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

Authors
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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 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.
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 revisit 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 stratigraphic 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 Robledo Mountains, Franklin Mountains to the southeast, and Sacramento Mountains (cf. Williams, 1963; Jordan and Wilson, 1971). Further, 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 lithostratigraphic and formal nomenclature of 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 Pennsylvania nian 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 Schwingerinn, Pseudoschwingerinn and Dunbrinella.

Kottlowski (1960a), in his geologic map of the Las Cruces quadrangle, mapped a II the Paleozoic strata in the Robledo Mountains as "Magdalena Group" and noted these strata are intertongued with red bed s of the Abo "Sandstone."

Simpson (1976; also see LeMone et al., 1971, 1975) presented detailed stratigraphic and paleontologic data on the "Abo Tongue" and "upper member" of the Hueco in the Robledo Mountains. He used Jordan's 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 Mountain 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 will 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.

Mountains. The type section of the Shalem Colony Formation (Fig. 4) was measured in three north-south segments in the Elh Wih sec. 12, T22S, RIW 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 used 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 recrystallized. The Shalem Colony Formation thus is recognizable as a generally brownish, coarse-grained succession of interbedded, slope-forming shale and bench-forming limestone domes formed by calcirudites, calcarenites and grainstones. Its base is the stratiographically 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 Nih T22S, RIW (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 SE1/4 NW1/4 sec. 19, T22S, RIW (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 5. Selected photographs of Hueco Group strata in the Robledo Mountains. A, Slope of Shelfem Colony Formation in NW'4 NW71 sec. 18, T22S, R 1 W. Unit 20 of the type section of the Shelfem Colony Formation forms base of the cliff. B, Medium-bedded, brownish grainstones of Shelfem Colony Formation in SE'4 NE\3 sec 13, T22S, R 1W. C, Characteristic calcirudite of Shelfem 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 Formation (unit 13 of type section). F, Overview 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, RIW and the west-central part of T22S, RIE (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, RIW, where the unit is 124.4 m thick and consists of marine shale and nodular limestone, nonmarine red-bed sandstone, edgy 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, RIW-RIE (Kottlowski, 1960a; Seager et al., 1987; Lucas et al., 1999Sa). Here, it is readily identified because use 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 of 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, RIW, about 1.5 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, RIW). 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 as 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, RIW and the southwestern part of T22S, RIE, 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 "mega-tracksite" (numerous tracksites at a single stratigraphic level over an area of 20 km²; 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 *Sweatognathus expansus* (Perlmutter), and from limestones just above the tracks (units 6 and 8 of Hunt et al., 1993, fig. 4) he identified *Sweatognathus expansus* (Perlmutter), *Hindeodus excavatus* (Behnken), *Neostratogamodus clarki* Kozur, *Diplagnostus* sp. and *Sweetinatella stiva* (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-Wa rd law 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 -Sweatognathus expansus* Zone of Artinskian age. Their "Hueco I" interval is stratigraphically below the mega-tracksite level (Lucas, 1995, fig. 2 erroneously showed it as above), and thus their age determina tion is consistent with Wa rd law's age determina tion. The lower part of the Robledo Mountains Formation is of the late Wolfcampian (Artinskian) age.

Fossils from the uppermost Robledo Mountains Formation indicate an age very close to the Wolfcampian-earliest Leonardian. ostracods described by Kietzke and Lucas (1995) include *Cavellina edistoma* (Harris and Lalicker), which suggests an age of late Wolfcampian-earliest Leonardian. Kues (1995) described brachiopods and two ammonoid species (*Propernitina s bosi [Plummer and Scott] and Metaleugoceras baylousiense* [Whitely]) indicative of a late Wolfcampian age. The entire Robledo

<table>
<thead>
<tr>
<th>lithostratigraphic units</th>
<th>lithology (schematic)</th>
<th>key fossil occurrences</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache Dam Fm.</td>
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<td></td>
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<tr>
<td>Robledo Mountains Fm.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>LEO-</td>
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<tr>
<td>NARDIAN?</td>
<td></td>
<td></td>
<td>NARDIAN</td>
</tr>
</tbody>
</table>

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

Mountains Formation thus is of well-established late Wolfcampian age (Fig. 7). 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 Doñ.a 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 bioclasts, shaly limestone and micrite; (2) mid- to lower Hueco, about 76 m of bioclasts and micrite; (3) gastropod-bearing member, about 122 m of gastropod-rich limestone; and (4) Aba Formation (Seager et al., 1976; Mack et al., 1988) or Robledo Mountains Member (Lucas et al., 1995b), about 81 m of calcareous shale, packs tone and red-bed sandstone and siltstone. This unit (and the entire Hueco) is incomplete in the Doñ.a Ana Mountains due to erosion.

Clearly, the term Robledo Mountains Formation can be readily extended into the Doñ.a Ana Mountains (Lucas et al., 1995b) (Fig. 8). Direct extension of the Shalem Colony and Community Pit Formations into the Doñ.a Ana Mountains is not so straightforwardly, as their distinctive lithologies are not reflected in the more basinward facies of the Hueco Group in the Doñ.a Ana Mountains. As Seager et al. (1976, fig. 6) indicate, the Community
Pit Forma tion 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 in Formations (Williams, 1966; Jordan and Wilson, 1971). This is the same strataignor凤凰numeral ture 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 is the fact that the Cerro Alto Formation contains a late Wolf Ca. miu n fusa l nid assemblage (Williams, 1963), and this supports correlation to the late Wolf Ca. miu n 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 lithographic basis for these latter correlations is not definite.

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 Formation dominated by gra istones, algal-particle limestones and biolimestones, followed by the upper Hueco (about two-thirds of the unit) of wackestones, pa ckstone s and crossbedded siltstones. The Hueco in tertongu e s with and grades into overlying Abo red beds. Like Jordan (1975), we correlate these Abo red-beds to the Robledo Mountains Formation in the San Andres Mountains. Therefore, the Hueco Limestone in the San Andres Mountains is correlative 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 (Pend dle 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 Ab o Tongue is the Danley Ranch Tongue, whereas the upper Ab o Tongue is the Lee Ranch Tongue, both units named by Bachman and Hayes (1958). Otte (1959), Pray (1961) and Willia ms (1963) demonstrated biostratigraphically that the Pend dle Tongue in the southern Sacramento Mountains correlative to the Hueco Canyon, Cerro Alto and Alacran Mountain (lower part) Formations in the Hueco Mountains. This indicates that the Pend dle Tongue correlative to the Shalem Colony, Community Pit, and Robledo Mountains Formation 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 Yesso Formation. They did so because the Lee Ranch Tongue contains an assemblage of the *Sa puia* paleoflora (“Zone”), which Read and May (1964) identified as a Leona rdia paleoflora. However, as Hunt (1983) demonstrated, some localities of the *Sa puia* paleoflora are of Wolf Ca. miu n age, and the distribution of these paleofloras is more facies- and taphofa cies-controlled than the *Sa puia* tempora It signific a n. 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 the Shawl 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 bioher mal and shelf deposits (Apache Dam Formation). Correlation of these Hueco Group strata in the Robledo Mountains to more basinward facies in the Franklin 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

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

<table>
<thead>
<tr>
<th>Age</th>
<th>ROBLEDQ MOUNTAINS (Lucas et al. 1998)</th>
<th>HUECO MOUNTAINS (Williams, 1963)</th>
<th>FRANKLIN MOUNTAINS (Jordan &amp; Wilson, 1971)</th>
<th>SOUTHERN SACRAMENTO MOUNTAINS (Pray, 1961)</th>
<th>SAN ANDRES MOUNTAINS (Kottlowski et al., 1956)</th>
<th>DONA ANA MOUNTAINS (Geiger et al. 1976)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apache Dam Fm.</td>
<td>Alacran Mountain Formation</td>
<td>Alacran Mountain Formation</td>
<td>Yesso Formation</td>
<td>Yesso Formation</td>
<td>Robledo Mountains Member</td>
</tr>
<tr>
<td></td>
<td>Robledo Mountains Formation</td>
<td>Cerro Alto Formation</td>
<td>Cerro Alto Formation</td>
<td>Lee Ranch Tongue</td>
<td>Abo Formation</td>
<td>gastropod-bearing member</td>
</tr>
<tr>
<td>Wolfcamp</td>
<td>Community Pit Formation</td>
<td>Bursum Formation</td>
<td>Bursum Formation</td>
<td>Abo Formation</td>
<td>Robledo Mountains Member</td>
<td>lower and middle members</td>
</tr>
<tr>
<td></td>
<td>Shalem Colony Formation</td>
<td>Hueco Canyon Formation</td>
<td>Hueco Canyon Formation</td>
<td>Danley Ranch Tongue</td>
<td>lower Hueco Limestone</td>
<td>Bursum Fm.</td>
</tr>
</tbody>
</table>
even this section is fundamentally different in parts from the Robledo Mountains Hueco Group (note, for example the dissimila rity of the shelf/biothermal deposits of the Cerro Alto For ma tion and the appa rently correla tive Robledo Mountains Formation). These dissimilarity rites must reflect local differences in tectonics and subsidence during Wolfc a mpana sediments in the Oro grande basin. A more robust biostratigraphy and lithostratigraphy of these Wolfcampian strata is needed to further delineate these differences.

ACKNOWLEDGMENTS
The collaboration and comments of O. Anderson, A. Hunt and J. MacDonald made this work possible. W. Slade assisted in the field. The New Mexico Museum of Natural History, Smithsonian Institution and U.S. Bureau of Land Management support this research.

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APPENDIX

Shale Colono Formation Type Section

Section measured in 3 segments in the EI/2 of the W1/2 section 12, T22S, R1W. Section begins at UTM Zone 13, 321640N, 387839E, near (1971) RH section and ends at UTM Zone 13, 322008E, 388699N. Strata dip S'E, striking N7'E.

<table>
<thead>
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<th>unit</th>
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<th>thickness (m)</th>
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<tr>
<td>Huco Group</td>
<td>Community Pit Formation:</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Biopackstone; yellowish gray (SYR7/2) to pinkish gray (SYR8/1); forms a ledge along ridge crest.</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>Covered slope.</td>
<td>1.3</td>
</tr>
<tr>
<td>39</td>
<td>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.</td>
<td>1.2</td>
</tr>
<tr>
<td>38</td>
<td>Covered slope.</td>
<td>2.9</td>
</tr>
<tr>
<td>37</td>
<td>Bioclastaic grainstone; grayish orange pink (SYR7/2) to pale brown (SYR8/2) fresh; weathering rinds of moderate orange pink (SYR8/4) and light brown (SYR6/4); chert; forms a ledge.</td>
<td>1.1</td>
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<td>36</td>
<td>Covered slope.</td>
<td>4.6</td>
</tr>
<tr>
<td>35</td>
<td>Wackestone; moderate light gray (N6) with numerous light brownish gray (SYR6/1) chert nodules; weathers to light gray (N7) and moderate reddish orange (10R6/6) forms a ledge.</td>
<td>1.6</td>
</tr>
<tr>
<td>34</td>
<td>Shale; forms a mostly covered slope.</td>
<td>2.1</td>
</tr>
<tr>
<td>33</td>
<td>Bioclastic micrite; light brownish gray (SYR6/1) fresh; weathers pale yellowish brown (10YR6/2); some chert as in unit 22; some crinoid debris; top of segment at 3212164E, 3878730N; offset to SE at 3223434E, 3877069N.</td>
<td>1.5</td>
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<tr>
<td>32</td>
<td>Shale; forms a mostly covered slope.</td>
<td>1.4</td>
</tr>
<tr>
<td>31</td>
<td>Biopackstone; medium dark gray (N4) fresh; weathers light greyish brown; forms thin ledges; shale forms mostly covered slopes.</td>
<td>7.8</td>
</tr>
<tr>
<td>30</td>
<td>Interbedded wackestone and shale; wackestone is medium dark gray (N4) fresh, weathers light greyish brown; forms thin ledges; shale forms mostly covered slopes.</td>
<td>8.8</td>
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<tr>
<td>29</td>
<td>Shale Colono Formation:</td>
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<tr>
<td>29</td>
<td>Calcarinete; matrix is medium light gray (N6), clasts are dark gray (N3) fresh; weathers to light brown (SYR6/6) with rinds of very pale orange (10YR8/2); clasts predominantly 2-5 mm diameter limestone pebbles; bedding: beds are 0.5 to 0.7 m thick.</td>
<td>4.2</td>
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<tr>
<td>28</td>
<td>Calcarinete; pale brown (SYR3/2) fresh; weathers dusky brown (SYR3/2); fine- to medium-grained, subangular, well-sorted, graded beds and crossbeds.</td>
<td>2.7</td>
</tr>
<tr>
<td>27</td>
<td>Covered slope.</td>
<td>3.3</td>
</tr>
<tr>
<td>26</td>
<td>Biopackstone to calcisiltite; packstone is medium light gray (N6) fresh; weathers to crusts of brownish grey (SYR4/1) and light brownish grey (SYR6/1); calcisiltite is medium grey (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 at 322072E, 387739N.</td>
<td>5.2</td>
</tr>
<tr>
<td>25</td>
<td>Covered slope.</td>
<td>10.8</td>
</tr>
<tr>
<td>24</td>
<td>Calcarinete; medium dark gray (N4) fresh; weathers pale yellowish brown (10YR6/2); very fine-grained, subangular, well-sorted quartzose calcareinite; forms a ledge.</td>
<td>1.3</td>
</tr>
<tr>
<td>23</td>
<td>Calcarinete; matrix is light brownish gray (SYR6/1), clasts are medium dark gray (N4) fresh; weathers greyish orange pink (SYR7/2); well-rounded limestone clasts up to 15 mm in diameter; poorly sorted; forms a ledge.</td>
<td>1.8</td>
</tr>
<tr>
<td>22</td>
<td>Calcisiltite; medium clay (N5) fresh; weathers medium dark gray (N4); surrounded limestone and chert pebbles up to 3 mm diameter.</td>
<td>0.7</td>
</tr>
<tr>
<td>21</td>
<td>Calcisiltite; light brownish gray (SYR6/1) fresh; weathers pale brown (SYR5/2); fine-grained; surrounded ed, very well sorted calcareinite.</td>
<td>1.2</td>
</tr>
<tr>
<td>20</td>
<td>Calcisiltite; pale red purple (SRP6/2) fresh; weathers moderate brown (SYR4/1); fine- to coarse-grained, subangular, moderately poorly sorted quartz- and lithic-rich calcarenite; Jordan's locality pebbly; some crossbeds; graded beds.</td>
<td>3.3</td>
</tr>
<tr>
<td>19</td>
<td>Covered slope.</td>
<td>1.3</td>
</tr>
<tr>
<td>18</td>
<td>Biowackestone; medium dark gray (N4) fresh; weathering moderate reddish orange (10R6/6) to grayish orange pink (SYR7/2); pitted weathering; forms a ledge.</td>
<td>0.7</td>
</tr>
<tr>
<td>17</td>
<td>Covered slope.</td>
<td>3.0</td>
</tr>
<tr>
<td>16</td>
<td>Calcisiltite; medium light gray (N6) fresh; weathers greyish orange pink (SYR7/2); limestone clasts up to 5 mm in diameter; moderately well-sorted; forms a ledge.</td>
<td>1.0</td>
</tr>
<tr>
<td>15</td>
<td>Covered slope.</td>
<td>2.8</td>
</tr>
<tr>
<td>14</td>
<td>Calcarinete to calcisiltite; calcisiltite is pale brown (SYR5/2) 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.</td>
<td>1.4</td>
</tr>
<tr>
<td>13</td>
<td>Covered slope.</td>
<td>1.3</td>
</tr>
<tr>
<td>12</td>
<td>Algal boundstone; medium light gray (N6) fresh; weathers greyish orange pink (10R8/2); wavy stroma toltic texture; forms a cliff.</td>
<td>1.4</td>
</tr>
<tr>
<td>11</td>
<td>Grainstone to pebbly calcarenite; light brownish grey (SYR6/1) fresh; weathers light grey (N7); clasts are fine-grained to pebbly limestone; some yellow shale parings.</td>
<td>4.5</td>
</tr>
<tr>
<td>10</td>
<td>Grainstone to pebbly calcarenite; grainstone is light brownish grey (SYR6/1) fresh; weathers light brown (SYR6/4); calcarenite is light brownish gray (SYR6/1) to brownish grey (SYR4/1); fine-grained to pebbly; unit tops out at 321625E, 3878685N. Offset on top of unit 10 to SE at 321864E, 3878440N.</td>
<td>1.9</td>
</tr>
<tr>
<td>9</td>
<td>Packstone; brownish grey (SYR4/1) fresh; weathers to very pale orange (10YR8/2); greyish red (10R4/2) and moderate reddish brown (10R4/6) clasts; 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 hemmastic blooms; cherty; forms a cliff.</td>
<td>1.8</td>
</tr>
<tr>
<td>8</td>
<td>Grainstone; light brownish grey (SYR6/1) fresh; weathers greyish pink (10R8/2) rinds; cherty; some gastropods; hummocky bedded; forms a cliff.</td>
<td>2.9</td>
</tr>
<tr>
<td>7</td>
<td>Algal boundstone; same colors as unit 7; hummocky lamination; much shell debris; forms a cliff.</td>
<td>2.8</td>
</tr>
<tr>
<td>6</td>
<td>Bioclastic micrite; medium dark gray (N4); greyish orange pink (SYR7/2); much crinoid, gastropod, and brachiopod debris; unit forms base of large cliff.</td>
<td>2.6</td>
</tr>
<tr>
<td>5</td>
<td>Muddy siltstone and silty shale; greyish orange pink (SYR7/2); some ledges of wackestone that is pale yellowish brown (10YR6/2) fresh; weathers to greyish orange (10YR7/4).</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>Calcarenite; pale reddish brown (10RS5/4) fresh; weathers greyish orange (10YR7/4); fine grained, subrounded ed, well-sorted, quartz-rich calcarenite; forms a ledge.</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>Micrite, with minor calciturbide; micrite is medium gray (NS) fresh; calciturbide is medium dark gray (N4) fresh; both weather to very light grey (NB) and medium light grey (N6), with pale yellowish orange (10YR6/6) clasts; micrite is thick bedded in sets 0.3 to 0.5-mm-thick; locally bioclastic; forms a ledge.</td>
<td>2.7</td>
</tr>
<tr>
<td>2</td>
<td>Shale; greyish orange (10YR7/4); slightly silty; some ledges of calcarenite to calciturbide which are moderate red (10RS5/4) to light brownish grey (SYR6/1) fresh; weathers to greyish orange (10YR7/4) with greyish orange pink (10RS8/2) clasts.</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Interbedded calcirudite and calccarenite; limestone is moderate reddish orange (10R6/6) fresh; weathers grayish orange (10YR7/4); calccarenite is pale reddish brown (10R5/4) fresh; weathers dark gray (N3); fine- to medium-grained, subangular, moderately well-sorted calcarenite; ledge; thin-bedded calcarcous. 6.1+

Community Pit Formation Type Section

Section measured in two segments, the lower portion in the SEI/4 NWI/4 and the upper in the NWI/4 SEI/4 of section 19, T22S, R1W. Section begins at UTM zone 13, 322963E, 3584008N. Strata dip 11° to 50° SW in the lower segment (units 1-17) and 10° to 50° E in the upper segment (units 18-22).

unit  lithology  thickness (m)  
Hucuo 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 sublitharenite; ripple laminaed; calcareous.  not measured

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 (10R8/2) 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 orange pink (5YR8/4) and moderate red (5R5/4); forms a series of 0.75-t-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 (5YR4/1) 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 produstoid brachiopods. 1.8
6 Packstone; brownish gray (5YR4/1) fresh; weathers pale yellowish brown (10YR6/2); numerous crinoid and brachiopod 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; medium dark gray (N4) fresh; weathers medium light gray (N6) to light brown (5YR6/4); fine sand grains and shell debris; ripple. 0.7
2 Micrite; medium dark gray (N4) fresh; weathers medium light gray (N6) to light brown (5YR5/6); locally bioclastic. 1.2
1 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 NE44 NE45 SW4 sec. 30, T22S, R1W, begins at UTM zone 13, 322968E, 3582122N, and ends at UTM zone 13, 332061E, 3582159N. Strata dip 9° to 30° SW.

unit  lithology  thickness (m)  
Apache Dam Group:  
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 mottled 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, bryozoa, 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/1) 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 Bitopackstone; pale yellowish brown (10YR6/2) fresh; weathers light brown (5YR6/4); much algal and finely comminuted crinoid and gastropod debris; forms top of
Biopackstone and wackestone; medium gray (N4) fresh; 
weathers light brownish gray (5YR6/1) with crusts of 
light brownish gray (5YR6/1); similar to unit 8 with less 
packstone; some chalk nodules; forms a cliff. 

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. 

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

Biopackstone with chalk nodules up to 15 cm in diameter; 
medium dark gray (N4) fresh; weathers light brownish 
gray (5YR6/1); much finely comminuted shell debris; 
some gastropods and algal debris. 

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

Covered slope; some nodular limestone. 

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. 

Biopackstone; medium dark gray (N4) fresh; weathers to 
light brownish gray (5Y R6/1) 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. 

Robledo Mountains Formation: 

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