Middle Pennsylvanian (Desmoinesian) Fusulinids of the Bug Scuffle Limestone Member of the Gobbler Formation, Sacramento Mountains, South-Central New Mexico

Gregory P. Wahlman[1] and Benjamin Rendall[2]
[1]*Wahlman Geological Services, LLC, 8903 Westerkirk Drive, Austin, Texas 78750*
email: gregwahlman@aol.com
[2]*Department of Geosciences, University of Texas, Austin, Texas*

ABSTRACT: Analysis of fusulinids from the Bug Scuffle Limestone Member of the Gobbler Formation along the western escarpment of the Sacramento Mountains in south-central New Mexico demonstrates that all four Desmoinesian regional fusulinid zones documented in Midcontinent and Southwest North America are present in the stratigraphic unit. Earliest Desmoinesian (Df1 Zone) fusulinids from the basal Bug Scuffle limestone beds suggest that the carbonate unit transgressed northward on the Sacramento Shelf, with *Beedeina insolita* in basal beds of the southernmost canyon exposures, and the slightly more advanced *B. hayensis* and *B. curta* in basal limestone beds of more northern outcrops. Late early Desmoinesian (Df2 Zone) fusulinids are common and widespread throughout the escarpment outcrop belt indicating that it was the time period with the most widespread normal marine shelf paleoenvironmental conditions. The diverse assemblage of the Df2 Zone is characterized by *Beedeina novamexicana*, *B. euryteines*, *B. leei*, *B. socorroensis*, *B. joyitaensis*, *Wedekindellina euthysepta*, and *W. excentrica*. The microprobematical branching fossil *Komia* is also common in this zone. *Wedekindellina* and *Komia* do not range above the mid-Desmoinesian CSB1 composite sequence boundary. Above that sequence boundary, the early late Desmoinesian Df3 Zone is characterized by sparse *Beedeina haworthi,* and the closely related *B. illinoisensis* and *B. tumida.* The late late Desmoinesian Df4 Zone is represented by a diverse assemblage of fusulinids in the uppermost part of the Bug Scuffle Limestone Member in the southern canyon exposures, including *Beedeina acme*, *B. megista*, *B. mysticensis*, *B. lonsdalenesis*, *B. bellatula*, *B. gordonensis*, and *B. vintonensis*. No *Beedeina* identifiable to species were found in upper part of the Bug Scuffle Limestone Member in the northernmost canyon exposures, demonstrating that late Desmoinesian paleoenvironments became more restricted marine northward along the Sacramento Shelf. Above the CSB2 composite sequence boundary in the uppermost Bug Scuffle Limestone Member, the lower part of the uppermost depositional sequence continues to contain latest Desmoinesian Df4 Zone fusulinids in the southern canyon sections. Early Missourian conodonts have been reported in a limestone unit near the top of the Gobbler clastic detrital member in the north-central part of the outcrop belt (Wahlman and Barrick 2018; Lucas et al. 2021), but no early Missourian conodonts or fusulinids have been reported yet from the uppermost Bug Scuffle Limestone Member in the southern canyons.

Keywords: Fusulinids, Pennsylvanian, Desmoinesian, Orogrande Basin, New Mexico

INTRODUCTION

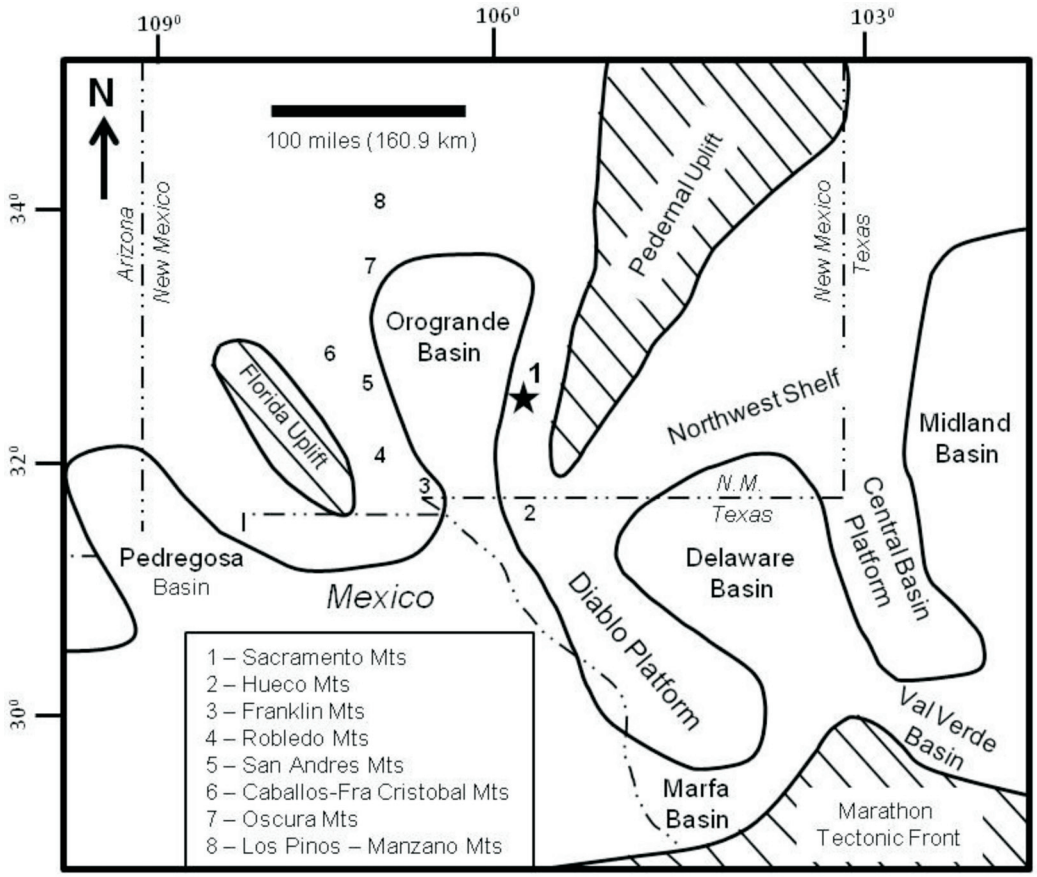
The Pennsylvanian stratigraphic succession of the Sacramento Mountains is one of the most studied Late Paleozoic outcrop sections in the Southwest USA because the facies and depositional history reflect the contemporaneous tectonic evolution and Icehouse stratigraphic architecture of the adjacent Permian Basin petroleum province to the southeast, as well as the Ancestral Rocky Mountains region to the west and northwest (text-figs. 1-2). Surprisingly, this important Pennsylvanian stratigraphic section has received relatively little detailed biostratigraphic documentation. Pray (1961) cited biostratigraphic age-dates for the Pennsylvanian stratigraphic units, but did not document the index fossils. Lucas et al. (2021) recently presented new biostratigraphic data from the Pennsylvanian sections in the north-central and northern parts of the outcrop belt, including data on conodonts, calcareous algae, and smaller foraminifers, and very sparse data on fusulinids. The biostratigraphic data from the Bug Scuffle Limestone Member presented herein provides the first detailed fusulinid biostratigraphic framework for the Desmoinesian aged strata and will enable improved correlations of stratigraphic events with adjacent areas (text-figs. 3-4).

The present study documents new Desmoinesian fusulinid biostratigraphic data from the Bug Scuffle Limestone Member of the Gobbler Formation (text-figs. 4-5), and summarizes previous fusulinid biostratigraphic work done on the Early Pennsylvanian to early Late Pennsylvanian (Morrowan-earliest Missourian) Gobbler Formation in outcrops along the western escarpment of the Sacramento Mountains (text-figs. 1-2). In addition, conodont data from the Gobbler Formation from studies by Lane (1974), and Benne (1975), and James E. Barrick in LaPeter (2007), Wahlman and Barrick (2018), and Lucas et al. (2021), are integrated where appropriate.

STUDY MATERIALS

The Bug Scuffle Limestone Member fusulinid samples analyzed for this study came from three sources. Sample localities are shown in text-figure 2, and sample distributions in the measured sections are shown in text-figure 5. Photomicrographs of the lithologies and fusulinids from the thin-sections analyzed are shown in Plates 1-12.

In 1992, James Lee Wilson sent a small number of fusulinid samples from his Grapevine Canyon (text-figs. 2 and 5) field collections (GC basal bed, GC-150-1, GC-150-2) to Wahlman for



TEXT-FIGURE 1
Regional Pennsylvanian paleogeographic map of westernmost Texas and southern New Mexico showing the location of the Sacramento Mountains on the Pennsylvanian Sacramento Shelf between the Pedernal Uplift to the east and the Orogrande Basin to the west, and other important Pennsylvanian and Lower Permian outcrop areas around the Orogrande Basin. Map adapted from Wahlman (2019).

fusulinid age-dating. Oriented fusulinid thin-sections of those samples were made at the Amoco Earth Science Laboratory in Houston and analyzed by Wahlman.

In 2010, David Lemone (University of Texas at El Paso) sent 25 oriented fusulinid thin-sections to Wahlman from a UTEP masters thesis study on Bug Scuffle Limestone Member fusulinids by Kerry Wilrich (1999). Those fusulinid thin-sections came from three measured sections in the southernmost outcrop area of the Bug Scuffle Limestone Member (text-figs. 2 and 5), one section in the mouth of Bug Scuffle Canyon, one section in the central and upper parts of Bug Scuffle Canyon, and one measured section in the uppermost Bug Scuffle Limestone Member in the adjacent Ed Canyon (text-fig. 2). It should be noted that species identifications of the fusulinids herein differ from those in the Wilrich (1999) thesis.

The third and largest source of fusulinids studied herein are field samples collected by Ben Rendall during his recent stratigraphic mapping of the Bug Scuffle Limestone Member of the Gobbler Formation (Rendall et al. 2019; Rendall 2022) (text figures 2 and 5). In a north to south direction, the Rendall samples analyzed herein are from: (a) the High Rolls Tunnel Section along U.S. Highway 82 (text-fig. 6), (b) three measured sections on the north (Mesa Section, SMTM 1.7) and south (Long Ridge Sections, ACLR-3, ACLR-4) sides of Alamo Canyon, (c) two measured sections in Dog Canyon (SMDC-2, SMDC-4), and (d) the Table Top Mesa measured section (SMTT) between Ed Canyon and Bug Scuffle Canyon (text-figs. 2 and 5). Samples from some of Rendall's measured sections were analyzed only from unoriented petrographic thin-sections, but oriented fusulinid thin-sections were made from many samples of other measured sections by the senior author (see sample distributions on text-fig. 5).

Some additional Bug Scuffle Limestone fusulinid data are discussed that were cited in previous studies by Otte (1959), Pray (1961), Benne (1975), Van Wagoner (1977a, 1977b), Wilson (1989), and Lucas et al. (2021). Those data have been incorporated into this study when pertinent, but the most of the data are considered tentative because the fusulinids cited in all those studies, except for Lucas et al. (2021), were not illustrated and the specimens are not available for examination and verification. In addition, a small amount of fusulinid data cited in previous studies do not agree with more recent fusulinid and conodont data, and so those data are rejected (e.g., see discussion of High Rolls Tunnel section.)

Also cited when applicable are conodont biostratigraphic data from studies by Lane (1974) and Benne (1975), and by James

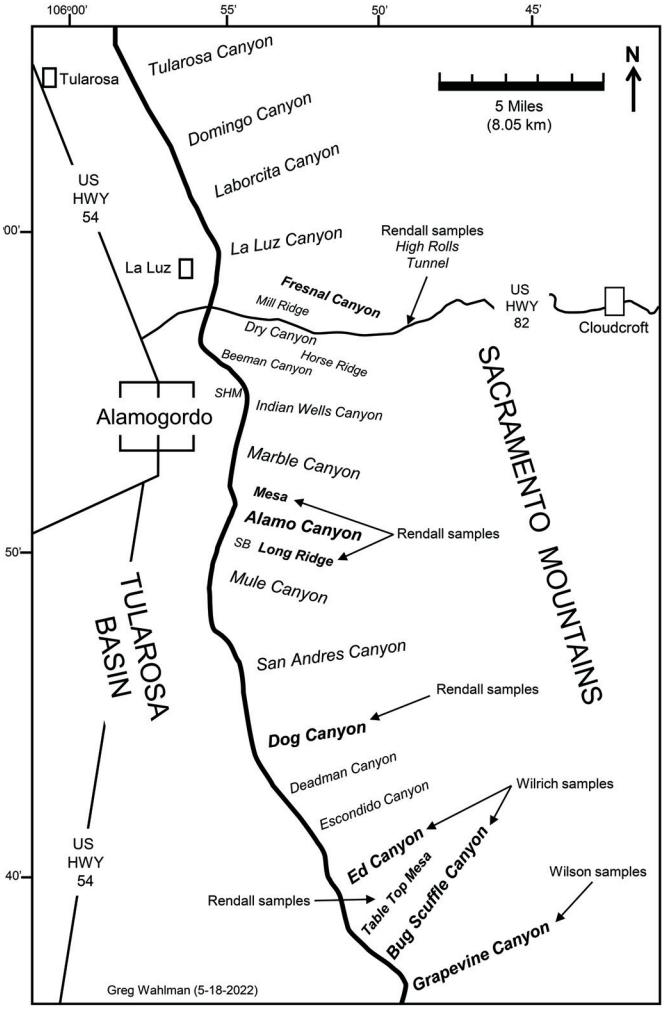
Barrick as cited in LaPeter (2007), Wahlman and Barrick (2018), and Lucas et al. (2021). Additionally, Dr. Barrick generously provided some new unpublished conodont biostratigraphic data and insightful comments regarding those new data during this study.

PENNSYLVANIAN PALEOGEOGRAPHY

During pre-Desmoinesian Late Paleozoic time, the Sacramento Mountains escarpment study area was part of a broad southward (present-day) dipping ramp near the Laurussia continental margin. Mississippian carbonate strata, including well-known Waulsortian mudmounds, were deposited on the broad southward-dipping carbonate ramp (Pray 1961). Early to lower middle Pennsylvanian (Morrowan-Atokan) siliciclastic sediments unconformably overlie the Mississippian carbonates (text-fig. 5). During later middle Pennsylvanian (Desmoinesian) time, the Pedernal Uplift arose to the east, and the Orogrande Basin began to subside to the west, and a narrow Sacramento Shelf was formed between, with its depositional dips shifting more toward the southwest and west (Rendall et al. 2019; Rendall 2022) (text-fig. 1).

PENNSYLVANIAN STRATIGRAPHY OF SACRAMENTO MOUNTAINS

Pray (1954, 1959, 1961) described the Upper Paleozoic stratigraphy of the Sacramento Mountains western escarpment and divided the Pennsylvanian section into three formations, which are in ascending order, the Gobbler, Beeman, and Holder formations (text-fig. 3). His stratotype for the three formations was at Long Ridge on the south side of Alamo Canyon (text-fig. 2). The Gobbler Formation unconformably overlies Mississippian limestones, and based on conodont and fusulinid data the formation is Morrowan to earliest Missourian in age (Pray 1961; Wahlman and Barrick 2018; Lucas et al. 2021; data presented herein) (text-fig. 3). As presently known, the Bug Scuffle Limestone Member of the Gobbler Formation is entirely Desmoinesian in age. Based on integrated fusulinid and conodont data recently presented by Wahlman and Barrick (2018), the overlying Beeman Formation is early Missourian to early middle Virgilian in age (text-fig. 3). Based mainly on fusulinid data, the next higher Holder Formation is middle and late Virgilian in age (Pray 1961; Wahlman in preparation 1). Overlying the Holder is the Laborcita Member of the Bursum Formation (late Virgilian - early Wolfcampian), which is lithostratigraphically transitional between the underlying mostly marine Holder Formation and the overlying nonmarine redbeds of the Abo Formation (Otte 1959; Pray 1961; Wahlman, in preparation 2) (text-fig. 3).

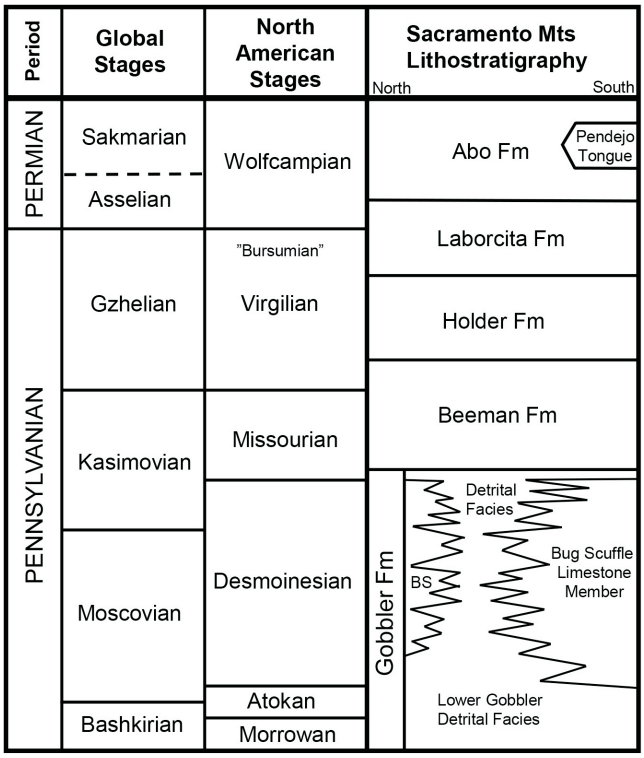


TEXT-FIGURE 2
Sketch map of western escarpment of Sacramento Mountains showing canyons and ridges with important Pennsylvanian stratigraphic sections. The localities from where Bug Scuffle Limestone Member fusulinid samples are discussed herein are in bold print and are labelled as to who collected the samples (i.e., James Lee Wilson, Kerry Wilrich, and Ben Rendall). Note that the clastic detrital tongue of the Gobbler Formation is in the Indian Wells Canyon area, and the Gobbler Formation is composed of mostly the carbonate facies of the Bug Scuffle Limestone Member to the north and south of that area. SHM = Space History Museum. SB = Steamboat Hill.

STRATIGRAPHY OF THE GOBBLER FORMATION

Pray (1961) described the Gobbler Formation as being 1200-1600 ft thick and consisting of clastic detrital facies and limestone facies that vary in their proportions both vertically and laterally along the Sacramento Mountains western escarpment (text-fig. 3). He named the limestone facies of the formation, which reaches over 1000 ft thick in the more southern Sacramento Mountains canyons, the Bug Scuffle Limestone Member. Pray did not formally name the clastic strata of the formation and referred to them informally as the detrital facies. Through most of the Sacramento Mountains escarpment, the lower and uppermost parts of the Gobbler Formation are composed predominantly of clastic detrital facies with sparse limestone interbeds. The lower Gobbler detrital facies unconformably overlie Mississippian carbonate strata, and in the northern Sacramento escarpment area there are erosional channels cut as much as 100 ft deep into the underlying Mississippian limestones (Pray 1961).

Lucas et al (2021) recently proposed renaming the Bug Scuffle Limestone Member and referring the carbonate unit to the Grey Mesa Formation, a lithostratigraphic unit recognized in outcrop areas to the north and west of the Sacramento Mountains, but his co-author James Barrick (p. 32 of Lucas et al. 2021) disagreed with applying that lithostratigraphic name in the Sacramento Mountains strata. We also retain the original Bug Scuffle Limestone Member name because of apparent facies, sequence stratigraphic, and age differences from the Grey Mesa Formation



TEXT-FIGURE 3
Pennsylvanian and lowermost Permian stratigraphic chart of the Sacramento Mountains escarpment showing lithostratigraphy, and North American and global chronostratigraphic stages. Note that the lower part of the Gobbler Formation, and the uppermost Gobbler Formation, are predominantly clastic detrital facies. In the north-central part of the Gobbler Formation outcrop belt, directly east of the town of Alamogordo, New Mexico, the Gobbler Formation consists of a tongue of the detrital clastic facies with only sparse limestone beds, but north and south of that clastic tongue the formation consists predominantly of the Bug Scuffle Limestone Member. BS = Bug Scuffle Limestone Member. Pendejo Tongue of Wolfcampian Hueco Limestone extends northward from the Hueco Mountains into Abo redbed section of the southernmost Sacramento Mountains.

(text-fig. 3). We fully support, however, the continued efforts to correlate and compare the characteristics of Desmoinesian strata throughout the region.

The proportions of the limestone facies and detrital clastic facies in the Gobbler Formation vary significantly in a lateral north-south direction (Pray 1961; Rendall et al. 2019; Rendall 2022) (text-figs. 2 and 3). In the southern part of the Sacramento Mountains escarpment outcrop belt, the lower detrital facies of the Gobbler Formation vary from 200-500 ft (61-152 m) thick, and the overlying Bug Scuffle Limestone Member reaches over 1000 ft (305 m) thick. According to Pray (1961, fig. 23), the base of the Bug Scuffle Limestone Member becomes younger northward, reflecting a northward marine transgression on the Sacramento Shelf during Desmoinesian time. In the north-central part of the Gobbler outcrop belt, east of the town of Alamogordo, north of Alamo Canyon, and mostly in the Indian Wells Canyon area (text-fig. 2), the Gobbler Formation is composed of mostly siliciclastic detrital facies with sparse interbedded limestones (text-fig. 3). These predominantly clastic detrital sediments have been interpreted to be a tongue of fluvial-deltaic and coastal clastic deposits shed down a depositional low passage from the western flank of the adjacent Pedernal Uplift. Much of the stratigraphic and biostratigraphic data documented by Lucas et al. (2021) comes from this mostly clastic lithofacies segment of the outcrop belt. North of this predominantly clastic detrital tongue, in the Fresnal Canyon area, the Gobbler Formation thins and consists again of mostly of Bug Scuffle limestone facies with a few interlayered detrital clastic units (text-figs. 2 and 3).

Rendall et al. (2019) and Rendall (2022) described the lithofacies and sequence stratigraphy of the Bug Scuffle Limestone Member and recognized two major composite sequences. The lower composite sequence boundary in the middle part of the Bug Scuffle Limestone Member was termed as the CSB1 composite sequence boundary, and the composite sequence boundary near the top of the Bug Scuffle Limestone was termed the CSB2 composite sequence boundary. Fusulinid biostratigraphy documented herein shows that the composite sequences below and above the CSB1 boundary are early and late Desmoinesian in age, and correlate to the Cherokee and Marmaton Groups of the classic North American Midcontinent Desmoinesian section, respectively. According to fusulinid data presented herein, the thin uppermost Bug Scuffle limestone sequence immediately above the CSB2 boundary continues to be latest Desmoinesian in age (Df4 Zone) in the southernmost canyon exposures. Early Missourian conodonts have been reported from a limestone unit in the uppermost Gobbler clastic detrital tongue in the Indian Wells Canyon area (Wahlman and Barrick 2018; Lucas et al. 2021), which Pray (1961) interpreted to be a tongue of the Bug Scuffle Limestone Member, but to date no early Missourian conodonts or fusulinids have been found from the uppermost massive Bug Scuffle Limestone Member above the CSB2 boundary. Clearly more detailed biostratigraphic sampling and analyses are needed to better document the Desmoinesian-Missourian boundary in the uppermost Bug Scuffle Limestone Member and the adjacent uppermost Gobbler clastic detrital facies.

EARLY AND MIDDLE PENNSYLVANIAN (MORROWAN-ATOKAN-DESMOINESIAN) FUSULINID BIOSTRATIGRAPHY OF NEW MEXICO

Important Morrowan-Atokan-Desmoinesian fusulinid studies in New Mexico include papers by Needham (1937), Thompson (1942, 1948), Van Sant (1958), Kottlowski and Stewart (1970), Stewart (1970), Verville et al (1986), Meyers (1988), Clopine et al (1991), Clopine (1992a, 1992b), Baltz and Myers (1999), and Wilde (2006). There are also several additional applicable studies on Morrowan-Atokan-Desmoinesian fusulinids in adjacent areas, including north-central Texas (White 1932; Stewart 1958; Nestell 1989; Groves 1991), the Glass Mountains of west Texas (Ross 1965, 1967), Colorado (Roth and Skinner 1931), southeastern Arizona (Ross and Sabins 1965; Ross and Tyrrell 1965; Ross 1969), and the Midcontinent (Dunbar and Condra 1927; Skinner 1931; Dunbar and Henbest 1942; Alexander 1954; Bebout 1963; Waddell 1966).

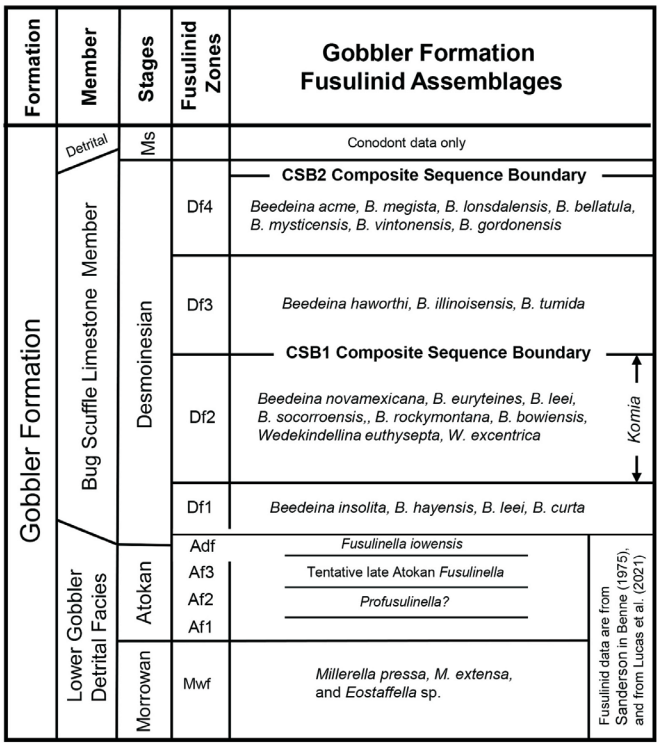
Wahlman (2013, 2019) recently reviewed the fusulinid biostratigraphy of the Pennsylvanian and Lower Permian sections in the Midcontinent and Southwest United States, and Wahlman (2019) proposed an alpha-numeric fusulinid zonation for the Permian Basin and surrounding regions. Those regional reviews demonstrated that the Morrowan-Atokan-Desmoinesian fusulinid zonation of the Midcontinent and Southwest

USA are essentially the same, with many shared species and related regional species. Text-figure 4 herein shows the Morrowan-Atokan-Desmoinesian alpha-numeric fusulinid zonation of Wahlman (2019) and lists the zonal fusulinid assemblages recognized in the Gobbler Formation.

The lowermost Pennsylvanian Morrowan Stage is characterized by the most primitive small fusulinids of the genera *Millerella* and *Eostaffella* (Mwf Zone) (text-fig. 4). The overlying Atokan Stage contains three fusulinid zones, which are in ascending order: the early Atokan Af1 Zone characterized by *Eoschubertella* and *Pseudostaffella*; the middle Atokan Af2 Zone characterized by the first fusiform fusulinids of the genus *Profusulinella*; and the late Atokan Af3 Zone characterized by the genus *Fusuinella*. The upper part of the late Atokan (Af3 Zone) is characterized by relatively large, elongate fusiform species of *Fusulinella*, such as *F. devexa* Thompson 1948 and *F. juncea* Thompson 1948 (Wahlman 2019, figs. 2 and 5) (text-fig. 4). The Atokan-Desmoinesian boundary interval (ADf Zone of Wahlman 2019) has a fusulinid assemblage characterized by species that are transitional between late Atokan *Fusulinella* and early Desmoinesian *Beedeina* (= *Fusulina* of earlier studies). The interval is characterized by small inflated species such as *Fusulinella iowensis* Thompson 1934 and *F. famula* Thompson 1948 (text-fig. 4).

The Middle Pennsylvanian Desmoinesian Stage of North America is defined by the zone of the fusulinid genus *Beedeina* (= *Fusulina* of older publications). Wahlman (1999, 2013, 2019) recognized four widespread Desmoinesian fusulinid zones in North America, which are, in ascending order, the Df1, Df2, Df3, and Df4 Zones (text-fig. 4). The early Desmoinesian is composed of the Df1 and Df2 Zones, and the late Desmoinesian is composed of the Df3 and Df4 Zones. The fusulinid assemblages of these four zones are very similar in the Midlcontinent and Southwest USA, and are essentially equivalent to Wilde's (1990) Permian Basin Zones DS1, DS2, DS3, and DS4. In the Midcontinent region, early Desmoinesian strata compose the Cherokee Group and late Desmoinesian strata compose the Marmaton Group (Wahlman 2013). Throughout the Midcontinent and Southwest USA, there is typically a significant mid-Desmoinesian sequence boundary between the early and late Desmoinesian (i.e., between Cherokee and Marmaton Groups, and between Df2 and Df3 fusulinid zones). Rendall et al. (2019) and Rendall (2022) recognized that regional unconformity in the middle part of the Desmoinesian Bug Scuffle Limestone Member of the Sacramento Mountains section and labelled it the CSB1 composite sequence boundary (text-figs. 4 and 5). The genus *Wedekindellina* goes to extinction at the top of the Df2 Zone, but occasionally upper Df2 Zone species such as *W. ellipsoides* are reported from the lowest strata of the overlying Df3 Zone, which in some cases might be attributed to reworking and other cases might be due to misidentification of associated species of *Beedeina*.

The early early Desmoinesian Df1 Zone of Wahlman (2019) is characterized by small primitive species of *Beedeina*, such as *B. insolita* (Thompson 1948), *B. hayensis* (Ross and Sabins 1965), *B. kayi* (Thompson 1934), *B. lucasensis* (Thompson 1934), *B. pumila* (Thompson 1934), *B. curta* (Thompson 1945), *B. mutabilis* (Waddell 1966), and small forms of *B. leei* (Skinner 1931). Primitive species of *Wedekindellina* appear slightly above the first *Beedeina*, such as *W. matura* (Thompson 1945)

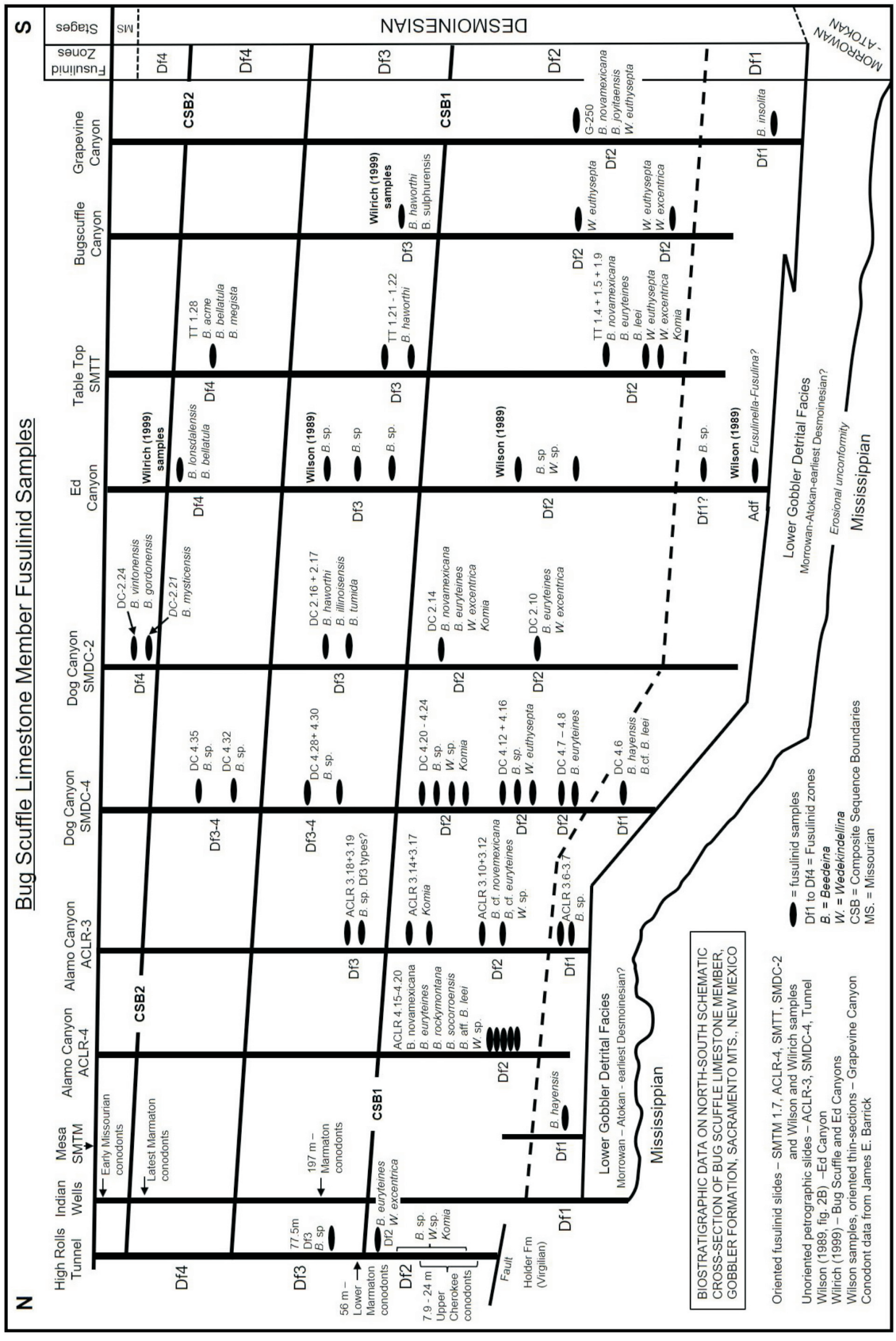


TEXT-FIGURE 4
Stratigraphic chart of Gobbler Formation, showing lithostratigraphy, North American chronostratigraphic stages, fusulinid zones of Wahlman (2019), and fusulinid assemblages of each zone in the study area. Desmoinesian fusulinid data are mostly from the present study. Morrowan and Atokan fusulinid data from the predominantly detrital clastic strata of the lower part of the Gobbler Formation are by George Sanderson in Benne (1975), and by Daniel Vachard in Lucas et al. (2021). Supporting conodont data, most of which are from the predominantly detrital clastic facies of the Gobbler Formation, are from Lane (1974), Benne (1975), and Barrick (personal communications; in Wahlman and Barrick 2018; and in Lucas et al. 2021). Ms = Missourian stage. *B.* = *Beedeina*, *W.* = *Wedekindellina*, *M.* = *Millerella.*

and other small morphotypes, some of which were questionably named as new species by Thompson (1934).

The late early Desmoinesian Df2 Zone is an interval characterized by moderate-sized species of *Beedeina* with irregular septal fluting, such as *B. novamexicana* (Needham 1937), *B. euryteines* (Thompson 1934), *B. leei*, and *B. rockymontana* (Roth and Skinner 1930), and common to abundant associated specimens of *Wedekindellina,* such as *W. euthysepta* (Henbest 1928), *W. excentrica* (Roth and Skinner 1930), and *W. henbesti* (Skinner 1931). The upper part of the Df2 Zone often has slightly larger species of *Beedeina*, such as *B. bowiensis* (Ross and Sabins 1965), and large inflated *Wedekindellina*, such as *W. ellipsoides* (Dunbar and Henbest 1942). The branching microfossil *Komia* ranges through the late Atokan and Desmoinesian in North America, but it is most characteristic of this Df2 Zone. In the Permian Basin region, the strata of the Df2 Zone are usually significantly thicker than the strata of the underlying Df1 Zone.

The early late Desmoinesian Df3 Zone overlies the CSB1 boundary and is characterized by moderate-sized fusiform to inflated fusiform species of *Beedeina* with more regular septal fluting,

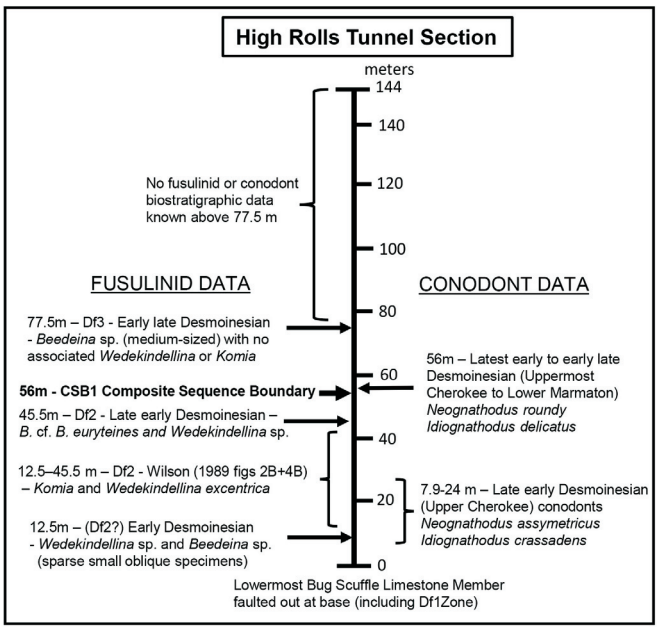


TEXT-FIGURE 5
Schematic North-South cross-section of the Gobbler Formation showing the distribution of fusulinid data, and some conodont data, in the Bug Scuffle Limestone Member. The cross-section is based generally on the more detailed cross-section of Rendall et al. (2019) and Rendall (2022), but this schematic section is not drawn to precise scale vertically or laterally. Most of the fusulinid data are based on analyses done herein on samples collected by Rendall. Additional fusulinid data from the southern canyons are based on analyses by the senior author of this study for fusulinid samples previously collected by Kerry Wilrich (1999) from Bug Scuffle Canyon and Ed Canyon, and by James Lee Wilson (1989) from Grapevine Canyon. The sparse conodont data were mostly provided by James E. Barrick (pers. comm.; in Wahlman and Barrick 2018; and in Lucas et al. 2021), with some additional fusulinid and conodont data taken from Lane (1974) and Benne (1975). Abbreviations are: *B.* = *Beedeina*, *W.* = *Wedekindellina*. M-A-D = Morrowan-Atokan-earliest Desmoinesian.

such as *B. haworthi* (Beede 1916), *B. illinoisensis* (Dunbar and Henbest 1942), *B. girtyi* (Dunbar and Condra 1927), and *B. tumida* (Alexander 1954) (Wahlman 2013, 2019). Other *Beedeina* species sometimes reported from this zone in New Mexico include *B. retusa* (Thompson 1953) and *B. sulphurensis* (Ross and Sabins 1965), which are species originally described from outcrop areas to the west and northwest of this study area. Fusulinids that appear to be transitional between *B. haworthi* and the larger *B. megista* (Thompson 1934) are commonly reported around the boundary of the Df3 and Df4 Zones.

The late late Desmoinesian Df4 Zone is characterized by relatively large, elongate to fusiform species of *Beedeina* with more regular septal fluting and often minor axial filling. Species that characterize the Df4 Zone in the Permian Basin region are *B. acme* (Dunbar and Henbest 1942), *B. megista* (Thompson 1934), *B. eximia* (Thompson 1934), *B. mysticenesis* (Thompson 1934), and *B. lonsdalensis* (Dunbar and Henbest 1942). Also occurring in this Df4 interval are *Beedeina* species described by Stewart (1958) from the upper part of the Strawn Group in north-central Texas, such as *B. cappsensis, B. bellatula, B. vintonensis* and *B. gordonensis* (Wahlman 2019, fig. 12).

Basal Missourian strata overlying the Desmoinesian in the Midcontinent and Southwest USA commonly contain a thin interval with the fusulinid genus *Eowaeringella*, soon followed by the earliest primitive species of *Triticites* (Stewart 1968; Wilde 1990; Wahlman 2013, 2019; Allen and Lucas 2018;). James Barrick (in Wahlman and Barrick 2018, and in Lucas et al. 2021) documented the occurrence of early Missourian conodonts in a limestone unit in the upper 25 m of the clastic detrital tongue of the Gobbler Formation in the north-central outcrop belt (Indian Wells Canyon and Beeman Canyon), but no early Missourian conodonts or fusulinids have yet been found in the uppermost strata of Bug Scuffle Limestone Member. As previously stated, more detailed biostratigraphic sampling is needed from both the uppermost Bug Scuffle Limestone Member and the adjacent Gobbler clastic detrital facies.



TEXT-FIGURE 6
Fusulinid and conodont data for the High Rolls Tunnel section on Highway 82 between Alamogordo and Cloudcroft, New Mexico (see text-figure 2). Fusulinid data are mostly from the present study. Some earlier questionable fusulinid data from Van Wagoner (1977) and Wilson (1989) are not cited here (see text discussion of section). Conodont data are by James E. Barrick as cited in Lapeter (2007) and Lucas and others (2021). Note that the lowermost Bug Scuffle Limestone Member, probably including the entire Df1 fusulinid zone, are faulted out at the base of this roadcut section. The CSB1 composite sequence boundary is from Rendall et al. (2019) and Rendall (2022), and that boundary is equivalent to the Early-Late Desmoinesian (Df2-Df3 fusulinid zones) boundary, and it correlates to the Cherokee-Marmaton Group boundary in the North American Midcontinent.

BIOSTRATIGRAPHY OF CLASTIC DETRITAL FACIES OF LOWER GOBBLER FORMATION

As previously stated, Pray (1961) named the carbonate lithofacies of the Gobbler Formation the Bug Scuffle Limestone Member, but only informally referred to the clastic lithofacies of the formation as the "detrital facies". In the southern part of the outcrop belt, below the Bug Scuffle Limestone Member, the lower 200-500 ft of the Gobbler Formation are composed of predominantly clastic detrital facies with sparse interbedded limestones (Pray 1961) (text-figs. 3-5). Benne (1975) reported the age of the detrital clastic strata of the lower Gobbler Formation as being early Morrowan to early Desmoinesian in age (text-fig. 4). His age-dates were based on biostratigraphy from conodont data provided by H.R. Lane (1974) of the Amoco Research Center, fusulinid data provided by George Sanderson of the Amoco Research Center, and brachiopod and other macrofossil data provided by Patrick Sutherland of the University of Oklahoma. Based on those biostratigraphic data, Benne (1975) subdivided the detrital facies of the lower Gobbler Formation into four intervals: Lower Morrowan, Upper Morrowan, Atokan, and Lower Desmoinesian. He stated that the two Morrowan intervals were composed of overall transgressive facies over the unconformity at the top of the Mississippian, the Atokan interval was composed of mostly regressive facies, and the Lower Desmoinesian interval was again composed of overall transgressive facies that graded up into the overlying Bug Scuffle Limestone Member.

Based on conodont data (Lane 1974; Benne 1975), the lowermost strata of the detrital facies of Gobbler Formation were age-dated as early to middle Morrowan in age. Sanderson in Benne (1975) recognized the primitive Morrowan fusulinid genera *Millerella* and *Eostaffella* in limestone beds of the Lower Morrowan Interval, supporting the conodont age-date. Conodont data (Lane 1974; Benne 1975) age-dated the Upper Morrowan Interval as middle to late Morrowan, and the primitive fusulinids *Millerella* and *Eostaffella* continued to be cited from interbedded limestones of this interval. Most of the overlying Atokan Interval was reported by Banne (1975) to be unfossiliferous, but the upper part was age-dated as late Atokan based on conodonts and questionable poor fusulinid data. Benne (1975) reported that the Atokan-Desmoinesian boundary was tentatively recognized in Deadman Canyon based on conodont data, but the stratigraphic tracing of the boundary was difficult because of marked lateral facies changes. The Lower Desmoinesian Interval of Benne (1975) was based on very limited conodont and brachiopod data in Grapevine and Mule Canyons, and Benne reported that George Sanderson recognized early Desmoinesian fusulinids in limestone beds up to 50 ft below the base of the Bug Scuffle Limestone Member in those canyons. Finally, Benne (1975) stated that

Sanderson's fusulinid data suggested that the base of the Bug Scuffle Limestone Member was transgressive and diachronous, becoming younger northward.

Recently, James Barrick in Lucas et al. (2021) provided conodont age-dates of the so-called detrital facies of the Gobbler Formation in the Indian Wells Canyon area of the Sacramento Mountains escarpment outcrop belt where detrital clastic facies are predominant throughout the Gobbler section (text-figs. 2 and 3). Most of their Gobbler conodont samples came from the clastic detrital tongue in the vicinity of the Space History Museum and Indian Wells Canyon re-entrant directly east of Alamogordo (text-fig. 2). Their southernmost samples analyzed were from the lower part of the Gobbler Formation in Mule Canyon (text-fig. 2). The new conodont data (James Barrick, personal communication) confirmed the presence of early Morrowan, middle to late Atokan, and early Desmoinesian strata in the lower Gobbler clastic facies. In the Space History A measured section of Lucas et al. (2021), Daniel Vachard reported the Morrowan fusulinids *Millerella pressa* and *M. expressa* from 5 m (= 16.4 ft) above the unconformity at the top of the Mississippian, and the middle Atokan fusulinid genus *Profusulinella* slightly higher in the section (text-fig. 4). Wilson (1989, fig. 2B) also questionably reported *Profusulinella*? in the lower part of the Gobbler Formation at Ed Canyon.

In summary, the combined data from earlier fusulinid and conodont studies from several authors have age-dated the detrital clastic facies of the lower part of the Gobbler Formation below the Bug Scuffle Limestone Member as early Morrowan through earliest Desmoinesian. Pray (1961) and Benne (1975) suggested that the base of the Bug Scuffle Limestone Member was diachronous and becomes younger northward, reflecting the general northward transgression of the early Desmoinesian sea. That assertion is supported by data in this study.

NEW FUSULINID BIOSTRATIGRAPHIC DATA FROM THE BUG SCUFFLE LIMESTONE MEMBER OF THE GOBBLER FORMATION

Desmoinesian fusulinids from the Bug Scuffle Limestone Member of the Gobbler Formation have been cited in a few publications, but after the pioneering study of Needham (1937), the fusulinid assemblages of the Sacramento Mountains escarpment section received little documentation until Lucas et al (2021), where sparse fusulinids were reported and illustrated from the north-central and northern parts of the escarpment outcrop belt. The sample localities analyzed for fusulinid biostratigraphy herein are arranged below in a generally north to south direction along the Sacramento Mountains escarpment from Fresnal Canyon in the north to Grapevine Canyon near the southern end of the outcrop belt (text-fig. 2). Text-figure 5 is a schematic cross-section based on a much more detailed lithostratigraphic cross-section of Rendall et al. (2019) and Rendall (2022), and it summarizes the general distribution of fusulinid samples and species in the measured sections discussed in this study. Fusulinids from each section discussed are illustrated in Plates 1-12.

Note that in an upcoming publication by Rendall et al. (in preparation) on the lithostratigraphy and sequence stratigraphy of the Bug Scuffle Limestone, the Rendall measured sections discussed below will be referred to by section numbers progressing from north to south. In that numeric naming system, the measured sections discussed below will be designated as follows:

PLATE 1

Desmoinesian fusulinids of Bug Scuffle Limestone Member from Tunnel Measured Section in Fresnal Canyon along Highway 82 near High Rolls, New Mexico (see text-figure 2).
These illustrated fusulinids and smaller foraminifers are from unoriented petrographic thin-sections of Rendall's field samples.
Scale bar in figure 1 = 0.5 mm (×50); scale bars in figures 2-10 = 1 mm (×10); scale bars in figures 11-12 = 1 mm (×25).

1-2 Fragments of juvenile *Beedeina* sp. in spiculitic-crinoidal packstone, sample T1.36 (77.5 m = 254 ft) (×50 and ×10). Assignment to Df3 Zone based on stratigraphic position above CSB1 composite sequence boundary, associated conodont data (see Text-figure 6), and absence of *Wedekindellina* and *Komia*.

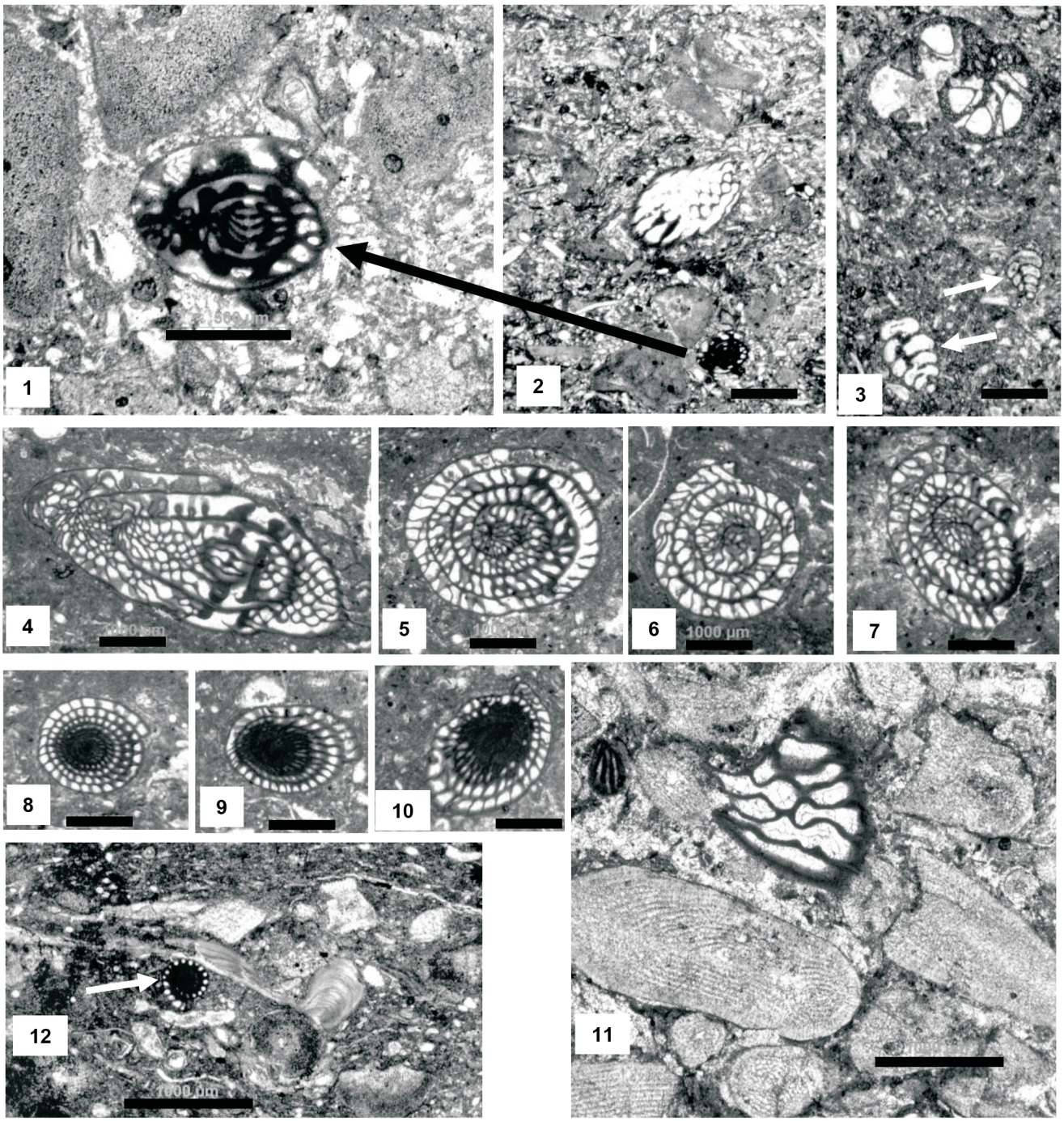
3 Smaller foraminifers *Bradyina* (top) and two palaeotextulariids (arrows) are common in this part of the section, sample T1.36 (77.5 m = 254 ft) (×10) (Df3 Zone).

4-7 Oblique specimens of *Beedeina* cf. *B. euryteines* (Thompson 1934), sample T1.22 (45.5 m = 149 ft) (×10) (Df2 Zone).

8-10 Oblique saggital specimens of *Wedekindellina* sp., sample T1.22 (×10) (Df2 Zone).

11 Small fragment of *Beedeina* sp. in *Komia* packstone, sample T1.12 (20.6 m = 67.6 ft) (×25) (Df2 Zone).

12 Very small specimen of a near parallel saggital *Wedekindellina* sp. (arrow) in crinoidal-bryozoan packstone, sample T1.10 (12.5 m = 41 ft) (×25) (Df2 Zone based partly on associated conodont data).


1
2
3
4
5
6
1000 µm
7
8
9
10
11
12
1000 µm

High Rolls Tunnel Section (SMTN-1) = 3; Mesa Section non north side of Alamo Canyon (SMTM-1) = 8; Alamo Canyon Long Ridge Section #3 (ACLR-3) = 10; Alamo Canyon Long Ridge Section #4 (ACLR-4) = 11; Dog Canyon Section #4 (SMDC-4) = 19; Dog Canyon Section #2 (SMDC-2) = 20; Table Top Section #1 ((SMTT-1) = 30; Grapevine Canyon Section #1 (SMGV-1) = 31.

High Rolls Tunnel Section, Upper Fresnal Canyon

This stratigraphic section is exposed in roadcuts along Highway 82 just west of the highway tunnel near High Rolls, New Mexico (text-fig. 2). It is the most northern measured section of the Bug Scuffle Limestone Member with fusulinid biostratigraphic data. The base of the Bug Scuffle Limestone Member in the roadcut exposure is truncated by the Fresnal Fault, and the Bug Scuffle Limestone overlies the Late Pennsylvanian (Virgilian) Holder Formation across the fault. It is uncertain how much of the lower part of the Bug Scuffle Limestone is faulted out, but the earliest Desmoinesian Df1 Zone appears to be completely missing.

Only sparse fusulinid biostratigraphic data have been reported from the High Rolls Tunnel section by Van Wagoner (1977a, b), Wilson (1989), and Lucas et al. (2021). Some conodont data from the Tunnel section have been reported by James Barrick in both the studies by LaPeter (2007) and Lucas et al. (2021). New fusulinid data from the Tunnel section presented herein are from the examination of twenty-one unoriented petrographic thin-sections from samples collected by Rendall. The fusulinid and conodont biostratigraphic data from the High Rolls Tunnel section are summarized in text-figure 6.

Van Wagoner (1977a, b) cited a few fusulinid samples from the Tunnel section that were later published on a stratigraphic cross-section published by James Lee Wilson (1989, fig. 2B). From 7.5 m (24.6 ft) above the base of the Bug Scuffle limestone section, those authors cited "*Fusulinella* or *Fusulina"*. At 24.75 m (81 ft) above the base of the section, they cited *Fusulina* (now *Beedeina*) *insolita*, which is the species that characterizes the earliest Desmoinesian fusulinid zone (Df1 Zone of Wahlman 2019). Unfortunately, however, there seems to be a problem with these data. As mentioned above, the lower part of the Bug Scuffle Limestone Member is faulted out at the base of the roadcut section, and conodont biostratigraphy by James Barrick in LaPeter (2007) and in Lucas et al. (2021) has documented late early Desmoinesian (upper Cherokee, Df2 Zone of Wahlman 2019) conodonts *Neognathodus assymetricus* and *Idiognathodus crassadens* from the lower 24 m (79 ft) of the Tunnel measured section (see zonation in Barrick et al. 2021, fig. 2) (text-fig. 6). In addition, it is important to note that the Tunnel section as measured by Van Wagoner (1977a, b) and as illustrated by Wilson (1989, fig. 2B) is shown as being 240 m (787 ft) thick, but their thickness is approximately 100 meters (328 ft) thicker than the Tunnel sections measured by both LaPeter (2007) and Rendall et al. (2019). That much thicker measured section, and the citation of earliest Desmoinesian fusulinids in the lower part of that section, suggest that Van Wagoner (1977a, b) and Wilson (1989) tacked on an additional 100 meters (328 ft) of strata at the base of their Tunnel section from some other exposure, but neither author provided an explanation. Wilson (1989, fig. 4B, and front piece) showed a photomicrograph of his *Komia* packstone-wackestone facies from the lower part of the Tunnel section that also illustrates a moderately large and slightly inflated specimens of the fusulinid *Wedekindellina excentrica*, and on his measured section (Wilson 1989, fig. 2B) he showed the range of *Komia* to be over an approximately 50 m (164 ft) interval in the lower middle part of the Bug Scuffle Limestone at the Tunnel section, and so the sample shown in the photograph is clearly from within that interval. The co-occurrence of *Komia* and *Wedekindellina excentrica* in that sample indicates that the sample horizon was late early Desmoinesian in age (Df2 Zone). Therefore, based on Barrick's conodont data and on Wilson's photomicrograph of *Wedekindellina excentrica* and *Komia*, the lower part of the Bug Scuffle Limestone Member in the Tunnel Section is age-dated as late early Desmoinesian in age (Df2 Zone).

At 56 m (184 ft) above the base of the Bug Scuffle Limestone Member in the Tunnel section, Barrick in LaPeter (2007) and Barrick in Lucas et al. (2021) reported the occurrence of the conodonts *Idiognathodus delicatus* and *Neognathodus roundy*, which based on correlation to the Midcontinent Desmoinesian section, range from the latest early Desmoinesian (uppermost Cherokee) to the early late Desmoinesian (lower Marmation) (see Barrick et al. 2021, fig. 2) (text-fig. 6). Barrick (pers. comm. 2020) considers the latter age date to be more likely. Significantly, Rendall et al. (2019) and Rendall (2022) placed the CSB1 composite sequence boundary between the early and late Desmoinesian (Cherokee-Marmaton) at 50 m (164 ft) in his measured section, which is supported by the conodont-based age determination for that part of the section.

Vachard in Lucas et al. (2021) cited very sparse fusulinid identifications from the Tunnel section. He identified *Wedekindellina* sp. from 38 m (125 ft), indicating an early Desmoinesian age date, which agrees with the conodont data and new fusulinid data. He cited the fusulinid *Nipperella* sp. from 63 m (207 ft) in the section, saying that the specimen most closely resembled *Wedekindellina matura*, which is a species originally described by Thompson (1945) from the earliest Desmoinesian (Df1 Zone) of Utah. Significantly, Solovieva (1984) erected the genus *Nipperella* based on the species *Fusulinella nipperensis*, which was described from the late Atokan of Arizona by Ross and Sabins (1965). Therefore, the citation of the genus *Nipperella* from strata dated as late Desmoinesian (Marmaton) by conodonts in this section seems unlikely. Higher in the section at 83 m (272 ft), Vachard in Lucas et al. (2021) identified *Beedeina schellwieni* (Staff), which is a species widely reported from late Moscovian strata in Eurasia, but the species has not been previously reported from North America, and so this species identification also needs further evaluation, but a late Desmoinesian age interpretation agrees with the conodont data. The illustrated specimen of *B. schellwieni* (Lucas et al. 2021, fig. 105E) is considered herein to be *Beedeina* aff. *B. haworthi*, which would support a Df3 Zone designation for the 83m sample.

In the present study, twenty-one unoriented petrographic thin-sections from Rendall's field samples of the Bug Scuffle Limestone Member in the Tunnel section were analyzed for biostratigraphy, and the sparse fragmentary fusulinids found in those samples are illustrated in Plate 1, figures 1-12. Samples T1.10 up to T1.22 (12.5 m = 45.5 m to 41 ft = 149 ft) from the lower part of the exposed Bug Scuffle Limestone contained common specimens of the microproblematical branching fossil *Komia*, which indicates a probable late early Desmoinesian age (Df2 Zone) (Plate 1, figures 11-12). As noted above, Wilson (1989, fig. 2B) also showed *Komia* ranging through the lower

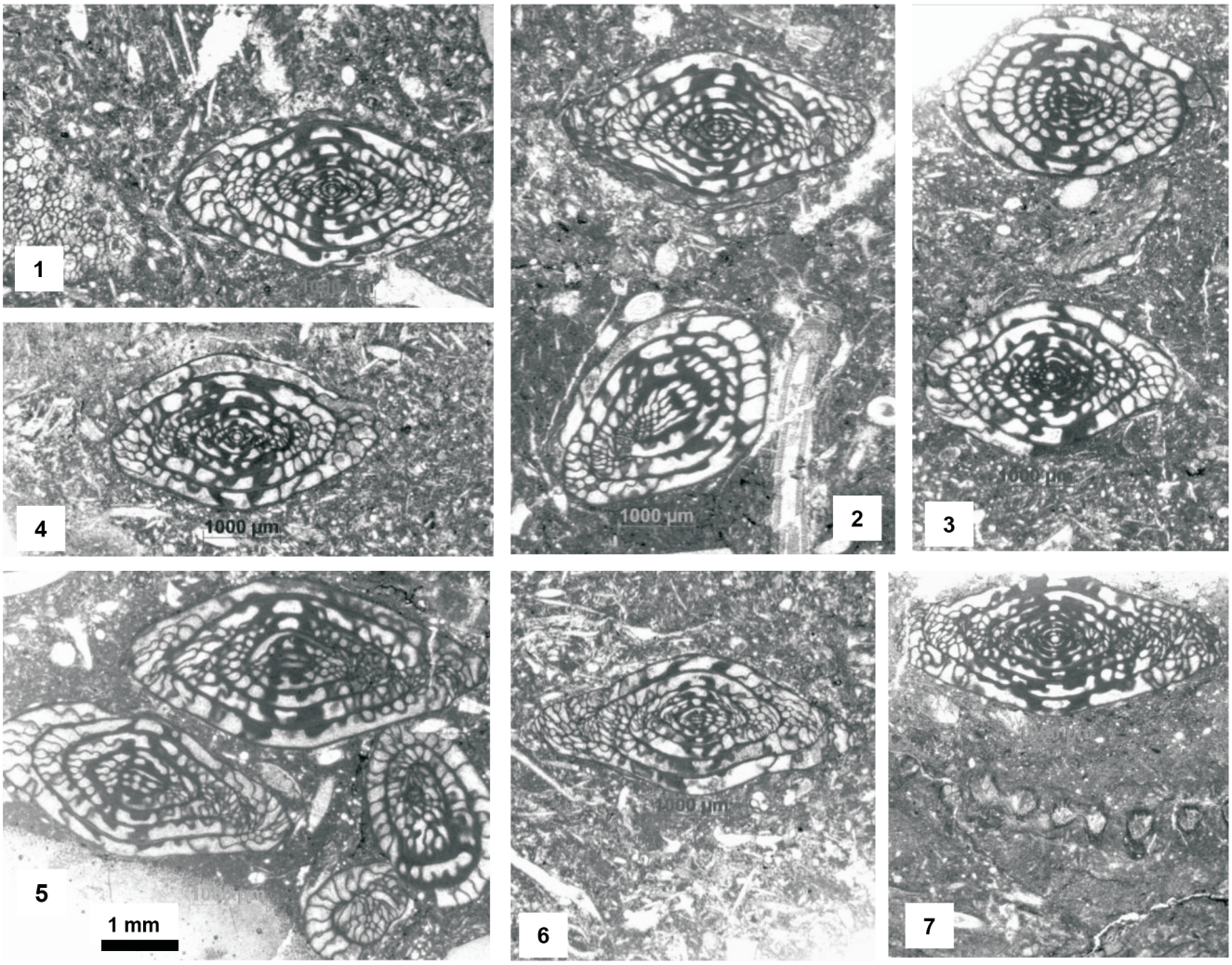


PLATE 2

Early Desmoinesian (Df1 Zone) fusulinids from near base of Bug Scuffle Limestone Member in the Mesa measured section on north side of Alamo Canyon (see text-figure 2).
All are oriented fusulinids from Sample SMTM 1.7 from 6 m (19.7 ft) above the base of the measured section.
All photos at ×10, scale bar = 1 mm.

1-7 *Beedeina curta* (Thompson 1945) in skeletal-spiculitic packstone matrix with common sponge spicules and fusulinids, and sparse bryozoan fragments, small crinoid ossicles, and other bioclasts. These primitive *Beedeina* are slightly larger than the type specimens of *B. curta* from northwestern Colorado, and are similar to early Desmoinesian specimens of *B*. aff. *B. curta* illustrated by Clopine (1992) from the northern Franklin Mountains of far west Texas.

middle part of the Bug Scuffle Limestone in the Tunnel section. The lowest samples T1.10 (12.5 m = 41 ft above base) and T1.12 (20.6 m = 68 ft above base) also contained rare small specimens of *Beedeina* sp. and *Wedekindellina* sp. (Plate 1, figs. 11-12), and are interpreted to be from the Df2 Zone. Sample T1.22 (45.5 m = 149 ft) contained several specimens of *Beedeina* cf. *B. euryteines* (Plate 1, figures 4-7) and larger *Wedekindellina* sp. (Plate 1, figures 8-10), indicating the sample is from the late early Desmoinesian (Df2 Zone). The only fusulinids seen in the thin-sections from the upper part of the Bug Scuffle section were in sample T1.36 (77.5 m = 254 ft), located about 27.5 m (90.5 ft) above the middle Desmoinesian CSB1 composite sequence boundary of Rendall et al. (2019) and Rendall (2022), and that sample contained only oblique fragments of *Beedeina* sp. (Plate 1, figures 1-2), with common associated bradyinid and palaeotextulariid smaller foraminfers (Pl. 1, figure 3), but with no associated *Wedekindellina* or *Komia*. Based on the presence of *Beedeina*, the absence of *Wedekindellina* and *Komia*, and the stratigraphic position above the CSB1 sequence boundary, the T1.36 sample is interpreted to be early late Desmoinesian in age (Df3 Zone), which agrees with the conodont data cited above.

In summary, based on limited conodont and fusulinid data, the Bug Scuffle Limestone Member in the High Rolls Tunnel section is age-dated as follows (text-fig. 6). The basal Desmoinesian (Zone Df1) part of the Bug Scuffle Limestone is apparently faulted out. The lower part of the exposed Bug Scuffle Limestone up to about 50 m (164 ft) is late early Desmoinesian (Df2 Zone, upper Cherokee) based on conodont data, and the presence of the fusulinids *Beedeina* cf. *B. euryteines* and *Wedekindellina excentrica*, and on the common occurrence of *Komia*. Conodonts that range from latest early Desmoinesian to early late Desmoinesian occur near 56 meters (184 ft) just above with the middle Desmoinesian CSB1 composite sequence boundary of Rendall et al. (2019) and Rendall (2022). A single fusulinid sample from 77.5 m (254 ft), 27.5 m (90.5 ft) above the mid-Desmoinesian CSB1 composite sequence boundary, contains poor specimens of *Beedeina*, with no associated *Wedekindellina* or *Komia*, and so that sample is tentatively interpreted to be early late Desmoinesian in age (Df3 Zone), which agrees with the conodont data. No biostratigraphically useful fossils were found in the samples from the overlying upper part of the Bug Scuffle Limestone in the Tunnel section, but based on lithostratigraphic correlations with Bug Scuffle Limestone sections to the south (Rendall 2022) that part of the section is considered to be late Desmoinesian.

Indian Wells Canyon and Space History Museum Sections

The Indian Wells Canyon area is located south of Dry and Fresnal Canyons, north of Alamo Canyon, and east of the town of Alamogordo (text-fig. 2). The Gobbler Formation in that area of the Sacramento Escarpment is composed of a tongue of mostly clastic detrital facies with only sparse limestone interbeds. This predominantly clastic tongue is considered to represent fluvial-deltaic and coastal facies deposited in a low area on the Sacramento Shelf along the western flank of the Pedernal Uplift (Pray 1961; Benne 1975; Van Wagoner 1977a, b; Rendall et al. 2019; Lucas et al. 2021; Rendall 2022). There are very limited fusulinid data known from this predominantly clastic detrital section, and no fusulinid samples from these detrital facies of the Indian Wells Canyon area were examined for this study.

Benne (1975) recognized Lower Morrowan, Upper Morrowan, Atokan, and Lower Desmoinesian intervals in the lower 149 m (490 ft) of the Gobbler Formation in this area (see previous section on the lower Gobbler detrital facies). Barrick in Lucas et al. (2021) provided several conodont age-dates from the Gobbler Formation in the Indian Wells Canyon and Space History Museum measured sections, which confirmed that the mostly clastic detrital facies of the Gobbler Formation include strata age-dated as early to late Morrowan, early to late Atokan, and early to late Desmoinesian. In addition, based on conodonts, Barrick in Wahlman and Barrick (2018) and in Lucas et al. (2021) age-dated a limestone unit in the upper 25 m (82 ft) of the uppermost Gobbler Formation clastic detrital section in the Indian Wells-Space History sections area as being early Missourian in age, and he correlated the conodonts with those of the Swope cyclothem in the Midcontinent region. More detailed

---

PLATE 3

Late early Desmoinesian (Df2 Zone) fusulinids of Bug Scuffle Limestone Member from ACLR-4 measured section at Long Ridge on south side of Alamo Canyon (see text-figure 2).
Oriented fusulinids from six closely-spaced samples at 44-50 m (144-164 ft) above the base of the Bug Scuffle Limestone Member.
All photos at ×10, scale bar = 1 mm.

1-4 *Beedeina euryteines* (Thompson 1934) from sample ACLR 4.20.

5-8 *Beedeina novamexicana* (Needham 1937) from sample ACLR 4.20.

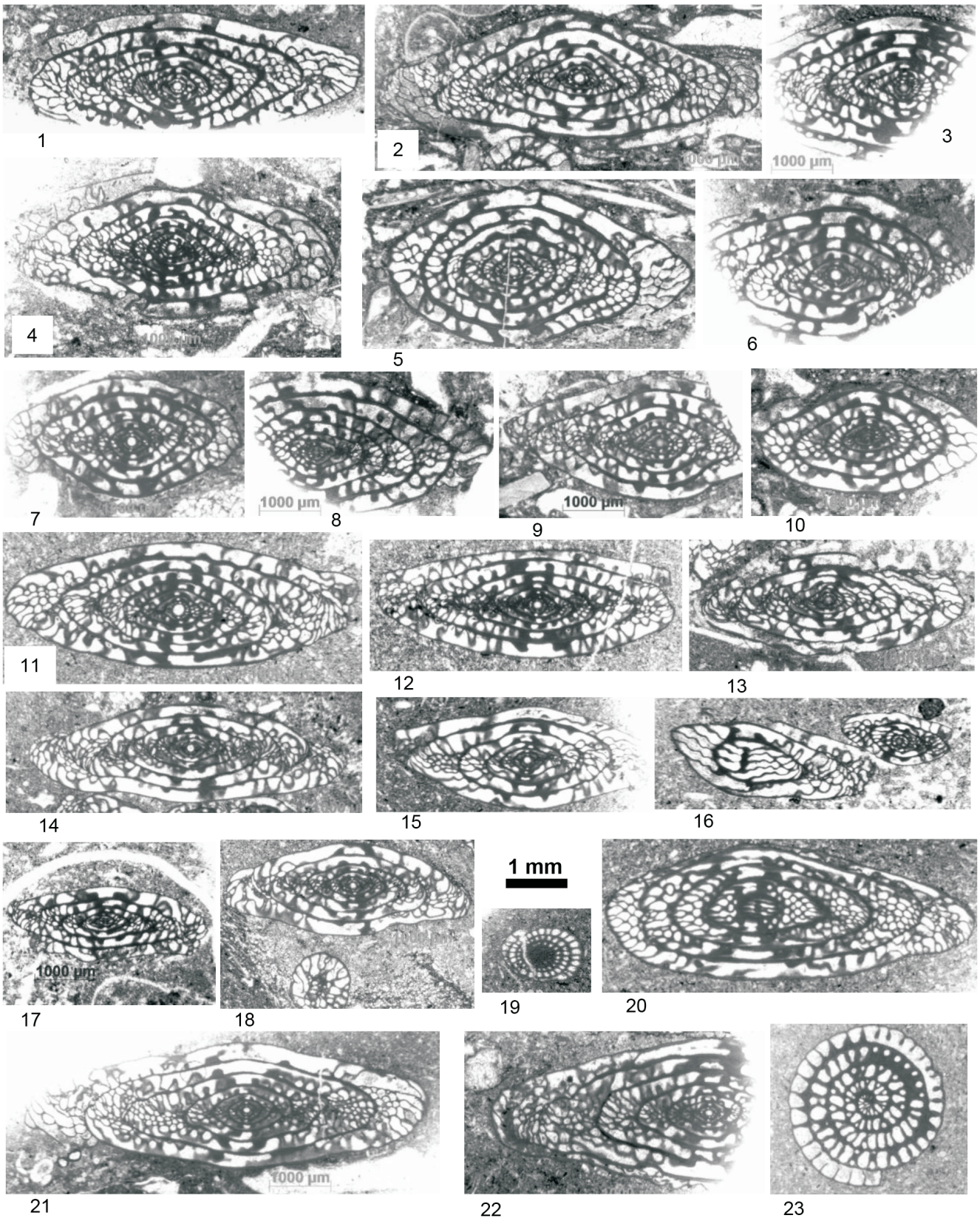
9-10 *Beedeina euryteines* (Thompson 1934) from sample ACLR 4.19.

11-13 *Beedeina rockymontana* (Roth and Skinner 1930) from sample ACLR 4.17.

14-18 *Beedeina socorroensis* (Needham 1937) from sample ACLR 4.16.

19 *Wedekindellina* sp. juvenile from sample ACLR 4.15.

20-23 *Beedeina* aff. *B. leei* (Skinner 1931) from sample ACLR 4.15.


1
2
3
1000 µm
4
5
6
7
1000 µm
8
1000 µm
9
10
11
12
13
14
15
16
1000 µm
17
18
1 mm
19
20
1000 µm
21
22
23

studies of the correlation of that uppermost limestone unit in the Gobbler clastic detrital section with and the uppermost Bug Scuffle limestones to the south are needed.

Vachard in Lucas et al. (2021) discussed a couple fusulinid samples from their Space History A section, citing the primitive Morrowan fusulinids *Millerella extensa* and *M. pressa* at about 3 m (10 ft) above the Mississippian-Pennsylvanian unconformity, and the middle Atokan (Af2 Zone) fusulinid *Profusulinella* sp. at 46 m (151 ft) above the base of the Gobbler section (text-fig. 4). Barrick in Lucas (2021) also reported significant new conodont data from the clastic detrital facies of the Indian Wells Canyon section.

Mesa Section (North side of Alamo Canyon)

The Mesa measured section of Rendall et al. (2019) and Rendall (2022) is on the north side of Alamo Canyon (text-fig. 2). The only fusulinid sample (SMTM 1.7) analyzed from this section was collected from a limestone bed at 6 m (19.7 ft) above the base of the measured section of the Bug Scuffle Limestone Member. Several oriented fusulinid thin-sections were made from that sample (Plate 2, figures 1-7). The lithology of sample SMTM 1.7 is a medium gray, poorly sorted, fine- to very coarse-grained, skeletal-spiculitic packstone (MDP), with common monaxon and tetraxon sponge spicules; moderately common crinoid ossicles and fusulinids; sparse fenestrate bryozoan and brachiopod fragments; sparse smaller foraminifers (*Tuberitina*, *Globivalvulina*, *Tetrataxis*, endothyrids); and very sparse ostracods and mollusk shell fragments, including a small silicified juvenile orthoconic cephalopod fragment. The limestone was deposited in a normal marine, low energy, slightly argillaceous and probably somewhat turbid setting.

The fusulinids in sample SMTM 1.7 are identified as *Beedeina curta* (Thompson 1945) (Plate 2, figures 1-7), an early Desmoinesian (Df1 Zone) species originally described from Youghall Formation of northwestern Colorado. The primitive *Beedeina* specimens shown herein resemble specimens of *B.* aff. *B. curta* illustrated by Clopine (1992) from his earliest Desmoinesian *Beedeina insolita* Zone (= Df1 Zone of Wahlman 2019) in the northern Franklin Mountains of westernmost Texas. As pointed out by Clopine (1992), *B. curta* is similar to *B. novamexicana*, but is more primitive, having less intense and more irregular septal fluting.

Long Ridge Sections (South Side of Alamo Canyon)

Fusulinid samples were collected from two of Rendall's (2022) measured sections (ACLR-3 and ACLR-4) at Long Ridge on the south side of Alamo Canyon (text-fig. 2). Pray (1961) proposed Long Ridge as the stratotype section of the Pennsylvanian Gobbler, Beeman, and Holder formations of the Sacramento Mountains. Lucas et al. (2021) also redescribed much of this section.

Alamo Canyon - Long Ridge ACLR-4 section

Of thirty-eight field samples collected by Rendall from his ACLR-4 measured section through the Bug Scuffle Limestone Member, only a set of six closely-spaced samples from the lower part of the measured section were found to contain fusulinids. Those six samples, ACLR 4.15 to ACLR 4.20, were collected from an interval at 44 m to 50 m (144 ft to 164 ft) above the base of the 212 m (695 ft) thick measured section of the Bug Scuffle Limestone Member (text-fig. 5). Oriented fusulinid thin-sections were made from the samples and are illustrated in Plate 3, figures 1-23. Petrographic descriptions of the samples and their fossil contents are given in Appendix 1. The CSB1 composite sequence boundary is at 72 m (236.2 ft) above base of the measured section and at 22 m to 28 m (72.2 to 91.9 ft) above the fusulinid samples described herein (Rendall 2022).

PLATE 4

Desmoinesian fusulinids of Bugscuffle Limestone Member from ACLR-3 measured section at Long Ridge on the south side of Alamo Canyon (see text-figure 2). These specimens are unoriented fusulinids from petrographic thin-sections and are mostly not well enough oriented for confident species identifications, but can be tentatively assigned to Desmoinesian fusulinid zones. Heights of samples in measured sections are given in the text and Appendix 1. All photos at ×10, scale bar = 1 mm.

1 *Beedeina* sp. from crinoid-fusulinid packstone in sample ACLR 3.19, probably Df3 Zone.

2-3 *Beedeina* sp. from similar lithology in sample ACLR 3-18, showing moderately intense septal fluting with minor secondary deposits, and no associated *Wedekindellina* or *Komia*, suggesting Df3 Zone.

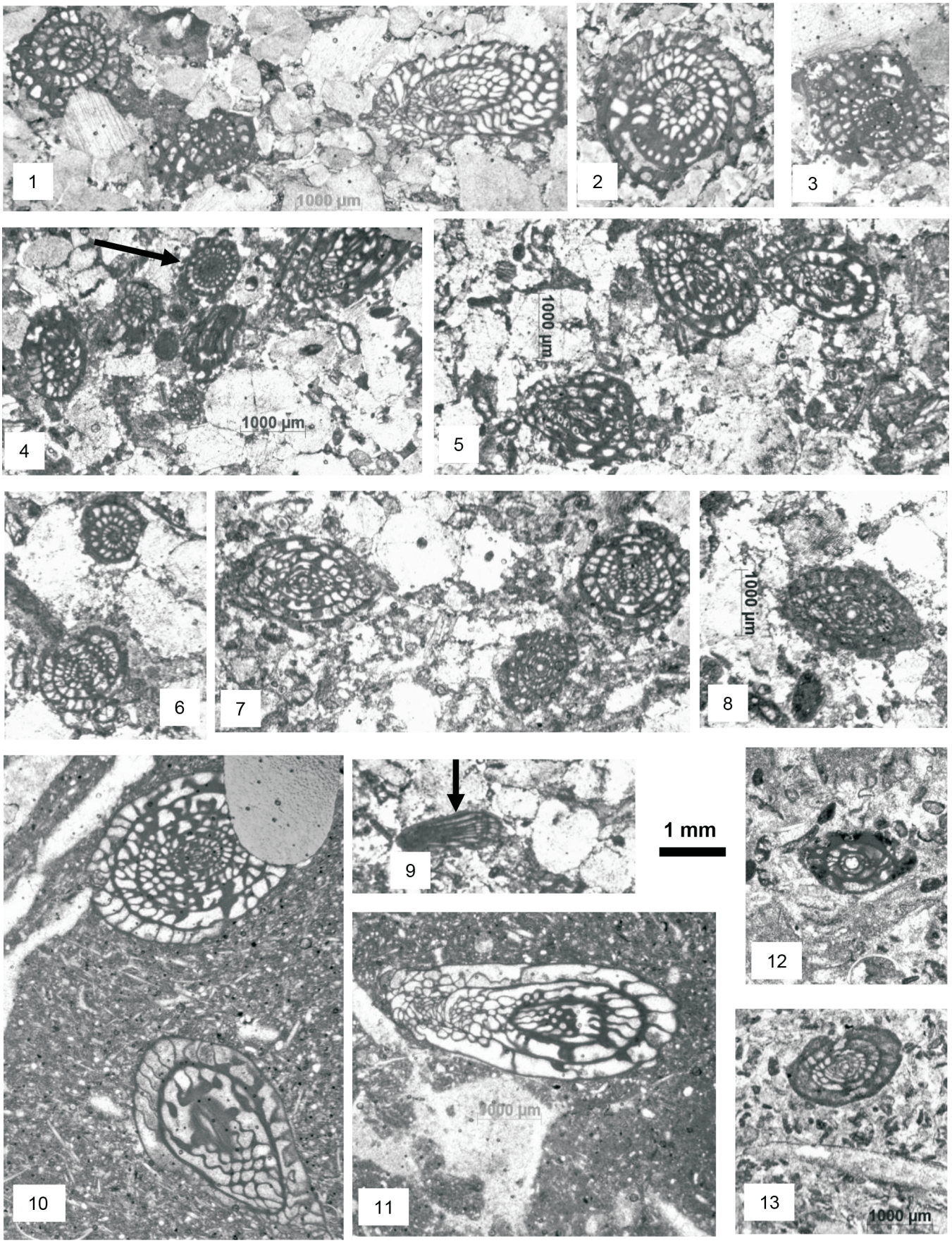
4-9 Similar crinoid-fusulinid packstone from sample ACLR 3.12, containing medium-sized and inflated *Beedeina* cf. *B. novamexicana* (Needham 1937) with intense irregular septal fluting, and sparse specimens of *Wedekindellina* sp. (arrows in 4 and 9), indicating Df2 Zone.

10 Moderately large *Beedeina* aff. *B. euryteines* (Thompson 1934) from sample ACLR 3.10 (Df2 Zone).

11 Relatively large morphotype of *Beedeina* aff. *B. leei* (Skinner 1931), sample ACLR 3.10 (Df2 Zone).

12 Small primitive *Beedeina* sp. juvenile from sample ACLR 3.7, possibly Df1 Zone.

13 Small primitive *Beedeina* sp. juvenile from sample ACLR 3.6, probably Df1 Zone.


1
1000 µm
2
3
4
1000 µm
5
1000 µm
6
7
8
1000 µm
9
1 mm
10
11
1000 µm
12
13
1000 µm

The fusulinid assemblage of the six closely-spaced samples (ACLR 4.15 to 4.20) consists of *Beedeina euryteines*, *B. novamexicana, B. rockymontana,*, *B. socorroensis*, *B.* aff. *B. leei,* and rare small specimens of *Wedekindellina* sp. (Plate 3, figures 1-23). This assemblage is considered to represent the lower part of the late early Desmoinesian Df2 Zone. It is noteworthy that the thin-sections of several of the samples contain common sponge spicules, probably indicating relatively turbid carbonate depositional paleoenvironments adjacent to the clastic detrital tongue of the Gobbler Formation just to the north of this section.

Alamo Canyon - Long Ridge ACLR-3 Section

Twenty-three unoriented petrographic thin-sections of field samples from Bug Scuffle Limestone Member of the ACLR-3 section of Rendall et al (2019) and Rendall (2022) were examined for fusulinid biostratigraphy (text-fig. 2). Only six of the thin-sections contained fusulinids, and most of those specimens were small juveniles or oblique fragments of adults. All the fusulinids in the thin-sections were clearly Desmoinesian-aged specimens of *Beedeina* and *Wedekindellina*, but because of the poor orientations of specimens, more precise identifications and age-dates are not possible.

The lithologies, fossils, and tentative age interpretations of the ACLR-3 samples that contain fusulinids and other biostratigraphically useful fossils are summarized in Appendix I, in descending stratigraphic order. The fusulinids and associated fossils are illustrated in Plate 4, figures 1-13. Many of the petrographic thin-sections examined have spiculitic mud-rich matrices, with faunal assemblages of sparse bryozoan and brachiopod bioclasts and crinoid ossicles. Those samples probably represent low energy, rather turbid, depositional settings adjacent to the Gobbler clastic detrital tongue. Samples from some other horizons are composed of lighter gray limestones containing fusulinids and phylloid algal fragments, and those samples represent cleaner, less turbid, paleoenvironments. *Komia* was present in samples 3.14 and 3.17, indicating that those samples are probably late early Desmoinesian in age (Df2 Zone).

In summary, based on the analyses of unoriented petrographic thin-sections, the ACLR-3 measured section is interpreted as follows. The CSB2 composite sequence boundary is at 156.5 m (513.5 ft), which is above any of the fusulinid-bearing samples. The uppermost fusulinid samples ACLR 3.19 (100.5 m = 329.7 ft) and ACLR 3.18 (97 m = 318.2 ft) contain medium sized oblique specimens of *Beedeina* sp. (Plate 4, figures 1-3), and contain no *Wedekindellina* or *Komia*, and are interpreted to represent the Df3 Zone. The CSB1 composite sequence boundary is lower in the section at 89 m (292 ft). The underlying samples ACLR 3.17 (89 m = 292 ft) and ACLR 3.14 (69.8 m = 229 ft) contain no fusulinids, but do have specimens of *Komia*, and are interpreted as Df2 Zone. Samples ACLR 3.12 (68 m = 223.1 ft) and ACLR 3.10 (56.6 m = 185.7 ft) contain *Beedeina* cf. *B. novamexicana*, *B.* cf. *B. euryteines*, *B.* aff. *B. leei,* and *Wedekindellina* sp. (Plate 4, figures 4-11), representing the Df2 Zone. The lowermost samples ACLR 3.7 (39.6 m = 130 ft) and ACLR 3.6 (38 m = 129.2 ft) contain only rare small oblique specimens of *Beedeina* sp. (Plate 4, figures 12-13), and can only be placed in the Df2-Df1 Zone.

PLATE 5

Desmoinesian fusulinids of Bug Scuffle Limestone Member from SMDC-4 measured section in Dog Canyon (see text-figure 2). Fusulinids are from unoriented petrographic thin-sections and so are tentatively identified and assigned to fusulinid zones. The heights of sample numbers in the measured section are given in the sample descriptions in the text and Appendix 1. All photos at ×10, scale bar = 1 mm.

1 *Beedeina* sp. from sample SMDC 4.34. (Df3 Zone). Specimens of *Beedeina* sp. in samples SMDC 4.34 and 4.30 are assigned to the Df3 Zone because the samples occur above the CSB1 composite sequence boundary, and above the uppermost occurrences of *Wedekindellina* and *Komia*.

2 *Beedeina* sp. from sample SMDC 4.30. (Df3 Zone, see note in figure 1 caption).

3 *Komia* fragment from sample SMDC 4.24 (Df2 Zone).

4-5 *Beedeina* sp. from sample SMDC 4.23 (Df2 Zone).

6-7 *Wedekindellina* sp. from sample SMDC 4.16 (Df2 Zone).

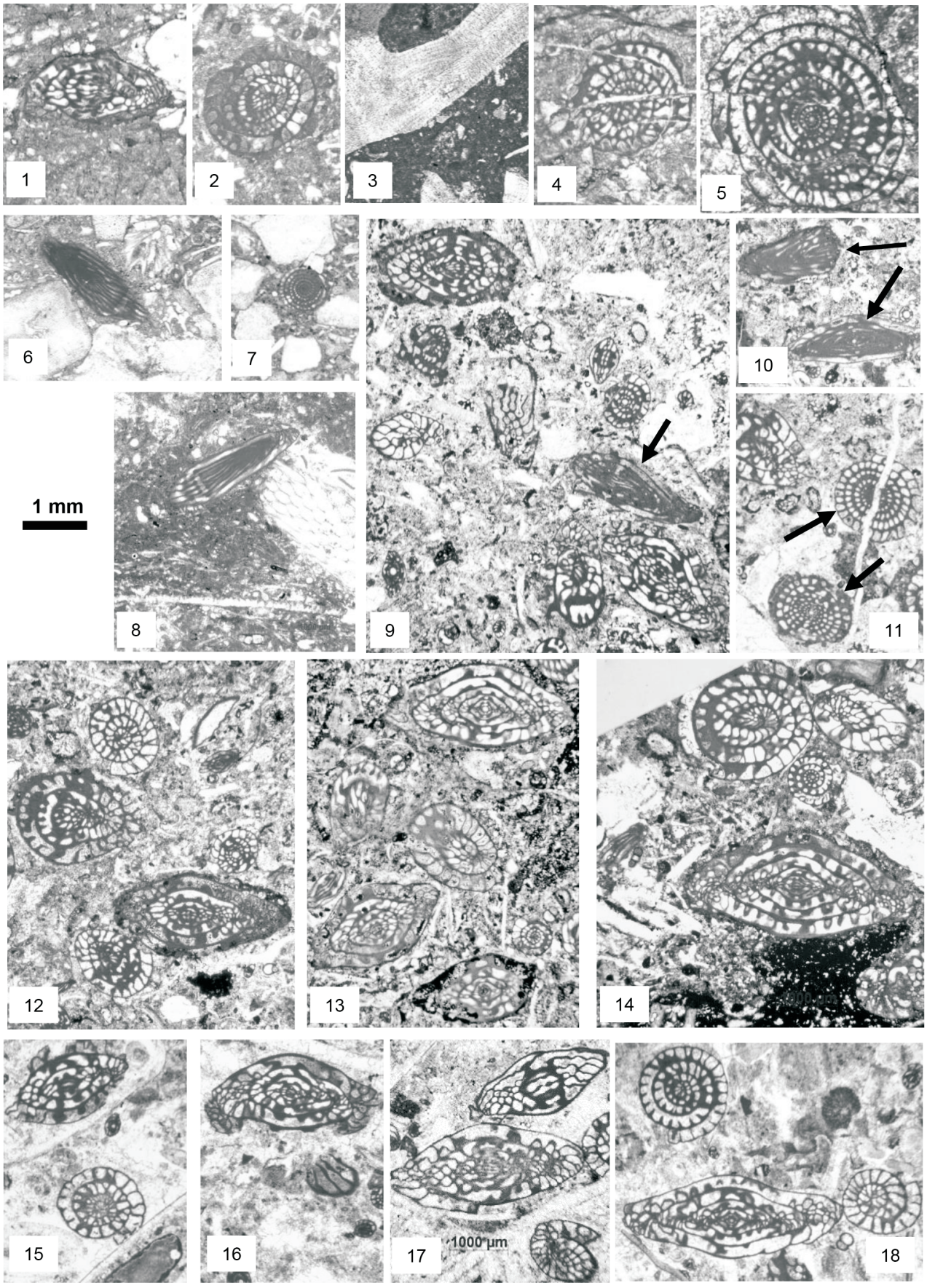
8 *Wedekindellina* sp. from sample SMDC 4.14 (Df2 Zone) with bryozoan and dasycladacean alga fragment.

9-12 *Beedeina* cf. *B. euryteines* (Thompson 1934) and *Wedekindellina* cf. *W. euthysepta* (Henbest 1928) (arrows in 9-11) from SMDC 4.8 (Df2 Zone).

13-14 *Beedeina* cf. *B. euryteines* (Thompson 1934) from SMDC 4.7 (Df2 Zone).

15-17 *Beedeina hayensis* (Ross and Sabins 1965) sp. from SMDC 4.6 (Df1 Zone).

18 Small morphotype of *Beedeina* cf. *B. leei* (Skinner 1931) from SMDC 4.6 (DF1 Zone).


1
2
3
4
5
6
7
8
9
10
11
1 mm
12
13
14
15
16
17
1000 µm
18

Dog Canyon Sections

Dog Canyon is the northernmost of a group of canyons in the southern part of the Bug Scuffle limestone outcrop belt (text-fig. 2) that have very thick sections of the Bug Scuffle Limestone Member. Samples from the measured sections SMDC-2 and SMDC-4 of Rendall et al. (2019) and Rendall (2022) were examined for biostratigraphic analysis.

Dog Canyon SMDC-4 Section

Unoriented petrographic thin-sections of 17 field samples from the SMDC-4 measured section were examined for biostratigraphic analysis. Many of the fusulinids in the petrographic thin-sections were not well-oriented and not well-preserved (Plate 5, figures 1-18), and so age determinations are somewhat tentative. The lithologies and fusulinids of the thin-sectioned samples are summarized in Appendix I, in descending stratigraphic order, with the heights above the base of the measured section following the sample numbers. The fusulinids in the samples are illustrated in Plate 5, figures 1-18.

The uppermost sample SMDC-4.38 (183.5 m = 602 ft) is from an organic mound facies in the uppermost Bug Scuffle limestone sequence above the CSB2 composite sequence boundary, and contains no biostratigraphically significant fossils. The CSB2 composite sequence boundary is about 22 m (72 ft) below. Samples SMDC 4.35 down to SMDC 4.28 (153.5 – 117 m = 503.6 – 384 ft) contained only very sparse, small, poor specimens of *Beedeina* sp. (Plate 5, figures 1-2), confirming a Desmoinesian age, and considering the stratigraphic position above the CSB1 composite sequence boundary and the absence of associated *Wedekindellina* or *Komia*, this interval is interpreted to be late Desmoinesian in age (Zone Df3-Df4). Samples SMDC-4.24 to SMDC-4.20 (84.5 – 68.5 m = 277 – 225 ft) contain *Komia* (plate 5, figure 3), sparse oblique specimens of *Beedeina* sp., one being large and complexly fluted (Plate 5, figures 4-5), and sparse small juvenile specimens of *Wedekindellina*, and so this interval is interpreted to be late early Desmoinesian (Zone Df2). Samples SMDC 4.16 down to SMDC 4.7 (48 – 14.5 m = 157.5 – 47.6 ft) contain *Beedeina* cf. *B. euryteines* and *Wedekindellina* cf. *W. euthysepta* (Plate 5, figures 6-14) and are interpreted the lower part of the Df2 Zone. Samples SMDC 4.6 and SMDC 4.5 (13.8 – 5.7 m = 45.3 – 18.7 ft) contain small specimens of *Beedeina hayensis* (Pl. 5, figs. 15-17), and *Beedeina* cf. *B. leei* (Plate 5, figure 18), and are interpreted to represent the early early Desmoinesian Df1 Zone. Samples below SMDC-4.5 contained no fusulinids or other biostratigraphically useful fossils.

Dog Canyon SMDC-2 Section

Twenty-three hand samples were examined from the Dog Canyon SMDC-2 measured section (text-fig. 2), and oriented fusulinid thin-sections were made from 6 samples. Plate 6 shows specimens from the upper part of the SMDC-2 section and Plate 7 shows fusulinids from the lower part of the section. The lithologies and fusulinids from those six fusulinid-bearing samples are briefly described in Appendix I, in descending stratigraphic order. Note that the uppermost samples from above the CSB2 composite sequence boundary were also analyzed by James Barrick for conodont biostratigraphy, and those results are discussed in the paragraph below.

Conodont analyses: The following uppermost samples of the Bug Scuffle Limestone Member from above the CSB2 composite sequence boundary were processed for conodont biostratigraphic analyses by James Barrick: SMDC-2.27 (240 m = 787.4 ft), SMDC-2.26 (236.5 m = 775.9 ft), SMDC-2.25 (230.5 m = 756.2 ft), SMDC-2.24 (224.7 m = 737.2 ft). Samples 2.24 and 2.26 contained undiagnostic shallow water conodonts (*Adetognathus latus*, *Idiognathodus* sp., and *Hindeodus* sp.), and sample 2.25 was barren. The uppermost sample 2.27 had a similar shallow water conodont assemblage as the lower samples, but also contained *Idiognathodus* P1 elements that possessed some early Missourian features, and the sample lacked any typical Desmoinesian conodonts. Nevertheless, Barrick (personal communication) concluded that the conodont assemblage in sample 2.27 could not be age-dated with confidence.

PLATE 6

Late Desmoinesian (Df3-Df4 Zones) oriented fusulinids from Bug Scuffle Limestone Member in upper part of SMDC-2 measured section in Dog Canyon (see text-figure 2). The heights of sample numbers in the measured section are given in the sample descriptions in the text and Appendix 1. Samples SMDC 2.24 and 2.21 (Figures 1-11) are from just above the CSB2 composite sequence boundary and contain Df4 Zone fusulinids, and samples SMDC 2.16 and 2.17 (Figures 12-16) are from somewhat above the CSB1 sequence boundary and contain Df3 Zone fusulinids. All specimens from oriented fusulinid thin-sections. All photos = ×10, scale bar = 1 mm.

1-3 *Beedeina vintonensis* (Stewart 1958) from sample SMDC 2.24 (Df4 Zone).

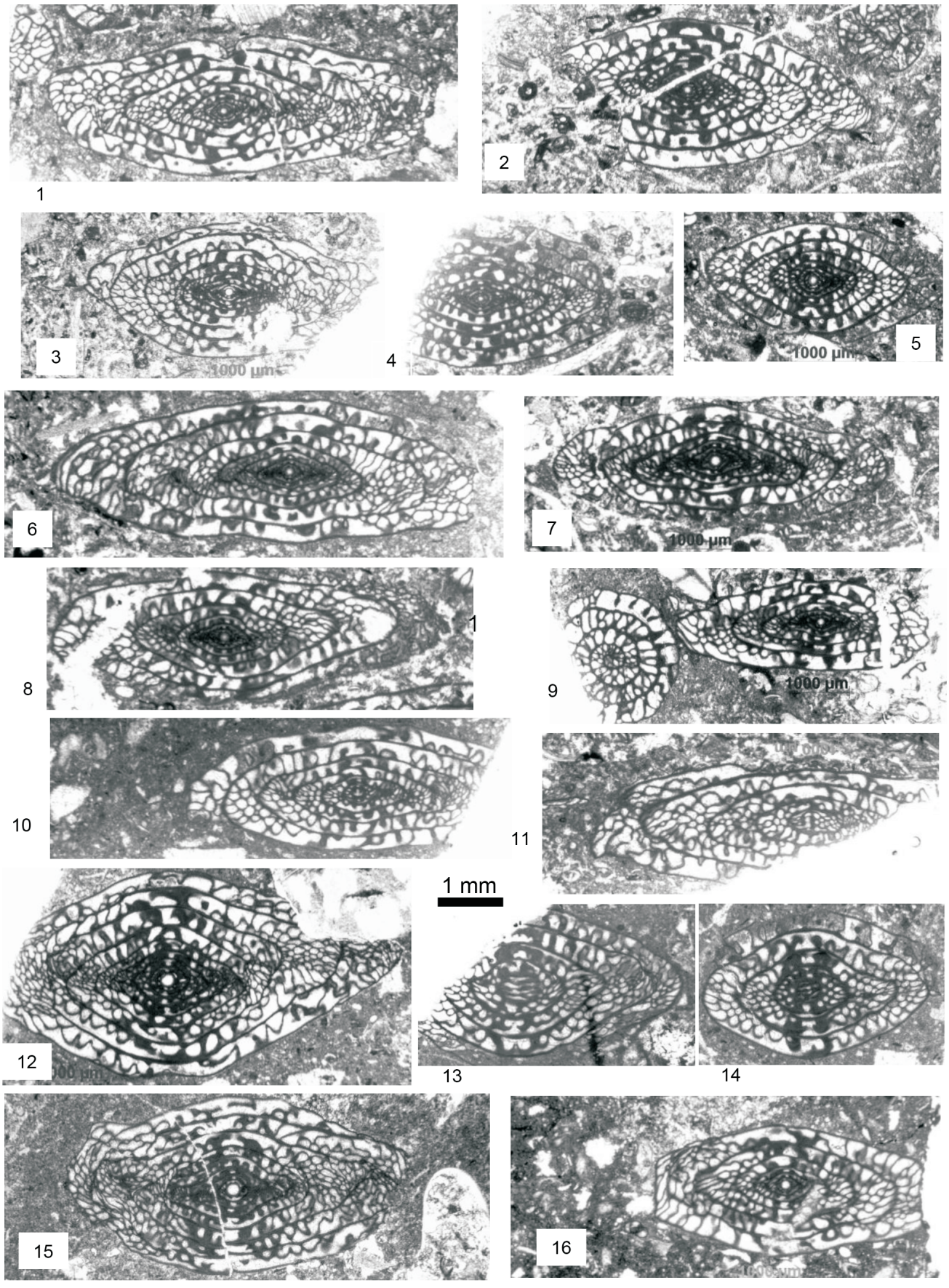
4-5 *Beedeina gordonensis* (Stewart 1958), from sample SMDC 2.24 (Df4 Zone).

6-11 *Beedeina mysticensis* (Thompson 1934), from sample SMDC 2.21 (Df4 Zone).

12-14 *Beedeina illinoisensis* (Dunbar and Henbest 1942), from sample SMDC 2.17 (Df3 Zone).

15 *Beedeina tumida* (Alexander 1954), from sample SMDC 2.16 (Df3 Zone).

16 *Beedeina haworthi* (Beede 1916), from sample SMDC 2.16 (Df3 Zone).


1
2
3
1000 µm
4
5
1000 µm
6
7
1000 µm
8
9
1000 µm
10
11
1 mm
12
13
14
15
16

The uppermost fusulinid samples analyzed were from above the CSB2 sequence boundary (212 m = 695 ft). Samples SMDC 2.24 (224.7 m = 737.2 ft) and SMDC 2.21 (214.9 m = 705 ft) contain *Beedeina vintonensis* (Pl. 6, figs. 1-3), *B. gordonensis* (Pl. 6, figs. 4-5), and *B. mysticensis* (Pl. 6, figs. 6-11), which indicate the late late Desmoinesian Df4 Zone. Lower samples that are still above the CSB1 composite sequence boundary (129 m = 423.2 ft), samples SMDC 2.17 (178.4 m = 585.3 ft) and SMDC 2.16 (152.5 m = 500.3 ft), contain *Beedeina illinoisensis* (pl. 6, figs. 12-14), *B. tumida* (Pl. 6, fig. 15), and *B. haworthi* (Plate 6, figure 16), which indicate the early late Desmoinesian Df3 Zone. Samples below the CSB1 surface, samples SMDC 2.14 (126.5 m = 415 ft) and SMDC 2.10 (58.5 m = 192 ft), contain *B. novamexicana* (Plate 7, figures 1-9), *B. euryteines* (Plate 7, figures 14-16), *Wedekindellina excentrica* (Plate 7, figures 10 and 11-13), and the microproblemtical fossil *Komia*, which indicate the late early Desmoinesian Df2 Zone.

Ed Canyon Section

Ed Canyon is near the southern end of the Bug Scuffle Limestone Member outcrop belt just to the north of Bug Scuffle Canyon (text-fig. 2). (Note that the historical name of the canyon has been shortened in order to remove an inappropriate adjective reference.) The graphic measured section of Ed Canyon illustrated by Wilson (1989, figure 2B) showed an approximately 410 m (1345 ft) thick Gobbler Formation section. Only the basal approximately 10 m (33 ft) of Wilson's measured section were shown as clastic facies. Wilson questionably cited fusulinid *Profusulinella*? (middle to late Atokan) from that basal clastic interval, but then also added a note on the cross-section saying: "It is possible that the basal strata are lower Desmoinesian". In the overlying approximately 30 m (98 ft) of limestone section, he cited the sclerosponge *Chaetetes* and the primitive fusulinid *Millerella*, which is an assemblage that is more characteristic of Morrowan-Atokan strata throughout the region. At around 100 m (328 ft) above the base of his measured section, Wilson cited *Fusulinella-Fusulina* twice, which translates into the transitional *Fusulinella iowensis* Zone that straddles the Atokan-Desmoinesian boundary (ADf Zone of Wahlman 2019). At approximately 120 m (394 ft) above the base of the measured section, Wilson cited *Fusulina* (= *Beedeina*), which based on the stratigraphic level is probably the early Desmoinesian Df1 Zone. From approximately 140 m to 170 m (459 – 558 ft), he cited both *Fusulina* (= *Beedeina*) and *Wedekindellina*, which indicate an early Desmoinesian age (Cherokee), and based on the stratigraphic level is probably the late early Desmoinesian Df2 Zone. At approximately 200 m (656 ft) he showed a bentonitic shale, which could be related to the middle Desmoinesian CSB1 composite sequence boundary. From approximately 270 m (886 ft) to the top of the section at 410 m (1345 ft), he cited *Fusulina* (= *Beedeina*) at four different horizons with no other associated fusulinids or other significant biostratigraphic data cited, which considering the high stratigraphic horizons and the apparent absence of *Wedekindellina* and *Komia*, almost certainly indicate a late Desmoinesian age (Df3-Df4 Zones, Marmaton).

Wilrich (1999) described a short measured section from the South Fork of Ed Canyon that covered only the uppermost 38.5 m (126.3 ft) of the Bug Scuffle Limestone Member. He described the basal 1.75 m (5.7 ft) of that interval as a sandy, mottled, wackestone with common fusulinids. The overlying 4.5 m (14.8 ft) was described as a cherty wackestone with crinoid ossicles, brachiopods, and horn corals. And the remainder of the overlying section (approximately 32 m =105 ft) was cited as unfossiliferous mudstone-wackestone with several covered intervals. The fusulinid thin-sections from Wilrich's (1999) sample horizon at 38.5 m (126.3 ft) below the top of the Bug Scuffle Limestone Member were re-evaluated herein and photomicro-

---

PLATE 7

Early Desmoinesian (Df2 Zone) fusulinids of Bug Scuffle Limestone Member from lower part of SMDC-2 measured section in Dog Canyon (see text-figs. 2 and 5). Fusulinid thin-sections were oriented. The heights of sample numbers in the measured section are given in the sample descriptions in the text and Appendix 1. All photos = ×10, except for figures 4 and 10 = ×25; all scale bars = 1 mm.

1-3 *Beedeina novamexicana* (Needham 1937) and associated *Komia* fragments in skeletal packstone of sample SMDC 2.14 (Df2 Zone).

4 *Komia* fragments in skeletal packstone of sample SMDC 2.14 (Df2 Zone).

5-9 *Beedeina euryteines* (Thompson 1934) in skeletal packstone with *Komia* fragments from sample SMDC 2.14 (Df2 Zone).

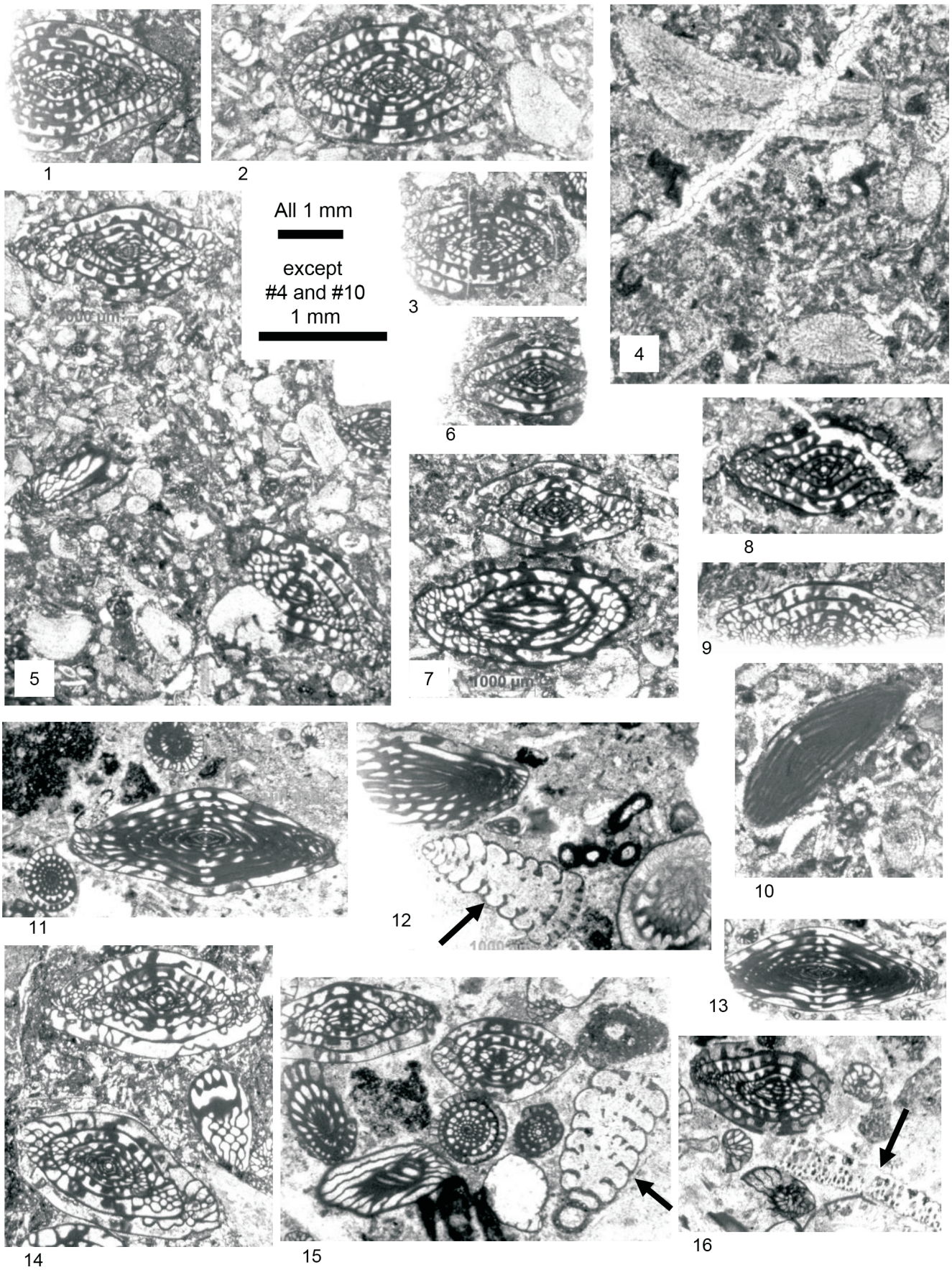
10 *Wedekindellina* cf. *W. excentrica* (Roth and Skinner 1930) and small *Komia* fragment (lower right) from sample SMDC 2.14 (Df2 Zone).

11-13 *Wedekindellina excentrica* (Roth and Skinner 1930) with associated smaller foraminifer *Climacammina* in figure 12 (arrow) from sample SMDC 2.10 (Df2 Zone).

14 *Beedeina euryteines* (Thompson 1934) from sample SMDC 2.10 (Df2 Zone).

15 *Beedeina euryteines* (Thompson 1934), a small sagittal section of *Wedekindellina* sp. (center), and a *Climacammina* smaller foraminifer (arrow) from sample SMDC 2.10 (Df2 Zone).

16 *Beedeina euryteines* (Thompson 1934) with a dasycladacean algal fragment (arrow) from sample SMDC 2.10 (Df2 Zone).


1
2
All 1 mm
except
#4 and #10
1 mm
3
4
5
6
7
8
9
10
11
12
13
14
15
16

graphs of his specimens are shown on Plate 8, figures 1-10. The fusulinids from that basal unit of the measured section are identified in this study as *Beedeina bellatula* Stewart (Plate 8, figures 1-9) and *B. lonsdalensis* Dunbar and Henbest (Plate 8, figures 9-10), both of which indicate the latest Desmoinesian Df4 Zone.

Table Top Mesa Section

Table Top Mesa is the ridge on the south side of Ed Canyon that separates it from Bug Scuffle Canyon, the next canyon to the south (text-fig. 2). Rendall collected 28 field samples from the Bug Scuffle Limestone in his Table Top Mesa measured section SMTT, and seven of those samples were found to contain fusulinids. Thirty-six oriented fusulinid thin-sections were made from those seven samples. Samples from the upper part of the section are partly silicified. The lithologies and fusulinid assemblages in the fusulinid-bearing samples are summarized in Appendix 1, in descending stratigraphic order, with heights above the base of the measured section following the sample numbers. Late Desmoinesian fusulinids (Zones Df3-Df4) are illustrated in Plate 9, figures 1-13, and early Desmoinesian fusulinids (Zone Df2) are illustrated in Plate 10, figures 1-24.

In summary, the uppermost fusulinid sample SMTT 1.28 (167.5 m = 549.5 ft), which is from just below the CSB2 boundary (185.5 m = 608.6 ft) near the top of the Table Top section, contains *Beedeina megista*, *B. acme*, and *B. bellatula*, which indicate the late late Desmoinesian Df4 Zone. This sample cannot be confidently correlated directly with the Ed Canyon fusulinid sample of Wilrich (1999) described in the above section, but both samples contain Df4 Zone fusulinids, including *Beedeina bellatula*. Samples SMTT 1.22 (114.4 m = 375.3 ft) and SMTT 1.21 (99 m = 324.8 ft) contain *Beedeina* cf. *B. haworthi*, which indicates the early late Desmoinesian Df3 Zone. Below the CSB1 composite sequence boundary (98 m = 321.5 ft), samples SMTT 1.9 (16 m = 52.5 ft), SMTT 1.8 (15.5 m = 50.8 ft), SMTT 1.5 (5.5 m = 18 ft), and SMTT 1.4 (4.5 m = 14.8 ft) contain *Beedeina euryteines*, *B. novamexicana*, *B.* cf. *B. leei*, *Wedekindellina euthysepta*, and *W. excentrica*, with associated *Komia*, which are indicative of the late early Desmoinesian Df2 Zone.

Bug Scuffle Canyon Section

Bug Scuffle Canyon is located near the southern end of the Bug Scuffle Limestone Member outcrop belt. with the Table Top Mesa ridge discussed above separating it from Ed Canyon (text-fig. 2). The fusulinids discussed herein are from the thin-section collection of Wilrich (1999), and are from two measured sections of the Bug Scuffle Limestone Member within Bug Scuffle Canyon. Measured Section #1 of Wilrich (1999) is near the mouth of Bug Scuffle Canyon and covers the lower part of the Bug Scuffle Limestone Member. Measured Section #2 of Wilrich (1999) was referred to as the Central and Upper Bug Scuffle Canyon section, and it partially covers the middle and upper parts of the Bug Scuffle Limestone Member. As discussed above, Wilrich (1999) also measured and sampled a third section just to the north in the adjacent Ed Canyon, and that measured section covered only the uppermost 38.5 m (126.3 ft) of the Bug Scuffle Limestone Member.

Bug Scuffle Canyon Measured Section #1 of Wilrich (1999) was in a northwest tributary canyon near the mouth of Bug Scuffle Canyon. The base of that section was said to be at an elevation of 4718 ft (1438 m) and the thickness of the measured section was 261.3 ft (79.65 m), which covered the lower part of the Bug Scuffle Limestone Member. Samples from that section were labelled BSCNWT (= Bug Scuffle Canyon Northwest Tributary). Wilrich (1999) cited six horizons containing fusulinids in this measured section, but he only described and illustrated one fusulinid from the section, and that specimen was from the uppermost sample near the top of the measured section. That sample was labelled BSCNWT 1-20, and the single thin-section in his slide collection contained one specimen of *Wedekindellina excentrica* (Plate 11, figure 14). That sample is interpreted here to indicate the lower part of the late early Desmoinesian Df2 Zone.

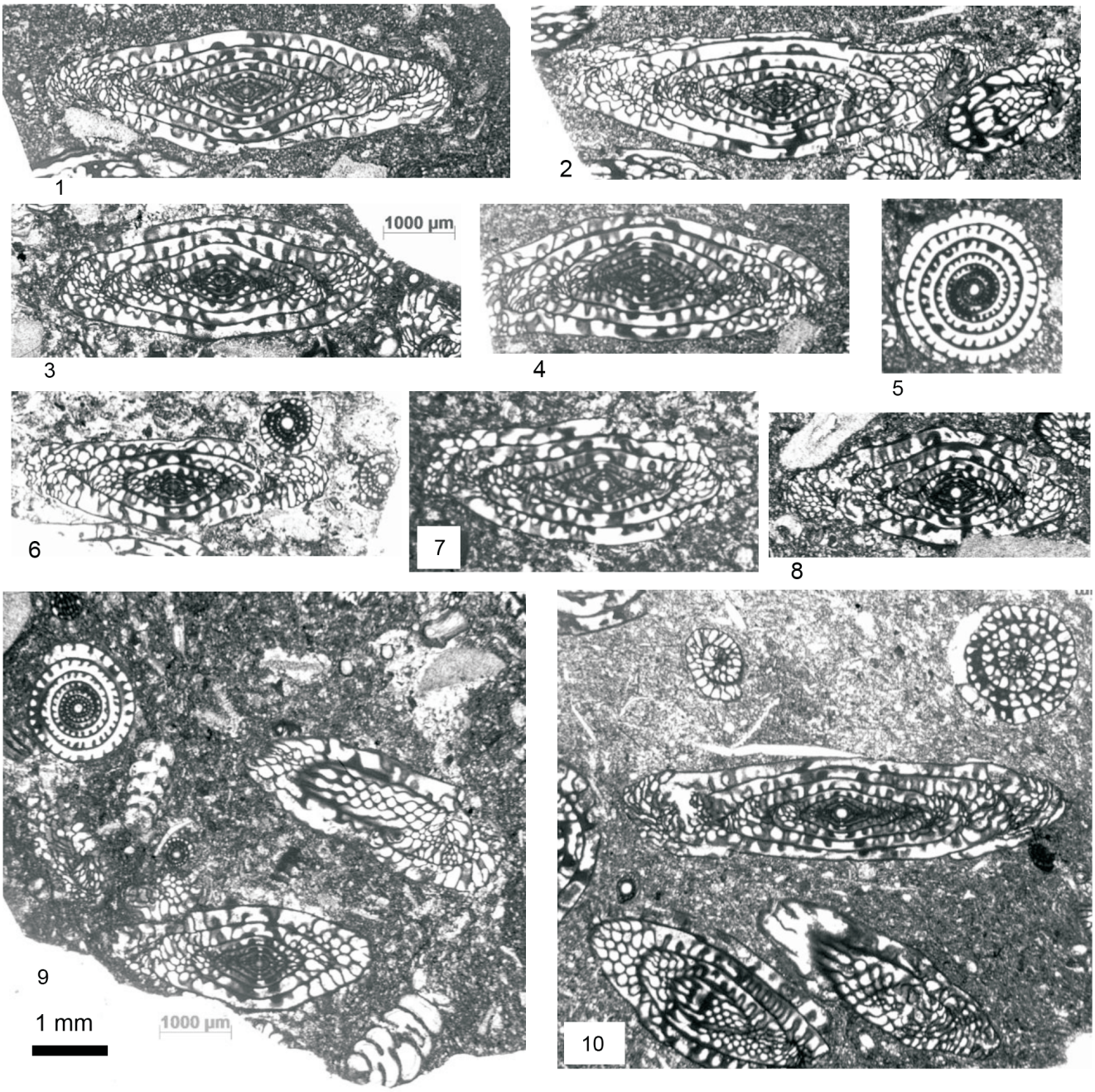
PLATE 8

Late late Desmoinesian (Df4 Zone) fusulinids of upper Bug Scuffle Limestone Member from Ed Canyon (see text-figs. 2 and 5).
Oriented fusulinid thin-sections from Wilrich (1999) collection.
All fusulinids from Sample SFNEC 3-1 at 38.5 m (126.3 ft) below the top of the member.
All photos = ×10, scale = 1 mm.

1-8 *Beedeina bellatula* (Stewart 1958). These specimens also resemble *B. sulphurensis* (Ross and Sabins 1965) from Arizona, but they have a larger shell size, a more fusiform shell shape, a smaller proloculus, and secondary deposits in the early volutions. These Bug Scuffle specimens are slightly larger than the types of *B. bellatula* from north-central Texas and have slightly less intense and regular septal fluting.

9 *Beedeina bellatula* (Stewart 1958) (lower middle of photo), and an oblique tangential section of an elongate specimen that is probably *B. lonsdalensis* (Dunbar and Henbest 1942) (right middle), a saggital section of a probable *B. lonsdalensis* (upper left), and two *Climacammina* sp. smaller foraminifers.

10 Elongate axial specimen of *Beedeina lonsdalensis* (Dunbar and Henbest 1942), and a few oblique specimens of *Beedeina* sp.


1
2
1000 µm
3
4
5
6
7
8
9
1 mm
1000 µm
10

Bug Scuffle Canyon Measured Section #2 of Wilrich (1999) was referred to as the Central to Upper Section of the Bug Scuffle Limestone Member. The base of that section was at an elevation of 5600 ft (1707 m) and the section was 321.7 ft (98.05 m) thick. Samples from that section were labelled BSCCUS or BSCCUST. Wilrich noted four fusulinid-bearing horizons in the lower 98 ft (30 m) of the measured section, but no fusulinids were reported from the overlying upper 223 ft (68 m) of the section. Sample BSCCUS 2-1 is from the basal 5.7 ft (1.75 m) thick unit of the measured section, and it is similar to the BSCNWT 1-20 sample from the section near the mouth of the canyon section, as it contains only *Wedekindellina euthysepta* (Plate 11, figures 10-13), and is assigned to the Df2 Zone. Samples labelled as BSCCUS 2-14 came from a unit 65 ft (19.8 m) above the base of the measured section and contained specimens identified herein as *Beedeina haworthi*, which indicates the Df3 Zone. In Wilrich's measured section, there is a thin conglomerate just below the BSCCUS 2-14 sample bed, which probably represents the CSB1 composite sequence boundary. Other thin-sections in the Wilrich slide set were labelled only as BSCCUS or BSCCUST (Plate 11, figures 1-4), the latter being said to be from a tributary canyon west of the measured section, but no exact heights in the measured section were given. According to the Wilrich (1999) measured section description, which notes the horizons of fusulinid occurrences, those fusulinids probably came from horizons either at 76.4 ft (23.3 m) or 98.4 ft (30 m) above the base of the section, as there are no other fusulinid samples cited from higher in the measured section description. Those samples contain similar moderately large-sized, fusiform specimens of *Beedeina* with fairly intense and irregular septal fluting, which are identified herein as *Beedeina haworthi* (Plate 11, figures 1-5) that appear to be forms that are grading into the more advanced *Beedeina megista*, and elongate fusiform morphotypes identified herein as *Beedeina sulphurensis* (Ross and Sabins 1965) (Plate 11, figures 6-8), a species originally described from the Horquilla Limestone in southeastern Arizona. Myers (1988) reported *B. sulphurensis* from the Df3 Zone of the Manzano Mountains section on the north side of the Orogrande Basin in south-central New Mexico. These samples are age-dated as early late Desmoinesian Zone Df3.

It should be noted that the three measured sections of Wilrich (1999) in Bug Scuffle Canyon and Ed Canyon add up to a total of 709.3 ft (216.2 m) of the Bug Scuffle Limestone Member, and he did not discuss or illustrate how the three sections correlated with one another. Wilrich (1999) cited the Bug Scuffle Limestone Member in the study area as being approximately 1000 ft (304.8 m) thick, but the sum of the thicknesses of Wilrich's three measured sections is considerably thinner. Both from the measured section locations and the contained fusulinid assemblages, it appears that his section #1 from near the mouth of Bug Scuffle Canyon is in the lower part of the Bug Scuffle Limestone Member (DF1 to lower Df2 Zone), the Central-to-Upper Bug Scuffle Canyon section #2 contains fusulinids representing the Df2 and Df3 Zones, and the Ed Canyon sample from the uppermost Bug Scuffle Limestone Member is in the Df4 Zone.

Grapevine Canyon Section

Grapevine Canyon is the southernmost canyon in the Sacramento Mountains escarpment with fusulinid data from the Bug Scuffle Limestone Member (text-figs. 2 and 5). Only three fusulinid samples are presently available from Grapevine Canyon. The three samples examined were sent to Wahlman by James Lee Wilson for fusulinid age-dating in 1992, but no measured section was provided. Photomicrographs of the fusulinids in those samples are in Plate 12, figures 1-12.

The first sample was labelled as being from the base of the Bug Scuffle Limestone Member, and it contains two specimens of *Beedeina insolita* (Plate 12, figures 10-12), which is considered to be the most primitive species of the genus. That species was cited as the characteristic nominative species of the earliest Desmoinesian fusulinid zone (Df1 Zone) by Thompson (1948), Clopine (1992), Wahlman (2019), and others.

PLATE 9

Late Desmoinesian (Df3-Df4 Zones) fusulinids of Bug Scuffle Limestone Member from the upper part of the Table Top Mesa measured section between Ed Canyon and Bug Scuffle Canyon (see text-figs. 2 and 5).
The heights of sample numbers in the measured section are given in the sample descriptions in the text and Appendix 1.
Fusulinid thin-sections were oriented. Fusulinids in figures 1-9 and 13 are silicified.
All photos = ×10, scale = 1 mm.

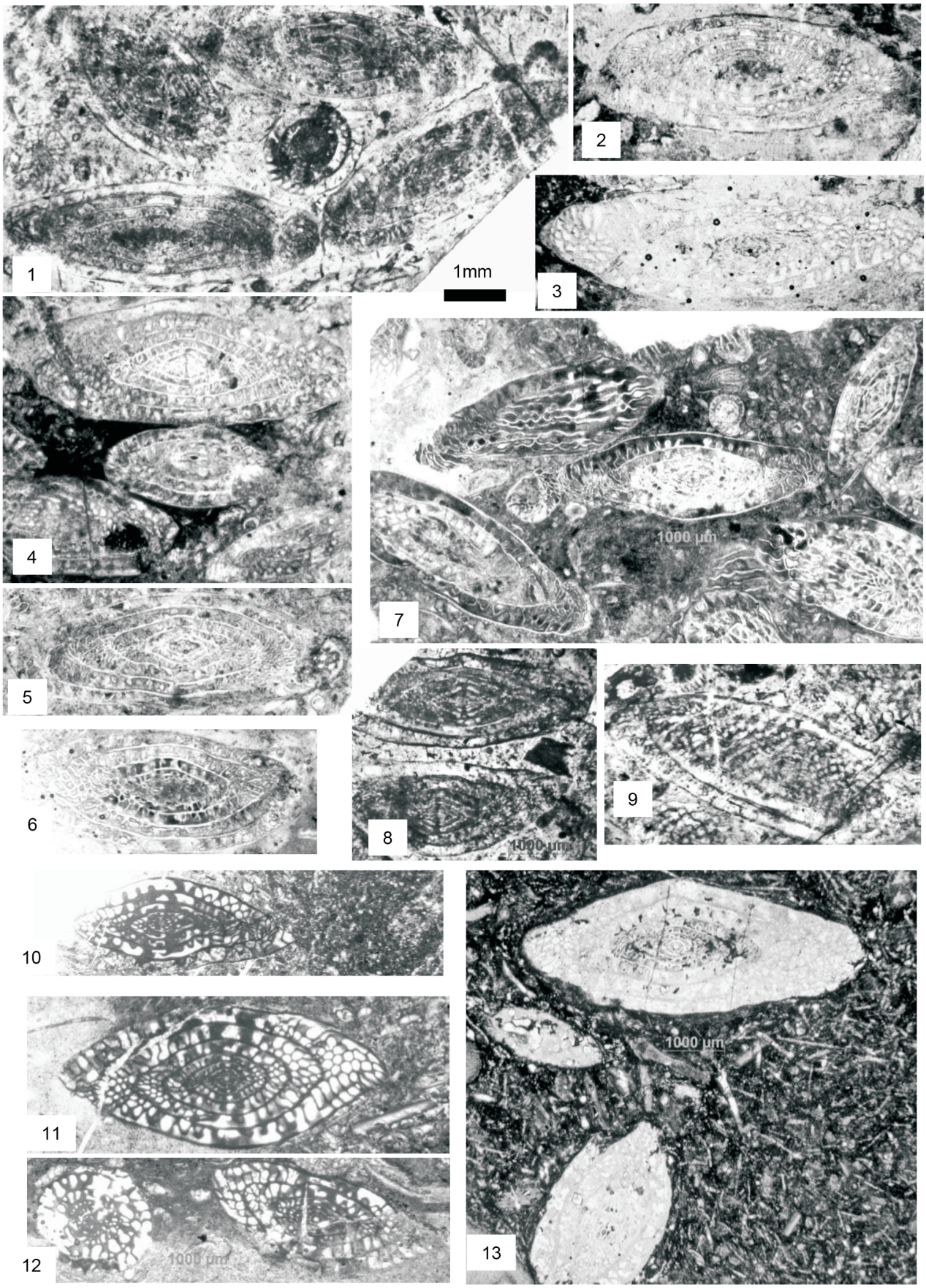
1-3 Silicified specimens of *Beedeina megista* (Thompson 1934), from sample SMTT 1.28 (Df4 Zone).

4-6 Silicified specimens of *Beedeina acme* (Dunbar and Henbest 1942) from sample SMTT 1.28 (Df4 Zone).

7-9 Silicified specimens of *Beedeina bellattula* (Stewart 1958), from sample SMTT 1.28 (Df4 Zone).

10 *Beedeina* cf. *B. haworthi* (Beede 1916), from sample SMTT 1.22 (Df3 Zone).

11-13 *Beedeina* cf. *B. haworthi* (Beede 1916), from sample SMTT 1.21 (Df3 Zone), with the silicified specimens in figure 13 surrounded by dark spicultic packstone matrix.


1
1mm
2
3
4
5
6
7
1000 µm
8
1000 µm
9
10
11
12
1000 µm
13
1000 µm

The other two Grapevine Canyon samples were labelled GC 250-1 and GC 250–2. Wilson did not specify the horizon where those samples were collected, but it is probable that they are from 250 ft (76 m) above the base of the Bug Scuffle Limestone in his Grapevine Canyon section. That tentative conclusion is supported by the species identified in the two samples, which are *Beedeina joyitaensis* (Plate 12, figures 1-3), *B. novamexicana* (Plate 12, figures 5-7), and *Wedekindellina euthysepta* (Plate 12, figures 4 and 8-9), all of which indicate the late early Desmoinesian Df2 Zone.

FUSULINID BIOSTRATIGRAPHIC ZONES IN THE BUG SCUFFLE LIMESTONE MEMBER OF THE GOBBLER FORMATION

As discussed previously, earlier publications and theses on the clastic detrital facies of the lower part of the Gobbler Formation cited fusulinid and conodont data indicating Morrowan, Atokan, and earliest Desmoinesian intervals (Benne 1975).

Fusulinid data from the Bug Scuffle Limestone Member, which constitutes most of the Gobbler Formation in the southern and northern parts of the outcrop belt, range in age from earliest Desmoinesian through latest Desmoinesian. The fusulinid samples studied herein from the Bug Scuffle Limestone Member document that all four Desmoinesian fusulinid zones (Zones Df1, Df2, Df3, and Df4 of Wahlman 2019) are present. Conodont data (Barrick in Wahlman and Barrick 2019, and Barrick in Lucas et al. 2021) from the uppermost limestone unit in the clastic detrital tongue of the Indian Wells Canyon area indicates that the uppermost Gobbler Formation in that area is early Missourian, but thus far no Missourian conodonts have been found in the uppermost Bug Scuffle Limestone Member in the northern and southern outcrop areas. In addition, thus far no early Missourian fusulinids, i.e., *Eowaeringella* and primitive *Triticites*, have been found in the uppermost Bug Scuffle Limestone Member.

The fusulinid assemblages and biostratigraphic zones (per the alpha-numeric zonation of Wahlman 2019) of the Gobbler Formation are summarized in text-figure 4 and are discussed briefly below, in ascending stratigraphic order.

Morrowan (Zone Mwf): According to Sanderson in Benne (1975) and Vachard in Lucas (2021), the lowermost part of the clastic detrital facies of the lower Gobbler Formation of Pray (1961) is characterized by the primitive fusulinids *Millerella* and *Eostaffella*, and the absence of any more advanced fusulinids.

Early Atokan (Zone Af1): No fusulinid data have documented this fusulinid zone, but Benne (1975) cited early Atokan conodonts in the clastic detrital facies of the lower Gobbler Formation.

Middle Atokan (Zone Af2): Wilson (1989, fig. 2B) cited a questionable *Profusulinella* sp. in the lower part of the Gobbler Formation in Ed Canyon, but that occurrence is questionable and cannot be verified.

Late Atokan (Zone Af3): Benne (1975) cited tentative age-dating by George Sanderson of late Atokan (Zone Af3) fusulinid samples from the upper part of the clastic detrital facies of the lower Gobbler Formation in Indian Wells and Grapevine Can-

---

PLATE 10

Late early Desmoinesian (Df2 Zone) fusulinids of Bug Scuffle Limestone Member from lower part of Table Top Mesa measured section between Ed Canyon and Bug Scuffle Canyon (see text-figure 2).
The heights of sample numbers in the measured section are given in the sample descriptions in the text and Appendix 1.
Fusulinid thin-sections were oriented.
All photos = ×10, scale = 1 mm.

1-8 *Beedeina* cf. *B. euryteines* (Thompson 1934) from sample SMTT 1.9.

9-10 *Wedekindellina excentrica* (Roth and Skinner 1930) from sample SMTT 1.9.

11 *Wedekindellina euthysepta* (Henbest 1928) from sample SMTT 1.9.

12 *Beedeina novamexicana* and the smaller foraminifer *Climacammina* from sample SMTT 1.9.

13-14 *Beedeina novamexicana* (Needham 1937) and *Wedekindellina euthysepta* (Henbest 1928) (arrows) from sample SMTT 1.9.

15 *Beedeina novamexicana* (Needham 1937) from sample SMTT1.8.

16 Oblique parallel saggital section of *Wedekindellina* sp. from sample SMTT 1.8.

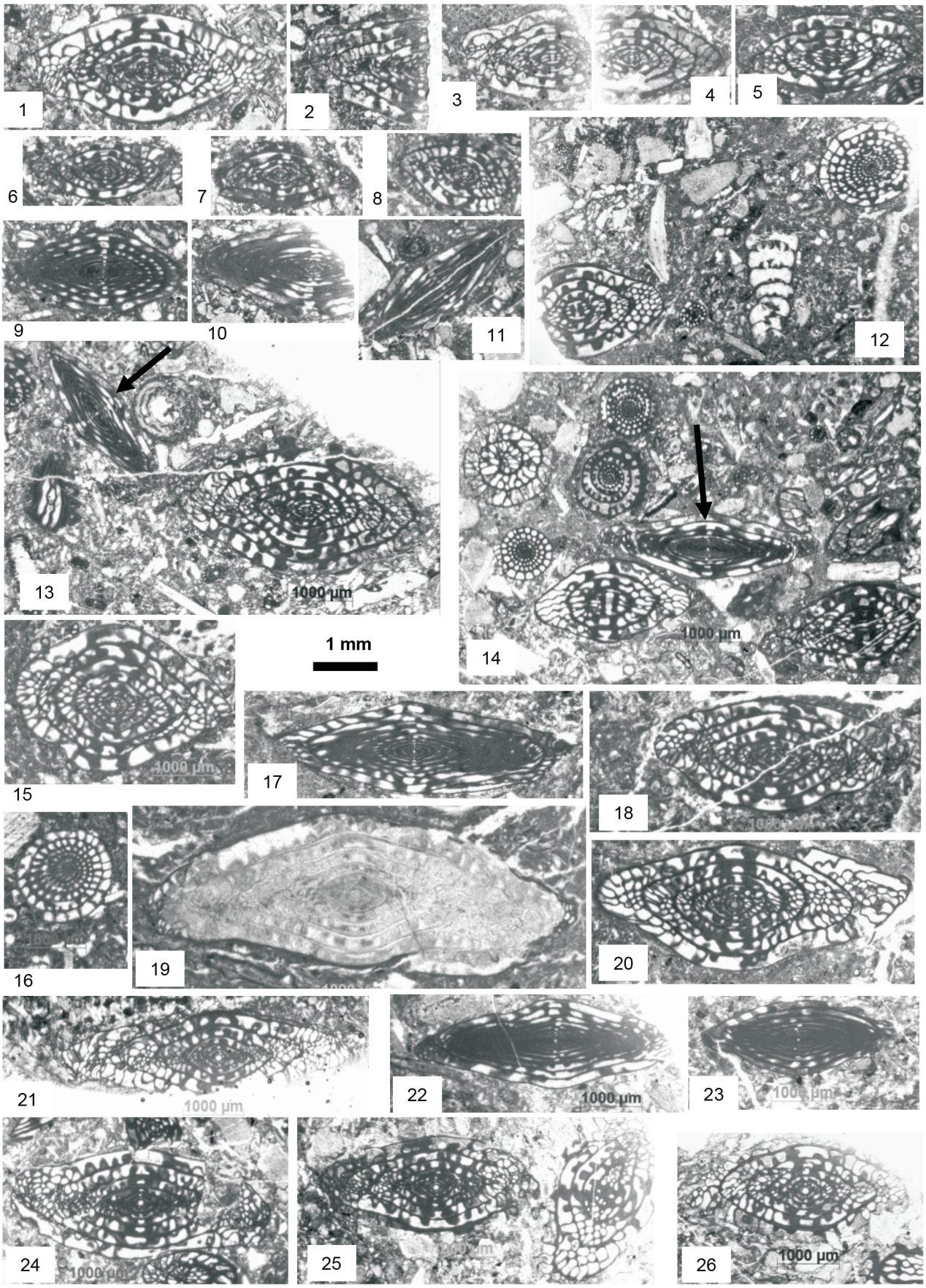
17 *Wedekindellina excentrica* (Roth and Skinner 1930) from sample SMTT 1.5.

18-20 *Beedeina euryteines* (Thompson 1934), with the specimen in figure 19 being silicified, from sample SMTT 1.5.

21 *Beedeina* aff. *B. leei* (Skinner 1931) from sample SMTT 1.4.

22-23 *Wedekindellina excentrica* (Roth and Skinner 1930) from Sample SMTT 1.4.

24-26 *Beedeina euryteines* (Thompson 1934) from sample SMTT 1.4.


1
2
3
4
5
6
7
8
9
10
11
12
13
1000 µm
1 mm
14
1000 µm
15
1000 µm
17
18
16
19
20
21
1000 µm
22
1000 µm
23
1000 µm
24
1000 µm
25
26
1000 µm

yons, but there is no documentation of identified species of *Fusulinella* to confirm the presence of this zone.

Atokan-Desmoinesian Transition (Zone ADf): This zone is characterized by *Fusulinella iowensis, F. famula,* and similar species that are morphologically transitional between late Atokan *Fusulinella* and early Desmoinesian *Beedeina* (formerly *Fusulina*). Such transitional forms were often referred to as *Fusulinella-Fusulina* in early reports and publications. In his stratigraphic cross-section of the Bug Scuffle Limestone, Wilson (1989, fig. 2B) cited two horizons with occurrences of *Fusulinella-Fusulina*, both at approximately 100 m (328 ft) above the base of the Gobbler Formation in Ed Canyon. This zone has not been documented from any of the new fusulinid collections discussed herein.

Early early Desmoinseian (Zone Df1) (Lower Cherokee of some reports): The fusulinid marker for this zone, *Beedeina insolita*, was recognized in this study from J. L. Wilson's sample from the base of the Bug Scuffle Limestone Member at Grapevine Canyon. The slightly more advanced *Beedeina hayensis* and small specimens of *B.* cf. *B. leei* were identified in this study from the lower beds of the Bug Scuffle Limestone Member in the Dog Canyon SMDC-4 section. Also in this study, near the base of the Mesa measured section of Rendall (2022) on the north side of Alamo Canyon, *Beedeina curta* was identified.

Late early Desmoinesian (Zone Df2) (Upper Cherokee of some early reports): This zone was recognized in most of the stratigraphic sections of the Bug Scuffle Limestone Member analyzed in this study by the occurrences of *Beedeina novamexicana*, *B. euryteines*, *B. rockymontana*, *B. leei*, *B. joyitaensis*, *B. socorroensis*, *Wedekindellina euthysepta*, and *W. excentrica*. The zone is also characterized in many of the measured sections by the common occurrences of the branching microfossil *Komia*.

Early late Desmoinesian (Zone Df3) (Lower Marmation of some reports): Fusulinids representing this zone were relatively uncommon, partly because the carbonate facies of the zone are somewhat more inner shelf and probably slightly restricted marine. The fusulinids identified that are indicative of this zone were *Beedeina haworthi*, which typifies the zone throughout Midcontinent and Western North America, the closely related species *B. illinoisensis* and *B. tumida* from the Dog Canyon SMDC-2 section, and *B. sulphurensis* from the Bug Scuffle Canyon section. In a few sections (Tunnel, ACLR-3, SMDC-4), poor specimens of *Beedeina* sp. with medium-sized shells and complex septal fluting were assigned to this zone based on resemblance to *B. haworthi*, stratigraphic occurrence just above the middle Desmoinesian CSB1 composite sequence boundary, and above the uppermost occurrences of *Wedekindellina* and *Komia*, which typify the underlying Df2 Zone.

Late late Desmoinesian (Zone Df4): In the Sacramento Mountains escarpment outcrop belt, the latest Desmoinesian zone is recognized in some of the southern canyon exposures of the Bug Scuffle Limestone Member in the Dog Canyon SMDC-2, Ed Canyon, and Table Top Mesa sections. The fusulinid assemblage that characterizes the Df4 zone in the Sacramento Mountains consists of *Beedeina acme*, *B. megista*, *B. lonsdalensis*, *B. bellatula*, *B. vintonensis*, and *B. gordonensis*. This latest Desmoinesian zone has not been recognized in many previously studied stratigraphic sections farther north in New Mexico either because of more restricted marine facies development or because of nondeposition or erosion around the Desmoinesian-Missourian boundary. Interestingly, the uppermost Bug Scuffle

---

PLATE 11

Late early Desmoinesian (Df2 Zone) and early late Desmoinesian (Df3 Zone) fusulinids of Wilrich (1999) samples from Bug Scuffle Canyon (see text-figs. 2 and 5). Figures 1-13 are from Wilrich's Central to Upper Canyon measured section (BSCCUS), and figure 14 is from Wilrich's Mouth of Canyon measured section (sample BSCNWT 1-20). The positions of sample numbers in the measured sections are discussed in the sample descriptions in the text. Figures 1 and 3-14 are all at ×10, scale bar = 1 mm; and figure 2 is at ×50, scale bar = 0.5 mm.

1-2 Large advanced specimen of *Beedeina haworthi* (Beede 1916) (grading into *Beedeina megista*) from sample BSCCUS. Figure 2 is a close-up of the double proloculi of specimen in Figure 1. (Df3 Zone)

3 Large advanced specimens of *Beedeina haworthi* (Beede 1916) (grading into *Beedeina megista*).

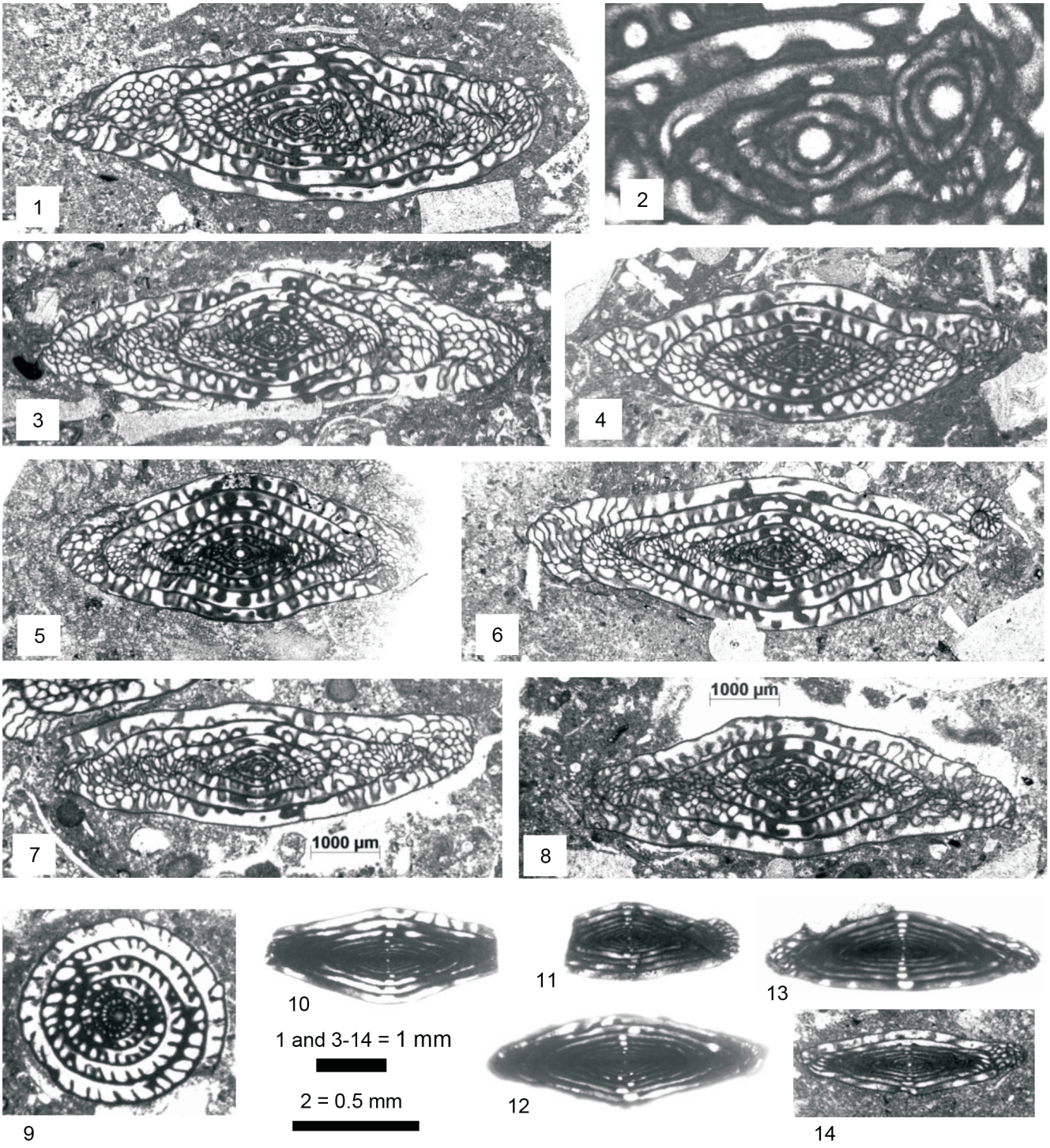
5 *Beedeina haworthi* (Beede 1916) from sample BSCCUS 2-14. (Df3 Zone)

6-8 *Beedeina sulphurensis* (Ross and Sabins 1965) labelled only as being from sample BSCCUS. (Df3 Zone)

9 Saggital section of *Beedeina* sp. from sample BSCCUS. (Df3 Zone)

10-13 *Wedekindellina euthysepta* (Henbest 1928) from sample BSCCUS 2-1. (Df2 Zone)

14 *Wedekindellina excentrica* (Roth and Skinner 1930) from sample BSCNWT 1-20 in the mouth of canyon section (1.75 m above base). (Df2 Zone)


1
2
3
4
5
6
7
1000 µm
8
1000 µm
9
10
11
12
13
14
1 and 3-14 = 1 mm
2 = 0.5 mm

sequence above the CSB2 is characterized by organic mound facies that contain phylloid algae and thrombolitic microbialite, which probably represents a transgressive systems tract (TST) transgression. Latest Desmoinesian (Df4 Zone) fusulinids were found above the CSB2 sequence boundary in the Dog Canyon SMDC-2 section, and possibly in the Wilrich (1999) sample from near the top of the Ed Canyon section.

Earliest Missourian (Zone Mf1): James Barrick in Wahlman and Barrick (2017) and in Lucas et al. (2021), has documented early Missourian conodonts in the uppermost limestone unit in the predominantly clastic detrital tongue of the Gobbler Formation in the north-central outcrop belt (Indian Wells Canyon area), which Pray (1961) interpreted to be a tongue of the Bug Scuffle Limestone. In this study, no Missourian conodonts or fusulinids were found in the uppermost parts of the thick Bug Scuffle Limestone Member sections in the southern part of the outcrop belt. In several New Mexico localities to the north and west of the Orogrande Basin, earliest Missourian strata have been recognized by occurrences of the earliest Missourian fusulinid *Eowaeringella* (Stewart 1968; Allen and Lucas 2018), which sometimes overlaps with very primitive species of *Triticites*, but unfortunately no Missourian fusulinids have been found yet in the uppermost Bug Scuffle Limestone Member of the Gobbler Formation in the Sacramento Mountains.

SUMMARY AND CONCLUSIONS

Data presented in this study demonstrate that all four widely recognized Desmoinesian fusulinid zones (Df1, Df2, Df3, Df4 of Wahlman 2019) are present in the Bug Scuffle Limestone Member of the Gobbler Formation. Conodont and fusulinid data cited by Lane (1974), Benne (1975), and Lucas and others (2021) indicate that the predominantly clastic detrital facies of the lower part of the Gobbler Formation range from early Morrowan through earliest Desmoinesian. As interpreted by Pray (1961), data in this study indicate that the base of the Bug Scuffle Limestone facies is transgressive, becoming younger northward. According to Benne (1975), George Sanderson (Amoco Research Center) identified early Desmoinesian fusulinids from limestone beds in the southern outcrop area in the lower Gobbler clastic detrital facies up to 50 ft (15.2 m) below the Bug Scuffle Limestone Member. He also stated that Sanderson suggested that fusulinids in the basal beds of the Bug Scuffle Limestone Member become younger northward, reflecting the early Desmoinesian northward transgression.

According to Wilson (1989, fig. 2B), in his Ed Canyon measured section about 100 m above the base of the Gobbler Formation, fusulinids referrred to *Fusulinella-Fusulina* occurred. Those transitional forms are most likely fusulinids of the *Fusulinella iowensis* group, which indicate the ADf zone of Wahlman (2019) that straddles the Atokan-Desmoinesian boundary. Unfortunately, Wilson's samples are not available for verification.

In Grapevine Canyon, the southernmost canyon sampled, fusulinids collected by James Lee Wilson from the base of the Bug Scuffle Limestone Member were identified herein as *Beedeina insolita*, which indicates the earliest Desmoinesian Df1 Zone. In sections to the north, samples from near the base of the Bug Scuffle Member contained *Beedeina hayensis* and *Beedeina curta* , which are early Desmoinesian (Df1 Zone) species that are slightly more advanced than *B. insolita*. Those occurrences appear to support the interpretation that the base of the Bug Scuffle Limestone Member becomes younger northward, reflecting the transgression of the carbonate unit.

Many samples from the lower half of the Bug Scuffle Limestone Member contained fusulinids of the late early Desmoinesian Df2 Zone. Fusulinids characteristic of the lower part of the Df2 Zone are *Beedeina novamexicana*, *B. euryteines*, *B. socorroensis*, *B. leei, B. rockymontana, B. joyitaensis, Wedekindellina euthysepta* and *W. excentrica*. The small branching fossil *Komia* is common in strata of the Df2 Zone of the Sacramento Mountains escarpment.

Rendall et al. (2019) recognized a composite sequence boundary (CSB1) between strata containing Df2 and Df3 fusulinid assemblages. That middle Desmoinesian composite sequence boundary correlates with the regional sequence boundary between the Cherokee and Marmaton Groups in the North American Midcontinent.

Fusulinid-bearing beds are sparse in the upper part of the Bug Scuffle Limestone Member above the CSBI composite sequence boundary. The early late Desmoinesian Df3 Zone was recognized in a few of the sections examined, and was represented by *Beedeina haworthi, B. illinoisensis, B. tumida* and *B. suphurensis.*

Fusulinids of the late late Desmoinesian Df4 Zone were identified in the southernmost measured sections at Table Top Mesa and Ed Canyon. The Df4 Zone assemblage at those localities consists of *Beedeina acme*, *B. megista*, *B. lonsdalensis*, *B. mysticensis, B. bellatula*, *B. vintonensis*, and *B. gordonensis*. Large elongate *Beedeina* of these types were seen also in hand samples from the upper Dog Canyon SMDC-2 section.

The distribution of fusulinids in the upper part of the Bug Scuffle Limestone Member is noteworthy. Late Desmoinesian (Zones Df3 and Df4) fusulinids are relatively common in the southern outcrop belt from Dog Canyon to Grapevine Canyon (text-fig. 2). On the contrary, in the northern part of the Bug Scuffle outcrop belt from Alamo Canyon to Fresnal Canyon, late Desmoinesian fusulinids are sparse to absent. That contrast in fusulinid distribution indicates that the carbonate facies in the upper part of the Bug Scuffle Limestone Member in the southern area were deposited in more normal marine conditions, whereas the upper Bug Scuffle facies in the northern outcrop belt were deposited in more shallow-water restricted marine conditions.

Barrick in Wahlman and Barrick (2018), and in Lucas and others (2021), reported early Missourian conodonts in a limestone unit in the upper 25 m (82 ft) of the clastic detrital tongue of the Gobbler Formation exposed in the north-central outcrop belt (Indian Wells Canyon and Beeman Canyon), but no early Missourian fusulinids or conodonts have been found yet in the uppermost Bug Scuffle Limestone Member in the thick carbonate sections of the more southern canyons. More detailed biostratigraphic sampling and analyses of the uppermost Bug Scuffle Limestone Member is needed.

ACKNOWLEDGMENTS

We thank the late James Lee Wilson for contributing the fusulinid-bearing samples from the Bug Scuffle Limestone in Grapevine Canyon to this study, and we thank the late David Lemone of the University of Texas at El Paso for providing the fusulinid thin-sections from the late Kerry Wilrich's (1999) the-

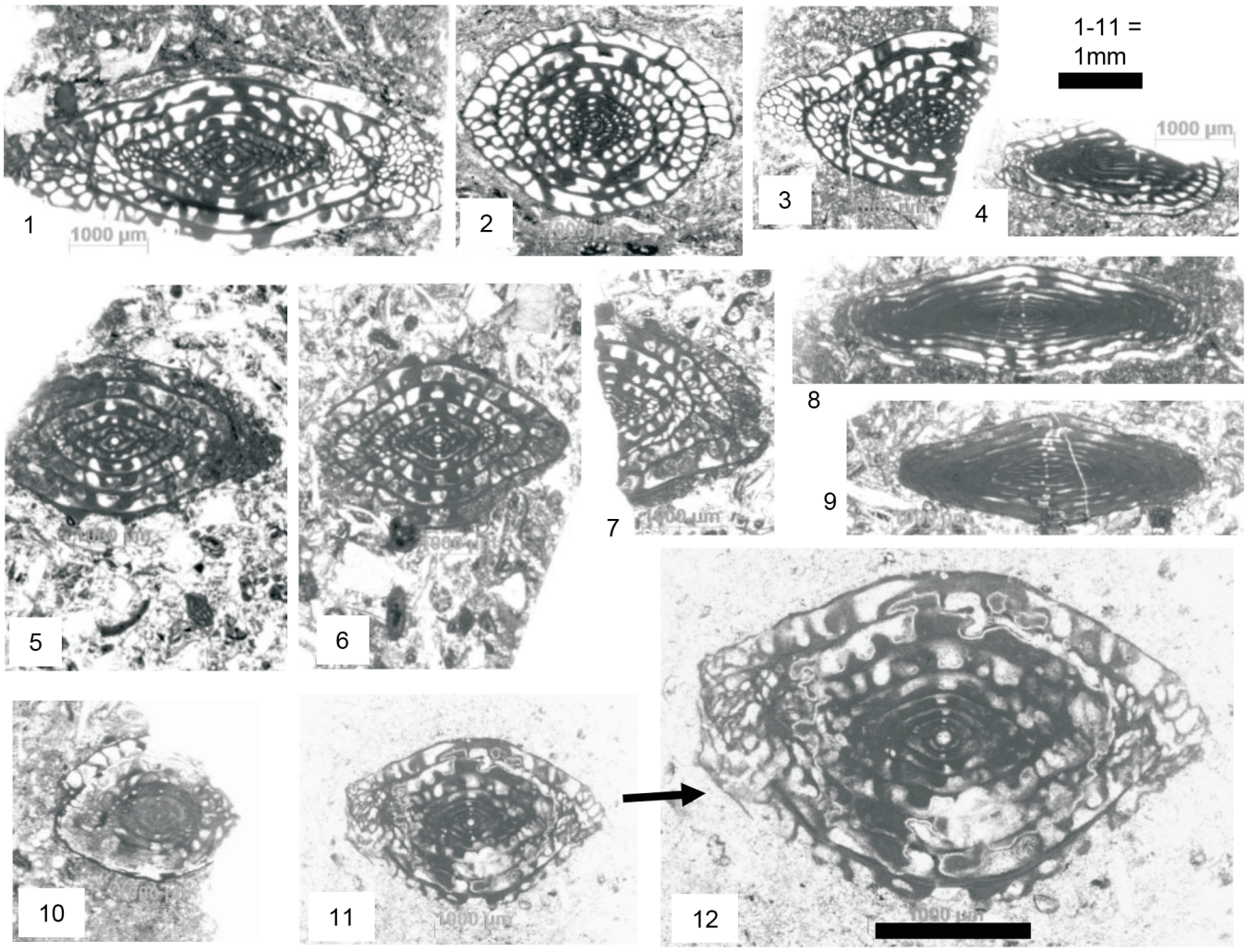


PLATE 12

Early Desmoinesian (Df1-Df2 Zones) fusulinids of Bug Scuffle Limestone Member from Grapevine Canyon (see text-figs. 2and 5). Oriented fusulinid thin-sections from samples collected by James Lee Wilson from the lower part of his Grapevine Canyon measured section. Figures 1-9 are from samples labelled GC250 and are thought to be from 250 ft (76 m) above the base of the measured section. Figures 10-12 were labelled from the basal beds of the Bug Scuffle Limestone. All photos at ×10 except figure 12, which is ×25; all scale bars = 1 mm.

1-3 *Beedeina joyitaensis* (Stewart 1970) from sample GC250-2 (Df2 Zone).

4 *Wedekindellina* cf. *W. euthysepta* (Henbest 1928) from sample GC250-2 (Df2 Zone).

5-7 *Beedeina novamexicana* (Needham 1937) from sample GC250-1 (Df2 Zone).

8-9 *Wedekindellina euthysepta* (Henbest 1928) from sample GC250-1 (Df2 Zone).

10 *Beedeina insolita* (Thompson 1948) from sample near base of Bug Scuffle Limestone Member (Df1 Zone).

11-12 Two photos at ×10 and ×25 of same specimen of *Beedeina insolita* (Thompson 1948) from sample near base of Bug Scuffle Limestone Member (Df1 Zone). The close-up photo shows the transition from more splayed *Fusulinella*-like chomata in juvenile volutions to more *Beedeina*-like massive knob chomata in adult volutions. Specimen is very similar to Thompson (1948, pl. 38, fig. 12) paratype from Mud Spring Mountains of central New Mexico.

sis study at the University of Texas at El Paso. We greatly appreciate James Barrick (Texas Tech University) generously sharing his conodont data and insights with us. We also thank Charles Kerans and the Department of Geological Sciences of the University of Texas at Austin for funding Ben Rendall's field work and the costs for making the petrographic and fusulinid thin-sections from Rendall's field samples. Finally, we appreciate the helpful comments by the reviewers James Barrick and Spencer Lucas, and by editor Jean Self-Trail.

REFERENCES

ALEXANDER, R. D., 1954. *Desmoinesian fusulinids of northeastern Oklahoma*. Norman: Oklahoma Geological Survey, Circular 31, 67 pp.

ALLEN, B. D. and LUCAS, S. G., 2018. The Late Pennsylvanian (Missourian) index fusulinid *Eowaeringella* in the Manzanita Mountains of central New Mexico. *New Mexico Geology*, 40: 35–42.

BALTZ, E. H. and MYERS, D. A, 1999. *Stratigraphic framework of upper Paleozoic rocks, southeastern Sangre de Cristo Mountains, New Mexico, with a section on speculations and implications for regional interpretation of Ancestral Rocky Mountains paleotectonics*. Socorro: New Mexico Bureau of Mines and Mineral Resources, Memoir 48, 269 p.

BARRICK, J. E., ALEKSEEV, A. S., BLANCO-FERRERA, S., GOREVA, N. V., HU, K., LAMBERT, L. L., NEMYROSVSKA, T. I., QI, Y., RITTER, S. M. and SANZ-LOPEZ, J., 2021. Carboniferous conodont biostratigraphy. In: Lucas, S. G., Schneider, J. W., Wang, X., Nikolaeva, S., Eds., *The Carboniferous Timescale. London: Geological Society of London, Special Publication* 512, 695–768.

BEBOUT, D. G., 1963. *Desmoinesian fusulinids of Missouri*. Rolla: Missouri Geological Survey and Water Resources, Rolla, Report of Investigations, No. 28, 79 pp.

BEEDE, J. W., 1916. New species of fossils from Pennsylvanian and Permian rocks of Kansas and Oklahoma. *Indiana University Studies*, 3: 1–15.

BENNE, R. E., 1975. "The stratigraphy of the lower Gobbler Formation, Sacramento Mountains, New Mexico." Unpublished M.S. Thesis, University of Oklahoma, Norman, 141pp.

CLOPINE, W. W., 1992a*. Lower and Middle Pennsylvanian fusulinid biostratigraphy of the type Derryan region, southern New Mexico and westernmost Texas. Socorro: New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 143, 67 pp.

———, 1992b. Middle Pennsylvanian fusulinid biostratigraphy in south-central New Mexico and south-central Oklahoma. *Oklahoma Geological Survey Circular,* 94: 125–143.

CLOPINE, W. W., MANGER, W. L., SUTHERLAND, P. K. and KAISER, P. K., 1991. Lower and Middle Pennsylvanian stratigraphic relations, type Derryan region, southern New Mexico and westernmost Texas. *New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 137: 173–192.

DUNBAR, C. O. and CONDRA, G. E., 1927. *The Fusulinidae of the Pennsylvanian System in Nebraska. Lincoln: Nebraska Geological Survey, Bulletin 2 (Second Series)*, 135 pp.

DUNBAR, C. O. and HENBEST, L. G., 1942. *Pennsylvanian Fusulinidae of Illinois*. Urbana-Champaign: Illinois State Geological Survey Bulletin 67, 218 pp.

GROVES, J. R., 1991, Fusulinacean biostratigraphy of the Marble Falls Limestone (Pennsylvanian), western Llano region, central Texas. *Journal of Foraminiferal Research*, 21: 67–95.

HENBEST, L. G., 1928. Fusulinellas from the Stonefort Limestone member of the Tradewater Formation. *Journal of Paleontology*, 2: 70–85.

KOTTLOWSKI, F. E. and STEWART, W. J., 1970. The Wolfcampian Joyita Uplfift in central New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Memoir* 23, Part I: 1–31.

LANE, H. R., 1974. Mississippian of southeastern New Mexico and west Texas – a wedge on wedge relation. *American Association of Petroleum Geologists Bulletin*, 58: 269–282.

LAPETER, D. R., 2007. "Lithofacies and stacking architecture of a Middle Pennsylvanian inner platform, Bug Scuffle Member, Gobbler Formation, Fresnal Canyon, New Mexico." Unpublished M.S. Thesis, Texas Tech University, Lubbock, 121 pp.

LUCAS, S. G., DIMICHEL, W. A., KRAINER, K., BARRICK, J. E., VACHARD, D., DONOVAN, M. P., LOOY, C., KERP, H. and CHANEY, D.S., 2021. The Pennsylvanian System in the Sacramento Mountains, New Mexico, USA: stratigraphy, petrography, depositional systems, paleontology, biostratigraphy and geologic history. *Smithsonian Contributions to Paleobiology*, 104: 1–215.

MYERS, D. A., 1988. Stratigraphic distribution of some Pennsylvanian fusulinids from the Sandia Formation and the Los Moyos Limestone, Manzano Mountains, New Mexico. *U.S. Geological Survey, Professional Paper,* 1446-A: 1–21.

NEEDHAM, C. E., 1937. Some New Mexico Fusulinidae: New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 14: 1–88.

NESTELL, M. K., 1989. The Desmoinesian-Missourian fusulinacean succession in the Brazos River Valley, north-central Texas. In: Boardman, D. R., Cocke, J., and Nestell, M. K., Eds., *Middle and Late Pennsylvanian chronostratigraphic boundaries in north-central Texas: glacial-eustatic events, stratigraphy and paleoecology,* 95–112. Lubbock: Texas Tech University Studies in Geology No. 2.

NEWELL, N. D. and KEROHER, R., 1937. The fusulinid *Wedekindellina* in the mid-Pennsylvanian rocks of Kansas and Missouri. *Journal of Paleontology*, 11: 698–705.

OTTE, C., Jr., 1959. Late Pennsylvanian and early Permian stratigraphy of the northern Sacramento Mountans, Otero County, New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 50: 1–111.

PRAY, L. C., 1954. Outline of the stratigraphy and structure of the Sacramento Mountains escarpment: *New Mexico Geological Society, 5th Field Conference, Guidebook on Southeastern New Mexico*, p. 92–107.

———, 1959. Stratigraphic and structural features of the Sacramento Mountains escarpment, New Mexico. *Roswell Geological Society and Permian Basin Section SEPM, Guidebook of the Sacramento Mountains*, 86–130.

———, 1961. Geology of the Sacramento Mountains Escarpment, Otero County, New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 35: 1–144.

RENDALL, B. E., 2022. "Regional and global controls on carbonate factory composition and stratigraphic architecture during global icehouse: Examples from the Pennsylvanian, New Mexico and the

Pleistocene, Bahamas". Unpublished PhD Dissertation, University of Texas at Austin. 486 pp.

RENDALL, B. E., WAHLMAN, G. P. and KERANS, C., 2019. Stratigraphic architecture of the Desmoinesian Bug Scuffle Limestone, Sacramento Mountains, New Mexico – analogs to Strawn and Canyon reservoirs in the Permian Basin (Abstract): *AAPG Search and Discovery Article #90350, American Association of Petroleum Geologists Annual Meeting*.

ROSS, C. A., 1965. Late Pennsylvanian Fusulinidae from the Gaptank Formation, west Texas. *Journal of Paleontology*, 39: 1151–1176.

———, 1967, Stratigraphy and depositional history of the Gaptank Formation (Pennsylvanian), West Texas. *Geological Society of America Bulletin*, 78: 369–384.

———, 1969. Middle and Upper Pennsylvanian fusulinaceans, Gila Mountains, Arizona. *Journal of Paleontology,* 43: 1405–1422.

ROSS, C. A. and SABINS, F. F., 1965. Early and Middle Pennsylvanian fusulinids from southeast Arizona. *Journal of Paleontology*, 39: 173–208.

ROSS, C. A. and TYRELL, W. W., Jr., 1965. Pennsylvanian and Permian fusulinids from the Whetstone Mountains, southeast Arizona. *Journal of Paleontology*, 39: 615–635.

ROTH, R. and SKINNER, J. W., 1930. Fauna of the McCoy Formation, Pennsylvanian, Colorado. *Journal of Paleontology*, 4: 332–352.

SKINNER, J. W., 1931. Primitive fusulinids of the midcontinent region. *Journal of Paleontology*, 5: 253–259.

SOLOVIEVA, M. N., 1984. Lower boundary of the middle Carboniferous by means of the foraminiferal fauna of Yugorski: *Ministersvo Geologii SSSR, Akademiya Nauk SSR, Mezhvedomstyennyi Stratigraficheski Komitet, Trudy,* 13: 121–155. (In Russian)

STEWART, W. J., 1958. Some fusulinids from the upper Strawn, Pennsylvanian, of Texas. *Journal of Paleontology*, 32: 1051–1070.

———, 1968. *The stratigraphic and phylogenetic significance of the fusulinid genus Eowaeringella, with several new species. Washington: Cushman Foundation for Foraminiferal Research,* Special Publication 10, 29 pp.

———, 1970. Fusulinids of the Joyita Hills, Socorro County, central New Mexico*. New Mexico Bureau of Mines and Mineral Resources, Memoir 23,* Part II: 32–82.

THOMPSON, M. L., 1934. The fusulinids of the Des Moines Series of Iowa. *University of Iowa Studies in Natural History,* 16: 277–332.

———, 1936. Fusulinids from the Black Hills and adjacent areas of Wyoming. *Journal of Paleontology*, 10: 95–113.

———, 1942. Pennsylvanian System in New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 17: 1–92.

———, 1945. Pennsylvanian rocks and fusulinids of east Utah and northwest Colorado correlated with Kansas section. *Kansas Geological Survey, Bulletin* 60: 19–84.

———, 1948. *Early Pennsylvanian fusulinids of New Mexico and western Texas.* In: Studies of American Fusulinids: Lawrence: University of Kansas Paleontological Contributions, Protozoa, Article 1, Part III, p. 68–96.

———, 1953. Fusulinids of the Casper Formation of Wyoming. *Geological Survey of Wyoming, Bulletin*, 46: 1–56.

VAN SANT, J. F., 1958. "Pennsylvanian fusulinids from Whiskey Canyon, New Mexico*".* Unpublished M.A. Thesis, University of Wisconsin, Madison*,* 152 pp.

VAN WAGONER, J. C., 1977a. "Lower and Middle Pennsylvanian rocks of the northern Sacramento Mountains: a study of contemporaneous carbonate and siliciclastic deposition in an active tectonic Setting". Unpublished PhD dissertation, Rice University, Houston, Texas, 179 pp.

———, 1977b. Carbonate and siliciclastic facies of the Gobbler Formation. *West Texas Geological Society, Publication* 1977–68: 57–72.

VERVILLE, G. J., SANDERSON, G. A. and MADSEN, M. E., 1986. Pennsylvanian fusulinids from the Fra Cristobal Range, Sierra County, New Mexico. Socorro: *New Mexico Geological Society Guidebook, 37th Field Conference*: 215–223.

VERVILLE, G. J., THOMPSON, M. L. and LOKKE, D. H., 1956. Pennsylvanian fusulinids of eastern Nevada. *Journal of Paleontology*, 30: 1277–1287.

WADDELL, D. E., 1966. Ardmore Basin fusulinids*. Oklahoma Geological Survey, Bulletin,* 113: 1–128.

WAHLMAN, G. P., 1999. Fusulinid biostratigraphy of the Honaker Trail section, San Juan River Canyon, southeastern Utah. In: Heckel, P. H., Ed., *Middle and Upper Pennsylvanian cyclothem succession in midcontinent USA, 208–216. Lawrence: Kansas Geological Survey Open-file Report 99–2*.

———, 2013. Pennsylvanian to Lower Permian (Desmoinesian–Wolfcampian) fusulinid biostratigraphy of Midcontinent North America. In: Heckel, P. H., Ed., Pennsylvanian genetic stratigraphy and biostratigraphy of Midcontinent North America. *Stratigraphy*, 10: 73–104.

———, 2019. Pennsylvanian and Lower Permian fusulinid biostratigraphy of the Permian Basin region, southwestern USA. In: Ruppel, S.C., Ed., *Anatomy of a Paleozoic Basin: the Permian Basin, USA: Volume 1,* 167–227. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 285, and American Association of Petroleum Geology Memoir 118.

WAHLMAN, G. P. and BARRICK, J. E., 2018. Fusulinid and conodont biostratigraphy of the Beeman Formation (Pennsylvanian), Sacramento Mountains, New Mexico*. New Mexico Geological Society Guidebook, 69th Field Conference, Las Cruces Country III:* 83–91.

WHITE, M. P., 1932. Some Texas Fusulinidae. *University of Texas Bulletin,* 3211: 1–105.

WILDE, G. L., 1990. Practical fusulinid zonation: the species concept; with Permian Basin emphasis. *West Texas Geological Society Bulletin*, 29: 5–15 and 28–34.

———, 2006. Pennsylvanian-Permian fusulinaceans of the Big Hatchet Mountains, New Mexico. *New Mexico Museum of Natural History and Science, Bulletin,* 38: 1–331.

WILRICH, K., 1999. "The biostratigraphy of the Middle Pennsylvanian (Desmoinesian) Fusulinidae of Bug Scuffle Canyon, Otero County, New Mexico". Unpublished M.A. thesis, University of Texas at El Paso, 75 pp.

WILSON, J. L., 1989. Lower and Middle Pennsylvanian strata in the Orogrande and Pedregosa basins, New Mexico*. New Mexico Bureau of Mines and Mineral Resources, Bulletin,* 124: 1–16.

APPENDIX 1

Brief petrographic descriptions of field samples, including listings of fusulinids and other fossils identified, are given below from measured sections in Alamo Canyon (ACLR-4 and ACLR-3), Dog Canyon (SMDC-4 and SMDC-2), and the Table Top Mesa section (SMTT) between Ed and Bug Scuffle Canyons. Note that the positions of the CSB1 and CSB2 composite sequence boundaries are also listed.

Alamo Canyon - Long Ridge ACLR-4 section

CSB1 composite sequence boundary (72 m = 236.2 ft)

ACLR 4.20 (50 m = 164 ft): Skeletal packstone with *Beedeina euryteines* (Plate 3, figs. 1-4), and *Beedeina novamexicana* (Plate 3, figures 5-8); smaller forams *Climacammina* and *Endothyra*). Df2 Zone.

ACLR 4.19 (49.5 m = 162.4 ft): Skeletal packstone (GDP), with: *Beedeina euryteines* (Plate 3, figures 9-10). Df2 Zone.

ACLR 4.17 (46 m = 150.9 ft): Fusulinid-skeletal mudstone-wackestone, with dark spiculitic mud matrix and sparse *Beedeina rockymontana* (Plate 3, figures 11-13). Lower part of Df2 Zone.

ACLR 4.16 (45.5 m = 149.3 ft): Skeletal-spiculitic packstone (MDP), with *Beedeina socorroensis* (Plate 3, figures 14-18). Lower part of Df2 Zone.

ACLR 4.15 (44.5 m = 146 ft): Spiculitic-skeletal-pelletal wackestone to packstone (MDP), sparse *Beedeina* aff. *B. leei* (Plate 3, figs. 20-23) and one small oblique saggital specimen of *Wedekindellina* sp. (Plate 3, figure 19). Lower part of Df2 Zone.

Alamo Canyon - Long Ridge ACLR-3 Section

CSB2 composite sequence boundary (156.5 m = 513.5 ft)

ACLR 3.19 (100.5 m = 329.7 ft): Crinoid-skeletal packstone-grainstone, oblique fragments of moderately large *Beedeina* sp. (Plate 4, figure 1) with intense septal fluting. Based on the position within in the measured section at 56 m (184 ft) below the CSB2 sequence boundary , and on the absence of associated *Wedekindellina* or *Komia*, this sample is interpreted as late Desmoinesian **(**Df3 Zone).

ACLR 3.18 (97 m = 318.2 ft): Crinoid-skeletal grainstone-packstone, with moderately large *Beedeina* sp. (Plate 4, figures 2-3) with intense fluting and some secondary deposits. Similar to the above sample, this sample has no associated *Wedekindellina* or *Komia*, and is interpreted as representing the Df3 Zone.

CSB1 composite sequence boundary (89 m = 292 ft)

ACLR 3.17 (89 m = 292 ft): Peloidal-skeletal grainstone, with *Komia*, but no fusulinids. Based on stratigraphic position immediately below the CSB1 composite sequence boundary and the presence of *Komia*, this sample is interpreted to be late early Desmoinesian age (Df2 Zone).

ACLR 3.14 (69.8 m = 229 ft): Spiculitic packstone with *Komia* fragments, and no fusulinids. Df2 Zone.

ACLR 3.12 (68 m = 223.1 ft): Crinoid-skeletal packstone, with moderately common medium-sized *Beedeina* cf. *B. novamexicana* and *Wedekindellina* sp. (Plate 4, figure 4). Df2 Zone.

ACLR 3.10 (56.6 m = 185.7 ft): Phylloid algal-skeletal packstone, with common moderate-sized *Beedeina* cf. *B. euryteines* (Plate 4, fig. 10), *B.* cf. *B. leei* (Plate 4, figure 11), and rare small *Wedekindellina* sp. (Plate 4, figure 9). Df2 Zone.

ACLR 3.7 (39.6 m = 130 ft): Skeletal-peloidal packstone, with only rare small juvenile *Beedeina* sp. (Plate 4, figure 12). Df1 or Df2 Zone.

ACLR 3.6 (38 m = 129.2 ft): Skeletal-peloidal grainstone-packstone with rare small juvenile *Beedeina* sp. (Plate 4, figure 13). Df1 or Df2 Zone.

Dog Canyon SMDC-4 Section

SMDC 4.38 (183.5 m = 602 ft): Crinoidal-skeletal packstone with fine peloidal matrix that could be clotted thrombolitic microbialite; poorly sorted fine- to very coarse-grained bioclasts crinoid ossicles, brachiopod and fenestrate bryozoan fragments, tubular forams, and very sparse small palaeotextulariid forams. No fusulinids or other biostratigraphically significant fossils. Mound facies above composite sequence boundary CSB2.

SMDC 4.37 (171 m = 561 ft): Interlayered skeletal packstone and wackestone, with brachiopod and fenestrate bryozoan fragments, and crinoid ossicles with articulated compositid and productid brachiopods and very sparse small palaeotextulariid forams.

CSB2 Composite Sequence Boundary (161.5 m = 530.5 ft)

SMDC 4.35 (153.5 m = 503.6 ft): Skeletal wackestone- packstone, with crinoid ossicles, brachiopod fragments, bryozoan fragments, possible phylloid algal fragments and sponge spicules, and rare tubular forams, Based on stratigraphic position and one small *Beedeina* sp. juvenarium. it can only be age-dated as late Desmoinesian (Df3-Df4?).

SMDC 4.34 (144.5 m = 474 ft): Skeletal mudstone-wackestone, with sparse crinoid ossicles, brachiopod and bryozoan fragments, and a *Beedeina* sp. fragment (Plate 5, figure 1). Based on fusulinid and stratigraphic position, age dated as late Desmoinesian (Df3-Df4).

SMDC 4.32 (131 m = 430 ft): Phylloid algal wackestone, with one small *Beedeina*? juvenarium. Late Desmoinesian. Age-dated as probably Df3 Zone, based on the presence of *Beedeina*, absence of *Wedekindellina* and *Komia*, and stratigraphic position above the CSB1 sequence boundary.

SMDC 4.30 (121.5 m = 399 ft): Skeletal grainstone, with disconitinuous sloping wackestone-packstone crinoid ossicles, brachiopod and bryozoan fragments, fusulinids (mostly juvenaria), and smaller forams (palaeotextulariids and *Climacammina*); sparse gastropods and ostracods. A couple of larger *Beedeina* sp. fragments (Plate 5, figure 2), and moderately common fusulinid juvenaria. Based on the presence of *Beedeina*, absence of *Wedekindellina* and *Komia*, and stratigraphic position above the CSB1 sequence boundary, age-dated as probably Df3.

SMDC 4.28 (117 m = 384 ft): Bryozoan-skeletal wackestone-packstone, with crinoid ossicles, bryozoan (fenestrate and

ramose) and brachiopod fragments, rare smaller forams (*Globivavlvulina*), and rare

small fusulinid fragments of *Beedeina*. Based on the presence of *Beedeina*, absence of *Wedekindellina* and *Komia*, and stratigraphic position just above the CSB1 sequence boundary, age-dated as Df3.

CSB1 Composite Sequence Boundary (88 m = 288.7 ft)

SMDC 4.24 (84.5 m = 277.2 ft): *Komia*-skeletal wackestone, with rare fusulinid juvenile fragments (Plate 5, figure 3), including the highest specimens of *Wedekindellina*. The stratigraphic position just below CSB1, and the occurrence of *Komia* and *Wesdekindellina* sp. indicate late early Desmoinesian Df2 Zone.

SMDC 4.23 (80.6 m = 264 ft): *Komia*-skeletal-peloidal packstone-wackestone, with two oblique specimens of adult *Beedeina* sp. (upper Cherokee types) (Plate 5, figures 4-5), one tiny *Wedekindellina* juvenile, and associated *Komia* indicating late early Desmoinesian Df2 Zone.

SMDC 4.22 (77.5 m = 254.3 ft): *Komia*-skeletal wackestone, with small *Beedeina* and *Wedekindellina* juvenaria, with associated *Komia* indicating Df2 Zone.

SMDC 4.21 (73 m = 239.5 ft): *Komia*-skeletal-peloidal packstone, one tiny *Wedekindellina* juvenile. Df2 Zone.

SMDC 4.20 (68.5 m = 224.7 ft): Crinoidal-skeletal packstone, with sparse juvenile *Beedeina*, palaeotextulariid and pseudobradyinid small forams, and rare *Komia* fragments, indicating Df2 Zone.

SMDC 4.18 (62.5 m = 205 ft): Microbial-sponge mound boundstone with biostratigraphically significant fossils.

SMDC 4.16 (48 m = 157.5 ft): Crinoid-skeletal packstone, with crinoid ossicles, bryozoan (ramose and fenestrate) and brachiopod fragments, and a couple small *Wedekindellina* sp. (Plate 5, figures 6-7), suggesting the Df2 Zone.

SMDC 4.14 (36 m = 118 ft): Skeletal-pelletal packstone, with rare smaller forams (palaeotextulariid, endothyrid, and one oblique tangential specimen of an elongate *Wedekindellina* cf. *W. euthysepta* (Plate 5, figure 8), suggesting Df2 Zone.

SMDC 4.13 (34 m = 111.5 ft): Skeletal packstone, with only rare small juvenile specimens of *Beedeina*. Probably Df2 Zone.

SMDC 4.12 (31 m = 101.7 ft): Crinoidal-skeletal packstone, several compacted and distorted *Beedeina* sp. and *Wedekindellina* sp., indicating Df2 Zone.

SMDC 4.11 (29 m = 95.1 ft): Skeletal packstone, with common crinoid ossicles, a probable *Prismopora* bryozoan and sparse other bryozoan fragments, very sparse smaller forams (*Bradyina*, *Pseudobradyina*, palaeotextulariid, endothyrid and tubular smaller forams), and one small juvenile *Beedeina*. Probably Df2 Zone.

SMDC 4.8 (16 m = 52.5 ft): Fusulinid-skeletal wackestone-packstone with common fusulinids and crinoid ossicles, moderately common smaller foraminifers (*Climacammina*, palaeotextulariids, *Globivalvulina*, *Bradyina*, *Pseudobradyina*, *Tuberitina*, *Endothyra*), mollusk shell fragments, and probable phyloid algal fragments. Common *Beedeina euryteines* and *B. leei* (Plate 5, figures 9-12), sparse *Wedekindellina* cf. *W. euthysepta* (Plate 5, figures 8-10), and very sparse specimens of the primitive fusulinids *Eoschubertella*, *Millerella*, and *Staffella* indicate the Df2 Zone.

SMDC 4.7 (14.5 m = 47.6 ft): Skeletal wackestone-packstone with brachiopod and bryozoan fragments; sparse crinoid ossicles and smaller forams (palaeotextulariids, *Climacammina*, *Pseudobradyina*), and moderately common *Beedeina* cf. *B. euryteines* (early forms) (Plate 5, figures 13-14), indicating lower part of Df2 Zone.

SMDC 4.6 (13.8 m = 45.3 ft): Fusulinid-skeletal wackestone-packstone, partly recrystallized and silicified, with common *Beedeina hayensis* (Plate 5, figures 15-17) and *B.* cf. *B. leei* (Plate 5, figures 18), indicating the early early Desmoinesian Df1 Zone.

SMDC 4.5 (5.7 m = 18.7 ft): Skeletal-peloidal packstone, with crinoid ossicles, bryozoan and brachiopod fragments, mollusk fragments possible phylloid algal fragments, smaller foraminifera (one endothyrid, two *Climacammina*), and very sparse small juvenile *Beedeina* sp., indicating probable Df1 Zone.

Dog Canyon SMDC-2 Section

SMDC-2.24 (224.7 m = 737.2 ft): Tan skeletal-peloidal packstone with common crinoid ossicles, moderately common fusulinids; and sparse smaller foraminifers (palaeotextulariids, *Pseudobradyina*, *Globivalvulina*, tubular forams), fenestrate bryozoan and brachiopod fragments. Fusulinids identified from this sample are *Beedeina vintonensis* (Stewart 1958) (Pl. 6, figs. 1-3) and *Beedeina gordonensis* (Plate 6, figures 4-5). The specimens of *B. vintonensis* are characterized by a fusiform shell shape, a rather irregular mode of coiling, and irregular loose septal fluting. Stewart (1958) named this species based on specimens from the Bishop Cap Limestone Member of the Magdalena Formation in the Franklin Mountains of West Texas. The specimens identified herein as *Beedeina gordonensis* agree with the types from the Village Bend Limestone (Zone Df4) in north-central Texas by their moderately inflated shell form, rather tight coiling, the very small proloculus, and the intense closely-spaced septal fluting. Stewart (1958) stated that *B. gordonensis* commonly occurs with *Beedeina bellatula*, *B. acme*, and *B. megista*, all of which are Df4 Zone fusulinids. Sample is age-dated as late late Desmoinesian Df4 Zone.

SMDC-2.21 (214.9 m = 705 ft): Tan phylloid algal-skeletal wackestone-packstone, with large, elongate fusiform fusulinids in this sample are identified as *Beedeina mysticensis* (Plate 6, figures 6-11), a typical Df4 Zone fusulinid throughout the Midcontinent and Southwest regions.

CSB2 Composite Sequence Boundary (212 m = 695.5 ft)

SMDC-2.17 (178.4 m = 585.3 ft): Phylloid algal-crinoid-skeletal wackstone-packstone with sparse *Beedeina illinoisensis* (Dunbar and Henbest 1942) (Plate 6, figures 12-14), a morphotype of the *B. haworthi* species group that typifies the Df3 Zone throughout Midcontinent and Western North America.

SMDC- 2.16 (152.5 m = 500.3 ft): Phylloid algal-skeletal wackestone-packstone, with sparse fusulinids. Specimens with elongate fusiform shells and nearly straight lateral slopes that are identified as *Beedeina haworthi* (Plate 6, figure 16), and one specimen with a more inflated shell and broadly rounded poles is identified

as *Beedeina tumida* (Plate 6. figure 15). Both species indicate the early late Desmoinesian Df3 Zone.

CSB1 Composite Sequence Boundary (129 m = 423.2 ft)

SMDC-2.14 (126.5 m = 415 ft): *Komia*-skeletal packstone, with common *Komia* fragments, crinoid ossicles and fusulinids, and sparse brachiopod and bryozoan fragments, smaller foraminifers (*Globivalvulina*, palaeotextulariids, endothyrids, bradyinids), and ostracods. This sample has common *Beedeina novamexicana* (Plate 7, figures 1-9), sparse small specimens of *Wedekindellina* cf. *W. excentrica* (Plate 7, figure 10), and common *Komia*, all of which characterize the Df2 Zone.

SMDC- 2.10 (58.5 m = 192 ft): Fusulinid-skeletal packstone, dark gray, argillaceous; with common *Beedeina euryteines* (Plate 7, figures 14-16) and *Wedekindellina excentrica* (Plate 7, figures 11-13) indicating the Df2 Zone.

Table Top Mesa Section

CSB2 composite sequence boundary (185.5 m = 608.6 ft)

SMTT 1.28 (167.5 m = 549.5 ft): This sample from near the top of the SMTT section is composed of mostly silicified fusulinid-skeletal packstone that contains abundant fusulinids and silicified ghosts of shell fragments and bryozoans. The sample contained silicified specimens of large advanced morphotypes of *Beedeina* that were identified as *B. megista* (Plate 9, figures 1-3), *B. acme* (Plate 9, figures 4-6), and *B. bellatula* (Plate 9, figures 7-9), all of which are indicative of the late late Desmoinesian Df4 Zone.

SMTT 1.22 (114.4 m = 375.3 ft): Skeletal wackestone, with crinoid ossicles, sparse fenestrate bryozoan and brachiopod fragments, and very sparse fusulinids identified as *Beedeina* cf. *B haworthi* (Plate 9, figure 10), which indicates the early late Desmoinesian Df3 Zone.

SMTT 1.21 (99 m = 324.8 ft): Partly silicified, spiculitic-skeletal packstone, with abundant sponge spicules, moderately common crinoid ossicles and fenestrate bryozoan fragments, and sparse fusulinid identified as *Beedeina* cf. *B. haworthi* (Plate 9, figures 11-13), indicating the early late Desmoinesian Df3 Zone.

CSB1 composite sequence boundary (98 m = 321.5 ft)

SMTT 1.9 (16 m = 52.5 ft): Fusulinid-skeletal packstone, with common fusulinids, crinoid ossicles, brachiopod and bryozoan fragments (mostly fenestrate bryozoans, and *Prismopora*), and sparse sponge spicules and smaller foraminifers (*Climacammina*, *Globivalvulina*, *Tetrataxis*, palaeotextulariids, *Syzrania*, endothyrids, and tubular forams), and very sparse *Komia* fragments. The fusulinids are *Beedeina euryteines* (Plate 10, figures 1-8), *B. novamexicana* (Plate 10, figures 12-15), *Wedekindellina excentrica* (Plate 10, figures 9-10), *W. euthysepta* (Plate 10, figures 11, 13-14), and *W.* sp. (Plate 10, figure 16). This sample is typical of the late early Desmoinesian Df2 Zone.

SMTT 1.8 (15.5 m = 50.8 ft): Skeletal pelleted packstone with common crinoid ossicles, brachiopod and bryozoan fragments, and tubular encrusting foraminifers; sparse small foraminifers (*Globivalvulina*, *Tetrataxis*, palaeotextulariids); and very sparse fusulinids (mostly juveniles) that are identified as *Beedeina novamexicana* (Plate 10, figures 12-15), and *Wedekindellina* sp. (Plate 10, figure 16), which indicate the late early Desmoinesian Df2 Zone.

SMTT-1.5 (5.5 m = 18 ft): Skeletal packstone to grainstone with sparse to common fusulinids, crinoid ossicles, brachiopod and fenestrate bryozoan fragments, sponge spicules, and smaller foraminifers (*Climacammina*, *Globivalvulina*, *Syzrania*, *Tetrataxis*, and endothyrids); and very sparse *Komia.* The fusulinids are identified as *Beedeina euryteines* (Plate 10, figures 18-20, 24-26), *B.* cf. *B. leei* (Plate 10, figure 21), *Wedekindellina excentrica* (Plate 10, figures 17, 22-23), which indicate the lower part of the late early Desmoinesian Df2 Zone.

SMTT-1.4 (4.5 m = 14.8 ft): Skeletal packstone-grainstone, with some silicified bioclasts, including common fusulinids and crinoid ossicles; sparse brachiopod and fenestrate bryozoan fragments, sponge spicules, and smaller foraminifers (*Climacammina*, palaeotextulariids, *Globivalvulina*, and endothyrids); and rare *Komia* fragments. The fusulinids are identified as *Beedeina euryteines* (Plate 10, figures 18-20, 24-26), *B.* cf. *B. leei* (Plate 10, figure 21), and *Wedekindellina excentrica* (Plate 10, figures 17, 22-23), which with the associated *Komia*, indicate the lower part of the late early Desmoinesian Df2 Zone.