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G.P. Wahlman and J.E. Barrick

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FUSULINID AND CONODONT BIOSTRATIGRAPHY OF THE BEEMAN FORMATION (PENNSYLVANIAN), SACRAMENTO MOUNTAINS, NEW MEXICO

Gregory P. Wahlman[1], and James E. Barrick[2]

[1]Wahlman Geological Services, LLC, 8903 Westerkirk Drive, Austin, Texas 78750, gregwahlman@aoil.com;
[2]Department of Geosciences, Texas Tech University, Lubbock, Texas, 79409

Abstract—Fusulinid and conodont biostratigraphic analyses date the Pennsylvanian Beeman Formation in the Sacramento Mountains of south-central New Mexico as early middle Missourian to the early to early middle Virgilian. Based on conodont data, the Desmoinesian-Missourian boundary is in the uppermost part of the underlying Gobbler Formation, and based on fusulinid and conodont data, the Missourian-Virgilian boundary is in the upper part of the Beeman Formation.

INTRODUCTION

The Upper Pennsylvanian stratigraphic succession of the Sacramento Mountains in south-central New Mexico is one of the most studied stratigraphic sections in the American Southwest and has served as one of the classic field trip training areas for North American geologists for many years (Figs. 1, 2). Although a large amount of sedimentologic and stratigraphic research has been published on these strata, there has been surprisingly little biostratigraphic documentation of this classic section. The least biostratigraphic information exists for the Beeman Formation, to which a Missourian age has been generally assigned based on reports of middle to late Missourian fusulinids from the upper part of the Beeman by Pray (1959, 1961). This paper documents the fusulinids and conodonts of

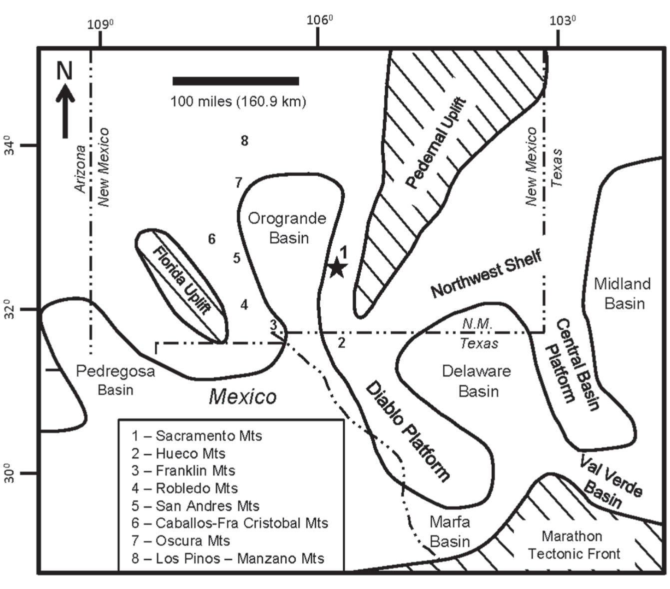


FIGURE 1. Index map of the Late Paleozoic Permian Basin region showing modern mountain ranges (numbers) with significant Pennsylvanian stratigraphic sections around the Orogrande Basin in south-central New Mexico. Crosshatched areas represent Late Paleozoic highlands.

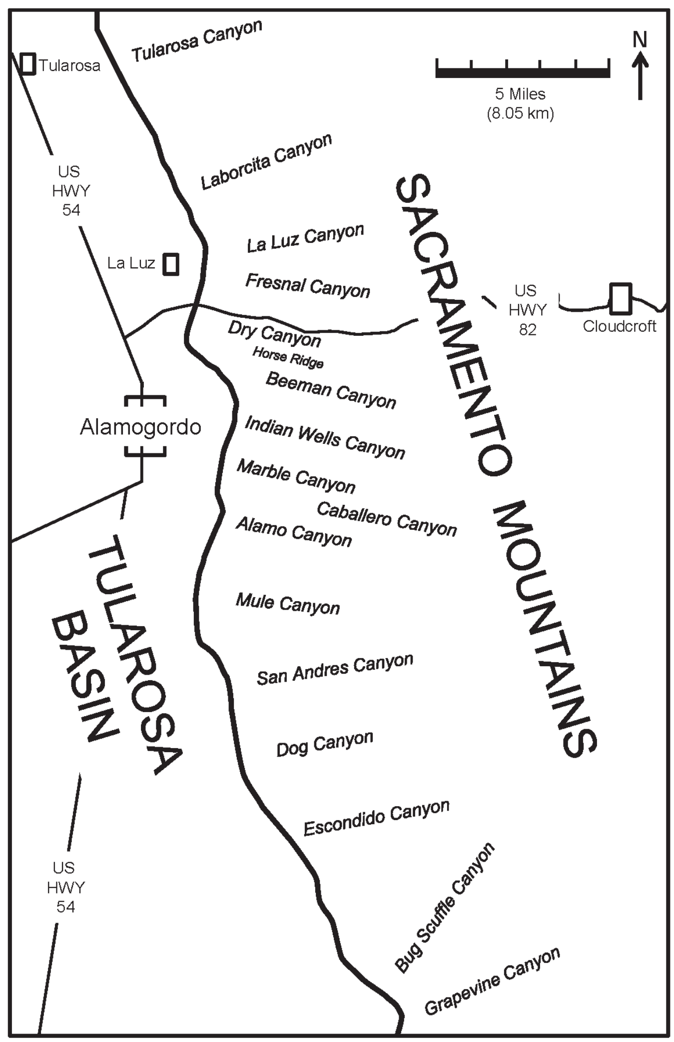


FIGURE 2. Sketch map of western escarpment of Sacramento Mountains showing locations of canyons where biostratigraphic samples for this study were collected.

the Beeman Formation and designates its age range from early middle Missourian to early to early middle Virgilian (Figs. 3, 4). Additional studies by Wahlman are in progress on the fusulinid biostratigraphy of the overlying Holder and Laborcita formations (Virgilian and earliest Wolfcampian?). Conodonts of the underlying Gobbler Formation and the Beeman Formation are undergoing further study by Barrick.

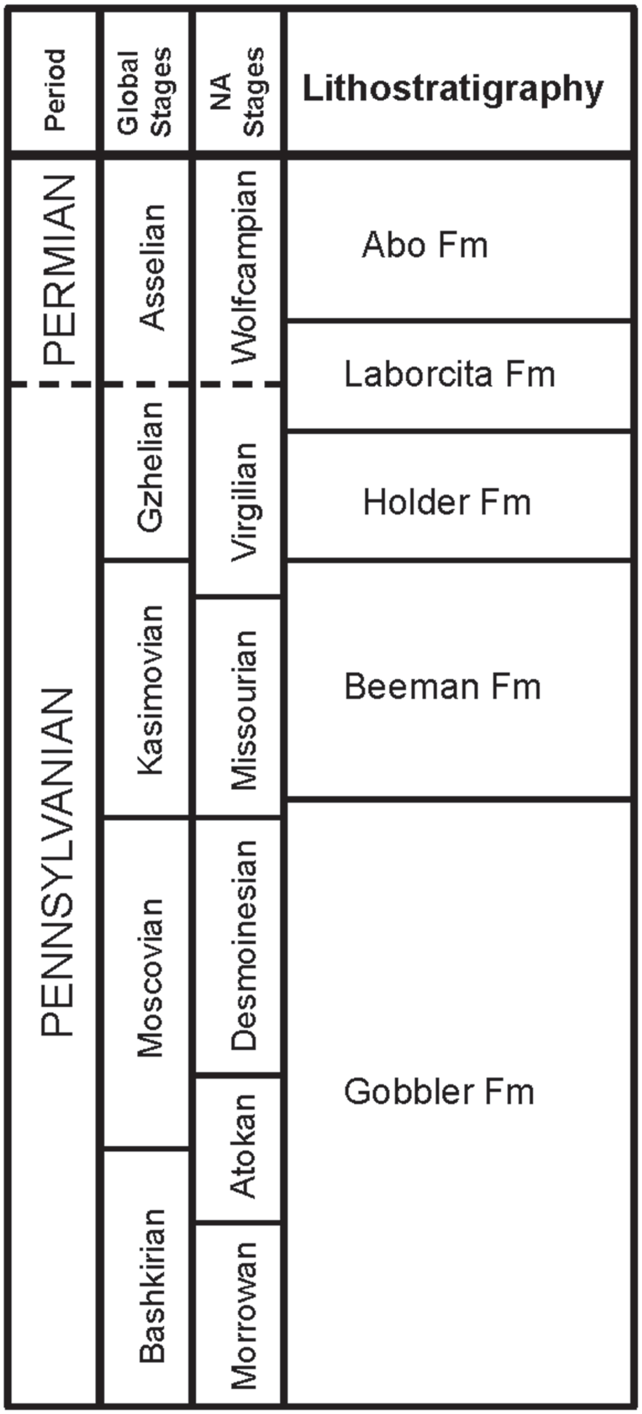


FIGURE 3. Chart with Pennsylvanian and earliest Permian stratigraphic units in the Sacramento Mountains, and the global and North American regional stage boundaries. Based on conodont and fusulinid biostratigraphic data presented herein, the Beeman Formation ranges in age from the early Missourian to the early to early middle Virgilian.

STRATIGRAPHY

Thompson (1942) reviewed the Pennsylvanian stratigraphy of New Mexico, made many important observations, and named numerous lithostratigraphic units. Later stratigraphic work demonstrated that his formations and groups were largely based on fusulinid biostratigraphy and new lithostratigraphic names were proposed in different mountain ranges around the State. Nevertheless, Thompson's work presented the first age dates for many key stratigraphic sections and enabled regional correlations throughout New Mexico. Pray (1952, 1959, 1961) mapped the Sacramento Mountains western escarpment and

Beeman Fm Biostratigraphy, Sacramento Mts, New Mexico

Stages	Wahlman (2018) Fusulinid Zones	Midcontinent equivalents		BASIN Conodonts	SHELF Fusulinids	Beeman Seq Strat
VIRGILIAN	Vf1	Shawnee	Lecompton	*S. vitali*	*Triticites coronadoensis*	4C-1C
			Oread	*S. pawhuskensis*		4C-1
			Toronto	*S. pawhuskensis*		3C-1a
		Douglas	Haskell-Cass	*S. pawhuskensis*	Intervals not present on shelf	2C-7a
MISSOURIAN			Iatan	*S. pawhuskensis*		2C-6a
	Mf4	Lansing	South Bend	Early types of *S. pawhuskensis* and *S. firmus*	*Triticites* aff. *kawaensis*	2C-5a
			Stanton			
			Plattsburg	*S. gracilis*	*Triticites* cf. *collus*	2C-4b 2C-4a
	Mf3	Kansas City	Wyandotte	*S. gracilis*		2C-3b
			Iola	*S. gracilis*	*Triticites collus* *T. ohioensis*	2C-3a
			Dewey	*I. magnificus*	*T. ohioensis*	2C-2a 2C-1c
	Mf2		Cherryvale	*I. symmetricus*	*T. nebraskensis* *T. celebroides*	2C-1a
			Dennis?			1S-4a 1S-3a 1S-2a 1S-1a
			Swope	*I. cancellosus*		upper Gobbler

FIGURE 4. Chart with occurrences of fusulinids and conodonts in Beeman stratigraphic sequences (right column) recognized by Raatz (1996) and Raatz and Simo (1998), their correlation to equivalent strata in the North American Midcontinent section, and their correlation to Permian Basin fusulinid zones of Wahlman (in press). Crosshatched intervals in the Shelf column represent lowstand periods when there was Beeman deposition only in down dip basin margin areas. Abbreviations: T. = *Triticites*, S. = *Streptognathodus*, I. = *Idiognathodus*.

named three Pennsylvanian lithology-based formations, which are, in ascending order, the Gobbler, Beeman, and Holder formations. In addition, Otte (1959) named the Laborcita Formation for interbedded redbeds and limestones (similar to the Bursum Formation in other parts of the region) overlying the Holder, which at that time were considered to be earliest Permian in age. According to Pray (1961), the Gobbler Formation was dated as Morrowan–Desmoinesian, the Beeman as middle to late Missourian, and the Holder as Virgilian, but he did not cite specific biostratigraphic data.

The Beeman Formation has been the least studied of the three Pennsylvanian formations in the Sacramento Mountains, largely because its argillaceous facies form mostly recessive slopes between the more massive limestone bounding units. The Beeman Formation consists of 350–500 feet of mostly medium to dark gray, thin-bedded argillaceous limestone and interbedded shale, with local greenish-gray feldspathic sandstone and relatively light colored and pure limestone beds (Pray, 1961). Raatz (1996) and Raatz and Simo (1998) recognized 18 depositional lithofacies in the Beeman, mapped out the facies distributions, and arranged the facies into sequence stratigraphic units.

Raatz (1996) and Raatz and Simo (1998) demonstrated that during the late Desmoinesian and early Missourian, the Pedernal Uplift to the east underwent a pulse of tectonism, and immature clastics were transported eastward to the narrow Sacramento Shelf and adjacent Orogrande Basin. The middle and late Missourian was a period of tectonic quiescence and relatively high sea levels. In the early Virgilian, renewed tectonism created a series of north-south trending folds and faults that significantly influenced depositional facies and facies distribution patterns of the uppermost Beeman, Holder, and Laborcita formations.

Raatz and Simo (1998, fig. 11) illustrated the shelf-to-basin facies and sequences of the Beeman Formation. The Beeman section on the Sacramento Shelf is relatively thin and contains relatively shallow-water shelfal limestones. To the west along the margin of the Orogrande Basin, the Beeman section is significantly thicker, and it contains several depositional sequences that are restricted to the basin margin and pinch out up dip below the shelf. Of significance to this study, Raatz sampled shelfal limestone beds for fusulinids and the more basinward sequences for conodonts, which enabled the construction of an integrated multidisciplinary biostratigraphic scheme to date Beeman stratigraphic sections throughout the study area and assisted in shelf-to-basin sequence correlations.

FUSULINID BIOSTRATIGRAPHY

Previously, no fusulinid species have been identified or illustrated from the Beeman Formation. Needham (1937) described and illustrated a few Virgilian fusulinid species from the Virgilian (now Holder Formation) in the Sacramento Mountains. Thompson (1942) described the Pennsylvanian stratigraphic section of the Sacramento Mountains and named and age-dated stratigraphic units, but he did not provide any details on the fusulinid faunas. At that time, the Missourian–Virgilian boundary was placed at base of the massive phylloid algal mound limestone interval at the base of the present-day Holder Formation (Thompson, 1942; Lloyd, 1949; Otte, 1959; Pray, 1961). Otte (1959) and Pray (1959, 1961) both stated that based on fusulinid biostratigraphy the Beeman Formation was considered to be middle to late Missourian in age, but they did not cite any specific data or data sources. Thompson (1954) and Steiner and Williams (1968) described fusulinids from the Laborcita Formation in the northern Sacramento Mountains.

The fusulinids studied herein are from field samples collected by William Raatz, who submitted non-oriented petrographic thin-sections of his field samples to Wahlman for fusulinid biostratigraphic analyses. Fusulinid samples are from the following canyons along the Sacramento Mountains western face: Alamo Canyon (AC), Alamo Canyon West (ACW), and Caballero Canyon (CC2) (Fig. 2). Sample numbers used in this paper can be located stratigraphically on the measured sections of Raatz (1996). Photomicrographs of the Beeman fusulinid faunas are shown here in Figures 5 and 6.

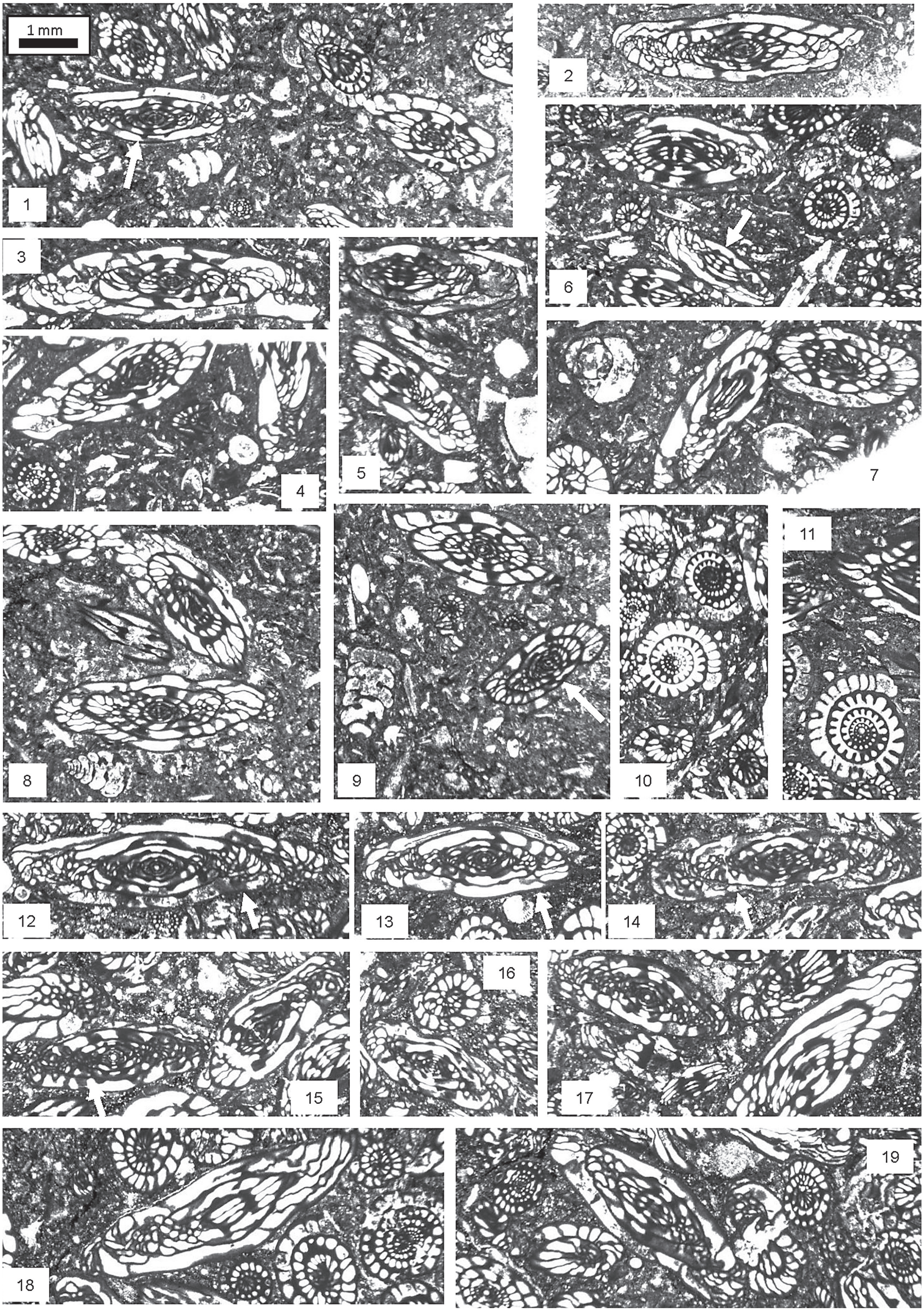
The fusulinid samples collected by Raatz (1996) from Beeman sequences 2C-1a to 2C-4b in the lower part of the Beeman Formation yielded a relatively low diversity Missourian fusulinid fauna, including *Triticites nebraskensis*, *T. celebroides*, *T. ohioensis*, and *T. collus*, which correlate to the middle and upper parts of the Kansas City Group of the classic North American Midcontinent section (see Wahlman, 2013, for Midcontinent distribution of these species). A sample from the higher sequence 2C-5a contained fusulinids tentatively identified as *Triticites* cf. *collus*. Stratigraphically higher samples from lowstand sequences restricted to the basin margin yielded conodont data that are correlative with the Lansing and lower part of the Douglas groups of the Midcontinent. Uppermost Missourian and lowermost Virgilian strata were not deposited on the shallow-water shelf (see Raatz and Simo, 1998, fig. 11), and above the stratigraphic gap on the shelf, the uppermost Beeman shelfal strata contain *Triticites* cf. *coronadoensis*, which is Virgilian in age, correlating to the lower part of the Shawnee Group of the Midcontinent. Therefore, the Missourian-Virgilian stage boundary in the Sacramento Mountains section lies within the upper part of the Beeman Formation.

Sequence stratigraphic units for the Beeman Formation are listed by Raatz and Simo (1998, fig. 11). The sequence stratigraphic occurrences of fusulinids in the Beeman Formation are summarized below (in ascending order) and in Figure 4.

<u>Sequence 2C-1a: Early Missourian</u> — Sample CC2-8180 contained abundant elongate thin-walled *Triticites* identified at *T. nebraskensis* Thompson, 1934, and *T. celebroides* Ross, 1965, which were described from early Missourian strata in the Midcontinent and Glass Mountains of west Texas, respectively. Fusulinids from this sequence are shown in Figure 5.

<u>Sequence 2C-2a: Early to middle Missourian</u> — Sample CC2-10500 contains *Triticites ohioensis,* which is a widespread common species in early to middle Missourian strata. Fusulinids from this sequence are shown in Figure 6.

<u>Sequence 2C-3a: Middle Missourian</u> — Samples AC-105 and ACW-15100 contained *Triticites collus* and *T. ohioensis* Thompson, 1936, which are common in the middle part of the Kansas City Group of the Midcontinent. Fusulinids from this sequence are shown in Figure 6.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<u>Sequence 2C-4a: Middle Missourian</u> — Sample CC2-13400 contained specimens assignable to *Triticites* cf. *collus* Burma, 1942, which was described from the middle part of the Kansas City Group of the Midcontinent region. Fusulinids from this sequence are shown in Figure 6.

<u>Sequence 2C-5a: Late Missourian</u> — Sample AC-12000 contained only a few poorly oriented small specimens of *Triticites*, but because of their fusiform shapes, thicker walls than fusulinids lower in the section, and moderate septal fluting, they most closely resemble *Triticites* aff. *kawaensis*, which was described by Thompson (1957) from the South Bend Limestone of Kansas. Fusulinids from this sequence are shown in Figure 6.

<u>Sequence 4C-1a: Late early Virgilian</u> — Sample AC 12700 contained moderately large, inflated fusulinids that are tentatively identified as *Triticites* cf. *coronadoensis* Ross and Tyrrell, 1965, which was described from the lower part of the Virgilian in southeastern Arizona. Fusulinids from this sequence are shown in Figure 6.

Many of these same Missourian fusulinid species were also reported and illustrated by Myers (1988) from the Wild Cow Formation in the Manzano Mountains just to the north of the Orogrande Basin.

Fusulinids currently under study from the shallow-shelf limestones and phylloid algal buildups in the lowest part of the overlying Holder Formation are correlative with faunas from the lower part of the Shawnee Group (early Virgilian) of the Midcontinent region (Wahlman, 2013; Wahlman, in prep.).

CONODONT BIOSTRATIGRAPHY

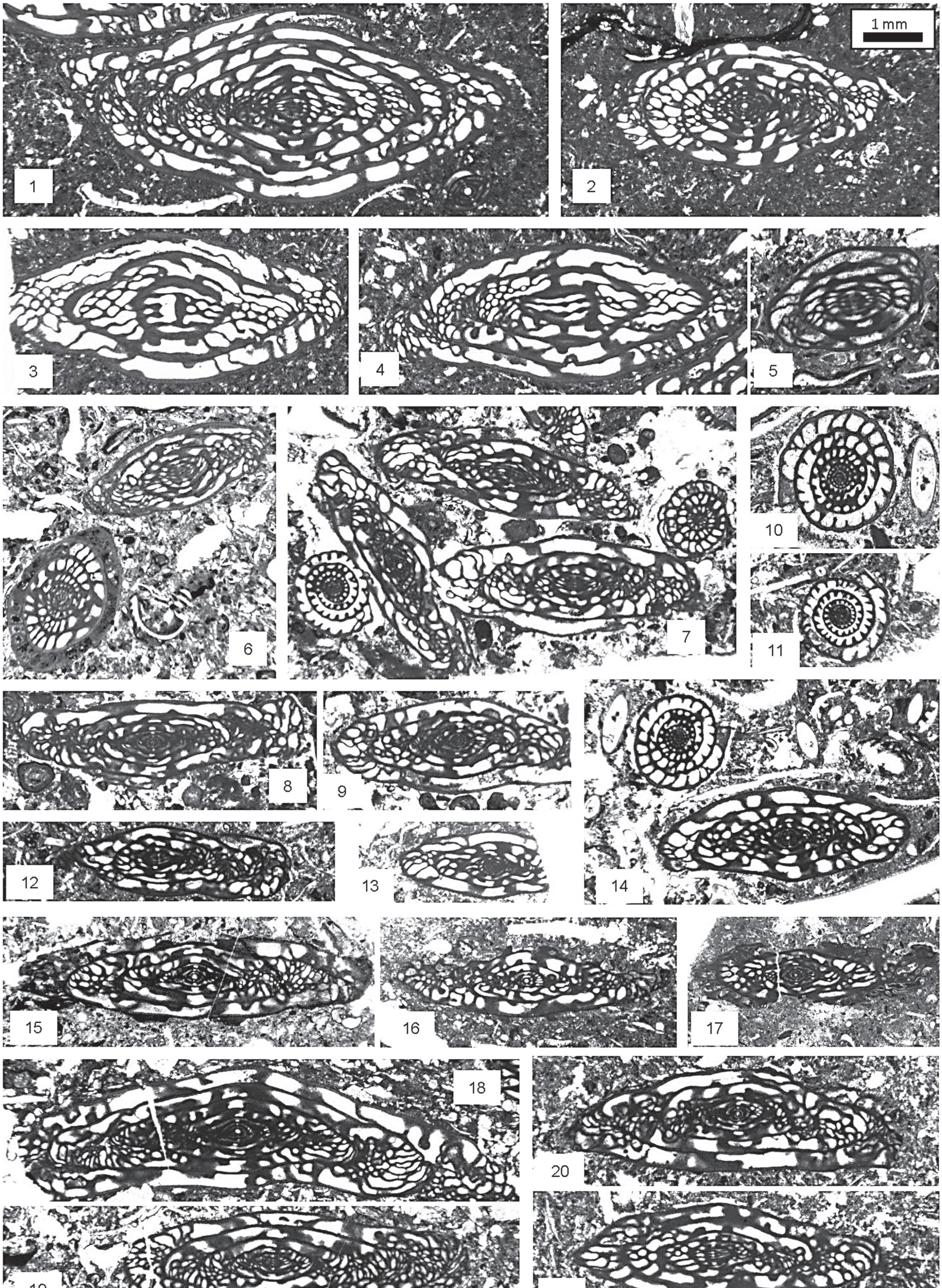
Raatz and others (1994), Raatz (1996), and Raatz and Simo (1998) incorporated sparse conodont data into the age resolution of the sedimentary cycles for the Beeman Formation in the northern part of the Sacramento Mountain. Raatz submitted a small number of conodont collections to Barrick for identification, but information linking most of these collections to specific sedimentary cycles was not provided at the time, nor is known to Barrick now. Since then, additional collections have been made in Dry Canyon (Keairns, 2002), and southward into Beeman Canyon, Horse Ridge, and Indian Wells Canyon as part of a larger study on Pennsylvanian strata in the northern Sacramento Mountains (Lucas et al., in prep.). Also, our understanding of Late Pennsylvanian conodont taxonomy and stratigraphic ranges have improved considerably since 1996, mostly based on faunas from cyclothems in the Midcontinent region (e.g., Rosscoe, 2008; Rosscoe and Barrick, 2009, 2013; Barrick and others, 2013).

Determination of the age of the base of the Beeman Formation is problematic because the lithological contact of the base of the Beeman with the underlying Gobbler Formation is not well defined. Raatz et al. (1994) indicated that the interval is transitional, without any well-defined lithological markers, and occurs within a sandstone-dominated section above definitive Desmoinesian (Gobbler) limestone beds and below middle Missourian limestone beds identified using fusulinid biostratigraphy. Raatz et al. (1994) reported a small gastropod and ammonoid fauna from a siltstone unit in Indian Wells Canyon, and later Raatz (1996) noted the presence of conodonts. The ammonoid fauna included species of *Eoschistoceras?, Glaphyrites*, and *Neoaganides* (see Boardman, et. al., 1994, p. 44). Raatz et al. (1994) and Raatz (1996, p. 172) proposed that this fauna is latest Desmoinesian in age. However, *Neoaganides* first appears in lower Missourian strata in the Midcontinent region, either near the base of the Missourian (Boardman, et al., 1994, fig. 16) or only as low as the Dennis cyclothem (Boardman and Work, 2013, text-fig. 1). The collection is possibly early Missourian in age, depending upon whether or not *Neoaganides* is actually present. Raatz et al. (1994) described this collection as coming from the second of five upper Gobbler-lower Beeman siliciclastic cycles and placed the base of the Beeman to coincide with the supposed oldest Missourian unit at the base of the third cycle, later cycle 1S-1a of Raatz (1996, p. 254; 1S-1a, bed 3) and Raatz and Simo (1998). The conodonts were collected later by Steve Schutter and Barrick from a shaly bed below a limestone ledge and its exact stratigraphic position is unknown. The only conodonts identified were a generalized form of *Idiognathodus,* questionably identified as *I. expansus*, a species known from highest Desmoinesian strata.

A few kilometers to the northeast of Indian Wells Canyon, a cliff-forming limestone (7 m thick) crops out along Horse Ridge and extends northward into Beeman Canyon. Below this limestone the section is comprised of mostly shale and thin limestone beds (Space History B, Space History C, Beeman Canyon sections; Lucas et al., in prep). The top of the limestone appears to be a major exposure surface and the overlying section consists of about 90 m of shale, siltstone, and sandstone, some units of which bear plant fossils. This distinct traceable lithological contact can be used as the best Gobbler-Beeman contact in this area. It is possible that this unit is the same limestone that was shown schematically by Raatz and others (1994) as the Gobbler limestone beneath their informal siliciclastic Horse Ridge LA (lithological association) and below the two siliciclastic units below where Raatz and others (1994), Raatz (1996) and Raatz and Simo (1998) placed their base of the Beeman.

Early Missourian conodonts appear in limestone beds in the uppermost parts of the Gobbler Formation at the Space History B, Space History C, and Beeman Canyon sections. The lowest Missourian fauna appears 22 m below the top of the Gobbler at Space History B, where *Idiognathodus cancellosus* occurs with *I. turbatus, I. swadei I. harkeyi* and similar species. Slightly higher samples 10 to 12 m below the top of the

FIGURE 5. Photomicrographs of stratigraphically lowest fusulinids in the Beeman Formation from Sequence 2C-1a. All photos at X10 magnification from petrographic thin-sections. Scale bar at upper left of page. **1**) *Triticites nebraskensis* Ross and Tyrrell, 1965, axial (white arrow) and oblique sections, and a partial specimen of the smaller foraminifer *Climacammina*, Sample ACW-11000. **2-11**) mostly *Triticites* cf. *celebroides* Ross1965, with some smaller *Triticites nebraskensis* (white arrows), and with specimens of the smaller foraminifers *Pseudobradyina* in 7 and *Climacammina* in 8 and 9, Sample ACW-11000. **12-19**) *Triticites* cf. *celebroides*, Sample CC2-8180.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Gobbler yielded a more abundant and diverse, but comparable fauna. This morphologically diverse fauna that includes *I. cancellosus* is characteristic of the lower Missourian Swope cyclothem (Hushpuckney Shale; Rosscoe and Barrick, 2013) and the corresponding *I. cancellosus* Zone (Barrick, et al., 2013) in the Midcontinent region.

No conodonts were recovered in the overlying siliciclastic-dominated section in the lower part of the Beeman Formation along Horse Ridge and in Beeman Canyon (the Horse Ridge LA of Raatz et al. 1994). The age of the lowest part of the Beeman Formation (S sequences of Raatz, 1996; Raatz and Simo, 1998) is constrained by the age of the limestone at the top of the Gobbler Formation and the age of the overlying carbonate units.

The lowest conodont faunas in the Beeman Formation appear with the occurrence of sandy limestone 65 m above the base of the formation along Horse Ridge at the Space History C section and 87 m above the base at the Space History B section (Lucas et al., in prep.). These limestone beds should correspond approximately with the base of lowest carbonate sequence, 2C-1a, of Raatz (1996) and Raatz and Simo (1998). The most common form is *Idiognathodus symmetricus,* as characterized by Rosscoe (2008), in association with representatives of the *Streptognathodus excelsus* group of species, and *Hindeodus* (Fig. 7). A few specimens of *I. magnificus*, and other *Idiognathodus* morphotypes also occur. These faunas correspond to those of the middle Missourian Cherryvale cyclothem in the Midcontinent region (Barrick et al., 2013). Raatz (1996) and Raatz and Simo (1998) showed that *Streptognathodus confragus* occurs in 2C-1a, based on identifications by Barrick at that time. Since then, revisions of Missourian conodonts (e.g., Rosscoe, 2008; Rosscoe and Barrick, 2013) have clarified the taxonomy of early Missourian forms and show that the Beeman specimens previously called *S. confragus* are likely *I. symmetricus.*

The entire thickness of the underlying siliciclastic units at the base of the Beeman (Horse Ridge LA; all of the 1S sequences of Raatz, et al., 1994), Raatz, 1996) and Raatz and Simo, 1998) appears to span only the time represented by two Midcontinent cyclothems (Dennis and Hogshooter).

Slightly higher in the Space History B section, large well-preserved conodont faunas are dominated by two morphotypes of *Idiognathodus magnificus* that have been described by Hogancamp et al. (in press). The full spectrum of morphotypes of the *Streptognathodus excelsus* group occurs (*S. sulcatus*, *S. gracilis*, and *S. elegantulus)*, of which the lobed morphotypes are more common. Faunas strongly dominated by typical forms of *I. magnificus* are usually correlated with Dewey cyclothem (e.g., Barrick, et al., 2013). In the overlying limestone beds, *Streptognathodus* species, mostly ones with small (*S. gracilis*) to no lobes (*S. elegantulus*) occur. This faunal association where *Streptognathodus* species dominate and *Idiognathodus* species are rare is characteristic of Missourian Midcontinent cyclothems overlying the Dewey and ranging up to the base of the Stanton cyclothem at the top of the *S. gracilis* Zone, but the individual cyclothem cannot be resolved using conodonts. Conodont faunas bearing the *S. gracilis* group were reported by Raatz (1996) and Raatz and Simo (1998) as occurring in the 2C-2 through 2C3a sequences.

In Dry Canyon, in the roadcuts along US Highway 62, the *Streptognathodus gracilis* fauna continues to near the top of the carbonate-dominated section in the middle of the Beeman (Raatz, 1996, cycle 2C-4a). About 4 m higher in the overlying section of mixed siliciclastic and carbonate beds (Raatz, 1996, cycle 2C-5a), a 1.5 m interval of dark shale with zones of *Dunbarella* molds produced an abundant conodont fauna dominated by morphotypes of *S. pawhuskaensis*, many of which possess a relatively long carina, apparently gradational with the older species *S. firmus* (Fig. 7). This fauna was originally reported to correlate with the South Bend cyclothem (Raatz, 1996), but Keairns (2002) suggested that this late Missourian fauna could correlate with either the South Bend or the overlying Iatan cyclothem.

Conodont faunas from higher in the Beeman Formation at Dry Canyon and the nearby La Luz B section (Lucas et al, in prep.) are difficult to correlate precisely. A variety of morphotypes of *Streptognathodus pawhuskaensis* dominate the collections, but provide little correlation information. In the Midcontinent, *S. pawhuskaensis* ranges from the upper Missourian South Bend cyclothem up into middle to upper Virgilian strata. Lower samples contain mostly slender unnoded morphotypes, but a few have a couple accessory nodes, and some show the deflection of the carina that Ritter (1995) named *S. pawhuskaensis deflectus*. Rare forms from higher in the La Luz section possess the squat platform of *S. bitteri*. Ritter (1995) indicated that *S. p. deflectus* and *S. bitteri* occur from the Oread cyclothem (early Virgilian; basal Gzhelian) to the Lecompton cyclothem, but their ranges are still poorly constrained. A more definitive faunal association appears near the top of the Beeman in the La Luz section where *Streptognathodus* elements grading from *S. vitali* to *S. virgilicus* occur. This association is no older than the Lecompton cyclothem of the Shawnee Group (Barrick and others, 2013). Keairns (2002) reported a similar species association from the lower beds of the Holder Formation in Dry Canyon (Holder cycles J to I2, in Cox, 1998).

In summary, based on conodont biostratigraphy the Beeman Formation ranges in age from the early middle Missourian to the early to early middle Virgilian. Earliest Missourian cono-

FIGURE 6. Photomicrographs of fusulinids from Beeman limestone samples. All photos at X10 magnification from petrographic thin-sections. Scale bar at upper right of page. **1-4**) *Triticites coronadoensis* Ross and Tyrrell, 1965, Sample AC-12700 [Sequence 4C-1a]. **5-6**) *Triticites* aff. *kawaensis* Thompson, 1957, Sample AC-12000 [Sequence 2C-5a]. **7**) *Triticites ohioensis* Thompson, 1936, and *T. collus* Burma, 1942 (lower right), Sample ACW-15100 [Sequence 2C-3a]. **8-9**) *Triticites collus*, Sample ACW-15100 [Sequence 2C-3a]. **10-12**) *Triticites ohioensis*, two saggitals and an oblique axial, Sample AC-105 [Sequence 2C-3a]. **13**) *Triticites collus*, small axial specimen with an excentric juvenarium, Sample AC-105 [Sequence 2C-3a]. **14**) *Triticites collus*, axial and oblique saggital, Sample AC-105 [Sequence 2C-3a]. **15-17**) *Triticites ohioensis*, Sample CC2-10500 [Sequence 2C-2a]. **18-19**) *Triticites ohioensis*, Sample AC-9250 [Sequence 2C-2a]. **20-21**) *Triticites ohioensis,* Sample AC-9300 [Sequence 2C-2a].

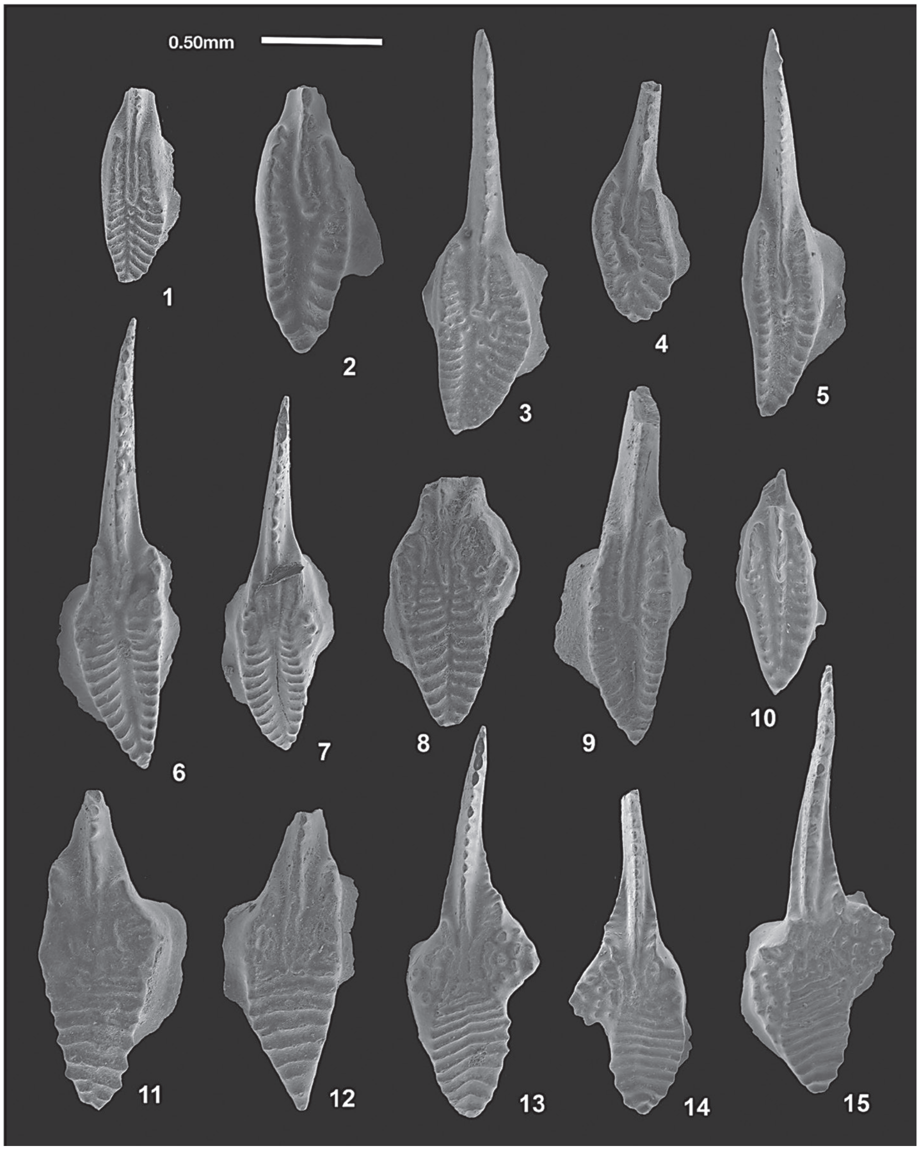

FIGURE 7. Conodonts from the Beeman Formation. All are upper views of P_1 elements at 50X magnification. Scale bar at upper left of page. Additional images and locality details will be published in Lucas et al. (in prep). Interpreted positions in the sequences of Raatz (1996) are given in brackets. **1**) *Streptognathodus virgilicus*?, La Luz section, sample 47t [Sequence 4C]. **2, 9**) *Streptognathodus pawhuskaensis,* La Luz section, sample 24t [Sequence 2C7-3C]. **3**) *Streptognathodus pawhuskaensis?,* La Luz section, sample 47t [Sequence 4C]. **4**) *Streptognathodus bitteri?,* La Luz section, sample 33 [Sequence 3C]. **5**) *Streptognathodus pawhuskaensis,* Dry Canyon section, sample 1[Sequence 2C5a]. **6**) *Streptognathodus excelsus*, Space History C section, sample 44t [Sequence 2C-1a]. **7-8**) *Streptognathodus excelsus*, Space History B, sample 235 [2C-1c to 2C-2a]. **10**) Specimen transitional from *Streptognathodus firmus* to *S. pawhuskaensis,* Dry Canyon section, sample 1 [Sequence 2C5a]. **11-12**) *Idiognathodus symmetricus*, Space History C section, sample 44t [Sequence 2C-1a]. **13**) *Idiognathodus magnificus,* Space History B section, sample, 235 [Sequence 2C-1c to 2C-2a]. **14-15**) *Idiognathodus magnificus,* Space History section, sample 229 [Sequence 2C-1c to 2C-2a].

donts equivalent to the Midcontinent Swope cyclothem first appear in limestones of the underlying uppermost Gobbler Formation. No conodonts have been found in the overlying siliciclastic section of the lowermost Beeman Formation. The lowest conodonts found in the Beeman Formation are from the base of the lowest carbonate sequence 2C-1a of Raatz (1996), and they are middle Missourian in age, approximately equivalent to the Cherryvale cyclothem of the Midcontinent region (Barrick and others, 2013). The limestone beds of the upper Beeman Formation contain Late Missourian conodont assemblages. Near the top of the Beeman, early to middle Virgilian conodonts occur, which are no older than the Midcontinent Lecompton cyclothem, and which are similar conodonts reported from the overlying lower Holder Formation.

BIOSTRATIGRAPHIC SUMMARY

Conodont data indicate that the Desmoinesian-Missourian stage boundary is in the uppermost part of the Gobbler Formation, which underlies the Beeman Formation (Fig. 3). There are no biostratigraphic data from the predominantly clastic strata of the lowest part of the Beeman Formation, which can be no older than the Swope cyclothem of the lower part of the Kansas City Group (early Missourian) of the Midcontinent. Conodont and fusulinid data indicate that the overlying Beeman carbonate sequences 2C-1a through 2C-3b correlate to the middle Missourian Kansas City Group of the Midcontinent, and sequences 2C-4a to 2C-5a correlate to the late Missourian Lansing Group to lower part of the Douglas Group of the Midcontinent. Down dip strata of lowstand sequences 2C-6a to 3C-1a in the upper part of the Beeman, which were deposited only in the basin margin, lack fusulinids but contain late Missourian-early Virgilian conodonts. Samples near the top of the Beeman Formation (sequence 4C-1) contain early to early middle Virgilian fusulinids and conodonts. Therefore, the Missourian-Virgilian boundary is in the upper part of the Beeman Formation.

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View to the northeast of rhyolite dikes that intruded along the northern margin of the Doña Ana caldera. Photograph by Greg H. Mack.