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THE PENNSYLVANIAN SECTION AT PRIEST CANYON, SOUTHERN MANZANO MOUNTAINS, NEW MEXICO

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Abstract—The Pennsylvanian section at Priest Canyon in the southern Manzano Mountains includes the type sections of units named by Myers and long applied to Pennsylvanian strata throughout the Manzano and Manzanita mountains. Detailed restudy indicates it is very similar to the Pennsylvanian section in the Cerros de Amado, ~60 km to the SW, so, the stratigraphic nomenclature introduced by Thompson in 1942 and elaborated by Rejas in 1965 and Lucas, Krainer and Barrick in 2009, can be applied at Priest Canyon. The base of this section is the ~70 m thick Sandia Formation, mostly covered slopes and beds of sandstone, limestone and conglomerate that are in fault contact with the Proterozoic basement. The overlying Gray Mesa Formation (= Los Moyos Limestone) is ~192 m thick and mostly cherty limestone, divided into three members (ascending): (1) Elephant Butte Member, ~24 m of limestone and shale; (2) Whiskey Canyon Member, ~84 m of cherty limestone; and (3) Garcia Member, ~84 m of non-cherty limestone and shale with lesser amounts of cherty limestone, sandstone and conglomerate. The overlying Atrasado Formation (= Wild Cow Formation) is ~272 m thick and divided into eight members (ascending): (1) Bartolo Member, ~66 m of slope-forming shale with thin beds of sandstone, limestone and conglomerate; (2) Amado Member, ~9 m of bedded, cherty, brachiopod-rich limestone; (3) Tinajas Member, ~115 m of shale with interbedded limestone and sandstone; (4) Council Spring Member, ~23 m of mostly algal limestone without chert; (5) Burrego Member, ~26 m of arkosic red beds and limestone; (6) Story Member, ~6 m of limestone; (7) Del Cuerto Member, ~16 m of arkosic red beds and limestone; and (8) Moya Member, ~11 m of bedded limestone and shale. The Pennsylvanian section is overlain by the Lower Permian Bursum Formation, which is at least 30 m of interbedded red-bed mudstone, sandstone, conglomerate and limestone. Deposition of the Sandia, Gray Mesa, Atrasado and Bursum formations took place mostly in normal, shallow-marine platform settings and in coastal, nonmarine fluvial paleoenvironments. At their type sections, Myers' members of the "Wild Cow Formation" clearly are fusulinid-based, biostratigraphic units, not lithostratigraphic units, as their contacts are not drawn at laterally traceable lithologic changes. Thus, Sol se Mete Member = Missourian fusulinids, Pine Shadow Member = early Virgilian fusulinids, and La Casa Member = middle-late Virgilian fusulinids. We thus recommend abandonment of all of Myers' Pennsylvanian lithostratigraphic terms because they are either synonyms of earlier named units or do not identify useful lithostratigraphic units. Available biostratigraphic data and regional correlations indicate that at Priest Canyon, the Sandia Formation is late Atokan-Desmoinesian, the Gray Mesa Formation and lower Atrasado Formation are Desmoinesian, and the rest of the Atrasado Formation is Missourian-Virgilian, with its uppermost strata Wolfcampian.

INTRODUCTION

The Pennsylvanian section exposed at Priest Canyon in the southern Manzano Mountains of Valencia County, New Mexico (Fig. 1), is an important section in the regional Pennsylvanian stratigraphy. This is because the Priest Canyon section encompasses the type sections of two Pennsylvanian formations and three members that Myers (1973) defined and mapped throughout the Manzano Mountains. Here, we present a detailed description (including petrography) of the Priest Canyon section to demonstrate the applicability of an older Pennsylvanian stratigraphic nomenclature (Thompson, 1942; Kelley and Wood, 1946; Rejas, 1965) to that section. We also briefly interpret the depositional environments and review available biostratigraphic data and correlation of the Priest Canyon Pennsylvanian strata.

PREVIOUS STUDIES

Priest Canyon is in the Abo Pass area, a topographic low between the southern tip of the Manzano Mountains and the northern end of the Los Pinos Mountains, which encompasses parts of Torrance, Valencia and Socorro counties (Fig. 1). Early workers (Herrick, 1900a, b; Gordon, 1907; Lee, 1909) were aware of the presence of Pennsylvanian strata in the Abo Pass area. They assigned these strata to the Magdalena Group divided into the Sandia Formation overlain by the Madera Limestone (Fig. 2). Thus, Darton (1922, pl. 38; 1928, pl. 17) mapped the geology of the Abo Pass area, assigning all of the Pennsylvanian strata to the Magdalena Group.

Read et al. (1944; also see Wilpolt et al., 1946; Read and Wood, 1947) used Herrick's (1900a) term "Sandia Formation" and Keyes' (1903) term "Madera Limestone" to refer to the Pennsylvanian section throughout the Sandia and Manzano mountains. Read and collaborators divided the Madera Limestone into a lower, gray limestone member and an upper, arkosic limestone member, and they brought the term Bursum Formation into use in central New Mexico (Fig. 2). Thus, section 13 of Read and Wood (1947) showed the Pennsylvanian section at Abo Pass assigned to these units (Fig. 2). Read and Wood (1947, fig. 1) also made it clear that their informal divisions of the Madera Limestone were equivalent to the Gray Mesa Member (= gray limestone member) and Atrasado Member (= arkosic limestone member) of the Madera Limestone named by Kelley and Wood (1946) in the Lucero uplift of Valencia County.

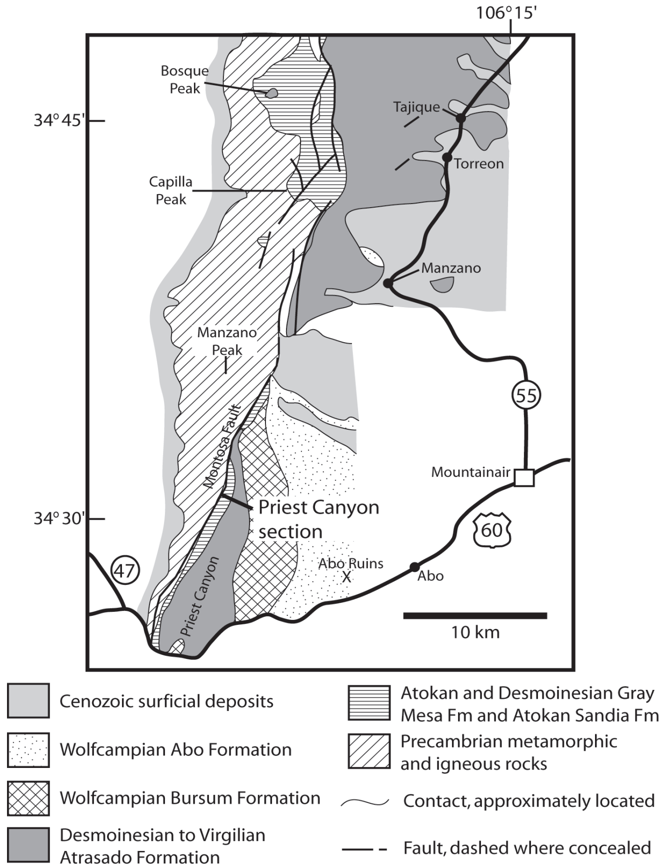


FIGURE 1. Simplified geologic map (modified from Myers, 1982) showing location of the Priest Canyon Pennsylvanian section described here.

Bates et al. (1947) mapped the Gran Quivira Quadrangle, which includes the Pennsylvanian outcrops at Priest Canyon that we measured. They assigned the section to the Sandia formation and the overlying Madera Limestone, divided into a lower marine limestone member and an upper arkosic limestone member. Nevertheless, Bates et al. (1947, p. 16) noted that "future detailed stratigraphic studies…will show some of Thompson's [1942] terminology to be applicable in treatment of faunal zones." Bates et al. (1947) also reported some fusulinids from the Pennsylvanian strata on the Gran Quivira Quadrangle, assigning them Atokan, Desmoinesian, Missourian and Virgilian ages (see below).

During the 1960s and 1970s, in the Manzano and Manzanita mountains, Donald Myers of the U. S. Geological Survey created a new lithostratigraphic nomenclature and correlation of the Pennsylvanian strata. Thus, Myers (1966, 1967, 1969, 1973, 1977, 1982, 1988a, b; Myers and McKay, 1970, 1971, 1972, 1974, 1976; Myers et al., 1986) assigned the Pennsylvanian section in this area to the (ascending order) Sandia, Los Moyos and Wild Cow formations. Los Moyos Limestone was a new, formal lithostratigraphic name for the gray limestone member of the Madera Formation of prior usage, and Wild Cow Formation was a formal name for the arkosic limestone member (Fig. 2). Myers also divided the Wild Cow Formation into new formal members, the Sol se Mete (lower), Pine Shadow and La Casa (upper) members (Fig. 2). Myers' new lithostratigraphy was published with fusulinid biostratigraphy that indicated the Sandia Formation is Atokan, the "Los Moyos Limestone" is Desmoinesian, and the "Wild Cow Formation" is Missourian-Virgilian in age.

Mapping in the Manzanita Mountains beginning in the 1990s as part of the U.S. STATEMAP Program involved a re-evaluation of Myers' work. Most of the geologists involved in this mapping effort (e.g., Karlstrom et al., 1994; Chamberlin et al., 1997; Read et al., 1998), working in areas previously mapped by Myers and McKay, could not apply Myers' stratigraphic nomenclature, especially with respect to Myers' member-level units of the Atrasado Formation. The result of this renewed mapping effort was that, for the most part, Myers' formal stratigraphic divisions were abandoned, and map-unit designations utilized by most STATEMAP mappers reverted to the mid-20th century nomenclature of the U.S. Geological Survey.

Most recently, working at Cedro Peak and other areas in the Manzano-Sandia uplift, Lucas et al. (2014) rejected all of Myers' Pennsylvanian lithostratigraphic nomenclature. That rejection, and replacement primarily by a 1940s nomenclature (Fig. 2), is discussed and justified later in this paper.

LITHOSTRATIGRAPHY AND PETROGRAPHY

Introduction

At Priest Canyon, a 534-m-thick succession of Pennsylvanian sedimentary rocks is well exposed, encompassing the Sandia Formation (approximately 70 m), Gray Mesa Formation (192 m) and Atrasado Formation (272 m) (Figs. 3-4).

Sandia Formation

Lithostratigraphy

At Priest Canyon, the Sandia Formation is approximately 70 m thick, although the upper part is poorly exposed (Krainer and Lucas, 2013) (Fig. 3). Most of the Sandia Formation section is covered (64% of the measured section), and the remainder is shale (18%), sandstone (12%), and minor limestone and conglomerate (6%).

The base of the Sandia Formation is a fault contact (Montosa fault) with Proterozoic rocks (though little section appears to be missing at the fault), and the formation is conformably overlain by the Gray Mesa Formation. At Priest Canyon, the Sandia Formation thus, is a poorly exposed, slope-forming unit between the Proterozoic granite and limestones of the Gray Mesa Formation.

At the base of the Sandia Formation, granite of the Proterozoic basement is overlain by 2 m of lithified granitic grus followed by 0.4 m of coarse-grained, pebbly sandstone. The next 32 m are composed of several sandstone units, a few thin limestone intervals, and covered intervals. The sandstone is mostly coarse grained, pebbly, and locally conglomeratic at the base. Sandstone units are 0.3-1.5 m thick and commonly trough crossbedded. Subordinately, sandstone is horizontally laminated, and, rarely, sandstone appears massive. The first limestone interval is exposed 19 m above the base of the Sandia Formation. This limestone is 0.7 m thick and contains fusulinids (*Fu-*

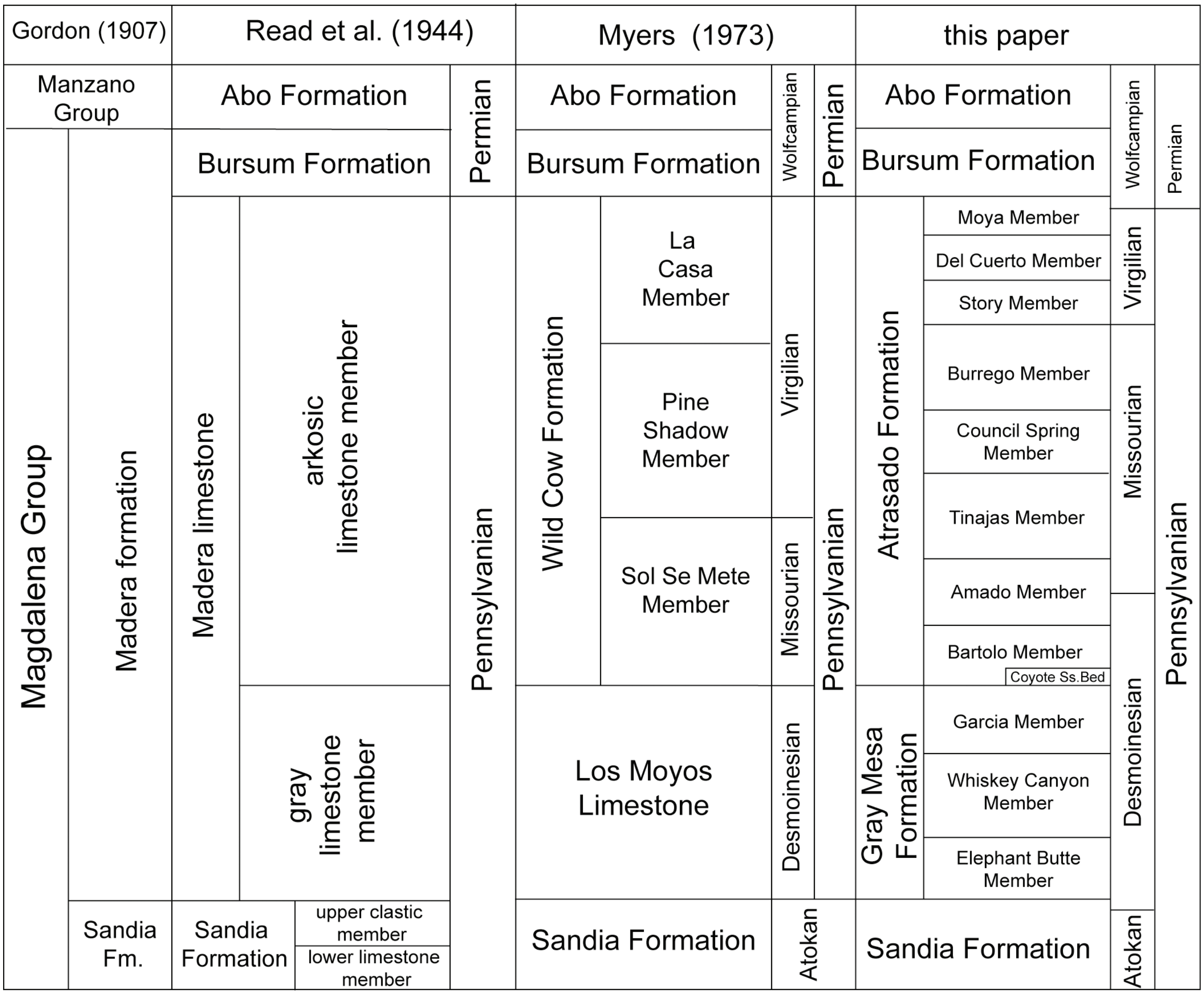


FIGURE 2. Evolution of Pennsylvanian lithostratigraphic nomenclature at Priest Canyon.

sulinella), *Syringopora* and *Chaetetes*. Another thin limestone bed (0.2 m) is exposed 31 m above the base.

The upper 38 m of the Sandia Formation are mostly covered (probably shale-siltstone), with one exposed limestone interval, which is 1.3 m thick and composed of three limestone beds. The basal limestone bed contains small quartz grains and rare chert nodules. The overlying bed is cherty limestone, contains silicified brachiopods, and is bioturbated near the top. The upper limestone bed is thin and fossiliferous. Near the top, a 1-m-thick conglomeratic sandstone and a 0.4-m-thick pebbly sandstone interval are exposed, both displaying crossbedding.

Petrography and Microfacies

Pebbly sandstone near the base of the Sandia Formation is moderately to poorly sorted and composed mostly of polycrystalline quartz grains and subordinately of monocrystalline quartz, rare chert grains and granitic rock fragments. Detrital potassium feldspar grains and mica (muscovite and biotite) are very rare (Fig. 5A). Polycrystalline quartz grains are dominantly non-schistose and composed of large subindividuals, indicating granitic source rocks. Schistose, fine-grained, polycrystalline quartz grains of metamorphic origin are rare. Sandstones are cemented by authigenic quartz overgrowths and locally by microcrystalline quartz cement. Some of the sandstones contain small amounts of fine-grained matrix. The sandstones are classified as quartz arenites and subarkoses.

Mixed siliciclastic-carbonate sandstone is poorly sorted and mostly composed of subangular detrital grains. This sandstone contains abundant monocrystalline and, subordinately, polycrystalline quartz grains, granitic rock fragments, a few schistose metamorphic rock fragments and a few carbonate grains. Detrital feldspars are common and include large grains with diameters up to a few millimeters. Most common are untwinned potassium feldspars and microcline. Some of the feldspar grains are partly replaced by calcite. Fossils include large fragments of echinoderms, brachiopods and rare bryozoans. Detrital grains and fossils are embedded in micritic matrix (Fig. 5B).

In the upper part of the succession, mixed siliciclastic-carbonate siltstone is composed of quartz and carbonate grains, a few micas and a few recrystallized skeletal grains (echinoderms, ostracods) that are embedded in micrite. The siltstone is locally bioturbated.

At Priest Canyon, limestone of the Sandia Formation is composed of packstone, grainstone, wackestone, rudstone and floatstone (Fig. 5C-H). Mudstone is rare. Grainstone, packstone and rudstone (Fig. 5C, G) contain a diverse fossil assemblage with echinoderms, brachiopods and bryozoans being the most abundant skeletal grains. Other fossils include ostracods, gastropods, fusulinids, smaller foraminifers and rare trilobites. Angular to subangular detrital quartz grains with diameters up to 5 mm are common (Fig. 5C).

In fusulinid wackestone, abundant fusulinid tests, subordinate brachiopod fragments, ostracods, a few echinoderms, gastropods, rare bryozoans, smaller foraminifers and silicified *Syringopora* are embedded in peloidal micrite. Phylloid algal floatstone (Fig. 5H) contains large fragments of completely recrystallized phylloid algae floating in peloidal micrite in which

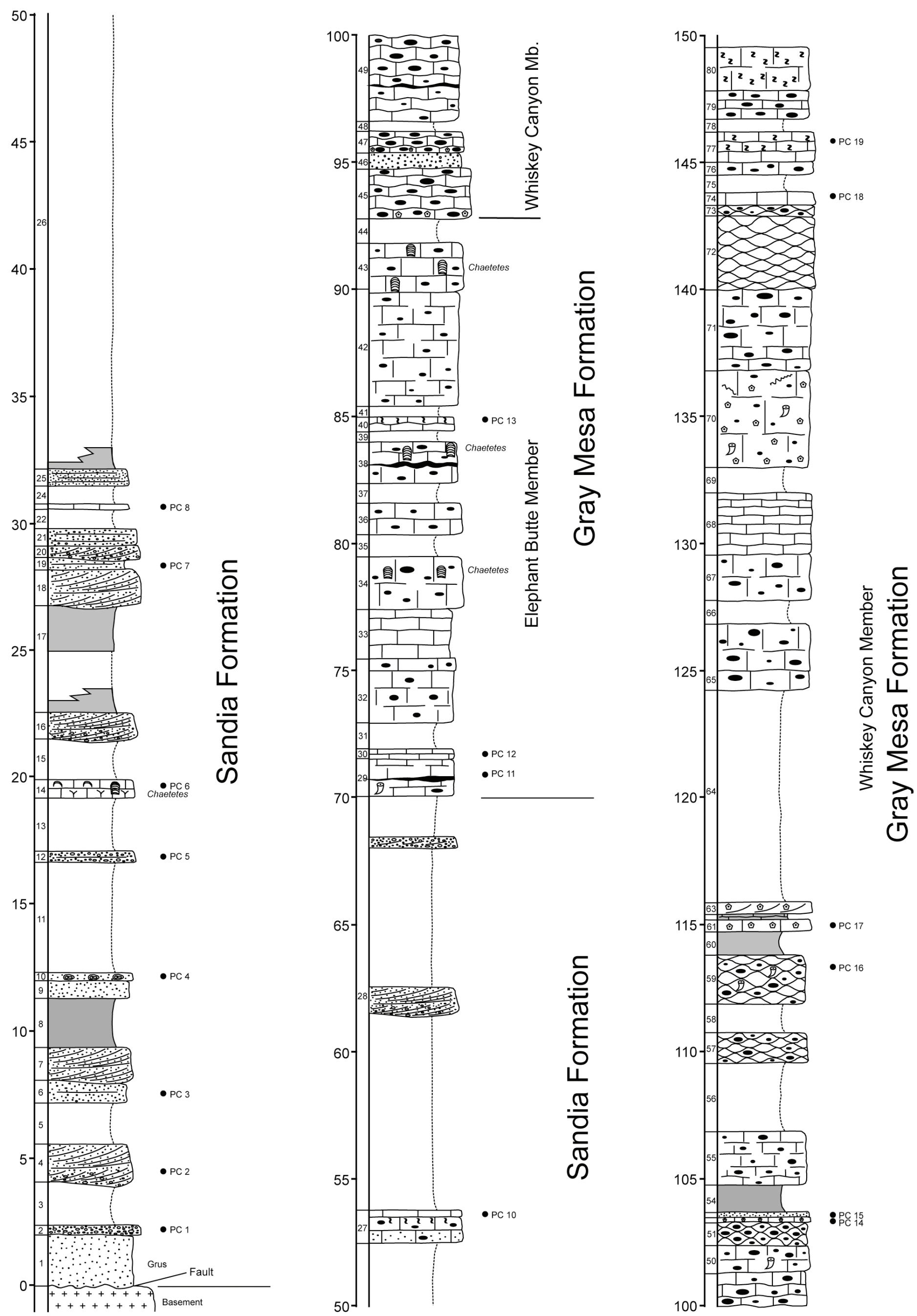


FIGURE 3. Measured section of Pennsylvanian rocks at Priest Canyon. The section was measured in section 7, T3N, R5E. Base is at UTM zone 13, 365416E, 3818683N, top is at 366849E, 3818386N (datum NAD 83). The combination of letters "PC" followed by numbers listed to the right of a column refers to a sample taken for thin sectioning.

a few smaller skeletons are present. This facies grades into bioclastic wackestone containing a diverse fossil assemblage, including brachiopods, bryozoans, ostracods, smaller foraminifers, echinoderms and rare trilobite fragments. Mudstone contains a few spicules and rare ostracods.

Gray Mesa Formation

Lithostratigraphy

The Gray Mesa Formation at Priest Canyon is approximately 192 m thick and is dominantly limestone, much of which is cherty (Fig. 3). The formation forms a prominent hogback

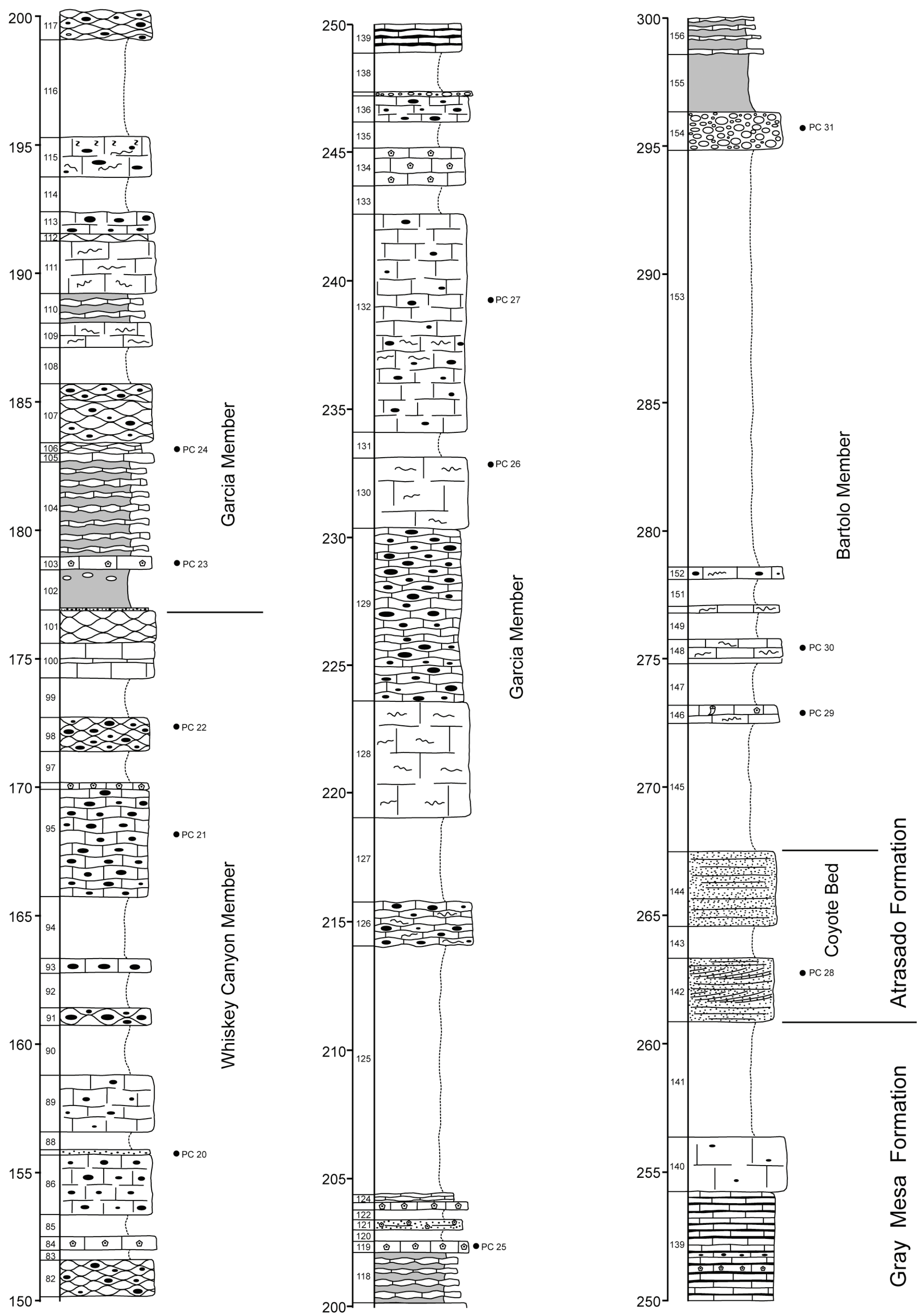


FIGURE 3. Continued.

above slope-forming Sandia Formation and beneath the Atrasado Formation, which forms slopes and low cuestas (Fig. 4). As noted elsewhere, the Myers (1973) type section of the Los Moyos Limestone is the Gray Mesa Formation section at Priest Canyon we describe here.

At Priest Canyon, the base of the Gray Mesa Formation is the first relatively thick (> 1 m) bed of cherty limestone that begins a cherty-limestone-dominated succession above the slope-forming Sandia Formation (Fig. 3). We divide the Gray Mesa Formation into the Elephant Butte, Whiskey Canyon and Garcia members, subdivisions recognized to the south in the Cerros de Amado of Socorro County (Rejas, 1965; Lucas et al., 2009) and to the north at Cedro Peak in the Manzanita Mountains of Bernalillo County (Lucas et al., 2014).

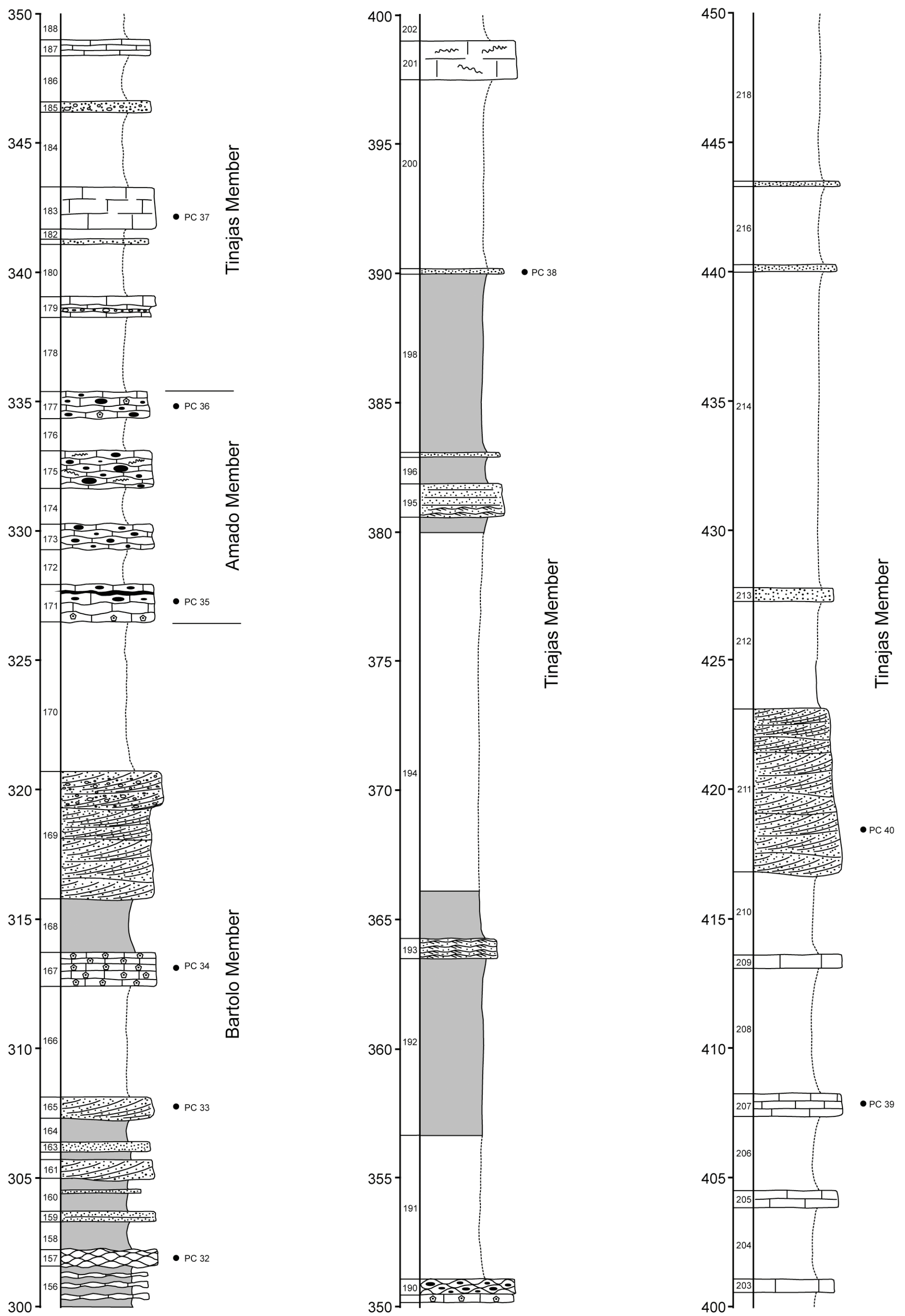


FIGURE 3. Continued.

Elephant Butte Member

At Priest Canyon, the Elephant Butte Member is ~24 m thick and is mostly limestone (78% of the measured section), about half of which lacks chert and the other half which has minor amounts of chert (Fig. 3). These limestones are indistinctly bedded, medium to thick bedded, and, rarely, thin bedded or massive. Bedding is even to wavy. One limestone bed is bioturbated. Limestone intervals are 0.6-4.5 m thick and separated by covered (likely shale) intervals that are 0.4-1.0 m thick. Silicified fossils of the demosponge *Chaetetes* are common in some limestone beds. Near the base of the Elephant Butte Member, limestone contains silicified brachiopods and solitary corals. One limestone bed (Fig. 3, top of unit 40) contains abundant fusulinids.

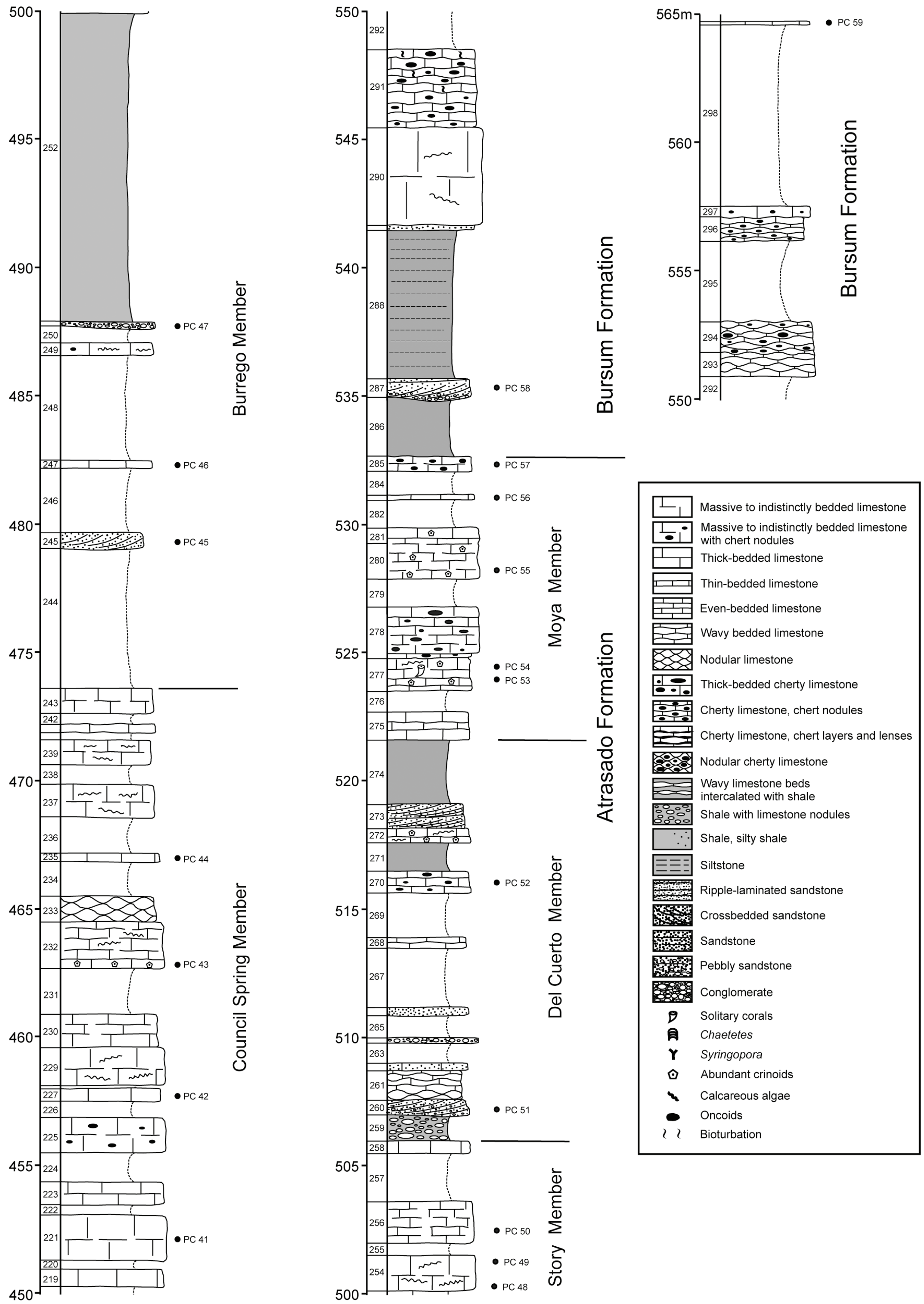


FIGURE 3. Continued.

FIGURE 4. Photographic overview of most of the Priest Canyon Pennsylvanian section.

Whiskey Canyon Member

At Priest Canyon, the Whiskey Canyon Member is ~84 m thick and is mostly very cherty limestone (46% of the measured section) and limestone with minor amounts of chert (15%) (Fig. 3). Covered intervals are common (35%), and sandstone is rare (3%). Cherty limestone is represented by wavy to nodular bedded, thin to thick bedded, indistinctly bedded, and rare massive limestone displaying a muddy texture. A few thicker limestone beds contain abundant crinoidal debris, and one crinoidal limestone bed displays crossbedding. Limestone intervals are as much as 4.1 m thick. Two thin greenish sandstone beds, each 0.2 m thick, are present. Limestone intervals are separated by covered intervals, which are mostly 0.4-2.7 m thick. In the middle of the member, one 8.3-m-thick covered interval (likely shale) is present.

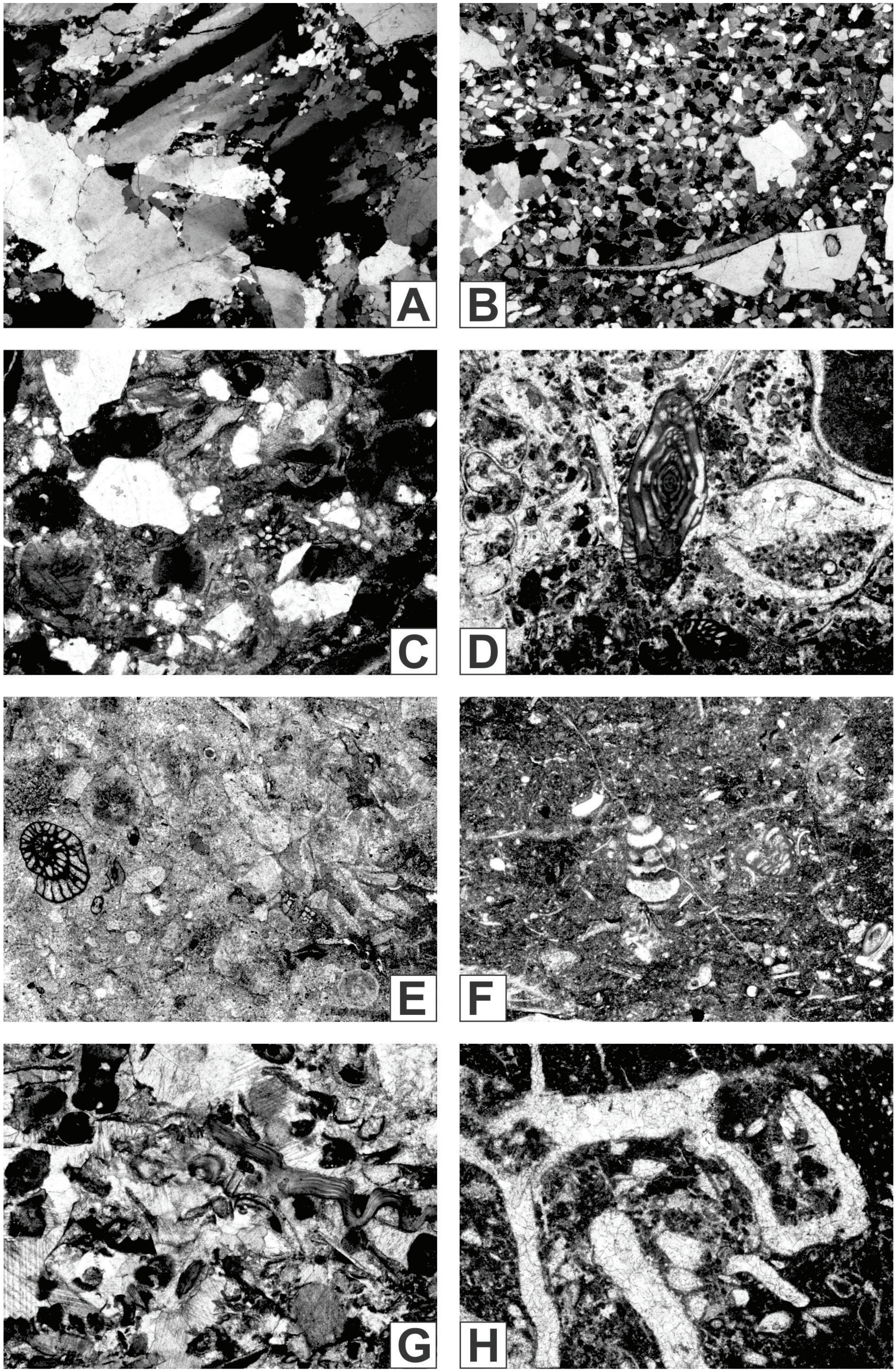
Fossils observed on outcrop are crinoidal debris, brachiopods, solitary corals and rare calcareous algae. In the upper part of the Whiskey Canyon Member, several individual limestone beds contain abundant fusulinids.

Garcia Member

At Priest Canyon, the Garcia Member is ~84 m thick and is mostly non-cherty limestone (39% of the measured section) and covered intervals (36%) (Fig. 3). Cherty limestone (18%) and shale, sandstone and conglomerate (7%) complete the section. The base of the Garcia Member at Priest Canyon is marked by a thin sandstone that fills fissures in the subaerially exposed limestone bed at the top of the Whiskey Canyon Member, an obvious sequence boundary.

Unlike the underlying Whiskey Canyon Member, the Garcia Member has much less chert and nodular limestone, and algal limestone is more abundant. The base of the Garcia Member is formed by a thin (0.1 m) sandstone bed. Limestone lithologies include nodular (rare) and wavy bedded, mostly cherty

FIGURE 5. Thin section photographs of sandstone and limestone of the Sandia Formation at Priest Canyon. **A** and **B** under polarized light, **C**-**H** under plane light. Width of all photographs is 6.3 mm. **A**) Coarse-grained, poorly sorted, pebbly sandstone composed of abundant polycrystalline (including schistose metamorphic) and a few monocrystalline quartz grains. The detrital grains are cemented by authigenic quartz overgrowths. Sample PC 2. **B**) Medium-grained sandstone containing a few larger grains. The sandstone is poorly sorted and composed of abundant monocrystalline and some polycrystalline quartz grains, detrital feldspar grains, a few granitic rock fragments, carbonate grains, and a few fossil fragments. The pore space is filled with micritic matrix. Sample PC 4. **C**) Rudstone to packstone composed of abundant echinoderm fragments, subordinate brachiopods and bryozoans, and many angular to subangular detrital quartz grains. Sample PC 5. **D**) Wackestone containing skeletons of fusulinids, echinoderms, brachiopods, gastropods, bryozoans and smaller foraminifers embedded in peloidal micrite. The wackestone is partly washed, grading into grainstone. Sample PC 6. **E**) Recrystallized grainstone composed of abundant echinoderm fragments, subordinate bryozoans, brachiopods and fusulinids. Sample PC 8. **F**) Bioclastic wackestone containing smaller foraminifers, ostracods, brachiopod fragments and other bioclasts embedded in micrite. Sample PC 10. **G**) Packstone to grainstone, coarse-grained and containing strongly fragmented bioclasts of echinoderms, brachiopods, bryozoans and trilobites. Sample PC 10A. **H**) Phylloid algal floatstone containing a few large and many small recrystallized phylloid algal fragments embedded in micrite with a few small fossils such as ostracods, smaller foraminifers, echinoderms and bryozoans. Sample PC 10a.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limestone; and medium- to thick-bedded, indistinctly bedded to massive limestone, mostly free of chert and commonly containing calcareous algae. Another lithotype is composed of thin, wavy limestone beds alternating with greenish-gray shale. Bioturbation is rare. In the upper part of the member, one thin, mud-supported carbonate conglomerate is intercalated containing clasts with diameters up to 7 cm (Fig. 3, unit 137).

Limestone intervals range in thickness from 0.5 to 6.8 m, and covered intervals (probably representing shale) are 0.4 to 9.7 m thick. Shale is exposed as a 1.6-m-thick interval at the base of the member on top of the thin sandstone bed. This shale contains limestone nodules. Fossils observed in the field are crinoid fragments, brachiopods, rare bryozoans and fusulinids. Calcareous algae are common. Oncoids are present near the top of the limestone of unit 105 (Fig. 3).

Gray Mesa Formation Petrography and Microfacies

Limestone of the Elephant Butte Member is dominantly wackestone, including bioclastic wackestone (Fig. 6A) and algal wackestone (Fig. 6B). Wackestone is commonly bioturbated and contains a diverse fossil assemblage composed of recrystallized fragments of phylloid algae (locally being abundant and forming algal wackestone), echinoderms, brachiopods, bryozoans, thin shells (likely bivalves), ostracods, smaller foraminifers (e.g., *Tuberitina*, *Endothyra*, *Tetrataxis*, *Syzrania*, and *Hemigordiellina*), fusulinids, rare trilobites, and the incertae sedis algae *Efluegelia* and *Komia*. Locally, fecal pellets are present. Individual beds contain abundant spicules that form spiculite. Spiculite is indistinctly laminated, cherty, locally bioturbated and composed of abundant monaxone spicules, which are oriented parallel to the bedding and embedded in cherty, muddy matrix (Fig. 6C). In individual layers, spicules are densely packed.

The main microfacies of the Whiskey Canyon Member is again wackestone (bioclastic wackestone; Fig. 6E; rare fusulinid wackestone), which may grade into floatstone. Spiculite and grainstone are rare microfacies types. Wackestone is commonly bioturbated and contains a diverse fossil assemblage similar to that of the Elephant Butte Member, although phylloid algae are very rare to absent. Spicules are present in many samples. Among the smaller foraminifers, *Bradyina* is also present. *Komia* is rare. Grainstone is composed of abundant echinoderm and bryozoan fragments (Fig. 6D). Also, fragments of brachiopod shells and spines, ostracods, echinoid spines, and a few smaller foraminifers (*Endothyra* and *Syzrania*) are present. The thin sandstone bed of unit 87 (Fig. 3) is mixed siliciclastic-carbonate in composition, moderately sorted and mainly composed of subangular grains. Detrital grains include mono- and polycrystalline quartz, many recrystallized carbonate grains, and a few opaque grains. The detrital grains are cemented by calcite, and locally dark brown cement is present.

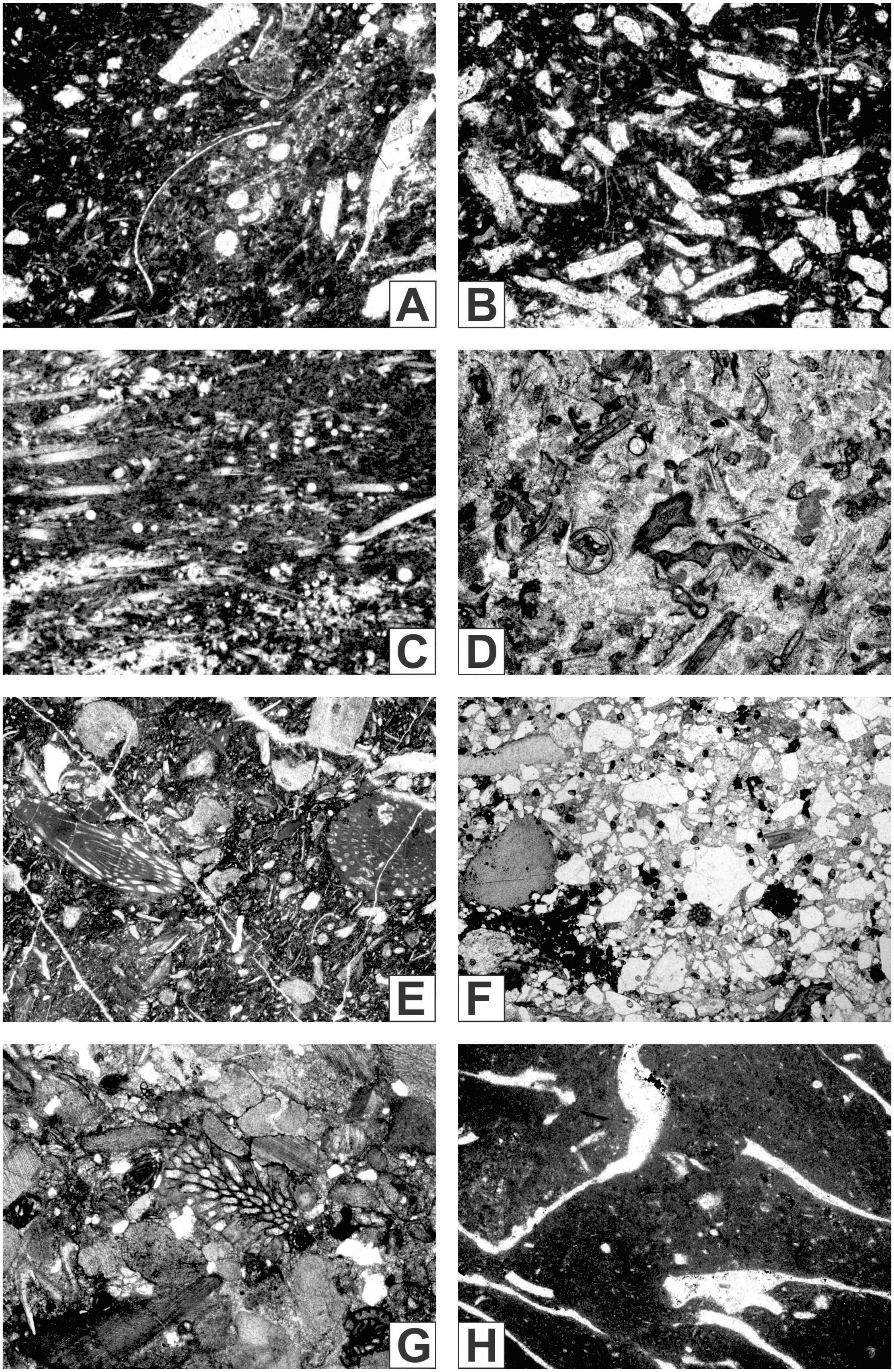
The most common microfacies of the Garcia Member is bioclastic wackestone to floatstone (Fig. 7C) containing a diverse fossil assemblage similar to that of the Elephant Butte and Whiskey Canyon members. Locally, spicules are abundant (spiculite), as are phylloid algae (phylloid algal wackestone to floatstone: Figs. 6H, 7B). Bioclastic packstone (Fig. 6G) contains abundant crinoid and *Komia* fragments, other subordinate skeletons, and many small quartz grains. Crinoidal packstone (Fig. 7A) contains a diverse fossil assemblage, with crinoids being the most abundant skeletal grain type.

Sandstone is moderately sorted and composed of subangular grains. Mono- and polycrystalline quartz grains are the most abundant grains. The sandstone also contains many detrital feldspar grains, mostly potassium feldspars (including perthitic grains and microcline), and rare plagioclase. Granitic rock fragments are common. Other grain types are mica (muscovite) and fine-grained carbonate rock fragments, some containing fossil fragments, opaque grains, tourmaline and rare garnets. The sandstones contain a few fossil fragments, mostly echinoderms, subordinate brachiopod shell fragments, bryozoans and rare fusulinids. The grains are cemented by coarse, blocky calcite (Fig. 6F).

Atrasado Formation

The Atrasado Formation at Priest Canyon is approximately 272 m thick, and we divide it into eight members (in ascending order): Bartolo, Amado, Tinajas, Council Spring, Burrego, Del Cuerto and Moya (Fig. 3). Its base is a sandstone-dominated interval that is the Coyote Sandstone of Herrick (1900a), termed the Coyote Bed of the Bartolo Member by Lucas et al. (2014). In general, the clastic-dominated members of the Atrasado Formation (Bartolo, Tinajas, Burrego, Del Cuerto) form slopes divided by prominent cuestas formed by its limestone-dominated members (Amado, Council Spring, Story, Moya) (Fig. 4). The basal contact of the Atrasado Formation is sandstone cut into shale/limestone, a likely disconformable sequence boundary. The Bursum Formation overlies the Atrasado Formation at Priest Canyon, and this contact is also an evident disconformity (Krainer and Lucas, 2009).

FIGURE 6. Thin section photographs of sandstone and limestone of the Gray Mesa Formation at Priest Canyon (**A**-**C**: Elephant Butte Member; **D**-**F**: Whiskey Canyon Member; **G**-**H**: Garcia Member). All are under plane light. Width of photographs is 6.3 mm except for **C**, which is 3.2 mm. **A**) Bioclastic wackestone containing recrystallized skeletons (possibly phylloid algae), echinoderms, bryozoans, thin shell fragments (possibly pelecypods), brachiopods, ostracods and spicules embedded in peloidal micrite. Sample PC 11. **B**) Phylloid algal wackestone containing abundant recrystallized broken algal fragments, a few echinoderms, ostracods and smaller foraminifers embedded in dark gray micrite. Sample PC 12. **C**) Spiculite composed of abundant monaxone sponge spicules that are oriented parallel to the bedding and embedded in fine-grained cherty matrix. Sample PC 13a. **D**) Grainstone composed of abundant echinoderm fragments, many bryozoans, some brachiopods and ostracods. Sample PC 17. **E**) Bioclastic wackestone to floatstone containing a diverse fossil assemblage of echinoderms, bryozoans, fusulinids, smaller foraminifers, ostracods and spicules. Sample PC 18. **F**) Medium-grained and moderately sorted sandstone containing mono- and polycrystalline quartz grains, many detrital feldspar grains, a few granitic rock fragments, carbonate grains and fossils, mostly echinoderms and few bryozoans. The grains are cemented by coarse, blocky calcite. Sample PC 22a. **G**) Bioclastic packstone containing abundant echinoderm fragments (mostly crinoids) and *Komia*, subordinate bryozoans, brachiopods, fusulinids, smaller foraminifers and detrital quartz grains. Sample PC 23. **H**) Phylloid algal floatstone. Recrystallized fragments of phylloid algae float in dark gray micrite that contains a few small bioclasts. Sample PC 24.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Bartolo Member

The Bartolo Member at Priest Canyon is ~66 m thick and is mostly covered shale slopes (70% of the measured section) with prominent sandstone beds (21%) and minor limestone and conglomerate (9%). At the base of the Bartolo Member, the Coyote Bed is two sandstone beds, 2.4 and 2.9 m thick, separated by a 1.3-m-thick covered interval.

In the Bartolo Member, shale is commonly green to greenish-gray and crops out as 0.3- to 2.3-m-thick intervals. Covered intervals are common in the lower part (1.0-16.3 m thick), and they most likely also represent shale units. Sandstone occurs as thin beds (0.1-0.4 m thick) and thicker sandstone units (0.7-4.9 m thick) that are massive, horizontally laminated or trough crossbedded. In the upper part of the Bartolo Member, sandstone is present between 302 and 321 m (Fig. 3), where it alternates with shale, one covered interval (4.3 m), and one limestone interval (1.3 m). Limestone forms thin intervals (0.3-1.3 m thick), either as single beds or as thin- to medium-bedded limestone intervals. Fossils are common, including crinoidal debris, calcareous algae, brachiopods and solitary corals. In one limestone interval, a few small chert nodules occur. In another unit, thin nodular limestone beds alternate with greenish-gray shale. Conglomerate forms one bed that is 1.4 m thick and fine grained, containing carbonate clasts up to 3 cm in diameter, quartz grains and crinoid debris.

Sandstone at the base of the Bartolo Member is medium grained, subangular and arkosic and contains mono- and polycrystalline quartz grains and many detrital feldspar grains (potassium feldspars, untwinned, perthitic, microcline; Fig. 7D). Some of the detrital feldspar grains are slightly altered. Mica (muscovite, biotite), granitic rock fragments, sedimentary (carbonate) rock fragments, and opaque grains are present in small amounts. The sandstone contains a few skeletal grains, including echinoderms, bryozoans, shell debris, ostracods and fusulinids (Fig. 7D). The grains are cemented by coarse, poikilotopic calcite. A thin, mud-supported carbonate breccia, composed of angular to subangular grains of mostly bioclastic wackestone (intraclasts) that float in fine bioclastic matrix, is intercalated in the basal sandstone. The matrix contains shell debris, echinoderms, foraminifers, bryozoans and a few small quartz grains.

The matrix of the conglomerate of unit 154 (Fig. 3) is mixed siliciclastic-carbonate sandstone composed of abundant quartz grains, many detrital potassium feldspars, carbonate grains and rare mica. Skeletal grains (echinoderms, brachiopods, brachiopod spines, bryozoans and foraminifers) are common, and the grains are cemented by calcite. The sandstone of unit 165 (Fig. 3) is moderately to poorly sorted and composed of angular to subangular grains of quartz, feldspar, some granitic and sedimentary rock fragments, and brownish carbonate matrix.

Limestone in the lower part of the Bartolo Member is bioturbated bioclastic wackestone containing a diverse fossil assemblage similar to that of the Gray Mesa Formation, including recrystallized fragments of phylloid algae. The nodular limestone interval is composed of bioclastic mudstone containing a few spicules, ostracods and echinoderm fragments. The uppermost limestone interval is composed of crinoidal grainstone to rudstone with a diverse fossil assemblage (Fig. 7E).

Amado Member

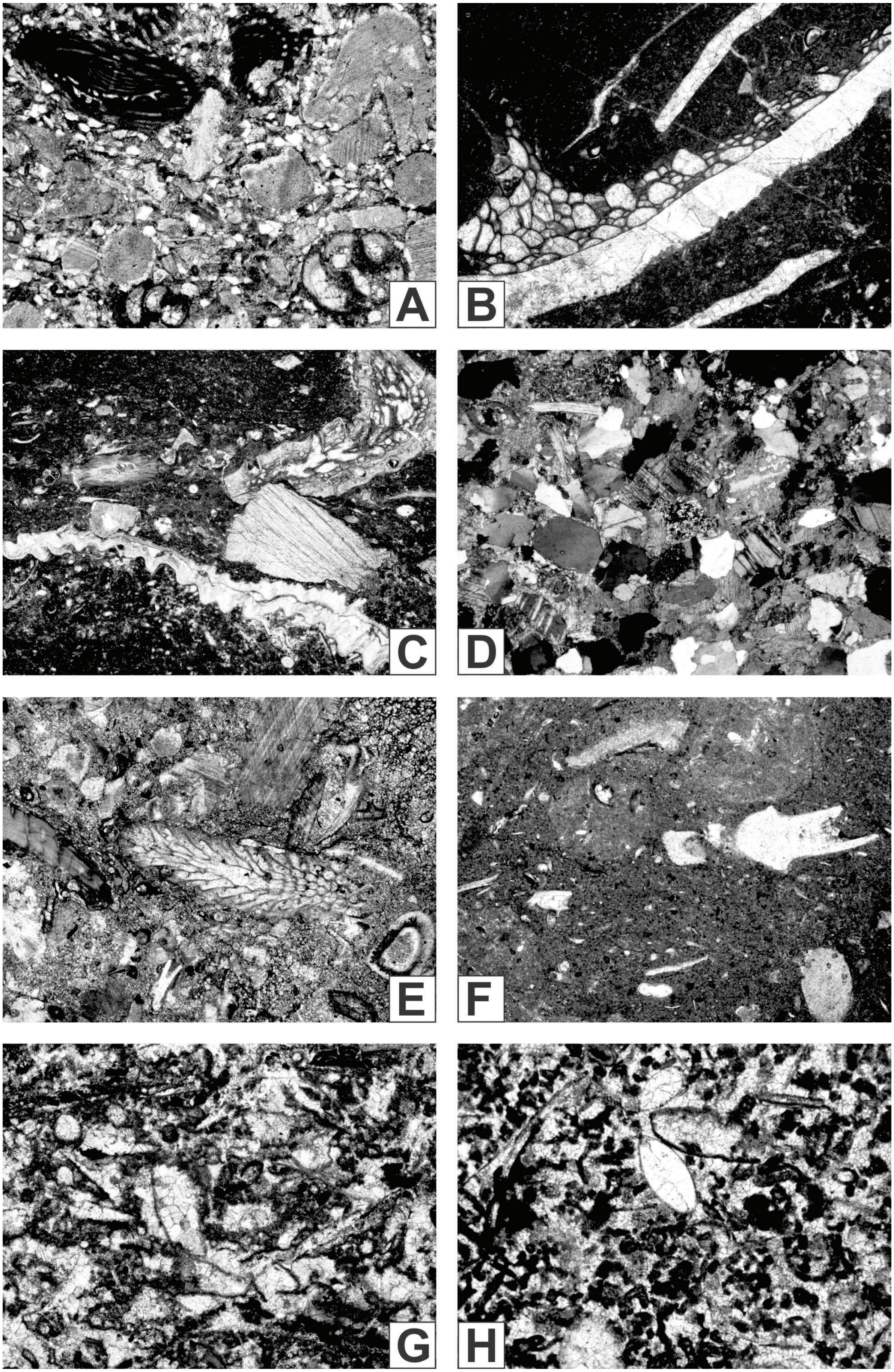
At Priest Canyon, the Amado Member is ~9 m thick and composed of four cherty limestone intervals (1-1.5 m thick), which are separated by covered intervals (1.3-1.4 m thick) (Fig. 3). The limestone is wavy bedded with bed thicknesses of 10-30 cm and contains chert nodules and rare chert bands. Fossils include abundant crinoid fragments, brachiopods and bryozoans. In thin section, limestone of the Amado Member is composed of bioturbated bioclastic wackestone (Fig. 7F) to floatstone containing a diverse fossil assemblage that locally includes recrystallized fragments of phylloid algae.

Tinajas Member

At Priest Canyon, the Tinajas Member is a slope-forming unit ~115 m thick. Approximately 74% of the section is covered (Fig. 3). Exposed lithologies are shale (12%), sandstone (8%) and limestone (6%).

Greenish shale is exposed in the middle of the Tinajas Member as intervals that are up to 6.9 m thick. Sandstone forms thin beds (0.2-0.5 m) and thicker units (0.8-6.2 m). Thin sandstone beds are mostly fine grained, and rarely coarse grained. These beds appear massive or display horizontal lamination and ripple lamination. The thicker (6.2 m) sandstone interval in the upper part of the Tinajas Member is trough crossbedded and shows an upward fining trend. Sandstone is greenish to greenish-gray. Limestone forms individual limestone beds (0.5 m thick) and thin intervals (0.6-1.6 m thick) that are thin to medium bedded (bed thickness 10-50 cm), and rarely massive or nodular. Nodular limestone contains abundant chert nodules, but all other limestone intervals lack chert nodules. In the limestone interval at the base of the Tinajas Member, a thin, matrix-supported conglomerate bed is intercalated and composed

FIGURE 7. Thin section photographs of sandstone and limestone of the Gray Mesa Formation (**A-C**, Garcia Member) and Atrasado Formation (**D-E**, Bartolo Member; **F**, Amado Member; **G-H**, Tinajas Member). **D** under polarized light, all others under plane light. Width of photographs **A**, **D** and **H** is 3.2 mm. Width of photographs **B**, **C**, **E**, **F**, **G** is 6.3 mm. **A**) Crinoidal packstone containing abundant crinoid fragments and subordinate fusulinids, smaller foraminifers, brachiopods, bryozoans, *Komia* and detrital quartz grains. Sample PC 25. **B**) Floatstone containing large recrystallized fragments of phylloid algae that float in peloidal micrite. The large algal fragment in the center of the photograph is encrusted by a bryozoan colony. Sample PC 27. **C**) Bioclastic wackestone to floatstone containing a diverse fossil assemblage of echinoderms, bryozoans, brachiopods, foraminifers, ostracods and spicules. Sample PC 27a. **D**) Arkosic sandstone composed of mono- and polycrystalline quartz, many detrital feldspars (mostly potassium feldspars), a few micas, a few granitic rock fragments, some carbonate rock fragments, and rare fossils cemented by coarse blocky calcite. Sample PC 28. **E**) Recrystallized grainstone to rudstone composed of abundant echinoderm (crinoid) fragments, subordinate brachiopods, bryozoans and smaller foraminifers. Sample PC 34. **F**) Bioclastic wackestone, bioturbated, containing skeletons of echinoderms, bryozoans, brachiopods, ostracods and smaller foraminifers. Sample PC 35. **G**) Packstone composed of recrystallized skeletons (likely phylloid algae), echinoderms, brachiopods, bryozoans, smaller foraminifers and ostracods. The packstone is moderately washed and locally contains peloidal micrite. Sample PC 37. **H**) Grainstone composed of abundant peloids and tubular foraminifers, and a few larger skeletons. Sample PC 38.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of carbonate clasts up to several centimeters in diameter. The massive limestone interval contains abundant calcareous algae. Other fossils observed in the field are crinoid fragments and brachiopods.

Sandstone of the thick unit 211 (Fig. 3) is moderately to well sorted and composed of angular to subangular detrital grains. The dominant grain type is monocrystalline quartz, and polycrystalline quartz grains are less abundant (including a few stretched metamorphic grains). The sandstone contains many detrital feldspar grains, which are slightly altered. Potassium feldspars dominate among plagioclase. Granitic rock fragments and fine-grained schistose metamorphic rock fragments are present in small amounts (Fig. 8A). Sedimentary rock fragments are dark brownish micritic grains. Micas are represented by muscovite, biotite and chlorite. The sandstone contains small amounts of matrix and, locally, some calcite cements.

The following limestone microfacies types are present in the Tinajas Member: bioclastic wackestone, grainstone and packstone-rudstone. Bioclastic wackestone is similar to that in the Gray Mesa Formation and characterized by a diverse fossil assemblage. Grainstone is composed of abundant peloids, tubular foraminifers and a few larger skeletons, which are completely recrystallized (Fig. 7H). Packstone to rudstone is composed of recrystallized fragments of phylloid algae, echinoderms, brachiopods, bryozoans, smaller foraminifers and some peloidal micrite (Fig. 7G).

Council Spring Member

At Priest Canyon, the Council Spring Member is ~23 m thick and composed of limestone intervals with little or no chert (67% of the section), alternating with covered intervals (Fig. 3). The Council Spring Member forms a prominent cuesta (Fig. 4). Limestone is rarely individual limestone beds (0.3 and 0.5 m thick) and more commonly intervals that are 0.9-1.8 m thick. Limestone is thick bedded to massive, thin to medium bedded, or nodular (rare). Bedding is even, and chert is rare. The only fossils observed in the field are crinoid fragments present in one crinoidal limestone bed. Covered intervals, which probably represent shale units, are 0.1-1.8 m thick.

Limestone of the Council Spring Member is composed of various types of wackestone to floatstone. Bioclastic wackestone to floatstone is most common, and algal wackestone to floatstone and fusulinid wackestone are less abundant. Wackestone to floatstone is characterized by a diverse fossil assemblage. The most abundant skeletons are echinoderms, brachiopods and bryozoans. Locally, phylloid algal fragments and fusulinids are the dominant fossils. Minor constituents are ostracods and smaller foraminifers (*Bradyina*, *Endothyra*, *Syzrania*, *Tuberitina* and *Tetrataxis*). Trilobite fragments are rare. Bioturbation is common in all limestone types.

Burrego Member

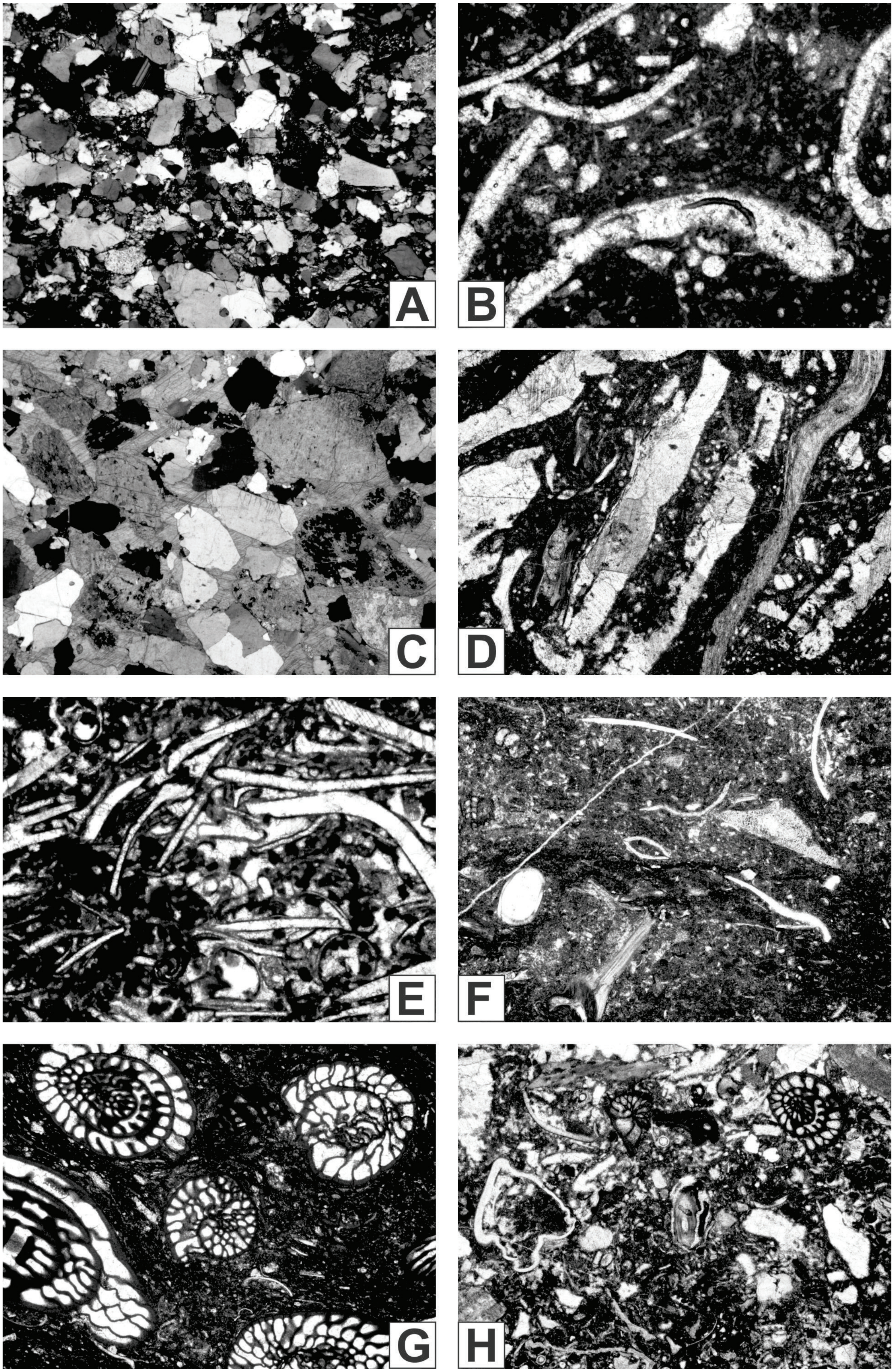
At Priest Canyon, the Burrego Member is ~23 m thick and is a slope-forming unit of mostly covered slopes and poorly exposed red mudstone (92% of the measured section) (Fig. 3). The lower part of the Burrego Member is composed of two sandstone and two limestone beds, separated by covered intervals. The lower sandstone bed is 0.6 m thick, crossbedded, greenish-gray, fine grained and micaceous. The upper sandstone bed is a coarse-grained, pebbly arkose. Limestone beds are 0.3 and 0.5 m thick. The upper limestone bed is algal (phylloid algal limestone). Sandstone and limestone beds are separated by covered intervals (shale) that are 0.6-5.5 m thick. The upper 12 m of the Burrego Member are composed of poorly exposed red mudstone.

The lower crossbedded sandstone of the Burrego Member is fine grained and mixed siliciclastic-carbonate in composition. Carbonate grains (sedimentary rock fragments) dominate, and quartz grains are present in smaller amounts (20-25%). Chlorite is common, and opaque grains are present, too. The upper, thin sandstone bed is coarse grained, moderately sorted and consists of angular to subangular detrital grains. Quartz is the dominant grain type, and detrital feldspar grains are common, mainly untwinned and perthitic potassium feldspars, which are slightly altered. The sandstone contains a few granitic rock fragments, a few fine-grained schistose metamorphic rock fragments, rare chert grains, and detrital muscovite (Fig. 8C). The detrital grains are cemented by coarse, poikilotopic calcite cement that randomly replaces detrital grains, particularly feldspars. The two limestone beds are composed of phylloid algal wackestone to floatstone (Fig. 8B, D) composed of abundant recrystallized fragments of phylloid algae and other skeletons of a diverse fossil assemblage embedded in micrite.

Story Member

At Priest Canyon, the Story Member is an approximately 6-m-thick succession of three limestone intervals (0.5-1.6 m thick), separated by two covered intervals (0.5 and 1.9 m thick) (Fig. 3). Limestone (66% of the section) is indistinctly bedded to massive and partly algal in the lower part. The main microfacies of the Story Member is bioclastic wackestone, and subordinately phylloid algal floatstone is present.

FIGURE 8. Thin section photographs of sandstone and limestone of the Atrasado Formation (**A**: Tinajas Member; **B**, **C**, **D**: Burrego Member; **E**: Del Cuerto Member; **F**, **G**: Moya Member) and Bursum Formation (**H**). **A** and **C** under polarized light, all other photographs under plane light. Width of **A** is 3.2 mm. All other photographs are 6.3 mm wide. **A**) Moderately- to well-sorted, fine-grained sandstone composed of mono- and polycrystalline quartz grains, many detrital feldspar grains and a few granitic rock fragments. Sample PC 40. **B**) Phylloid algal wackestone to floatstone. Large recrystallized thalli of phylloid algae float in a dark gray micrite that contains a few smaller skeletons of ostracods, echinoderms, bryozoans and foraminifers. Sample PC 46. **C**) Coarse-grained arkosic sandstone containing mono- and polycrystalline quartz, many detrital feldspar grains (mostly untwinned potassium feldspar) and a few granitic rock fragments cemented by coarse blocky calcite. Sample PC 47. **D**) Phylloid algal floatstone containing recrystallized fragments of phylloid algae, subordinate brachiopods, bryozoans, echinoderms, smaller foraminifers and ostracods. Sample PC 49. **E**) Rudstone containing abundant recrystallized shell fragments displaying thin micritic envelopes, subordinate phylloid algae, echinoderms, ostracods and small gastropods. Sample PC 52. **F**) Bioclastic wackestone containing a diverse fossil assemblage of echinoderms, bryozoans, brachiopods, trilobites, smaller foraminifers and ostracods embedded in micrite. Sample PC 53. **G**) Fusulinid wackestone composed of mostly unbroken fusulinid tests and some other bioclasts such as smaller foraminifers, echinoderms, ostracods, bryozoans and brachiopods embedded in micrite. Sample PC 55. **H**) Bioclastic wackestone to packstone composed of fragmented fossils including brachiopods, bryozoans, fusulinids, smaller foraminifers and other skeletons. Sample PC 59.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The bioclastic wackestone and phylloid algal floatstone contain a diverse fossil assemblage of echinoderms, fusulinids, bryozoans, brachiopods, phylloid algae, ostracods, small gastropods, smaller foraminifers (*Bradyina*, *Globivalvulina*, *Spireitlina*, *Syzrania*, *Tetrataxis* and *Tuberitina*), brachiopod spines and rare trilobite fragments. Locally, fusulinids (*Triticites*) are abundant (fusulinid wackestone). In phylloid algal floatstone, recrystallized fragments of phylloid algae are the most abundant skeletal grains. Rarely, phylloid algal fragments are encrusted by bryozoans. The wackestone is commonly bioturbated.

Del Cuerto Member

At Priest Canyon, the Del Cuerto Member is ~16 m thick. It is a slope-forming, dominantly clastic interval of cover/shale (64% of the section), limestone (22%) and arkosic sandstone/conglomerate (14%) (Fig. 3). Shale at the base is 1 m thick, poorly exposed and contains abundant limestone nodules. In the upper part, two shale intervals are present (1.1 and 2.6 m thick). Limestone is bedded nodular limestone in the lower part (1.1 m thick) and three even to slightly wavy, bedded algal limestone intervals (0.4-0.8 m thick) in the upper part. Chert nodules are present in the lower two intervals, and the uppermost limestone interval contains crinoid debris. Sandstone is fine to coarse grained, pebbly, arkosic, and forms one thin, massive bed (0.3 m) and beds of trough crossbedded sandstone (0.6 and 0.9 m thick). Fine-grained arkosic conglomerate is present as one massive bed (0.2 m) containing clasts up to 2 cm in diameter.

The sandstone of the Del Cuerto Member is moderately sorted, and detrital grains are subrounded to rounded. The sandstone is arkosic in composition, containing mono- and polycrystalline quartz, and abundant detrital feldspar grains (mainly potassium feldspars and rare plagioclase). Most feldspar grains are slightly altered, and some of the grains are partly replaced by calcite. Granitic rock fragments and fine-grained, schistose, metamorphic rock fragments are present in small amounts. Detrital muscovite is rare, and the detrital grains are cemented by coarse blocky calcite.

Limestone of the Del Cuerto Member consists of bioclastic wackestone, fusulinid wackestone and bioclastic rudstone (Fig. 8E), all characterized by a diverse fossil assemblage similar to that of the Council Spring and Story members. Rudstone is composed of abundant recrystallized mollusk shell fragments, small gastropods, phylloid algae, a few echinoderms, ostracods, abundant peloids and a few oncoids with diameters up to 1 cm.

Moya Member

The Moya Member is 11 m thick and represented by limestone (66% of the measured section) and covered intervals (Fig. 3). Limestone forms one thin bed, which is a fusulinid limestone (0.2 m), and intervals that are 0.6-2 m thick. Limestone intervals are medium bedded (20-50 cm), partly cherty, and composed of mudstone and wackestone. At the top of the uppermost limestone, root structures are present. Covered intervals are 0.8-1.1 m thick. The limestone intervals contain calcareous algae, crinoidal debris, fusulinids (*Triticites*), solitary corals and large bryozoans.

The dominant limestone microfacies of the Moya Member is wackestone (Fig. 8F) to floatstone, particularly bioclastic wackestone to floatstone, and fusulinid wackestone (Fig. 8G), which are commonly bioturbated and contain a diverse fossil assemblage, as in the underlying members of the Atrasado Formation. Locally, solitary corals are present, which are partly encrusted by bryozoans, and bryozoan colonies are encrusted by *Tubiphytes*. Commonly, some larger skeletons float in fine bioclastic matrix. The topmost limestone of the Moya Member is a recrystallized carbonate mudstone to siltstone, laminated and contains abundant irregular voids filled with coarse calcite cement (possibly root structures). Fossils are absent.

Bursum Formation

At Priest Canyon, the Lower Permian Bursum Formation rests disconformably on the Moya Member of the Atrasado Formation (Fig. 3). The exposed thickness of the Bursum Formation is at least 35 m. The unit is mostly covered/mudstone (64% of the section) and limestone (32%, mostly bioclastic wackestone to floatstone; Fig. 8H) with a bed of sandstone near its base. We describe these Bursum strata elsewhere in this volume.

DEPOSITIONAL ENVIRONMENTS

The Pennsylvanian section at Priest Canyon is very similar to that at Cedro Peak, ~57 km to the north (Lucas et al., 2014), and in the Cerros de Amado, ~60 km to the southwest (Lucas et al., 2009; Barrick et al., 2013). The Sandia Formation thickens from Cedro Peak to Priest Canyon. At Cedro Peak, the Sandia Formation is probably completely nonmarine (Lucas et al., 2014), but at Priest Canyon only the lowermost 12 m are entirely siliciclastic and may be nonmarine. Above, are siliciclastic sediments and intercalated thin fossiliferous limestone beds composed of microfacies such as rudstone, grainstone, packstone and wackestone with a diverse fossil assemblage indicating deposition in a low- to high-energy shelf environment. The limestone facies are similar to those of the Sandia Formation lectostratotype section in the southern Sandia Mountains of Bernalillo County (Krainer et al., 2011; Krainer and Lucas, 2013). At Priest Canyon, the upper part of the Sandia Formation is poorly exposed and probably of shallow marine origin.

The Gray Mesa Formation of Priest Canyon is thicker than at Cedro Peak, but composed of similar lithologies. The Elephant Butte Member is as thick as at Cedro Peak, but the Whiskey Canyon and Garcia members are considerably thicker at Priest Canyon compared to Cedro Peak and the Cerros de Amado (Lucas et al., 2009, 2014). Nevertheless, the limestone lithotypes are very similar, as are microfacies and fossil assemblages, indicating that limestone was deposited in a dominantly low-energy, shallow marine, shelf environment with open, normal marine conditions. Limestone deposition was interrupted several times by the influx and deposition of fine-grained siliciclastic material (shale intervals, mostly covered).

The relatively greater thickness of the Gray Mesa Formation at Priest Canyon indicates relatively high subsidence rates, which were compensated by higher sedimentation rates. As at Cedro Peak, the well-developed upward shallowing cycles in the Gray Mesa Formation described by Wiberg (1993) and Wiberg and Smith (1994) from the Sandia Mountains and by Scott and Elrick (2004) and Elrick and Scott (2010) from the Lucero uplift were not observed in the Priest Canyon section (see discussion in Lucas et al., 2014).

The Atrasado Formation is thicker at Priest Canyon (272 m) than at Cedro Peak (200 m), the Cerros de Amado (233 m), and the formation type section (100 m) in the Lucero uplift of Valencia County (Krainer and Lucas, 2004; Lucas et al., 2009, 2014). This is because most of those members containing a substantial amount of siliciclastic sediments (shale, siltstone and sandstone) – Bartolo, Tinajas and Del Cuerto members – are considerably thicker. An exception is the Burrego Member, which is much thinner (27 m) at Priest Canyon than at Cedro Peak (47 m). Limestone-dominated members are either thicker (Council Spring, Moya) or thinner (Amado, Story) compared to Cedro Peak.

The Bartolo Member at Priest Canyon contains much more sandstone than at Cedro Peak or in the Cerros de Amado, with a well-developed Coyote Sandstone near the base and several, up to ~5 m thick, sandstone units in its upper part. These sandstones in the upper part are absent at Cedro Peak, though the limestone facies is very similar to Cedro Peak. Sandstones and the intercalated conglomerate contain skeletal grains indicating deposition in a high-energy, nearshore environment.

The Amado Member is dominated by cherty limestone that contains a diverse fossil assemblage, including phylloid algae, suggesting formation in a low-energy, open, normal marine, shelf environment below wave base but within the photic zone. The thickness and facies of the Amado Member are quite uniform over a large area (Cedro Peak, Priest Canyon, Cerros de Amado).

The Tinajas Member is by far the thickest member of the Atrasado Formation and dominantly siliciclastic, composed of covered (shale) intervals with intercalated sandstone and thin limestone. The facies, particularly the amount of intercalated sandstone, vary laterally. Sandstone is missing at the type section, is rare in the Cerros de Amado sections, and is more common and thicker (up to 5 m) at Priest Canyon and also at Cedro Peak. Crossbedded sandstone and part of the siltstone and shale is probably nonmarine (fluvial to deltaic: Lorenz et al., 1992; Lucas et al., 2014). Intercalated limestone beds represent short periods of open, normal marine, low- to high-energy shelf conditions. The presence of phylloid algae indicates deposition within the photic zone.

The Council Spring Member at Priest Canyon is much thicker (24 m) than at Cedro Peak (7 m) and in the Cerros de Amado (5 m). Microfacies and a diverse fossil assemblage, including phylloid algae, point again to a shallow, open, normal marine, low-energy shelf environment.

Compared to Priest Canyon, the Burrego Member is thicker (47 m) at Cedro Peak but thinner (13 m) in the Cerros de Amado. This member is dominantly siliciclastic, with two thin limestone beds intercalated. The facies change considerably from Cedro Peak to Priest Canyon. At Cedro Peak, the Burrego Member is composed of several, up to about 10 m thick, units of crossbedded and ripple-laminated sandstone that are interpreted as fluvio-deltaic deposits (Lucas et al., 2014). At Priest Canyon, only two thin sandstone beds are intercalated. Here, the Burrego Member is composed mainly of mudstone, which is covered in the lower part and poorly exposed in the upper part. The thin limestone beds reflect short periods of marine flooding and normal marine conditions in a low-energy shallow marine environment.

Like the Amado Member, the Story Member is a very uniform stratigraphic interval with only minor variations in thickness (6-10 m). Its uniform limestone lithology indicates, again, deposition under shallow, open, normal marine, mostly low-energy shelf conditions.

The Del Cuerto Member at Priest Canyon is thicker than at Cedro Peak (9 m) and in the Cerros de Amado (7 m), and sandstone is more abundant. Sandstones are composed of subrounded to rounded grains, indicating a nearshore depositional environment. The microfacies of limestone are similar to those of the Council Spring and Story members, indicating deposition in a similar setting.

Compared to Priest Canyon, the Moya Member is thinner at Cedro Peak (5 m) but much thicker (18 m) in the Cerros de Amado. It is mostly composed of limestone with wackestone to floatstone with a diverse fossil assemblage being the main microfacies, indicating a depositional environment similar to that of the Story and Council Spring members. Probable root structures on the top of the Moya Member suggest a subaerial exposure surface.

At Priest Canyon, the Bursum Formation is mostly covered red siltstone/mudstone with rare sandstone and limestone. Siliciclastic sediments of the Bursum Formation are interpreted as mainly of nonmarine origin, whereas intercalated limestone intervals represent a shallow marine depositional environment (Krainer and Lucas, 2009). Due to the dominance of fine-grained siliciclastics, this Bursum section can be assigned to the Red Tanks Member, which represents a transitional facies from the underlying, predominantly calcareous shallow marine Atrasado Formation to the overlying siliciclastic red beds of the Abo Formation (Lucas and Krainer, 2004; Krainer and Lucas, 2009).

LITHOSTRATIGRAPHIC SUBDIVISIONS AND NOMENCLATURE

Myers (1973) created a Pennsylvanian lithostratigraphic nomenclature in the Manzano Mountains different from all previous local or regional lithostratigraphic nomenclature. As discussed here, we reject all of Myers lithostratigraphic terms as either unnecessary junior synonyms of earlier terms or as units unrecognizable on a lithostratigraphic basis (also see Lucas et al., 2014). Instead, we use formation rank terminology developed by the 1950s, and we apply primarily Thompson's (1942) lithostratigraphic nomenclature to member-level units. We thus differ from Myers (1973, p. F4), who stated that Thompson's

(1942) Pennsylvanian units "could not be recognized as lithologic entities in the Manzano Mountains."

Myers (1973, p. F4) named the Los Moyos Limestone, stating that "the lower part of the Madera Group is a sequence of massive cliff-forming medium- to light-gray cherty limestone with minor amounts of interbedded gray to black shale and lenticular beds of grayish-orange sandstone and conglomerate." Although the name was for Los Moyos Canyon, the type section of the Los Moyos Limestone is at Priest Canyon and is part of the section described here (Fig. 9). Myers (1973, p. F5) stated that the Los Moyos Limestone "is probably equivalent to the Gray Mesa Member of the Madera Limestone (Kelley and Wood, 1946)."

Indeed, the equivalence of the Gray Mesa Member and Los Moyos Limestone is well established (Lucas and Estep, 2000; Kues, 2001; Nelson et al., 2013a, b). Thus, Myers' (1973) Los Moyos Limestone is an unnecessary junior synonym of Kelley and Wood's (1946) Gray Mesa Member (Formation) and can

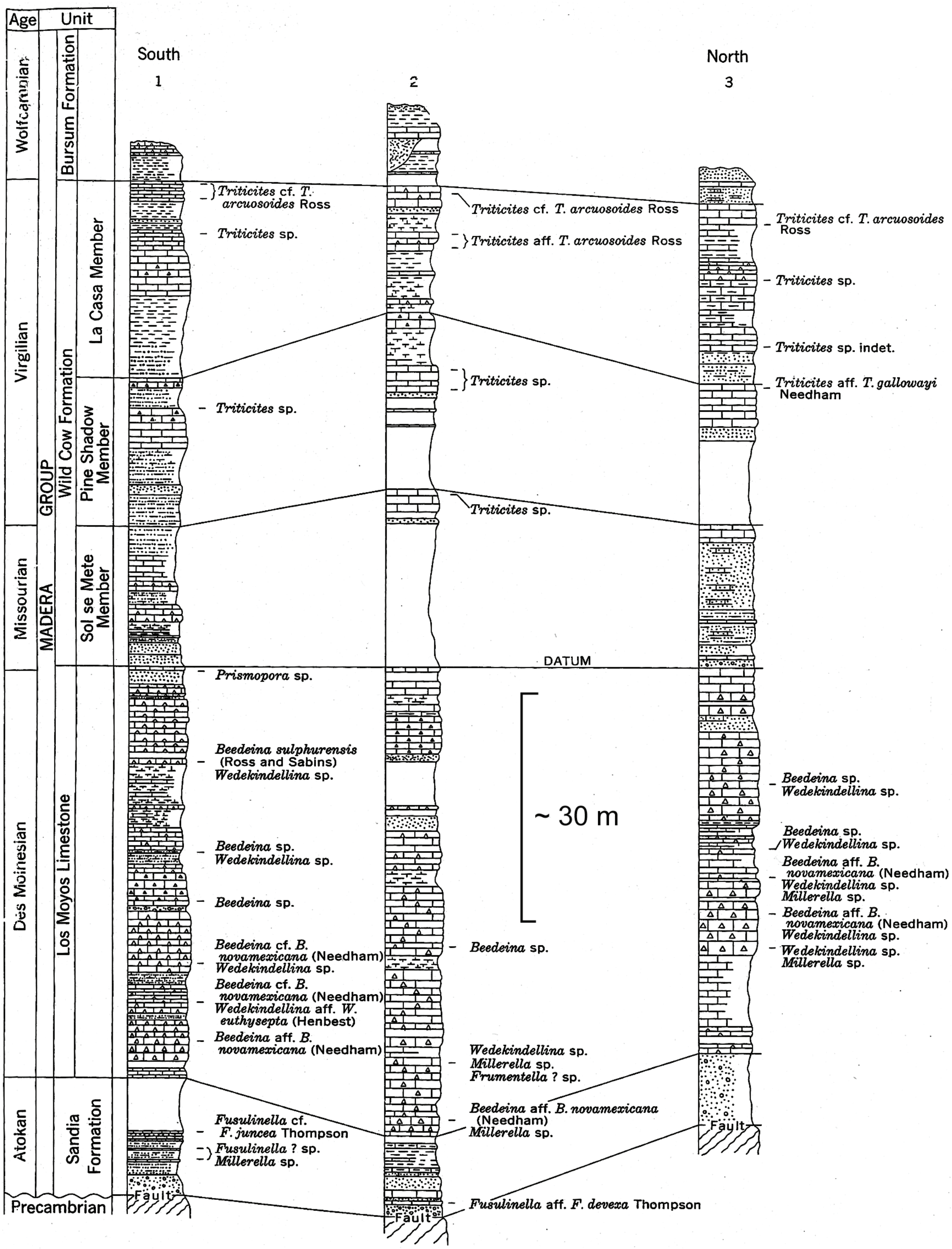


FIGURE 9. Myers and McKay's (1974) measured stratigraphic section at Priest Canyon (section 2), which encompasses the type sections of Myers' (1973) lithostratigraphic units, correlated to nearby sections 1.7 km to the south (section 1) and 0.8 km to the north (section 3) (all sections in the drainage of Priest Canyon).

be abandoned. Furthermore, Myers (1973, p. F4-F5) description of his Los Moyos Limestone indicates its tripartite nature, with sandy beds in its lower and upper parts, and its middle part comprising a "cliff-forming cherty gray limestone." These three parts are the Elephant Butte, Whiskey Canyon and Garcia members of Thompson (1942) recognized here.

Myers (1973, p. F8) proposed the term Wild Cow Formation (divided into three new, formal members) for strata between his Los Moyos Limestone and the Bursum Formation, acknowledging that "it is probably equivalent to the Atrasado Member of the Madera Limestone (Kelley and Wood, 1946)." That equivalence has also been well established (Lucas and Estep, 2000; Kues, 2001; Nelson et al., 2013a). Thus, Wild Cow is an unecessary junior synonym of Atrasado and can be abandoned.

Like the Los Moyos Limestone, the Wild Cow Formation (and the three formal members named by Myers) has its type section at Priest Canyon (Fig. 9), part of the section described here. The lower, Sol se Mete Member is shown by Myers as 200 ft (61 m) of siltstone-dominated strata that supposedly has a top marked by "30-60 ft of gray limestone, locally cherty, that forms a cliff," although the upper limestone is not present at the type section (Myers, 1973, p. F9). Indeed, there is no obvious lithologic break at the type section with which to differentiate the Sol se Mete and overlying Pine Shadow members (Fig. 9). Myers (1973, p. F8-9) identified the base of the Sol se Mete Member as the "Coyote Sandstone Member of the Madera" but stated that "inasmuch as the Coyote is not a mappable unit, its use is herein abandoned." However, mappability is not a criterion for recognition of member- (or bed-) level units, so we recognize the Coyote Bed as a useful lithostratigraphic unit at the base of the Atrasado Formation.

Myers (1973) stated that the base of the Pine Shadow Member is characteristically a conglomerate but not at its type section. Here, he described the Pine Shadow Member as 50-90 (15-27 m) ft of clastic strata overlain by limestone beds.

Myers (1973) described the type section of his La Casa Member as ~120 ft (37 m) of poorly exposed siltstone and shale, overlain by ~100 ft (30 m) of limestone, followed by a thin succession of red and gray shale and sandstone and capped by a 30-ft-thick (9 m) uppermost bed of limestone. Its base at its type section is thus clastic strata on limestone at the top of the underlying Pine Shadow Member (Fig. 9).

Myers' (1973) own stratigraphic sections of the members of the Wild Cow Formation he named indicate that they lack consistent lithological content and that their boundaries do not correspond to consistent lithologic changes (Fig. 9). Instead, what Myers three members of the Wild Cow Formation actually appear to be are three fusulinid-defined biostratigraphic intervals: Sol se Mete Member = Missourian, Pine Shadow Member = early-middle Virgilian and La Casa Member = late Virgilian. We contend that Myers' members of his Wild Cow Formation thus are not lithostratigraphic units and should be abandoned in favor of the member-level lithostratigraphy of the Atrasado Formation created by Thompson (1942), Rejas (1965) and Lucas et al. (2009). We conclude that at their type sections, the Sol se Mete Member of Myers is approximately the Bartolo Member of our usage; the Pine Shadow Member is approximately the Amado Member and much of the Tinajas Member; and the La Casa Member is the rest of the Tinajas Member and the entire Council Spring, Burrego, Story, Del Cuerto and Moya members. However, elsewhere in the Manzano and Manzanita mountains, Myers and McKay did not consistently map the members of the Wild Cow Formation, so their correspondence to the members of the Atrasado Formation we recognize varies locally (Lucas et al., 2014).

BIOSTRATIGRAPHY AND CORRELATION

Bates et al. (1947) published the earliest fusulinid-based ages of the Pennsylvanian strata on the Gran Quivira Quadrangle. Thus, they reported *Fusulinella* from the Sandia Formation, and assigned it a "Lampasas" (= Atokan) age. From the marine limestone member of the Madera Limestone (Gray Mesa Formation of our usage) they reported *Fusulina* (= *Beedeina*) and *Wedekindellina* and assigned these strata to the "Des Moines series." Bates et al. (1947, p. 23) reported "slender cylindrical species of *Triticites*" from the lower part of what we term Atrasado Formation, and "advanced, obese species of *Triticites*" from the upper part of the Atrasado Formation, and thus assigned these strata a Missourian-Virgilian age.

Myers and McKay (1974) listed fusulinids from the measured section at Priest Canyon (Fig. 9). Myers (1988a, pl. 1) later documented the fusulinids he collected from the Sandia Formation and the "Los Moyos Limestone" (= Gray Mesa Formation) at Priest Canyon. These are fusulinids from U. S. Geological Survey localities f10178-10180 (Sandia Formation) and f10181-10186 ("Los Moyos Limestone"). From the Sandia Formation, he documented *Fusulinella velmae* Thompson, *F. devexa* Thompson, *F. whitensis* Ross and Sabins, *Profusulinella* aff. *P. copiosa* Thompson and *Millerella* sp. Myers (1988a) assigned these fusulinids to his assemblage subzone of *Fusulinella whitensis* of late Atokan age.

From the lower part of the Gray Mesa Formation, Myers (1988a) documented *Beedeina* cf. *B. insolita* (Thompson), *B.* cf. *B. novamexicana* (Needham), *B.* aff. *B. novamexicana* (Needham), *Wedekindellina excentrica* (Roth and Skinner), *W.* cf. *W. henbesti* (Skinner), *W.* sp. A, *W.* cf. *W. euthysepta* (Henbest) and *Millerella* sp. These represent his assemblage subzones of *Beedeina insolita* (lower) and *Beedeina novamexicana* (upper). The lower part of the Elephant Butte Member is in the subzone of *Beeedina insolita*, and the upper part of the Elephant Butte Member and lower part of the Whiskey Canyon Member are in the subzone of *Beedeina novamexicana*.

From the upper part of the Gray Mesa Formation, Myers (1988a, pl. 4) documented *Beedeina sulphurensis* (Ross and Sabins), *B.* cf. *B. haworthi* (Beede), *B.* sp. B and *Wedekindellina* aff. *W. euthysepta*. These are from strata of the lower part of the Garcia Member, and Myers assigned them to his assemblage subzone of *Beedeina sulphurensis*, which he regarded as late Desmoinesian. Note, however, that the presence of *Wedekindellina* argues against a late Desmoinesian age (e.g., Wilde, 2006).

Myers (1988b) recovered very few fusulinids from the Atrasado Formation at Priest Canyon (Fig. 9). These are from two stratigraphic levels: U. S. Geological Survey locality f10253 in the "Pine Shadow Member" and f10254 near the top of the La Casa Member. From f10253, he documented *Triticites* aff. *T. cullomensis* Dunbar and Condra (Myers, 1988b, pl. 1, figs. 6-9). From f10254, he documented *Triticites* aff. *T. beedei* Dunbar and Condra (Myers, 1988b, pl. 10, figs. 16-19). He assigned these levels to his assemblage subzones of *Triticites cullomensis* (lower) and *Triticites beedei* (upper) of middle and late Virgilian age, respectively.

Fusulinids we collected (Figs. 10-12) allow us to make some age assignments (Fig. 13). Thus, our fusulinid samples, associated with smaller foraminifers, calcareous algae, and microproblematica, indicate:

1. A late Atokan age for Sandia Formation strata (Fig. 3, units 6, 14), is well characterized, notably by *Fusulinella juncea* Thompson, 1948 (Fig. 10A), *F. devexa* Thompson, 1948 and *Pseudoacutella* sp. 1 (= "*Millerella*" of the authors) (Fig. 11T). They are associated with *Komia* sp., *Climacammina* sp. and *Polytaxis* sp.

2. *Beedeina* cf. *insolita* (Thompson, 1948); i.e., a marker of the earliest Desmoinesian, appears in PC10 and PC12, which are located at the top of Sandia Formation (Fig. 3, unit 27) and bottom of the Gray Mesa Formation (Fig. 3, unit 30), respectively. It is associated with *Endothyra* sp., *Climacammina* sp., *Tetrataxis* ex gr. *acuta* Durkhina, 1959, *Polytaxis* sp. (Fig. 11F), *Eolasiodiscus* sp. (Fig. 11C), *Calcivertella* sp., and *Tuberitina bulbacea* Galloway and Harlton, 1928, which remain common during all of the Desmoinesian and early Missourian (Fig. 11G, M, O, Q), and *Syzranella*? sp., present up to the latest Pennsylvanian (Fig. 11H, S).

3. An early Desmoinesian age for the Elephant Butte and Whiskey Canyon members of the Gray Mesa Formation (Fig. 3, units 30, 40, 61, 77, 98) with *Beedeina* aff. *insolita* (Fig. 10C) and *Wedekindellina* cf. *euthysepta* (Henbest, 1928) (Fig. 10D) found in the Whiskey Canyon Member, from PC16 to PC25 (Fig. 3). The assemblage also encompasses *Komia eganensis* Wilson and Waines in Wilson et al., 1963, *Endothyranella* cf. *protracta* Rauzer-Chernoussova, 1938 (Fig. 11I, J, L), *Endothyra* sp., *Planoendothyra?* sp. (Fig. 11N), *Bradyina* sp., *Pseudoacutella* sp. 2, *Tetrataxis* sp., *Polytaxis* sp., *Climacammina* sp., *Palaeonubecularia* sp., *Calcivertella* sp., *Hemigordiellina* sp., *Syzrania bella* Reitlinger, 1950 (Fig. 11K) and *Syzranella?* sp.

4. The upper part of the Whiskey Canyon Member contains another species of the early Desmoinesian fusulinid *Beedeina socorroensis* (Needham, 1937) in PC22 (Fig. 10B), which is probably the *B.* cf. *novamexicana* (Needham) and/or *B.* aff. *novamexicana* (Needham) *sensu* Myers (1988a). The best preserved *Komia eganensis* (Fig. 10I) are present in this interval.

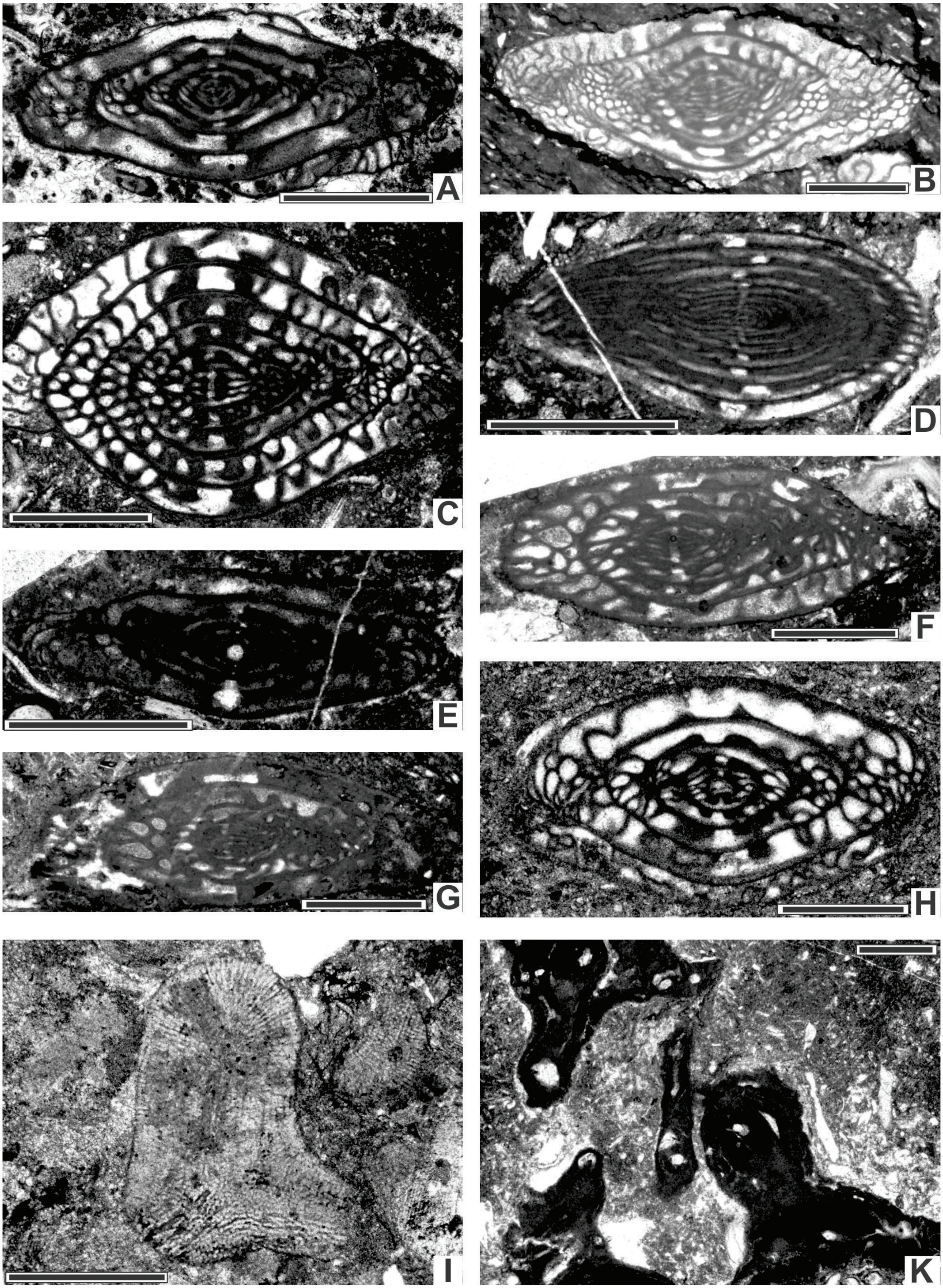
5. The lowermost part of the Garcia Member is still early Desmoinesian due to the presence of *Wedekindellina* in PC 25 (Fig. 3).

6. The Bartolo Member of the Atrasado Formation (Fig. 3, units 146, 148) is difficult to characterize biostratigraphically in the absence of large fusulinids, but it contains some smaller foraminifers such as *Mesolasiodiscus*? sp.; i.e., a transitional taxon between *Eolasiodiscus* and *Mesolasiodiscus* (Fig.11A-B), in PC29. Its probable ancestor is an *Eolasiodiscus* sp. (Fig. 11C) present as early as the earliest Desmoinesian (see above). It is noteworthy that, for the time, we can document true lasiodiscoid foraminifers mentioned in the USA. Thus, as indicated by Lucas et al. (2016), the so-called *Monotaxinoides transitorus sensu* Groves (1983, pl. 3, figs. 15-19; and then, Groves, 1992, pl. 3, figs. 27-33; Altiner and Savini, 1995, pl. 5, figs. 7-11; Pinard and Mamet, 1998, pl. 25, figs. 16, 21; and Wood et al., 2002, pl. 17, fig. 19) are in fact some Miliolata (porcelaneous-walled taxa) generally similar to the conical genus *Turrispiroides* Reitlinger in Rauzer-Chernousova and Fursenko, 1959, but with an infilled umbilicus. This new genus is endemic to the Americas (from the Canadian Arctic to Peru). Only the "*Monotaxinoides priscus*" *sensu* Groves (1992, pl. 3, figs. 34-40), although misinterpreted, might be the unique lasiodiscoid mentioned in North America, prior to our *Mesolasiodiscus*? sp. The Bartolo Member also contains the first occurrence of *Calcivertella* ex gr. *heathi* (Cushman and Waters, 1928) (Fig. 11D-E), which is relatively characteristic of the Late Pennsylvanian-early Cisuralian.

7. The Amado Member in PC36 (Fig. 3, unit 177) yielded *Plectofusulina ovata* Wilde, 2006 (Fig. 11R), a species relatively characteristic of the earliest Missourian (*Eowaeringella* Zone), even if the acme of the genus *Plectofusulina* is more generally late Desmoinesian in age in New Mexico (Wilde, 2006). *Plectofusulina ovata* is associated with *Tetrataxis*, *Calcitornella* sp. and *Pseudoacutella* sp. 2.

8. The Tinajas Member contains in PC39 (Fig. 3, unit 207), a microfauna totally unexpected in New Mexico, and even in North America, with a primitive form of *Biwaella* Morikawa and Isomi, 1960, transitional to an undeterminated schubertellid (Fig.10E), and another taxon similar to *Bartramella* Verville, Thompson and Lokke, 1956, *Putrella* Rauzer-Chernousova in Rauzer-Chernousova et al., 1951 (= ?*Annulofusulinella* Wilde, 2006), or *Pseudotriticites* Putrya, 1940 (Fig. 10F-G); i.e., a form exhibiting the septal folding and chomata of *Fusulina* Fischer de Waldheim, 1829 *sensu*

FIGURE 10. Main fusulinids and microproblematica from the Pennsylvanian succession at Priest Canyon. Scale bars = 1 mm. **A**) *Fusulinella juncea* (Thompson, 1948). Axial section. Late Atokan (Podolskian) of Priest Canyon (New Mexico). Sample PC6-1. **B**) *Beedeina soccoroensis* (Needham, 1937). Axial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC22-1. **C**) *Beedeina* aff. *insolita* (Thompson, 1948). Subaxial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC19-1. **D**) *Wedekindellina* cf. *euthysepta* (Henbest, 1928). Subaxial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC19-3. **E**) *Biwaella*? n. sp. Subaxial section. Earliest Missourian (early Kasimovian?) of Priest Canyon (New Mexico). Sample PC39-1. **F**-**G**) *Bartramella*? n. sp. **F**) Subaxial section. Earliest Missourian (early Kasimovian?) of Priest Canyon (New Mexico). Sample PC39-3. **G**) Subaxial section. Earliest Missourian (early Kasimovian?) of Priest Canyon (New Mexico) Sample PC39-2. **H**) *Triticites canyonensis* (Wilde, 2006). Axial section. Missourian (Kasimovian) of Priest Canyon (New Mexico). Sample PC48-1. **I**) *Komia eganensis* (Wilson & Waines in Wilson et al., 1963). Longitudinal section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC23-5. **J**) *Tubiphytes* ex gr. *obscurus* (Maslov, 1956). Differs from true *T. obscurus* by more numerous cavities filled by microsparite. Virgilian (Gzhelian) of Priest Canyon (New Mexico). Sample PC53-2.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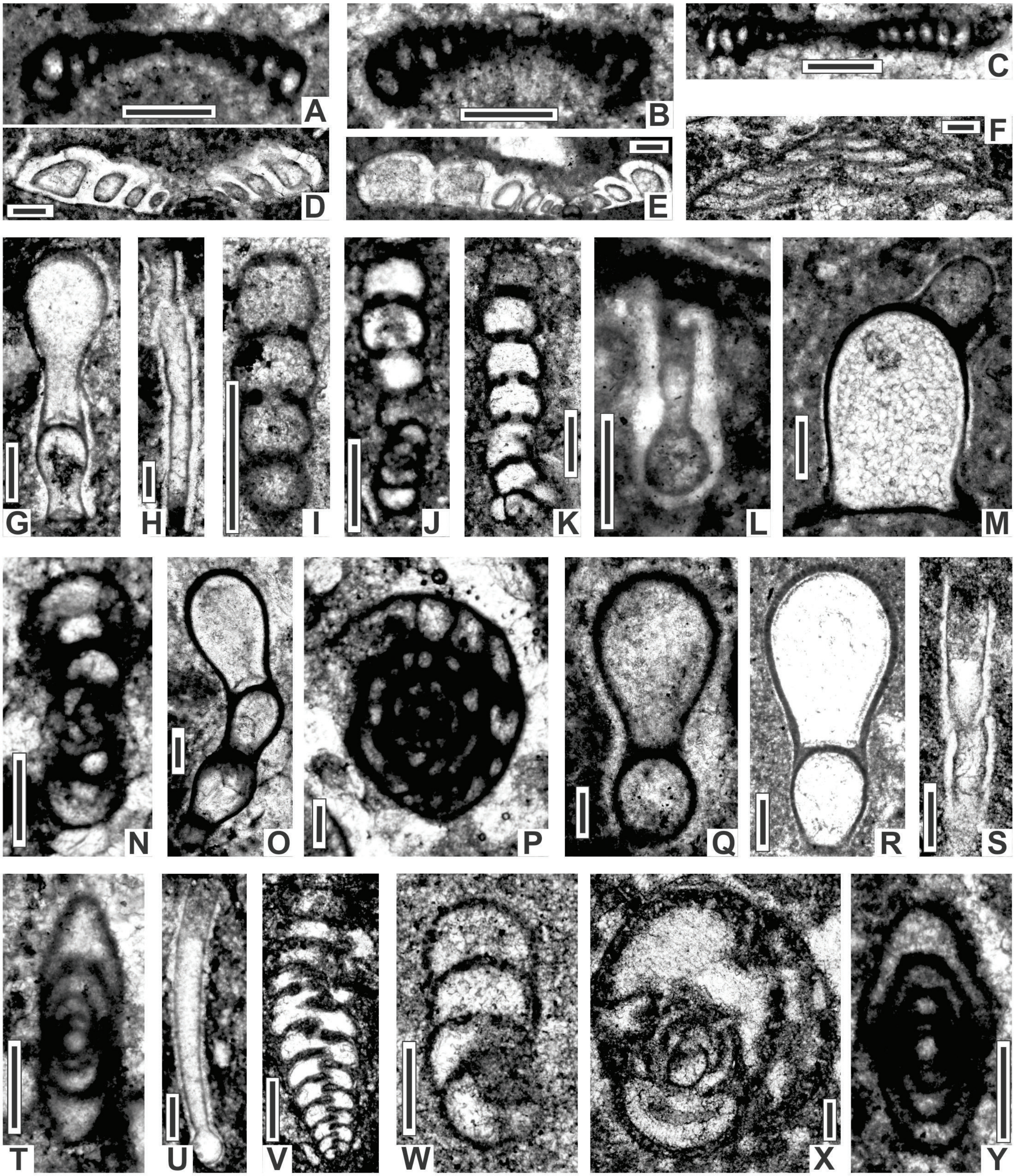
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stricto type with a wall that becomes porous in the last whorls. Similarly, the wall becomes porous in *Biwaella*, *Dutkevitchites* Davydov, 1984, *Oketaella* Thompson, 1951, some *Protriticites* Putrya, 1948, and *Praeobsoletes* Remizova, 1993, and announces the true keriothecal wall typical of the schwagerinoid fusulinids from the Late Pennsylvanian to late Guadalupian (Vachard et al., 2004). This episode, discovered here for the first time in North America, needs further study.

9. The Council Spring Member does not yield fusulinids. An interesting and unique feature is the replacement of *Tuberitina bulbacea* by *T. collosa* Reitlinger, 1950 (Fig. 11R) in PC44 (Fig. 3, unit 235).

10. The Burrego and/or Story members in PC 48 and PC 49 (Fig. 3, unit 254) contain the first *Triticites* of the section, *Triticites canyonensis* Wilde, 2006 (Fig. 10H), which are early/middle Missourian in age (Wilde, 2006). *Syzrania confusa* Reitlinger, 1950 replaces *S. bella* in PC48 (Fig. 11U).

11. A Virgilian age for the upper part of the Del Cuerto Member (Fig. 3, unit 270) and lower part of the Moya Member (Fig. 3, unit 277) is indicated by the FO (first occurrence) of *Triticites beedei* Dunbar and Condra, 1927 (Fig. 12A) in PC52 and common *Tubiphytes* ex gr. *obscurus* Maslov, 1956 (Fig. 10J) in PC53.

12. The upper part of the Moya Member (Fig. 3, units 280 and 283; in PC55 and 56) corresponds perhaps to the earliest Wolfcampian, because it contains *Triticites* ex gr. *cellamagnus* Thompson and Bissell in Thompson, 1954, and exhibits a transition between *Triticites* and *Leptotriticites* (Fig. 12B, D-K) and some primitive *Leptotriticites* (Fig. 12C). Smaller foraminifers are mainly *Climacammina* sp. (Fig. 11V), evolved *Endothyranella* sp. (Fig. 11W), *Polytaxis* sp., and *Palaeonubecularia* sp. In any case, the Virgilian has a reduced thickness in Priest Canyon, and the Carboniferous-Permian boundary may be in the Moya Member.

13. The Wolfcampian age of the Bursum Formation (PC59: Fig. 3, unit 299) is determined by forms of *Triticites* similar to those of the upper Moya Member (Fig. 12J) and not the typical *Leptotriticites*, evolved *Triticites* or *Thompsonites* (= "*Schwagerina*" of the authors). Among the smaller foraminifers, *Bradyina lucida* (Morozova, 1949) is not very indicative (Fig. 11X), and a primitive *Eostaffella* sp. (Fig. 11Y) is puzzling.

The main difference between our age assignments and those of Myers concerns the Desmoinesian-Missourian boundary. Myers put that boundary at the Gray Mesa-Atrasado contact, based on little evidence. Our fusulinid data are consistent with conodont data that place that boundary in the Amado Member in the Cerros de Amado (Lucas et al., 2009; Barrick et al., 2013).

Our age determinations are also similar to those of Lucas et al. (2011, 2014) and Vachard et al. (2012, 2013) at Cedro Peak. However, the differences are that at Priest Canyon, the base of the Desmoinesian appears to be in the uppermost Sandia Formation, and the base of the Virgilian may be relatively high, in the Del Cuerto Member, not the Council Spring Member (Fig. 13). However, we emphasize the preliminary nature of our data, which require further sampling and study to more precisely fix all of the Pennsylvanian stage boundaries in the Priest Canyon section.

CONCLUSIONS

1. Detailed restudy of the Pennsylvanian section at Priest Canyon in the southern Manzano Mountains indicates it is very similar to the Pennsylvanian section in the Cerros de Amado, ~60 km to the SW, so, the stratigraphic nomenclature introduced by Thompson in 1942 and elaborated by Rejas in 1965 and Lucas et al. in 2009, can be applied at Priest Canyon.

2. The base of the Priest Canyon Pennsylvanian section is the ~70 m thick Sandia Formation, which is mostly covered slopes and beds of sandstone, limestone and conglomerate that are in fault contact with the Proterozoic basement.

3. The overlying Gray Mesa Formation (= Los Moyos Limestone) is ~192 m thick and mostly cherty limestone, di-

FIGURE 11. Smaller foraminifers and primitive fusulinids from the Pennsylvanian-earliest Permian succession at Priest Canyon. Scale bars = 0.1 mm. **A-B**) *Mesolasiodiscus*? n. sp. **A**) Axial section. Desmoinesian/Missourian boundary interval (latest Myachkovian?) of Priest Canyon (New Mexico). Sample PC29-1. **B**) Axial section clear a conspicuous, clear umbilical filling and some sutural appendices. Desmoinesian/Missourian boundary interval (latest Myachkovian?) of Priest Canyon (New Mexico). Sample PC29-3. **C**) *Eolasiodiscus* sp. Axial section. Earliest Desmoinesian (= early Myachkovian) of Priest Canyon (New Mexico). Sample PC13-5. **D-E**) *Calcivertella* cf. *heathi* (Cushman and Waters, 1928). **D**) Subaxial section. Desmoinesian/Missourian (latest Myachkovian/earliest Kasimovian?) of Priest Canyon (New Mexico). Sample PC30-2. **E**) Axial section. Desmoinesian/Missourian (latest Myachkovian/earliest Kasimovian?) of Priest Canyon (New Mexico). Sample PC30-5. **F**) *Polytaxis* sp. Axial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC12-12. **G**), **M**), **O**) and **Q**) *Tuberitina bulbacea* (Harlton, 1928). **G**) Longitudinal section. Earliest Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC13.4. **M**) Longitudinal section. Subaxial section. Earliest Missourian (early Kasimovian?) of Priest Canyon (New Mexico). Sample PC30-1. **O**) Longitudinal section. Subaxial section. Earliest Missourian (early Kasimovian?) of Priest Canyon (New Mexico). Sample PC30-4. **Q**) Oblique section. Earliest Missourian (early Kasimovian?). Sample 43.5. **H**) and **S**) *Syzranella* sp. **H**) Subaxial section. Earliest Desmoinesian (= early Myachkovian) of Priest Canyon (New Mexico). Sample PC13a-3. **S**) Subaxial section. Missourian (Kasimovian) of Priest Canyon (New Mexico). Sample PC48-3. **I**), **J**) and **L**) *Endothyranella protracta* (Rauzer-Chernousova, 1938). **I**) Oblique section in the uncoiled, uniseriate part. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample 17-6. **J**) Subaxial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC19-7. **L**) Subtransverse section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC22-1. **K**) *Syzrania bella* (Reitlinger, 1950). Subaxial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC19-10. **N**) *Planoendothyra*? sp. Axial section. Axial section. Early Desmoinesian (early Myachkovian) of Priest Canyon (New Mexico). Sample PC25-4. **P**) *Plectofusulina ovata* (Wilde, 2006). Oblique section. Missourian (Kasimovian) of Priest Canyon (New Mexico). Sample PC36-1. **R**) *Tuberitina collosa* (Reitlinger, 1950). Axial section. Note the difference in the wall microstructure with Fig. 2Q. Missourian (Kasimovian). Sample PC44-1. **T**) *Pseudoacutella* sp. 1. Axial section. Late Atokan (Podolskian) of Priest Canyon (New Mexico). Sample PC6-5. **U**) *Syzrania confusa* (Reitlinger, 1950). Axial section. Missourian (Kasimovian) of Priest Canyon (New Mexico). Sample PC48a-1. **V**) *Climacammina* sp. Subaxial section. Virgilian (Gzhelian) of Priest Canyon (New Mexico). Sample PC52a-5. **W**) *Endothyranella*? cf. *armstrongi* (Plummer, 1930 *sensu* Pinard and Mamet, 1998) Virgilian (Gzhelian) of Priest Canyon (New Mexico). Sample PC53a-4. **X**) *Bradyina lucida* (Morozova, 1949). Wolfcampian (Asselian) of Priest Canyon (New Mexico). Sample PC59-6. **Y**) *Eostaffella* sp. Wolfcampian (Asselian) of Priest Canyon (New Mexico). Sample PC59.

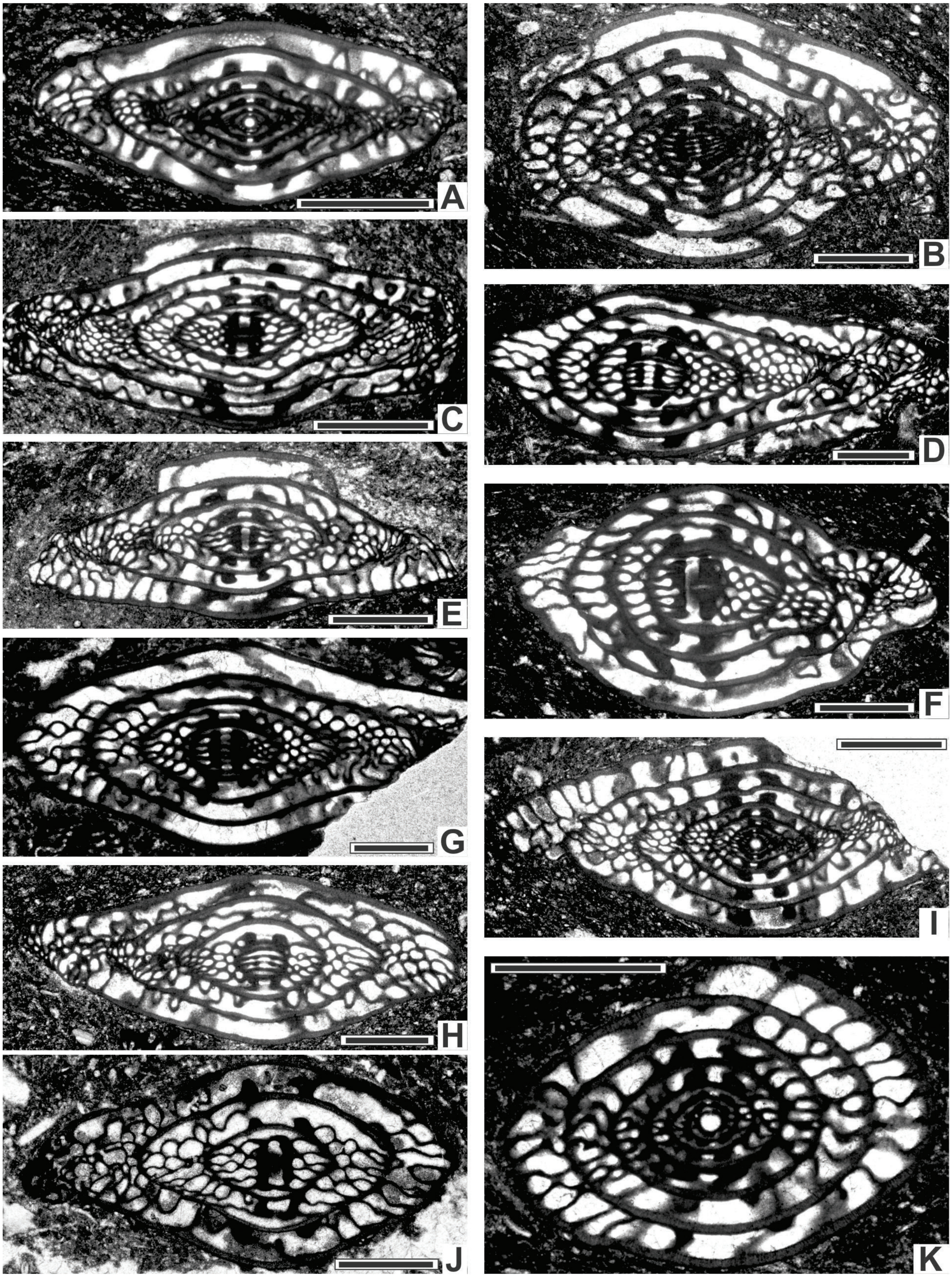

FIGURE 12.Triticitids of the Virgilian (Gzhelian)/Wolfcampian (Asselian) boundary interval of Priest Canyon (New Mexico). Scale bars = 1 mm. **A**), **D**), **E**), **H**) and **I**). *Triticites beedei* (Dunbar and Condra, 1927). **A**) Subaxial section. Sample PC52-2. **E**) Subaxial section. Sample PC55b-2. **H**) Subaxial section. Sample PC56a-1. **I**) Subaxial section. Sample PC55-3. **B**), **F**) and **K**) *Triticites* cf. *cellamagnus* (Dunbar and Condra, 1927). **B**) Subaxial section. Sample PC55-1. **F**) Subaxial section. Sample PC55-2. **K**) Oblique subaxial section. Sample PC55.4. **C**) *Triticites* transitional to *Leptotriticites*. Subaxial section. Sample PC55a-1. **G**) *Triticites* aff. *parabeedei* (Wilde, 2006). Subaxial section. Sample PC55b-1. **J**) *Triticites* sp. Subaxial section. Sample PC59-1.

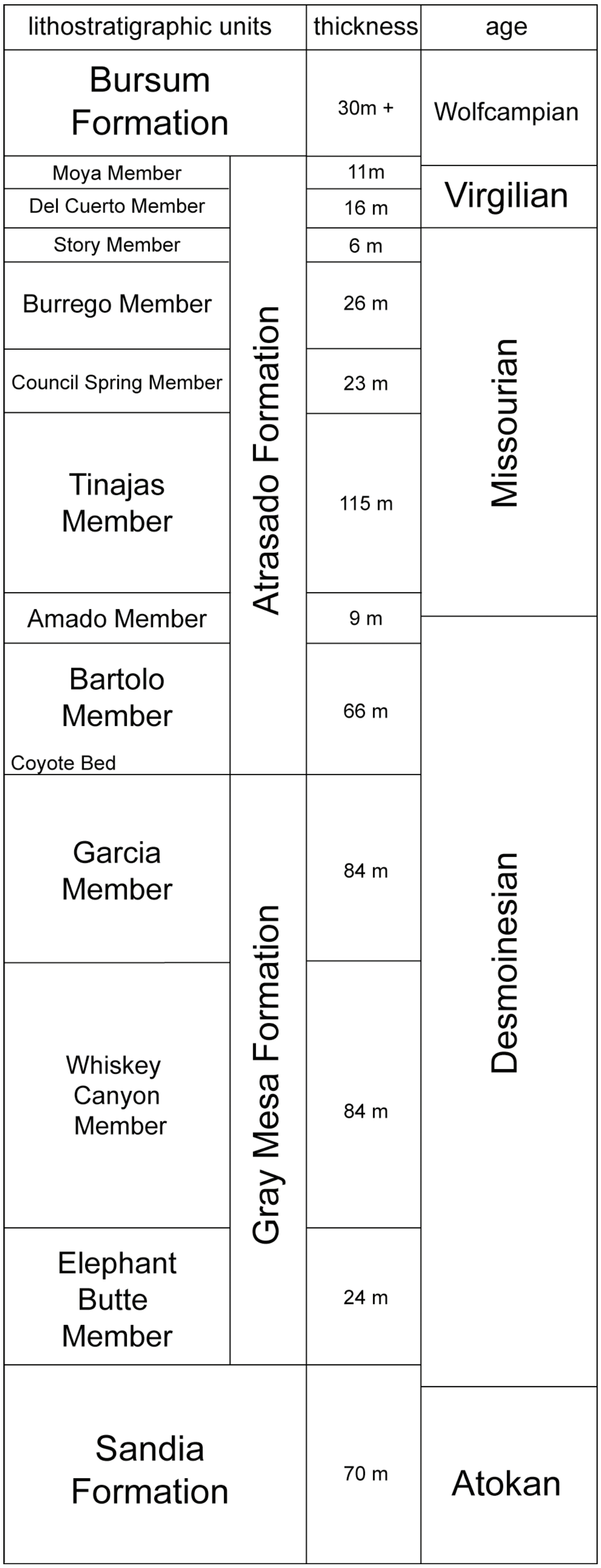

FIGURE 13. Summary of the lithostratigraphy and ages of the Priest Canyon Pennsylvanian section.

vided into three members (ascending): (1) Elephant Butte Member, ~24 m of limestone and shale; (2) Whiskey Canyon Member, ~84 m of cherty limestone; and (3) Garcia Member, ~84 m of non-cherty limestone and shale with lesser amounts of cherty limestone, sandstone and conglomerate.

4. The overlying Atrasado Formation (= Wild Cow Formation) is ~272 m thick and divided into eight members (ascending): (1) Bartolo Member, ~66 m of slope-forming shale with thin beds of sandstone, limestone and conglomerate; (2) Amado Member, ~9 m of bedded, cherty, brachiopod-rich limestone; (3) Tinajas Member, ~115 m of shale with interbedded limestone and sandstone; (4) Council Springs Member, ~23 m of mostly algal limestone without chert; (5) Burrego Member, ~26 m of arkosic red beds and limestone; (6) Story Member, ~6 m of limestone; (7) Del Cuerto Member, ~16 m of arkosic red beds and limestone; and (8) Moya Member, ~11 m of bedded limestone and shale.

5. The Pennsylvanian section at Priest Canyon is overlain by the Lower Permian Bursum Formation, which is at least 30 m of interbedded red-bed mudstone, sandstone, conglomerate and limestone.

6. Deposition of the Sandia, Gray Mesa, Atrasado and Bursum formation strata at Priest Canyon took place mostly in normal, shallow marine platform settings and in coastal nonmarine fluvial paleoenvironments.

7. At their type sections, which are at Priest Canyon, Myers members of the "Wild Cow Formation" clearly are fusulinid-based, biostratigraphic units, not lithostratigraphic units, as their contacts are not drawn at laterally traceable lithologic changes. We thus recommend abandonment of all of Myers' Pennsylvanian lithostratigraphic terms because they are either synonyms of earlier named units or do not identify useful lithostratigraphic units.

8. Available biostratigraphic data indicate that at Priest Canyon the Sandia Formation is late Atokan-Desmoinesian, the Gray Mesa Formation and lower Atrasado Formation are Desmoinesian, and the rest of the Atrasado Formation is Missourian-Virgilian with its uppermost strata Wolfcampian.

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Flooding along the Rio Puerco (9/16/2013). Photo courtesy of Maureen Wilks.