish gray (5YR6/1); much shell debris; some algal tubes; forms a ledge.	1.3
10	Covered slope.	7.6
9	Biopackstone; medium light gray (N6) fresh; weathers light brownish gray (5YR6/1); some shell debris; units 8 and 9 form a cliff.	3.8
8	Packstone; medium light gray (N6) fresh; weathers light brownish gray (5YR6/1); bedded in 0.3 to 0.5-m-thick sets; base of cliff.	2.3
7	Slope; mostly shale with some nodular packstone; numerous productoid brachiopods.	1.8
6	Packstone; brownish gray (5YR4/1) fresh; weathers pale yellowish brown (10YR6/2); numerous crinoid and bradiopod fragments; forms a ledge.	1.5
5	Shale; mostly covered slope; some packstone ledges of color and lithology similar to unit 6.	2.2
4	Packstone; dark gray (N3) fresh; weathers grayish orange pink (5YR7/2); much fragmentary shell material; forms a ledge.	0.3
3	Packstone; mediwn dark gray (N4) fresh; weathers medium light gray (N6) to light brown (5YR6/4); fine sand grains and shell debris; ripply.	0.7
2	Micrite; medium dark gray (N4) fresh; weathers medium light gray (N6) to light brown (5YR5/6); locally bioclastic.	1.2
	Micrite; light brownish gray (5YR6/1); weathers grayish orange pink (5YR7/2); ledge-forming.	1.8

Apache Dam Formation Type Section

Section measured in the NE\4 NE\4 SW\4 sec. 30, T22S, R1W, begins at UTM Zone 13, 322968E, 3582122N, and ends at UTM Zone 13, 323061E, 3582159N. Strata dip 9° to S30°W.

unit	lithology	thickness (m)
Hueco Group:		
Apache Dam Formation:		
26	Biopackstone; same colors and lithology as unit 24.	2.2
25	Shale; forms a mostly covered slope, some nodular limestone; same as unit 21.	1.4
24	Biopackstone; pale yellowish brown (10YR6/2) fresh; weathers to mottles of light brown (5YR5/6) and dark yellowish brown (10YR4/2); much silicified algal debris and comminuted shell debris.	0.4
23	Shale; forms a mostly covered slope, some nodular limestone; same as unit 21.	3.8
22	Bioclastic, sandy micrite; brownish gray (5YR4/1) fresh; weathers light brown (5YR6/4); many gastropods, bryozoans, and small brachiopods, forms a ledge; more massive than underlying units.	0.7
21	Shale; forms a mostly covered slope, some nodular gray limestone.	2.3
20	Packstone; medium dark gray (N4) fresh; weathers light brown (5YR6/4); much finely comminuted shell debris some productoid brachiopods, nodular weathering, forms a ledge.	2.0
19	Covered slope; probably shale.	1.8
18	Wackestone; brownish gray (5YR/41) fresh; weathers to grayish orange (10YR7/4); much comminuted shell debris in muddy matrix, some gastropods; nodular weathering; forms a ledge.	0.4
17	Covered slope; probably shale.	4.6
16	Packstone; medium gray (N4) fresh; weathers grayish orange pink (5YR7/2); much silicified algal debris, some shell debris.	0.3
15	Shale; mostly covered slope; same colors and lithologies as unit 13.	2.5
14	Wackestone to packstone; dark gray (N3) fresh; weathers medium gray (N4) and grayish orange pink (5YR7/2), with fossils between moderate orange pink (5YR7/2) and light brown (5YR6/4); much silicified algal debris; some shells and chert; forms a ledge.	0.2
13	Shale; mostly covered slope; same colors and lithologies as unit 11.	0.9
12	Biopackstone; medium dark gray (N4) and brownish gray (5YR4/1) fresh; weathers to light brownish gray (5YR6/1) and grayish orange (10YR7/4) with very pale orange (10YR2/2) crusts and rinds; abundant silicified algal sheets and debris; forms a ledge.	0.4
11	Silty mudstone and muddy siltstone; dark yellowish orange (10YR6/6); calcareous; forms a mostly covered slope above the main cliff.	5.6
10	Biopackstone; pale yellowish brown (10YR6/2) fresh; weathers light brown (5YR6/4); much algal and finely comminuted crinoid and gastropod debris; forms top of	

cliff. 3.0

9 Biopackstone and wackestone; medium gray (N4) fresh; weathers light brownish gray (5YR6/l) with crusts of light brownish gray (5YR6/1}; similar to unit 8 with less packstone; some chert nodules; forms a cliff. 3.6

8 Biopackstone with some wackestone; medium gray (N4); weathers grayish orange pink (5YR7/2}; thick beds of brown cherty algal debris alternating with biopackstone beds of bryozoans and gastropods; forms a cliff. 4.1

7 Slope; mostly covered, has a thin ledge of dark gray (N3) packstone with grayish orange (10YR7/4) laminations; weathers dark yellowish brown (lOYR/42). 3.9

6 Biopackstone with chert nodules up to 15on in diameter; medium dark gray (N4) fresh; weathers light brownish gray (5YR6/l}; much finely comminuted shell debris; some gastropods and algal debris. 3.4

5 Biopackstone; same colors and lithology as unit 2; thick-bedded with numerous algal plates; few gastropods; forms a cliff. 3.8

4 Covered slope; some nodular limestone. 4.8

3 Biopackstone; medium dark gray (N4) fresh; weathers to crusts of grayish orange pink (5YR7/2); abundant crinoid, bivalve and gastropod debris; some possible fusulinids; forms a ledge. 1.2

2 Biopackstone; medium dark gray (N4) fresh; weathers to light brownish gray (5YR6/l} and grayish orange (10YR7/4}; beds of stalked bryozoans, bellerophontid gastropods, and tubiphytic algal material 0.3 to 0.5 m thick; locally weathers to boulders. 4.4

Robledo Mountains Formation:

1 Sandstone; grayish orange (10YR7/4) and pale reddish brown (10R5/4) litharenite; ripple laminated; thinly bedded with some interbeds of calcareous shale; forms a steep slope. not measured