

Stratigraphic Distribution of Fusulinid Foraminifera from the Manzano Mountains, New Mexico

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Stratigraphic Distribution of Fusulinid Foraminifera from the Manzano Mountains, New Mexico

By DONALD A. MYERS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1446-A,B

*Stratigraphic and paleontological study of
Pennsylvanian and Permian fusulinid Foraminifera
from the Manzano Mountains, New Mexico*



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By DONALD A. MYERS

STRATIGRAPHIC DISTRIBUTION OF FUSULINID FORAMINIFERA FROM
THE MANZANO MOUNTAINS, NEW MEXICO

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1446-A

*Summarizes the stratigraphic distribution of fusulinid
Foraminifera from the Pennsylvanian Sandia Formation and the
Los Moyos Limestone in the Manzano Mountains, New Mexico*

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STRATIGRAPHIC DISTRIBUTION OF FUSULINID FORAMINIFERA
FROM THE MANZANO MOUNTAINS, NEW MEXICO

STRATIGRAPHIC DISTRIBUTION OF SOME PENNSYLVANIAN FUSULINIDS
FROM THE SANDIA FORMATION AND THE LOS MOYOS LIMESTONE,
MANZANO MOUNTAINS, NEW MEXICO

By DONALD A. MYERS

ABSTRACT

Fusulinid Foraminifera from Pennsylvanian strata in the Manzano Mountains, central New Mexico, indicate that the Sandia Formation (Atokan) lies in the zone of *Fusulinella*, and that the Los Moyos Limestone (Desmoinesian) lies mostly in the zone of *Beedeina*. Two assemblage subzones recognized in the Sandia Formation are those of *Fusulinella devexa* and *F. whitensis*. Four assemblage subzones recognized in the Los Moyos Limestone are those of *Beedeina insolita*, *B. novamexicana*, *B. rockymontana*, and *B. sulphurensis*. The presence of *Eowaeringella* in the uppermost beds of the Los Moyos Limestone indicates that the beds are of earliest Missourian age.

INTRODUCTION

The Manzano Mountains lie on the east side of the Rio Grande Valley and extend about 50 miles south from Albuquerque, New Mexico (fig. 1). The mountains are fault-block mountains, tilted east. They are composed of Pennsylvanian and Lower Permian rocks that rest on Precambrian rocks. Except for the Manzanita Mountains, included with the Manzano Mountains in this report, the west face of the Manzano Mountains is a near-vertical escarpment of Precambrian rocks with as much as 5,000 ft of relief. Except for local and minor exposures of Mississippian rocks, referred to as the Arroyo Peñasco Group (Armstrong, 1967), the strata consist of a sequence of Pennsylvanian and Lower Permian rocks that have been assigned to the Sandia Formation and to the Madera Group (Myers, 1973).

The study of fusulinids is important because large amounts of oil and gas have been found in rocks assigned to the Pennsylvanian and Permian Systems in which these fossils occur. Fusulinids have widespread

geographic distribution and generally are found in abundance in these systems. They first appeared in Late Mississippian time; they flourished during Pennsylvanian and most of Permian time; and they became extinct slightly before the end of Permian time. Within this time span, evolutionary changes were continuous and great. The widespread geographic distribution, the great abundance of specimens, and the rapid evolution within this group of fossils serve to make the genera and species of fusulinids valuable for correlating the rocks that contain them.

Much of the stratigraphic correlation in areas of marine Pennsylvanian and Permian rocks is based on age relations determined by study of fusulinids. Because fusulinids are small enough to be preserved intact in well cores and as identifiable fragments in cuttings, they provide an excellent tool to aid in determining the stratigraphic succession in subsurface rocks. Comparison of fusulinids from subsurface rocks with those from outcropping rocks is an important method of establishing correlation between the two.

With current and developing interest in the oil and gas potential of the Rio Grande valley and adjacent areas in New Mexico, the data presented herein will help the biostratigrapher working with subsurface rocks to establish correlation with outcropping Pennsylvanian and Permian rocks along the east side of the Rio Grande.

The use of fusulinids as a stratigraphic tool depends, in part, upon knowledge of the rock-stratigraphic sequence in areas from which fusulinid collections have been made. My studies in the Manzano Mountains have enabled me to obtain several hundred collections of fusulinid-bearing rocks from precisely defined positions in the rock-stratigraphic sequence.

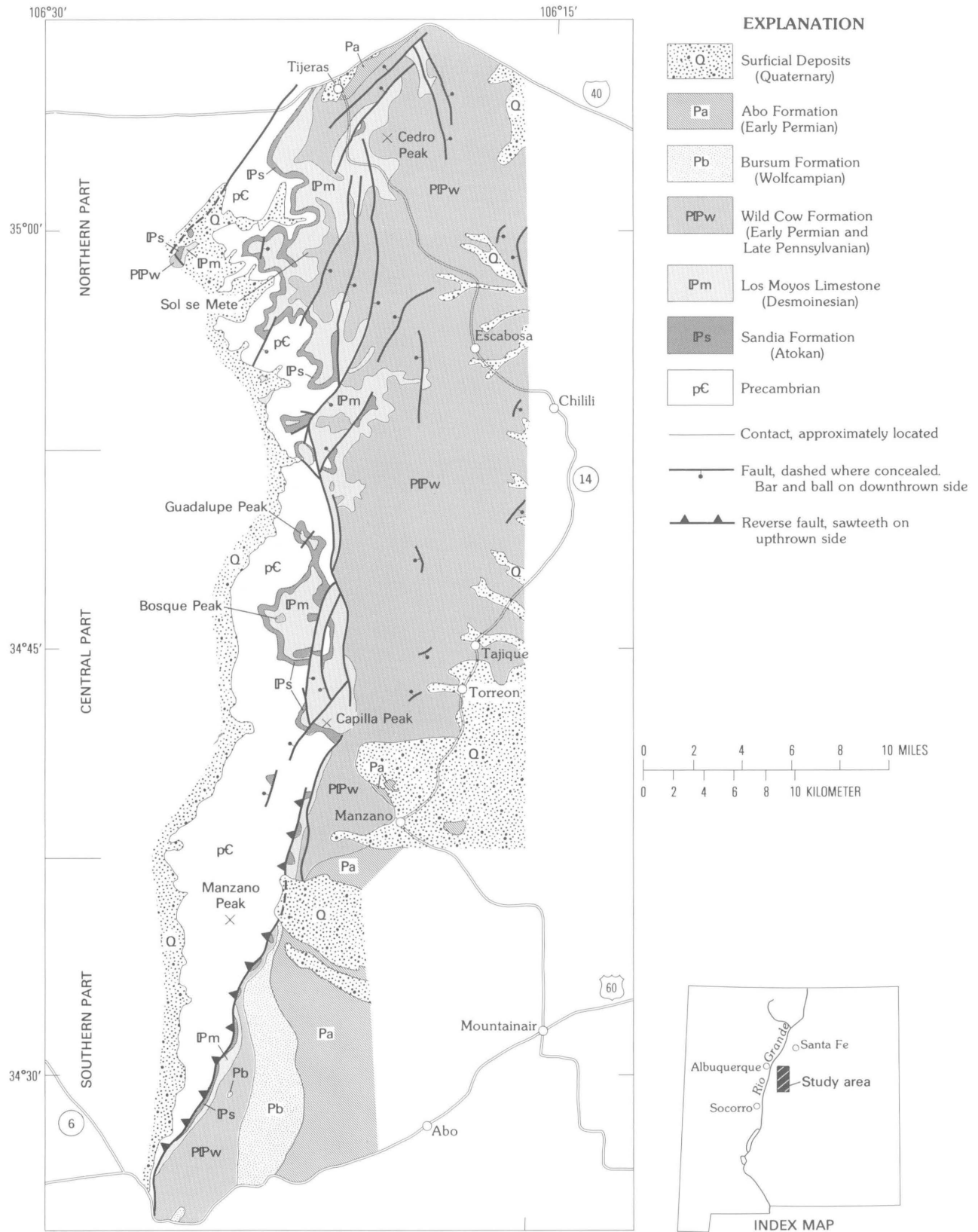


FIGURE 1.—Generalized geologic map of the Manzano Mountains, New Mexico. Modified from Myers (1966, 1967, 1977) and Myers and McKay (1970, 1971, 1972, 1974, 1976).

Fusulinid Foraminifera have been found in all units of Pennsylvanian and Lower Permian rocks in the Manzano Mountains. In this report, however, only those fusulinids from the Sandia Formation and the Los Moyos Limestone of Atokan and Desmoinesian ages, respectively, will be discussed. All illustrated material is from measured stratigraphic sections or, in a few cases, from beds that were correlated to the measured sections. The sections were measured between 1962-1976 during geologic mapping the Manzano Mountains. All formation and member contacts have been mapped in detail at a scale of 1:24,000.

About 50 partial and complete stratigraphic sections were measured, and from them, three composite sections were prepared. These are considered to be representative of the southern, central, and northern parts of the Manzano Mountains (fig. 2). The individual stratigraphic sections that were used to compile the composite sections are from Myers (1966, 1967, 1969) and Myers and McKay (1970, 1974, 1976).

Most fusulinid collections were made during geologic mapping. Where possible, sufficient material was collected to allow preparation of 30-50 oriented thin sections. Representative and unusual specimens from each collection were photographed at magnifications of 10 or multiples thereof.

The fusulinid faunas from the Sandia Formation and the Los Moyos Limestone have been assigned to the zones of *Fusulinella* and *Beedeina*.

The zone of *Fusulinella* has been subdivided into two assemblage subzones: *Fusulinella devexa* and the younger *F. whitensis*. The generic name *Beedeina* is now used for most North American species that were formerly referred to as *Fusulina* (Ishii, 1957, 1958). The zone of *Beedeina* has been subdivided into four assemblage subzones which are, in ascending order, *Beedeina insolita*; *B. novamexicana*, *B. rockymontana*, and *B. suphurensis*. The rocks that contain the zone of *Beedeina* are overlain by the Sol se Mete Member of the Wild Cow Formation, which is referred to the zone of *Triticites* and assemblage subzone of *Triticites nebraskensis*. The stratigraphic position of these zones and subzones is shown on figure 2.

FUSULINIDS FROM THE SANDIA FORMATION

STRATIGRAPHIC SUMMARY

The Sandia Formation is a succession of mostly terrigenous shale, siltstone, sandstone, and conglomerate that is olive drab and micaceous; the shale is locally

carbonaceous and coaly. A few thin beds of marine limestone and calcareous shale and siltstone are present. Fossil plant debris is common. The thickness of the Sandia ranges from less than 10 ft to about 300 ft; the range in thickness reflects, in part, the topographic configuration of the eroded surface of the underlying Precambrian rocks. The formation is of Atokan age and lies entirely within the zone of *Fusulinella* as defined by Thompson (1948, p. 23).

ASSEMBLAGE SUBZONE OF *FUSULINELLA DEVEXA*

The oldest fusulinids from the Manzano Mountains are referred to the assemblage subzone of *Fusulinella devexa* as defined by Ross and Sabins (1965, p. 177, 179). These fusulinids include *F. velmae* Thompson, 1936 (pl. 1, figs. 26-28), *F. cf. F. devexa* Thompson, 1945 (pl. 1, fig. 23, pl. 2, figs. 28-30) and *Profusulinella* aff. *P. copiosa* Thompson, 1948 (pl. 1, figs. 24, 25).

Profusulinella aff. *P. copiosa* is associated with *F. devexa* at a horizon about 100 ft below the top of the Sandia in the southern part of the mountains (pl. 1, figs. 23-25). There the base of the Sandia lies in fault contact with the Precambrian.

The assemblage subzone of *F. prospectensis* of Ross and Sabins (1965, p. 177, 179) has not been recognized in the Manzano Mountains.

ASSEMBLAGE SUBZONE OF *FUSULINELLA WHITENSIS*

The assemblage subzone of *F. whitensis* of Ross and Sabins (1965, p. 177, 179) contains *Fusulinella fugax* Thompson, 1948, from sections in the northern (pl. 3, figs. 20-23) and central (pl. 2, figs. 26, 27) sections; *F. whitensis* Ross and Sabins, 1965 (pl. 1, figs. 18-22; and *F. cf. F. famula* Thompson, 1948 from the uppermost beds of the Sandia in the northern (pl. 3, figs. 16-19) and central (pl. 2, figs. 19, 20) Manzano Mountains.

F. whitensis has been found only in the southern part of the mountains at about the middle of the Sandia. *F. famula* is seemingly restricted to the uppermost beds of the Sandia and to the lowermost beds of the overlying Los Moyos Limestone where it is associated with primitive species of *Beedeina*.

Millerella, although not illustrated in this report, has been found throughout the Sandia Formation with several of the species cited above.

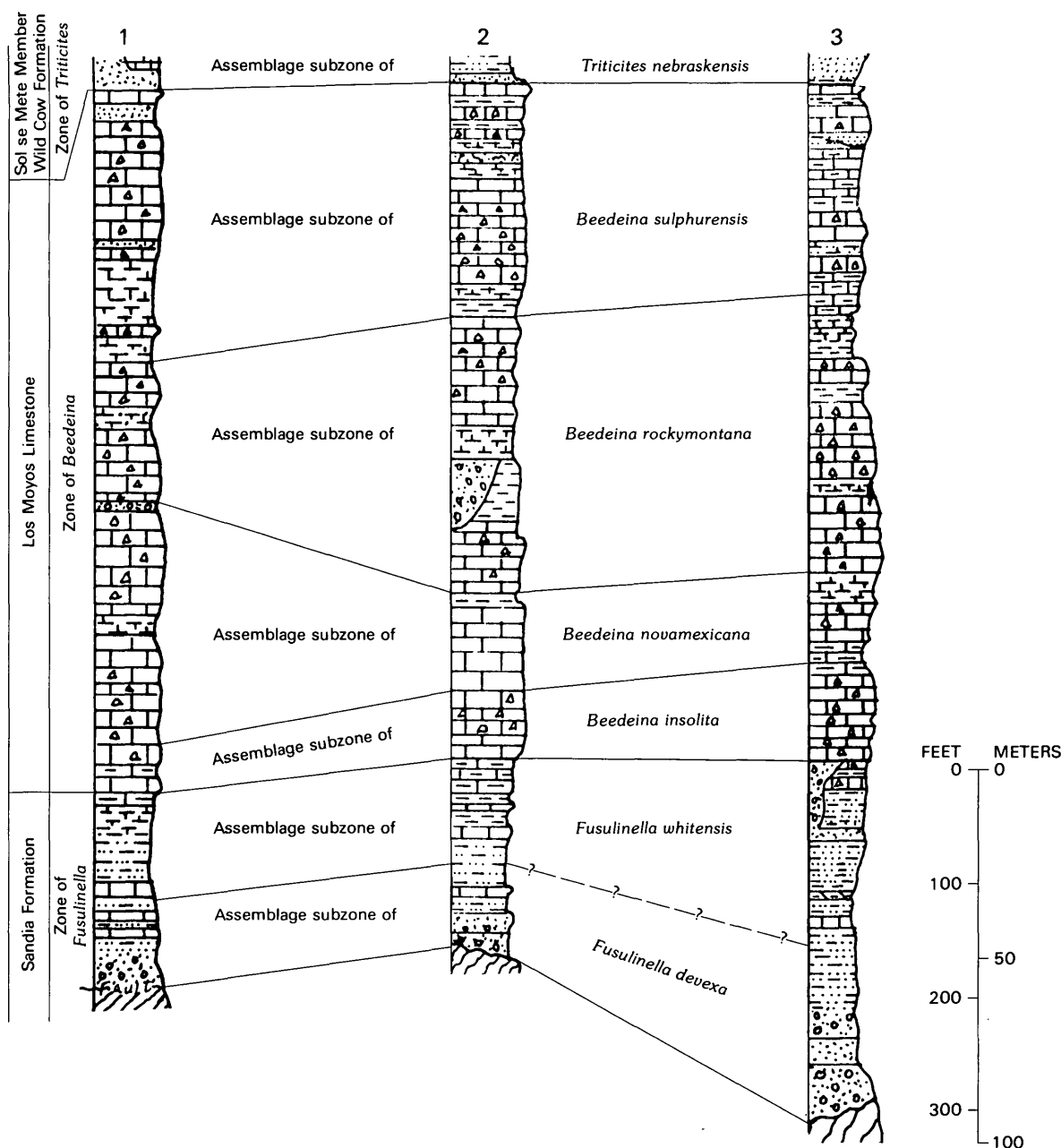


FIGURE 2.—Fusulinid zones and assemblage subzones in Middle Pennsylvanian rocks, Manzano Mountains, New Mexico. Numbers designate composite stratigraphic sections: 1, southern Manzano Mountains; 2, central Manzano Mountains; 3, northern Manzano Mountains. For explanation of symbols in graphic sections, see figure 3.

FUSULINIDS FROM THE LOS MOYOS LIMESTONE

STRATIGRAPHIC SUMMARY

The Los Moyos Limestone (Myers, 1973), the lowermost formation of the Madera Group, is dominantly cliff-forming, massive, cherty, gray limestone containing subordinate amounts of dark-colored calcareous

shale, sandstone, and minor conglomerate. Most of the formation is marine, but, locally, near the middle of the formation, some of the sandstone and conglomerate contains pieces of fossil wood, which are more than 3 ft long. The Los Moyos has an average thickness of 600 ft throughout the Manzano Mountains. The formation is of Desmoinesian age and lies mostly within the fusulinid zone of *Beedeina*. Its lower contact is gradational from the underlying Sandia Formation; for purposes of mapping, the contact has been picked at the base of the

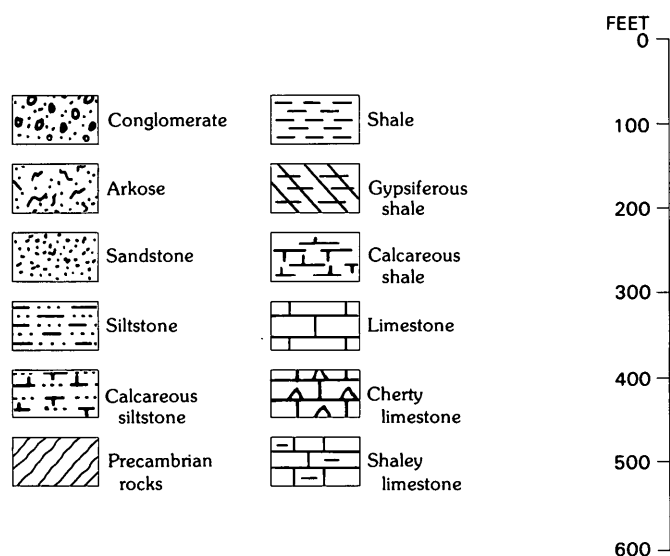


FIGURE 3.—Explanation of stratigraphic sections on figure 2, and plates 1-5. Scale does not apply to figure 2.

lowest cherty, ledge- to cliff-forming limestone. In the Manzano Mountains, this lowest limestone contains abundant chert that weathers a distinctive rusty orange. The Los Moyos Limestone is the lower gray limestone member of the Madera Limestone of Read and others (1944).

ASSEMBLAGE SUBZONE OF *BEEDEINA INSOLITA*

The oldest fusulinids from the Los Moyos are found near the base of the formation and are referred to *Bee-deina insolita* (Thompson), 1948, (pl. 1, fig. 15), and *Millerella* sp. (pl. 1, fig. 16, 17) in the southern part of the Manzano mountains; *B. aff. B. insolita* (pl. 2, figs. 18-20), and *Fusulinella famula* Thompson, 1948, (pl. 2, figs. 21-23) from the central part of the mountains; and *B. insolita* (pl. 3, fig. 13), and *Plectofusulina* sp. (pl. 3, figs. 14, 15) from the northern part of the mountains.

A few feet above the *B. insolita* fauna, *Bee-deina* aff. *B. arizonensis* (Ross and Sabins, 1965) appears in the northern part of the mountains (pl. 3, fig. 10), where it is associated with *Fusulinella* cf. *F. famula* and *Eoschubertella* aff. *E. bluensis* Ross and Sabins, 1965 (pl. 3, figs. 11, 12). *B. arizonensis* has been found throughout the Manzano Mountains at about this same horizon; however, it was not recovered from the areas of the southern and central stratigraphic sections.

ASSEMBLAGE SUBZONE OF *BEEDEINA NOVAMEXICANA*

About 25-50 ft above the horizon of *B. arizonensis*, fusulinids of the group of *B. novamexicana* first appear.

The oldest of these, *B. aff. B. novamexicana* (Needham), 1937 is illustrated on pl. 1, fig. 13, 14 and pl. 2, figs. 15, 16, where it is associated with *Wedekindellina* aff. *W. euthysepta* (Henbest), 1928, (pl. 2, fig. 17); and on pl. 3, figs. 7, 9, where it is associated with *Wedekindellina* aff. *W. pseudomatura* Ross and Tyrell, 1965 (pl. 3, fig. 8).

Next, above the initial occurrence of early forms of *B. novamexicana*, is an assemblage dominated by *Wedekindellina*. In the southern part of the mountains, the assemblage includes *W. excentrica* (Roth and Skinner), 1930, (pl. 1, fig. 10) and *W. cf. W. henbesti* (Skinner), 1931, (pl. 1, fig. 11) and *Millerella* sp. (pl. 1, fig. 12). In the central part of the mountains, *W. cf. W. coloradoensis* (Roth and Skinner), 1930, (pl. 2, fig. 12, 13) is associated with *B. cf. B. rockymontana* (Roth and Skinner), 1930, pl. 2, fig. 14). In the northern part, *B. aff. B. apachensis* (Ross and Sabins), 1965, pl. 3, fig. 4) is associated with *W. cf. W. henbesti* (pl. 3, figs. 5, 6).

Just below, or in, a sequence of calcareous shale and nodular limestone, *Bee-deina* cf. *B. novamexicana* (Needham), 1937 reappears (pl. 1, fig. 7) with *Wedekindellina* sp. A (pl. 1, figs. 8, 9); *B. aff. B. novamexicana* (pl. 3, fig. 2) and *W. cf. W. euthysepta* (Henbest), 1928, (pl. 3, figs. 1, 3) are found at the same horizon in the northern part of the mountains. In the southern part of the mountains, *Wedekindellina* aff. *W. euthysepta* (pl. 1, figs. 1, 4, 5), *Bee-deina* cf. *B. novamexicana* (pl. 1, figs. 2, 3) and *Millerella* sp. (pl. 1, fig. 6) are found a few feet above the shaley zone. Fusulinids were not found above the shaley zone in the central and northern parts of the mountains.

B. novamexicana is also found, only in the southern part of the mountains, in the lower part of the middle third of the Los Moyos, a short distance below and just above a thin bed of conglomerate. Occurring with *B. aff. B. novamexicana* (pl. 4, figs. 17, 20-23) are *Wedekindellina* aff. *W. elfina* (pl. 4, figs. 18, 19) above the conglomerate, and *Wedekindellina* cf. *W. excentrica* (Roth and Skinner), 1932 (pl. 4, fig. 24, 25) below the conglomerate. This is stratigraphically the highest occurrence of *B. novamexicana* in the Manzano Mountains.

ASSEMBLAGE SUBZONE OF *B. ROCKYMONTANA*

The subzone of *Bee-deina rockymontana* occupies the central part of the Los Moyos Limestone. *B. rockymontana* (Roth and Skinner), 1930, and closely related forms dominate the fusulinid fauna; associated with them are various species of *Wedekindellina*. Included in this subzone is *B. socorroensis* (Needham) 1937.

In the southern part of the mountains, *B. rockymontana* has not been found in the measured sections. The

subzone is represented by *Beedeina* cf. *B. socorroensis* (Needham), 1937 (pl. 4, figs. 15, 16), *B. cf. B. joyitaensis* Stewart, 1970 (pl. 4, figs. 10, 11, 14), *Beedeina* sp. B (pl. 4, figs. 6, 7), *Wedekindellina* sp. B (pl. 4, figs. 12, 13), and *Wedekindellina* aff. *W. euthysepta* (pl. 4, figs. 8, 9). In the central part of the mountains, *B. cf. B. rockymontana* (pl. 2, fig. 14) and *B. rockymontana* (pl. 2, figs. 9–11) are associated with *Wedekindellina* cf. *W. coloradoensis* (pl. 2, figs. 12, 13). In the northern part of the mountains, *B. rockymontana* (pl. 5, figs. 19–25) and *B. aff. B. rockymontana* (pl. 5, figs. 16–19) are present to the exclusion of other fusulinids.

ASSEMBLAGE SUBZONE OF *B. SULPHURENSIS*

The upper part of the Los Moyos Limestone embraces the subzone of *Beedeina sulphurensis*. In the southern part of the mountains, this subzone is represented by *Beedeina* cf. *B. haworthi* (Beede), 1916 (pl. 4, figs. 4, 5) near the base of the subzone, and by *Beedeina sulphurensis* (Ross and Sabins), 1965 (pl. 4, figs. 1, 2) associated with rare specimens of *Wedekindellina ellipsoides*? (pl. 4, fig. 3). The upper 140 ft of the Los Moyos in the southern part of the mountains are barren of fusulinids.

In the central part of the mountains, the subzone of *Beedeina sulphurensis* is represented by *B. cf. B. sulphurensis* (pl. 2, fig. 6); and an obese, large, rare fusulinid referred to *Beedeina* sp. A (pl. 2, figs. 4, 5). *Beedeina* sp. A has been found only in the uppermost beds of the Los Moyos, a few feet below the basal beds of rocks of Missourian age.

In the northern part of the mountains, the oldest fusulinids assigned to the subzone are an undescribed species here called *Beedeina* sp. C (pl. 5, figs. 12, 13). In the collection at hand, *Beedeina* sp. C is associated with reworked specimens of *Beedeina* aff. *B. rockymontana* (pl. 5, figs. 14, 15): all tests of *B. aff. B. rockymontana* are abraded and (or) broken, presumably by normal erosional processes. Rocks that contain *Beedeina* sp. C are overlain by rocks that contain *B. sulphurensis* (pl. 5, figs. 10, 11) where it is associated with uncommon specimens of *Wedekindellina ellipsoides* Dunbar and Henbest, 1942 (pl. 5, figs. 8, 9). Higher in the Los Moyos Limestone, *Beedeina retusa* (Thompson), 1953 (pl. 5, figs. 4–7) has been recorded. Near the top of the Los Moyos, reworked specimens of *Beedeina* aff. *B. retusa* (pl. 5, figs. 1–3) have been found.

Worthy of note, *Eowaeringella* cf. *E. joyitaensis*, Stewart 1970 (pl. 2, figs. 1–3) has been found locally in the uppermost beds of the Los Moyos Limestone. The occurrence of *Eowaeringella*, as far as is known, is

restricted to rocks of earliest Missourian age, hence, at least locally, deposition of the Los Moyos continued into earliest Missourian time.

FAUNAL CORRELATIONS

ZONE OF *FUSULINELLA*

The Sandia Formation lies within the fusulinid zone of *Fusulinella*. There is no evidence to indicate that the older zone of *Profusulinella* is present. The oldest assemblage subzone in the Sandia is represented by *F. devexa* (fig. 2). This assemblage subzone has been reported from southeast Arizona by Ross and Sabins (1965, p. 179 figs. 4) from the lower 180 ft of the Horquilla Limestone. Thompson (1942 and 1948, p. 94) described *F. devexa* from the upper part of his Cuchillo Negro Formation near the top of his Derry Series. In Thompson's measured sections, (1942, fig. 2) an unconformity? is shown at the top of the Derry. If the unconformity exists, rocks younger than the Derry are present in the Sandia in the Manzano Mountains, southeastern Arizona, and probably elsewhere.

The next younger assemblage subzone in the Sandia Formation is that of *Fusulinella whitensis*. This assemblage subzone correlates with that of Ross and Sabins (1965, pl. 179, fig. 4) where they have recorded it from the top of the *Fusulinella* zone in the Horquilla Limestone. It is younger than any recorded by Thompson (1948) from his Derry Series in southern New Mexico.

Although there are no species of *Fusulinella* in common, material figured by Thompson (1945, figs. 6, 7, pls. 2, 3) from his Hells Canyon Formation in northwestern Colorado is similar to that of the *F. whitensis* assemblage subzone in the Manzano Mountains.

ZONE OF *BEEDEINA*

The Los Moyos Limestone lies within the fusulinid zone of *Beedeina*. The oldest assemblage subzone in the Los Moyos is that of *B. insolita*, which has been found in the lower 40–80 ft of the formation (fig. 2). It is thinnest at the south end of the mountains and thickest at the north. The assemblage subzone is approximately equivalent to Ross and Sabins' (1965) *Beedeina hayensis* assemblage subzone which contains *B. hayensis*, *B. arizonensis*, *B. portalensis*, and *Fusulinella famula*. Thompson (1948, p. 96, 97) described *B. insolita* from the uppermost beds of his Derry Series and mentioned

that specimens of that species are rare and are associated with abundant specimens of *Fusulinella devexa*, *Pseudostaffella needhami*, *Eoschubertella mexicana*, and *Millerella*. Thompson did not describe the fusulinid faunas above his Derry Series; therefore, I do not know the vertical extent of the *B. insolita* assemblage subzone in southern New Mexico. In the Manzano Mountains, and in southeastern Arizona, the oldest representatives of *B. insolita* are apparently earliest Desmoinesian.

The next youngest assemblage subzone, that of *B. novamexicana*, occupies an interval of about 220 ft of strata in the southern part of the mountains; in the central and northern part, this stratigraphic interval is about 80 ft thick (fig. 2). *B. novamexicana* is associated with various slender species of *Wedekindellina*, and the assemblage subzone is probably equivalent to the *Wedekindellina euthysepta* assemblage subzone of Ross and Sabins (1965) in southeastern Arizona. The Manzano fauna is similar to that recorded from the *Wedekindellina* zone by Dunbar and Henbest (1942, fig. 2) in the Stonefort Limestone Member of the Spoon Formation of southern Illinois.

The *B. novamexicana* assemblage subzone is overlain by that of *B. rockymontana*. The *B. rockymontana* assemblage subzone is about 120 ft thick in the southern part of the mountains, and is about 240 ft thick in the central and northern part (fig. 2). It is a probable equivalent to the upper part of the *B. girtyi* subzone of Ross and Sabins (1965), but the faunas in this part of Ross and Sabins' sections are different enough from those of the Manzano Mountains that they are difficult to correlate. Ross (1969, p. 1409) has identified *B. rockymontana* from the Horquilla Limestone in the Gila Mountains, Arizona, 80–120 ft below an assemblage of *B. leei* and *Wedekindellina henbesti*.

The assemblage subzone of *B. sulphurensis*, at most places, is found in the upper 180–240 ft of the Los Moyos. It is thickest at the south end of the mountains. This assemblage subzone contains fusulinid faunas that are typical of those found in the upper beds of the Des Moines Series throughout the United States. It is equivalent to the *B. eximia* subzone in southeastern Arizona (Ross and Sabins, 1965), and its faunas are similar to those illustrated by Dunbar and Henbest (1942) from the upper part of the McLeansboro Group in southern Illinois. They also resemble those figured by Thompson (1934) from the upper part of the Des Moines Series in Iowa, and resemble those fusulinids figured by Myers (1960) and Stewart (1958) from the Capps Limestone Member of the Mineral Wells Formation in central and north-central Texas.

The upper 10 ft of the Los Moyos contains, at a single locality, representatives of the fusulinid *Eowaeringella*

cf. *E. joyitaensis* Stewart, 1968. The stratigraphic range of this genus is apparently restricted to early Missourian time (Stewart, 1968, p. 6, fig. 2). Therefore, these uppermost beds of the Los Moyos are interpreted to have been deposited during earliest Missourian time.

COLLECTING LOCALITIES

All listed collecting localities are from New Mexico, and all collections were made by the author between 1962–1972. Some collections from the central part of the Manzano Mountains were made on Isleta Indian Pueblo land; many collections from the northern part of the mountains were made on the Sandia Military Reservation. Access to these areas may be difficult; authorization to enter these areas should be obtained either from the Isleta Pueblo government at Isleta, or from military authorities at Sandia Military Reservation in Albuquerque. All topographic quadrangles listed are 7 1/2-minute unless otherwise noted.

- f10158. Sandia Formation. Valencia County, SW1/4 of Torreon 15-minute topographic quadrangle. From a section that was measured east through a gap in a hogback in the SW1/4NE1/4, sec. 6, T. 3 N., R. 5 E. This is the lower part of section 2 of Myers and McKay (1974). The base of the section is at a fault contact between the Sandia Formation and granite. Collection is from 21 ft above the granite and 103 ft below the top of the Sandia Formation.
- f10159. Los Moyos Limestone. See f10158 for locality. From 22 ft above base.
- f10160. Los Moyos Limestone. See f10158 for locality. From 112 ft above base.
- f10161. Sandia Formation. Bernalillo County, Mount Washington topographic quadrangle. From a section that was measured from the top of the Precambrian northeast to road along top of ridge, thence southeast to Sol se Mete Peak. This is section 1 of Myers and McKay (1970). Base of section is in the NW1/4SE1/4, sec. 29, T. 9 N., R. 5 E., 193 ft above base of Sandia Formation, Sandia Military Reservation.
- f10162. Sandia Formation. See f10161 for locality. From 10 ft below top. Sandia Military Reservation.
- f10163. Los Moyos Limestone. See f10161 for locality. From 65 ft above base. Sandia Military Reservation.
- f10164. Los Moyos Limestone. See f10161 for locality. From 86 ft above base. Sandia Military Reservation.
- f10165. Los Moyos Limestone. See f10161 for locality. From 226 ft above base. Sandia Military Reservation.
- f10166. Los Moyos Limestone. See f10161 for locality. From 279 ft above base. Sandia Military Reservation.
- f10167. Los Moyos Limestone. See f10161 for locality. From 383 ft above base. Sandia Military Reservation.
- f10168. Los Moyos Limestone. See f10161 for locality. From 481 ft above base. Sandia Military Reservation.
- f10169. Los Moyos Limestone. See f10161 for locality. From 491 ft above base. Sandia Military Reservation.
- f10170. Los Moyos Limestone. See f10161 for locality. From 505 ft above base. Sandia Military Reservation.
- f10171. Los Moyos Limestone. See f10161 for locality. From 527 ft above base and about 40 ft below top of Los Moyos Limestone. Sandia Military Reservation.

- f10172. Los Moyos Limestone. Valencia County, SW1/4 Torreon 15-minute topographic quadrangle. From a section that was measured east through a gap in a hogback in the NW1/4SE1/4, sec. 31, T. 4 N., R. 5 E. This is the lower part of section 3 of Myers and McKay (1974). From 161 ft above base.
- f10173. Los Moyos Limestone. See f10172 for locality. From 205 ft above base.
- f10174. Los Moyos Limestone. See f10172 for locality. From 258 ft above base.
- f10175. Los Moyos Limestone. See f10172 for locality. From 302 feet above base.
- f10176. Los Moyos Limestone. See f10172 for locality. From 395 ft above base.
- f10177. Los Moyos Limestone. Bernalillo County, Escabosa topographic quadrangle. Section measured in roadcuts along stream bed of Gotera Canyon in NW1/4NW1/4, section 20, T. 8 N., R. 6 E. This is part of section 1 of Myers (1969). From top of Los Moyos Limestone. Isleta Pueblo.
- f10178. Sandia Formation. Valencia county. SW1/4 Torreon 15-minute topographic quadrangle. Section measured from fault contact of Sandia Formation with granite, southeast through gap in hogback at south edge of quadrangle: sec. 7, T. 3 N., R. 5 E. This is the lower part of section 1 of Myers and McKay (1974). From 93 ft above fault contact; 81 ft below top of Sandia Formation.
- f10179. Sandia Formation. See f10178 for locality. From 108 ft below top.
- f10180. Sandia Formation. See f10178 for locality. From 126 ft below top.
- f10181. Los Moyos Limestone, type section. See f10178 for locality. From 58 ft above base.
- f10182. Los Moyos Limestone, type section. See f10178 for locality. From 110 ft above base.
- f10183. Los Moyos Limestone, type section. See f10178 for locality. From 163 ft above base.
- f10184. Los Moyos Limestone, type section. See f10178 for locality. From 253 ft above base.
- f10185. Los Moyos Limestone, type section. See f10178 for locality. From 330 ft above base.
- f10186. Los Moyos Limestone, type section. See f10178 for locality. From 463 ft above base.
- f10187. Los Moyos Limestone. Bernalillo County, Sedillo topographic quadrangle. Section measured east along bed of ravine that drains west from Cedro Peak. Base of section is in NW1/4NW1/4 sec. 36, T. 10 N., R. 5 E., at mouth of ravine at approximate elevation of 6,700 feet. This is the lower part of section 1 of Myers and McKay (1976). From 22 ft above base of Los Moyos Limestone.
- f10188. Los Moyos Limestone. See f10187 for locality. From 138 ft above base.
- f10189. Los Moyos Limestone. See f10187 for locality. From 371 ft above base.
- f10190. Los Moyos Limestone. See f10158 for locality. From 271 ft above base.
- f10191. Sandia Formation. Torrance County, Bosque Peak, and Tajique topographic quadrangles. Section measured in Los Moyos and Agua Azul Canyons. This is section 1 of Myers (1966). Base of section is at contact of Sandia Formation with Precambrian rocks in Los Moyos Canyon; about 2.6 miles N. 30° E. from Mosca Peak, at approximate elevation 6,960 feet. From 64 ft above depositional contact of Sandia with Precambrian. Isleta Pueblo.
- f10192. Sandia Formation. See f10191 for locality. From 118 ft above base. Isleta Pueblo.
- f10193. Sandia Formation. See f10191 for locality. From 7 ft below top. Isleta Pueblo.
- f10194. Los Moyos Limestone. See f10191 for locality. From base of Los Moyos Limestone. Isleta Pueblo.
- f10195. Los Moyos Limestone. See f10191 for locality. From 60 ft above base. Isleta Pueblo.
- f10196. Los Moyos Limestone. See f10191 for locality. From 119 ft above base. Isleta Pueblo.
- f10197. Los Moyos Limestone. See f10191 for locality. From 247 ft above base. Isleta Pueblo.
- f10198. Los Moyos Limestone. See f10191 for locality. From 361 ft above base. Isleta Pueblo.
- f10199. Los Moyos Limestone. See f10191 for locality. From 512 ft above base. Isleta Pueblo.
- f10200. Los Moyos Limestone. See f10191 for locality. From 12 ft below top. Isleta Pueblo.

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Plates 1-5 follow

Contact photographs of these plates are available, at
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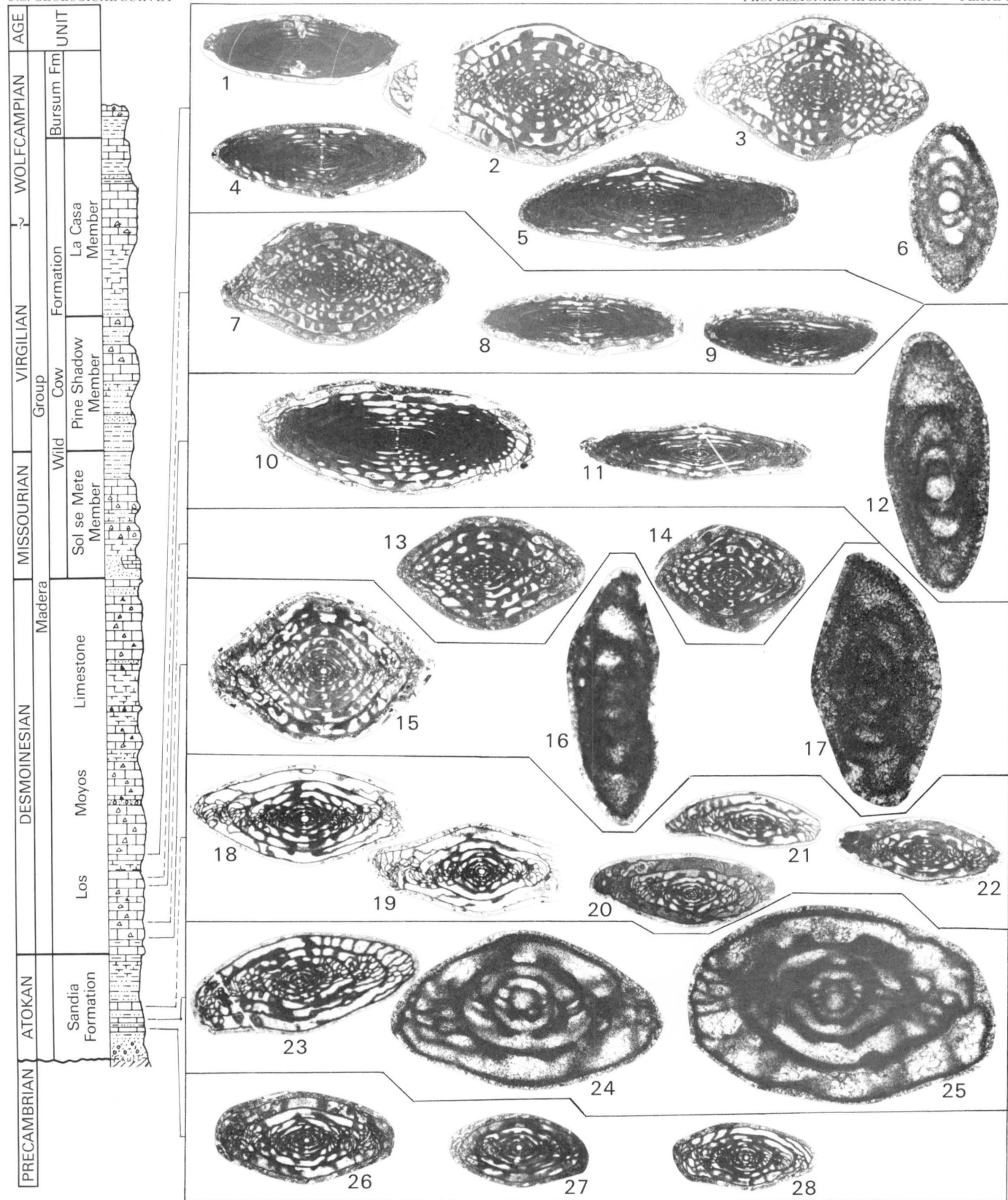
PLATE 1

Fusulinids from the Sandia Formation and the lower part of the Los Moyos Limestone in the southern part of the Manzano Mountains.

[All unretouched photographs; $\times 10$ except where otherwise indicated]

For explanation and scale of graphic section, see text figure 3.

- FIGURE
1. USGS f10183, *Wedekindellina* aff. *W. euthysepta* (Henbest), 1928. Axial section, slide 2, USNM 347052.
 - 2, 3. USGS f10183, *Beedeina* cf. *B. novamexicana* (Needham), 1937. Axial sections, slides 1, 4, USNM 347053, 347054.
 - 4, 5. USGS f10172, *Wedekindellina* aff. *W. euthysepta* (Henbest), 1928. Axial sections, slides 3, 2, USNM 347055, 347056.
 6. UGS f10172, *Millerella* sp. ($\times 100$). Axial section, slide 4, USNM 347057.
 7. USGS f10182, *Beedeina* cf. *B. novamexicana* (Needham), 1937. Axial section, slide 2, USNM 347058.
 - 8, 9. USGS f10182. *Wedekindellina* sp. A. Axial sections slides 1, 5, USNM 347059, 347060.
 10. USGS f10160. *Wedekindellina excentrica* (Roth and Skinner), 1930. Axial section, slide 1, USNM 347061.
 11. USGS f10160. *Wedekindellina* cf. *W. henbesti* (Skinner), 1931. Axial section, slide 3, USNM 347062.
 12. USGS f10160. *Millerella* sp. ($\times 100$). Axial section, slide 2, USNM 347063
 - 13, 14. USGS f10181. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial sections, slides 1, 4, USNM 347064, 347065.
 15. USGS f10159. *Beedeina insolita* (Thompson), 1948. Axial section, slide 3, USNM 347066.
 - 16, 17. USGS f10159. *Millerella* sp. ($\times 100$). Axial sections, slides 3, 2, USNM 347067, 347068.
 - 18, 19. USGS f10158. *Fusulinella whitensis* Ross and Sabins, 1965. Axial sections, slides 4, 2, USNM 347069, 347070.
 - 20–22. USGS f10178. *Fusulinella whitensis* Ross and Sabins, 1965. Axial sections, slides 5, 4, 1, USNM 347071, 347072, 347073.
 23. USGS f10179. *Fusulinella devexa* Thompson, 1948. Axial section, slide 11, USNM 347074.
 - 24, 25. USGS f10179. *Profusulinella* aff. *P. copiosa* Thompson, 1948. ($\times 50$). Axial sections, slides 5, 3, USNM 347075, 347076.
 - 26–28. USGS f10180. *Fusulinella velmae* Thompson, 1936. Axial sections, slides 5, 1, 4, USNM 347077, 347078, 347079.



WECKINELLA, BEEDEINA, MILLERELLA, FUSULINELLA,
AND PROFUSULINELLA FROM SOUTHERN MANZANO MOUNTAINS

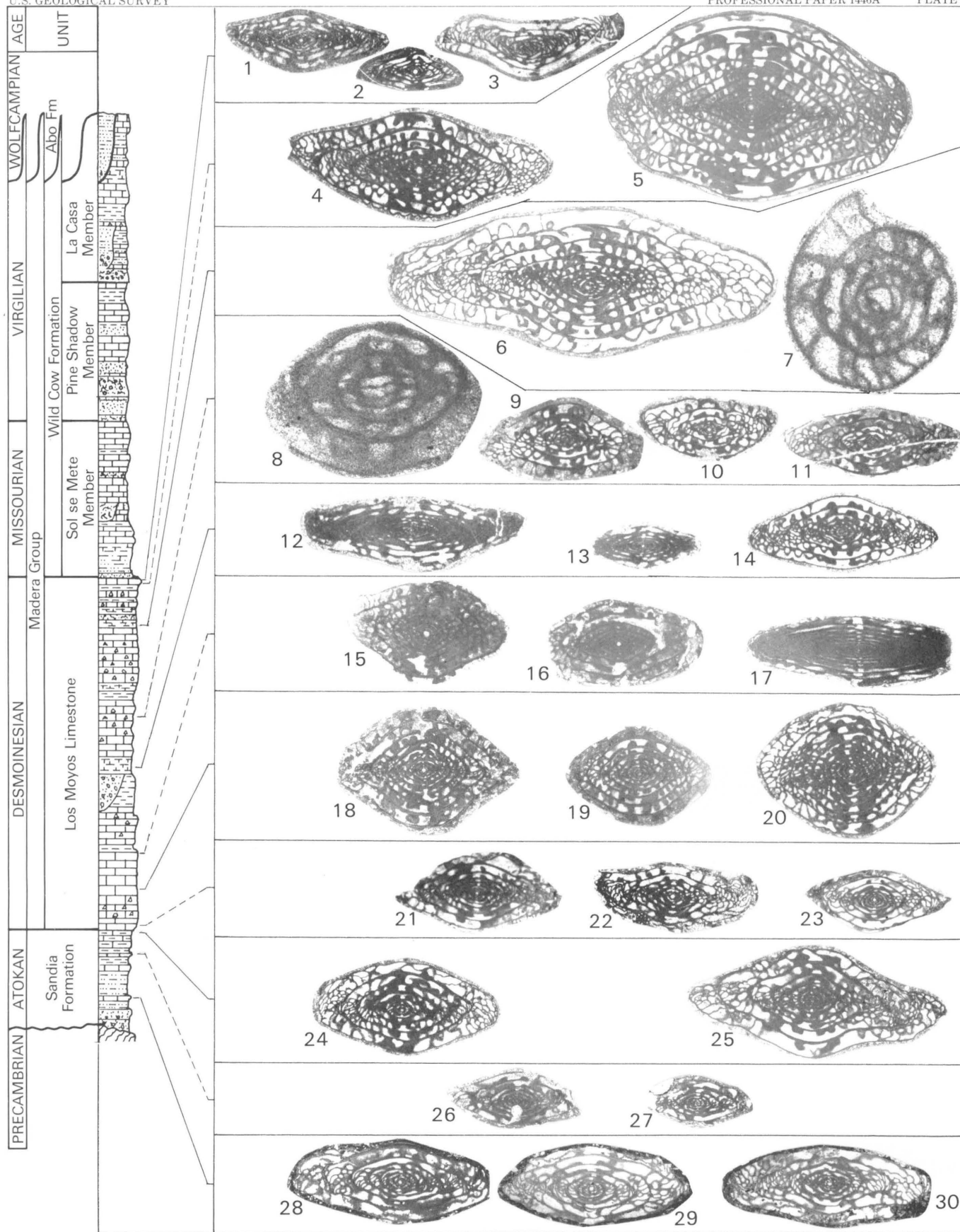
PLATE 2

Fusulinids from the Sandia Formation and the Los Moyos Limestone in the central part of the Manzano Mountains

[All unretouched photographs, $\times 10$ except where otherwise indicated]

For explanation and scale of graphic section, see text figure 3.

- FIGURE 1-3. USGS f10177. *Eowaeringella* cf. *E. joyitaensis* Stewart, 1968. Axial sections, slides 17, 16, 8, USNM 347080, 347081, 347082.
- 4, 5. USGS f10200. *Beedeina* sp. A. Axial sections, slides 3, 1, USNM 347083, 347084.
6. USGS f10199. *Beedeina* cf. *B. sulphurensis* (Ross and Sabins), 1965. Axial section, slide 5, USNM 347085.
7. USGS f10199. *Plectofusulina* sp. ($\times 50$). Equatorial section, slide 6, USNM 347086.
8. USGS f10198. *Plectofusulina* sp. ($\times 50$). Tangential section, slide 11. USNM 347087.
- 9-11. USGS f10198. *Beedeina rockymontana* (Roth and Skinner), 1930. Axial sections, slides 8, 7, 10, USNM 347088, 347089, 347090.
- 12, 13. USGS f10197. *Wedekindellina* cf. *W. coloradoensis* (Roth and Skinner), 1930. Axial sections, slides 1, 5, USNM 347091, 347092.
14. USGS f10197. *Beedeina* cf. *B. rockymontana* (Roth and Skinner), 1930. Axial section, slide 6, USNM 347093.
- 15, 16. USGS f10196. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial sections, slides 6, 4, USNM 347094, 347095.
17. USGS f10196. *Wedekindellina* aff. *W. euthysepta* (Henbest), 1928. Axial section, slide 3, USNM 347096.
- 18-20. USGS f10195. *Beedeina* aff. *B. insolita* (Thompson), 1948. Axial sections, slides 3, 6, 1, USNM 347097, 347098, 347099.
- 21-23. USGS f10194. *Fusulinella famula* Thompson, 1948. Axial sections, slides 3, 4, 2, USNM 347100, 347101, 347102.
- 24, 25. USGS f10193. *Fusulinella famula* Thompson, 1948. Axial sections, slides 6, 1, USNM 347103, 347104.
- 26, 27. USGS f10192. *Fusulinella* aff. *F. fugax* Thompson, 1948. Axial sections, slides 3, 2, USNM 347105, 347106.
- 28-30. USGS f10191. *Fusulinella* cf. *F. devexa* Thompson, 1948. Axial sections, slides 4, 1, 5, USNM 347107, 347108, 347109.



EOWAERINGELLA, BEEDEINA, PLECTOFUSULINA, WEDEKINDELLINA, AND FUSULINELLA FROM CENTRAL MANZANO MOUNTAINS

PLATE 3

Fusulinids from the Sandia Formation and the lower part of the Los Moyos Limestone in the northern part of the Manzano Mountains.

[All unretouched photographs; $\times 10$ except where otherwise indicated]

For explanation and scale of graphic section, see text figure 3.

- FIGURE
- 1, 3. USGS f10188. *Wedekindellina* cf. *W. euthysepta* (Henbest), 1928. Axial sections, slides 3, 1, USNM 347110, 347111.
 2. USGS f10188. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial section, slide 7, USNM 347112.
 4. USGS f10165. *Beedeina* aff. *B. apachensis* (Ross and Sabins), 1965. Axial section, slide 1, USNM 347113.
 - 5, 6. USGS f10165. *Wedekindellina* cf. *W. henbesti* (Skinner), 1931. Axial sections, slides 5, 6, USNM 347114, 347115.
 - 7, 9. USGS f10164. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial sections, slides 3, 2, USNM 347116, 347117.
 8. USGS f10164. *Wedekindellina pseudomatura* Ross and Tyrrell, 1965. Axial section, slide 5, USNM 347118.
 10. USGS f10163. *Beedeina* aff. *B. arizonensis* (Ross and Sabins), 1965. Axial section, slide 3, USNM 347119.
 11. USGS f10163. *Fusulinella* cf. *F. famula* Thompson, 1948. Axial section, slide 4, USNM 347120.
 12. USGS f10163. *Eoschubertella* aff. *E. bluensis* Ross and Sabins, ($\times 100$), 1965. Axial section, slide 5, USNM 347121.
 13. USGS f10187. *Beedeina insolita* (Thompson), 1948. Axial section, slide 4, USNM 347122.
 - 14, 15. USGS f10187. *Plectofusulina* sp. ($\times 50$), Axial sections, slides 5, 6, USNM 347123, 347124.
 - 16-19. USGS f10162. *Fusulinella famula* Thompson, 1948. Axial sections, slides 1, 3, 5, 2, USNM 347125, 347126, 347127, 347128.
 - 20-23. USGS f10161. *Fusulinella fugax?* Thompson, 1948. Axial sections, slides 2, 5, 4, 3, USNM 347129, 347130, 347131, 347132.

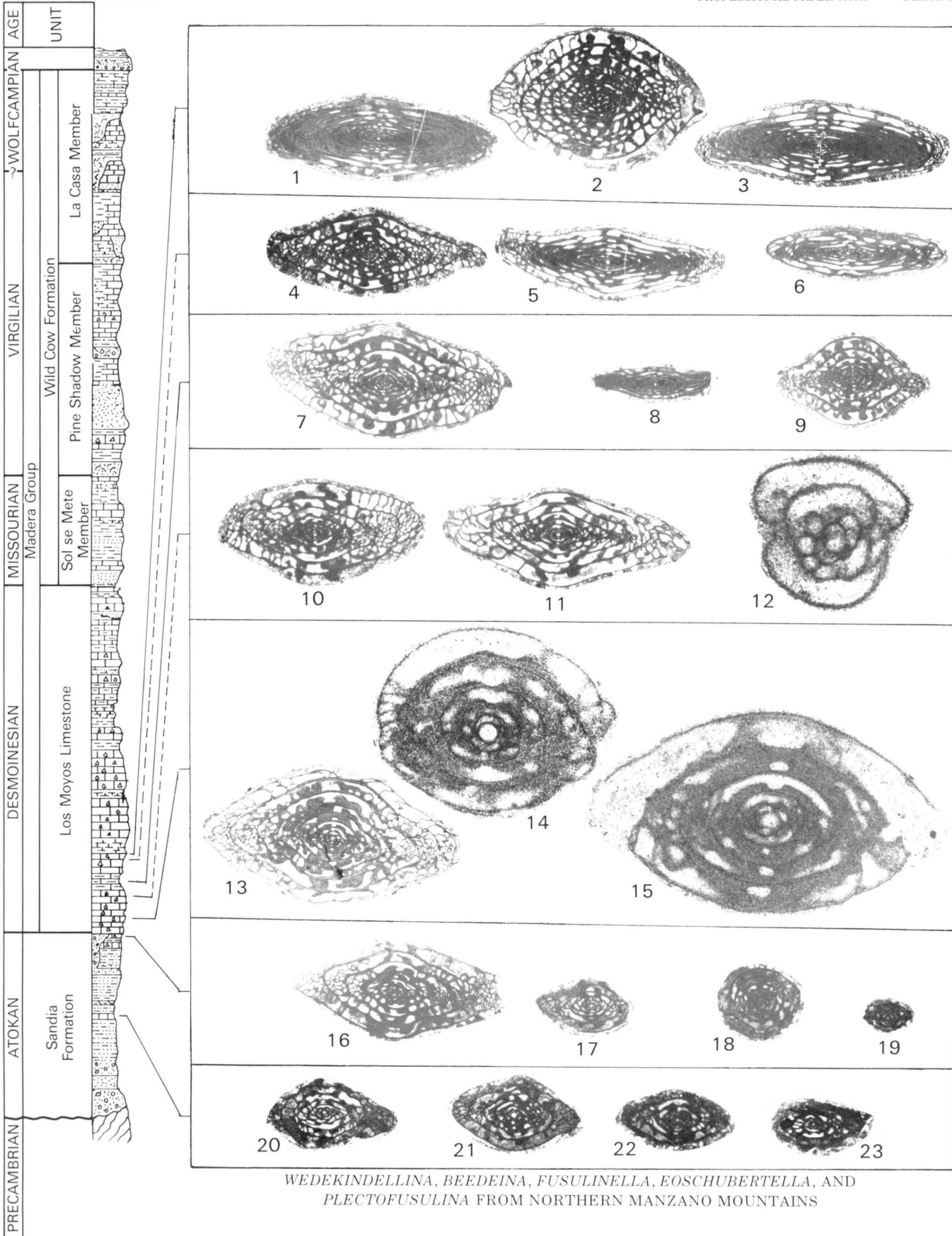


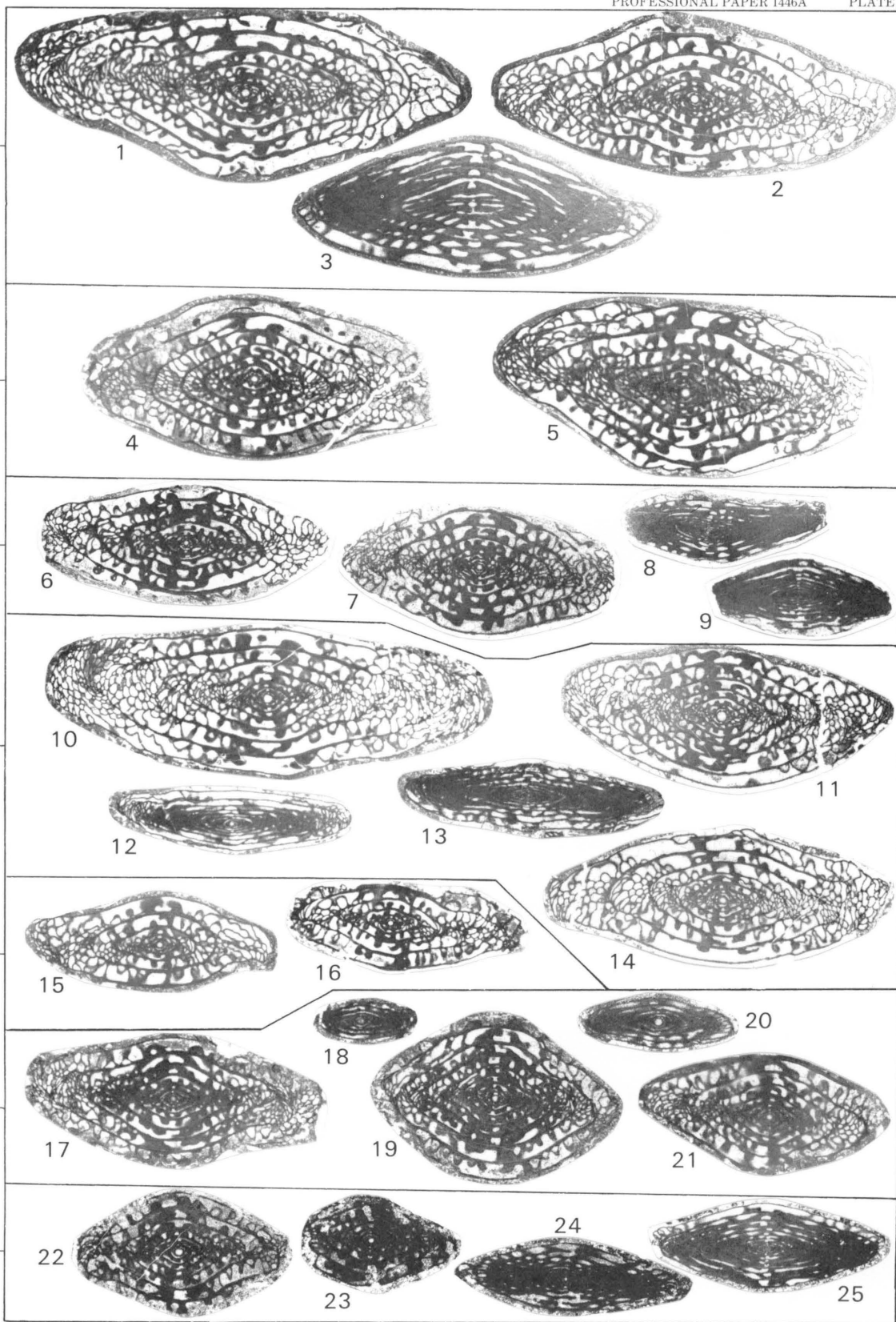
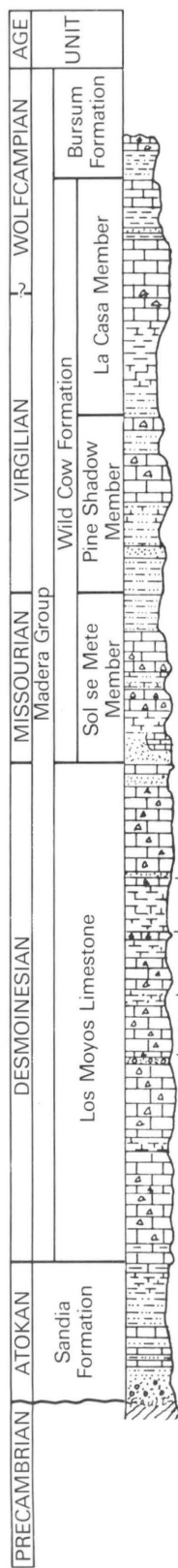
PLATE 4

Fusulinids from the upper part of the Los Moyos Limestone in the southern part of the Manzano Mountains

[All unretouched photographs; $\times 10$ except where otherwise indicated]

For explanation and scale of graphic section, see text figure 3.

- FIGURE
- 1, 2. USGS f10186. *Beedeina sulphurens* (Ross and Sabins), 1965. Axial sections, slides 7, 8, USNM 347133, 347134.
 3. USGS f10186. *Wedekindellina ellipsoides*? Dunbar and Henbest, 1942. Tangential section, slide 6, USNM 347135.
 - 4, 5. USGS f10176. *Beedeina* cf. *B. haworthi* (Beede), 1916. Axial sections, slides 5, 1, USNM 347136, 347137.
 - 6, 7. USGS f10185. *Beedeina* sp. B. Axial sections, slides 4, 7, USNM 347138, 347139.
 - 8, 9. USGS f10185. *Wedekindellina* aff. *W. euthysepta* (Henbest), 1928. Axial sections, slides 1, 3, USNM 347140, 347141.
 - 10, 11, 14. USGS f10175. *Beedeina* cf. *B. joyitaensis* Stewart, 1970. Axial sections, slides 3, 2, 1, USNM 347142, 347143, 347144.
 - 12, 13. USGS f10175. *Wedekindellina* sp. B. Axial sections, slides 6, 5, USNM 347145, 347146.
 - 15, 16. USGS f10190. *Beedeina* cf. *B. socorroensis* (Needham), 1937. Axial sections, slides, 4, 2, USNM 347147, 347148.
 - 17, 20, 21. USGS f10174. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial sections, slides 5a, 1, 2, USNM 347149, 347150, 347151.
 - 18-19. USGS f10174. *Wedekindellina* aff. *W. elfina* (Thompson), 1934. ($\times 20$). Axial sections, slides 5b, 4, USNM 347152, 347153.
 - 22-23. USGS f10173. *Beedeina* aff. *B. novamexicana* (Needham), 1937. Axial sections, slides 1, 2, USNM 347154, 347155.
 - 24-25. USGS f10173. *Wedekindellina* cf. *W. excentrica* (Roth and Skinner), 1930. Axial sections, slides 5, 4, USNM 347156, 347157.



BEEDEINA AND WEDEKIELLELLINA FROM SOUTHERN MANZANO MOUNTAINS

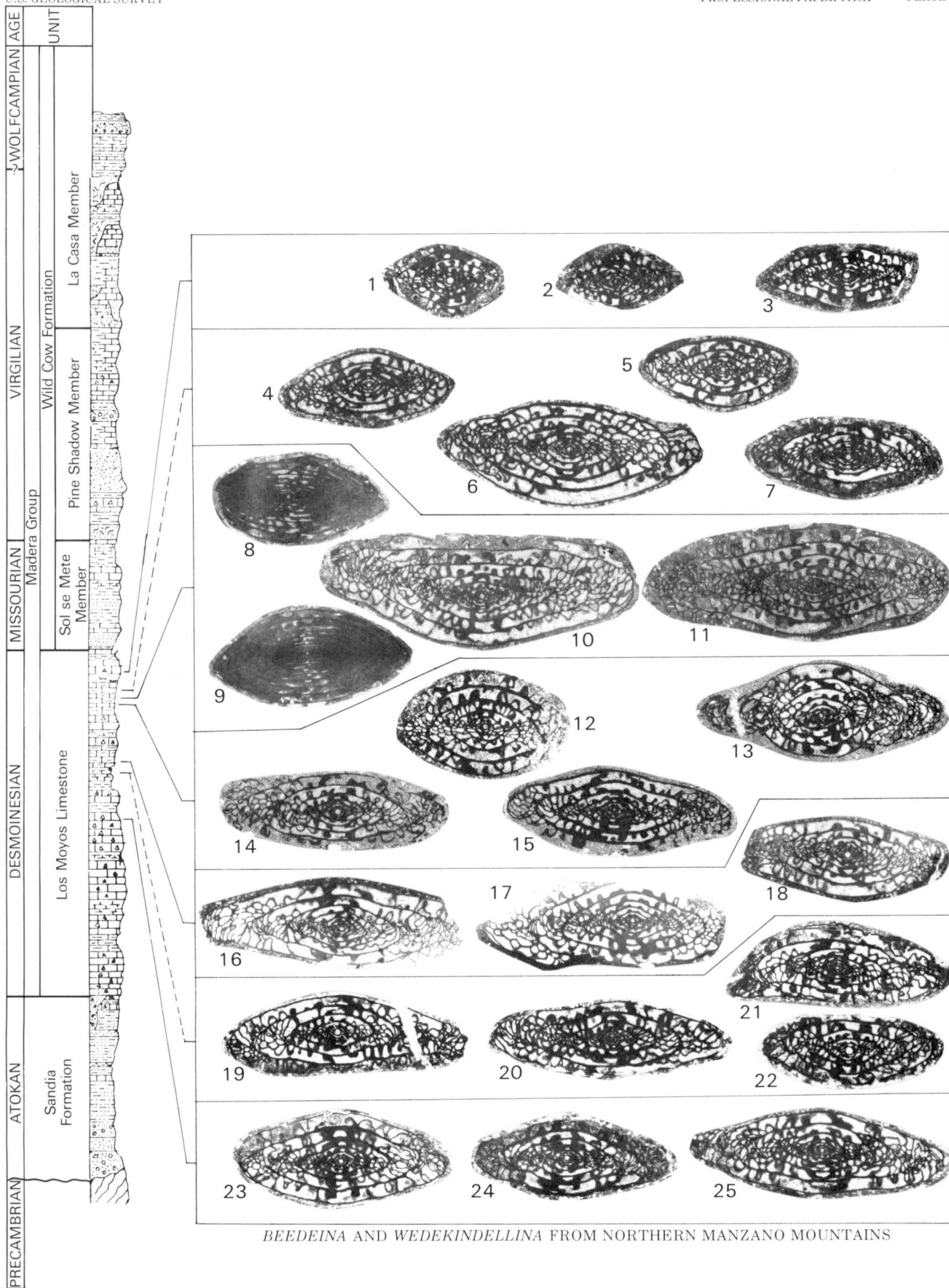
PLATE 5

Fusulinids from the upper part of the Los Moyos Limestone in the northern part of the Manzano Mountains.

[All unretouched photographs; $\times 10$ except where otherwise indicated]

For explanation and scale of graphic section, see text figure 3.

- FIGURE 1-3. USGS f10171. *Beedeina* aff. *B. retusa* (Thompson) 1953, detrital. Axial sections, slides 3, 1, 4, USNM 347158, 347159, 347160.
- 4-7. USGS f10170. *Beedeina retusa* (Thompson), 1953. Axial sections, slides 3, 6, 2, 4, USNM 347161, 347162, 347163, 347164.
- 8, 9. USGS f10169. *Wedekindellina ellipsoides* (Dunbar and Henbest), 1942. Axial sections, slides 3, 1, USNM 347165, 347166.
- 10, 11. USGS f10169. *Beedeina sulphurensis* (Ross and Sabins), 1965. Axial sections, slides 2, 4, USNM 347167, 347168.
- 12, 13. USGS f10168. *Beedeina* sp. C. Axial sections, slides 3, 2, USNM 347169, 347170.
- 14, 15. USGS f10168. *Beedeina* aff. *B. rockymontana* (Roth and Skinner), 1930. Detrital. Axial sections, slides 6, 5, USNM 347171, 347172.
- 16-18. USGS f10167. *Beedeina* aff. *B. rockymontana* (Roth and Skinner), 1930. Axial sections, slides 2, 1, 4, USNM 347173, 347174, 347175.
- 19-22. USGS f10189. *Beedeina rockymontana* (Roth and Skinner), 1930. Axial sections, slides 5, 3, 1, 2, USNM 347176, 347177, 347178, 347179.
- 23-25. USGS f10166. *Beedeina rockymontana* (Roth and Skinner), 1930. Axial sections slides 3, 4, 2 USNM 347180, 347181, 347182.



BEEDEINA AND WEDEKINDELLINA FROM NORTHERN MANZANO MOUNTAINS

Stratigraphic Distribution of some Fusulinids from the Wild Cow and Bursum Formations, Manzano Mountains, New Mexico

By DONALD A. MYERS

STRATIGRAPHIC DISTRIBUTION OF FUSULINID FORAMINIFERA
FROM THE MANZANO MOUNTAINS, NEW MEXICO

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1446-B

Summarizes the stratigraphic distribution of fusulinid Foraminifera from the Middle and Upper Pennsylvanian and Lower Permian rocks in the Manzano Mountains, New Mexico. Compares these faunas with similar faunas found in west and north-central Texas, in the mid-continent region, and in other States as far west as Nevada and eastern Arizona

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STRATIGRAPHIC DISTRIBUTION OF FUSULINID FORAMINIFERA
FROM THE MANZANO MOUNTAINS, NEW MEXICO

DISTRIBUTION OF SOME FUSULINIDS
FROM THE WILD COW AND BURSUM FORMATIONS,
MANZANO MOUNTAINS, NEW MEXICO

By DONALD A. MYERS

ABSTRACT

The Manzano Mountains, on the east side of the Rio Grande valley, extend about 50 mi south from Albuquerque. They are fault-block mountains, tilted east, and consist of Pennsylvanian and Permian rocks resting on a Precambrian core. Fusulinid Foraminifera have been found in all the Pennsylvanian and lower Permian rocks; however, only those from the Wild Cow and Bursum Formations are discussed here. The Wild Cow Formation, a rhythmically deposited sequence of marine and nonmarine rocks, is referred to the zone of *Triticites*. Eight assemblage subzones have been recognized in the Wild Cow Formation: two of Missourian age, five of Virgilian age, and one of Wolfcampian age. The Sol se Mete Member, the basal part of the Wild Cow Formation, contains the early Missourian assemblage subzones of *Triticites nebraskensis* and *T. ohioensis*; representatives of late Missourian time are missing. The Pine Shadow Member, the medial part of the formation, contains the early Virgilian assemblage subzones of *Triticites asperoides*, *T. bensonensis*, and *T. cullomensis*. The La Casa Member, the upper part of the formation, contains the late Virgilian assemblage subzones of *Triticites beedei* and *T. whetstonensis*; it also contains the early Wolfcampian assemblage subzone of *Triticites creekensis*. The assemblage subzone of *T. creekensis* is also present in the overlying Bursum Formation. The zone of *Schwagerina*, represented by that genus, is present higher in the Bursum Formation. Fusulinid faunas representative of late Missourian, earliest Virgilian, and midVirgilian time are not present; the presence of terrigenous clastic rocks suggests uplift and erosion during these time intervals.

INTRODUCTION

The study of fusulinids is important because large amounts of oil and gas have been found in rocks assigned to the Pennsylvanian and Permian Systems in which these fossils occur. Fusulinids have widespread geographic distribution and generally are found in abundance in these systems. They first appeared in Late Mississippian time; they flourished during Pennsylvanian

and most of Permian time; and they became extinct slightly before the end of Permian time. Within this time span, evolutionary changes were continuous and great. The widespread geographic distribution, the great abundance of specimens, and the rapid evolution within this group of fossils serve to make the genera and species of fusulinids valuable for correlating the rocks that contain them.

Much of the stratigraphic correlation in areas of marine Pennsylvanian and Permian rocks is based on age relations determined by study of fusulinids. Because fusulinids are small enough to be preserved intact in well cores and as identifiable fragments in cuttings, they provide an excellent tool to aid in determining the stratigraphic succession in subsurface rocks. Comparison of fusulinids from subsurface rocks with those from outcropping rocks is an important method of establishing correlation between the two.

With current and developing interest in the oil and gas potential of the Rio Grande valley and adjacent areas in New Mexico, the data presented herein will help the biostratigrapher working with subsurface rocks to establish correlation with outcropping Pennsylvanian and Permian rocks along the east side of the Rio Grande.

The use of fusulinids as a stratigraphic tool depends, in part, upon knowledge of the rock-stratigraphic sequence in areas from which fusulinid collections have been made. My studies in the Manzano Mountains have enabled me to obtain several hundred collections of fusulinid-bearing rocks from precisely defined positions in the rock-stratigraphic sequence.

The Manzano Mountains, the area of this report, are on the east side of the Rio Grande valley and extend about 50 mi south from Albuquerque (fig. 1). They are

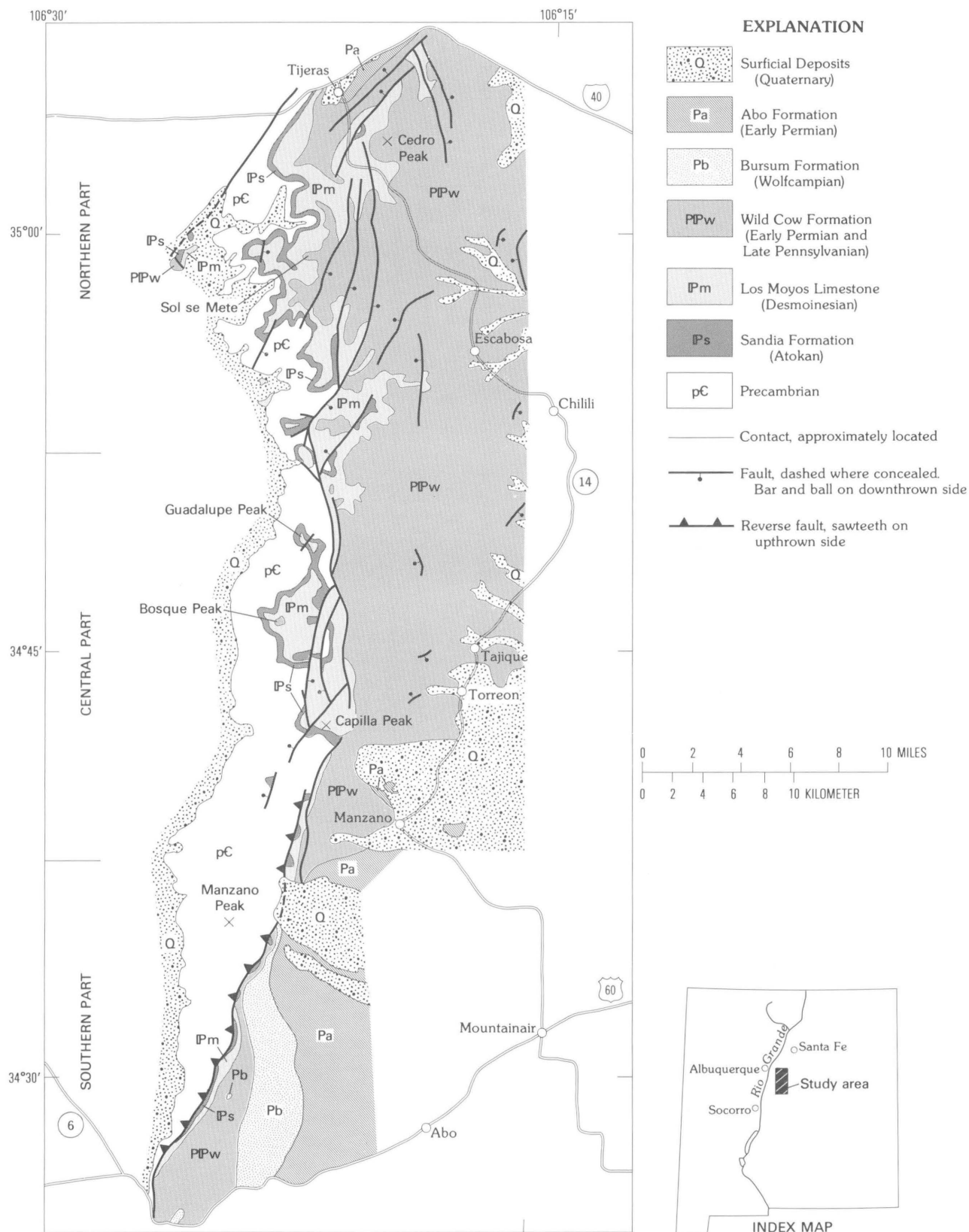


FIGURE 1.—Generalized geologic map of the Manzano Mountains, New Mexico. Modified from Myers (1966, 1967a, 1977), and Myers and McKay (1970, 1971, 1972, 1975, 1976).

fault-block mountains, tilted east, and consist of Pennsylvanian and Permian rocks resting on a Precambrian core. Except for the Manzanita Mountains, included with the Manzano Mountains in this report, the west face of the Manzano Mountains is a near-vertical escarpment of Precambrian rocks with as much as 5,000 ft of relief. The map (fig. 1) shows the general distribution of these rocks, with the exception of local, minor exposures of the Mississippian Arroyo Peñasco Group (Armstrong, 1967) which are not shown.

The Paleozoic rocks that crop out in the Manzano Mountains have been assigned to the Mississippian Arroyo Peñasco Group, to the Pennsylvanian Sandia Formation, to the Pennsylvanian and Permian Madera Group, and to the Permian Bursum and Abo Formations. The Madera Group contains, in ascending order, the Los Moyos Limestone, the Wild Cow Formation, and the Bursum Formation (Myers, 1973). The faunal zone of *Fusulinella* is in the Sandia Formation, the zone of *Beedeina* is in the Los Moyos Limestone, the zone of *Triticites* is in the Wild Cow Formation and in the lower part of the Bursum Formation, and the zone of *Schwagerina* is in the upper part of the Bursum Formation. Fusulinids or other marine fossils have not been found in the Abo Formation.

Fusulinid faunas in the above-mentioned marine rocks are abundant and varied; they are common in limestone and are found in many calcareous shales; they are rare in sandstone. In many of the rocks the fusulinids are associated with productid, spiriferid, and other brachiopods; crinoid-stem segments; tetracorals; bryozoans, and other marine faunas that suggest shallow tropical to subtropical waters. More than 450 samples of fusulinid-bearing rock were collected from Pennsylvanian and Lower Permian rocks in the Manzano Mountains. Many of these samples were from stratigraphic sections that were measured during various field seasons between 1962–1976; other samples were taken to provide stratigraphic control.

Chapter A has illustrated the stratigraphic distribution of the fusulinid faunas from the Middle Pennsylvanian Sandia Formation and Los Moyos Limestone. The present report illustrates the stratigraphic distribution of the fusulinid faunas from the Upper Pennsylvanian and Lower Permian Wild Cow and Bursum Formations. The illustrated specimens were prepared from samples collected from measured sections, or, less commonly, from nearby outcrops that were traced into the measured sections. The three illustrated sections (figs. 2, 3) are composite and represent the stratigraphy of the Wild Cow and Bursum Formations in the southern, central, and northern parts of the Manzano Mountains. The stratigraphic position of each assemblage of fusulinids is indicated on each of these composite sections on

plates 1–13; the various zones and assemblage subzones of fusulinids are shown on figure 2; the relations of these zones and assemblage subzones to the Missourian, Virgilian, and Wolfcampian Series of the Pennsylvanian and early part of the Permian Systems is shown on figure 4.

Little information has been published on the fusulinids in the Manzano Mountains. Needham (1937, p. 12, localities 7, 8, 9) listed several species from the northern end of the mountains and from along U.S. Highway 60 at the south end of the mountains. Stratigraphic data given by Needham for these fusulinids are sketchy. Myers (1966, 1967a, 1969, 1977), Myers and McKay (1970, 1971, 1972, 1974, 1976), and Myers, Sharps, and McKay (1981) indicated the stratigraphic position of some fusulinids on stratigraphic sections for various geologic maps of parts of the Manzano Mountains. Myers (1973) discussed, in general terms, the ages of fusulinids in the Madera Group. Myers (chapter A) illustrated the fusulinid faunas and their stratigraphic positions from the Sandia Formation and from the Los Moyos Limestone in the lower part of the Madera Group.

LATE PALEOZOIC STRATIGRAPHY OF THE MANZANO MOUNTAINS

The Mississippian Arroyo Peñasco Group (Armstrong, 1967) is locally present on the northwest side of Bosque Peak where it consists of less than 13 ft of gray, nonfossiliferous limestone that has a lateral extent of no more than a few hundred feet; it is also present southwest of Tijeras where it is less than 20 ft thick and is poorly exposed. For cartographic reasons, these rocks were included with the Sandia Formation (Myers and McKay, 1971, 1976).

The oldest Pennsylvanian formation, the Sandia Formation, is of Atokan age (Myers, chapter A) and it lies in erosional contact with the Precambrian. The Sandia is a slope-forming unit that ranges in thickness from less than 10 ft to about 300 ft; its average thickness is about 200 ft. The Sandia is mostly olive-drab, micaceous siltstone, sandstone, and conglomerate containing a few thin discontinuous beds of impure marine limestone. At most localities, the basal beds are conglomerate or coarse-grained sandstone derived from nearby Precambrian rocks. The limestone beds contain various species of *Fusulinella*, all of which indicate Atokan age (Myers, chapter A). The contact between the Sandia and the overlying Los Moyos Limestone is gradational.

The Los Moyos Limestone, the oldest formation of the Madera Group (Myers, 1973) is the lower gray limestone

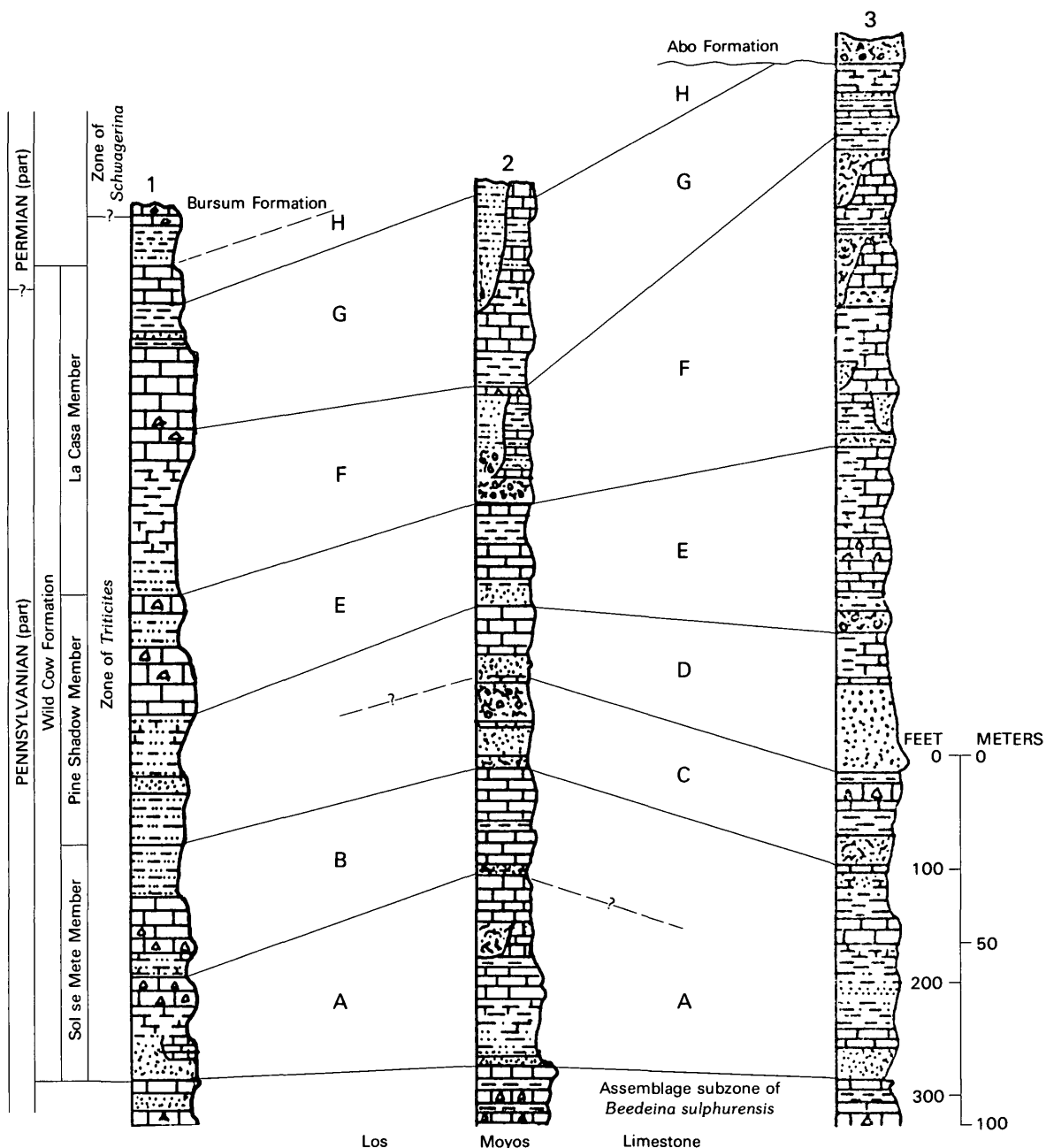


FIGURE 2.—Composite stratigraphic sections, fusulinid zones and assemblage subzones in Upper Pennsylvanian and Lower Permian rocks, Manzano Mountains, New Mexico. Composite stratigraphic sections: 1, southern Manzano Mountains (Myers and McKay, 1974); 2, central Manzano Mountains (Myers, 1966, 1967a, 1969); 3, northern Manzano Mountains (Myers, 1970, 1976). Assemblage subzones: A, *Triticites nebraskensis*; B, *T. ohioensis*; C, *T. asperoides*; D, *T. bensonensis*; E, *T. cullomensis*; F, *T. beedei*; G, *T. whetstonensis*; H, *T. creekensis*.

member of the Madera Limestone of Read and others (1944) and contains massive, cliff-forming, cherty gray limestone about 600 ft thick. The Los Moyos contains a few thin beds of pebble conglomerate, sandstone, and siltstone about 200 ft above the base. The upper part of the formation contains local beds of conglomeratic sandstone, sandstone, siltstone, and calcareous shale in-

terbedded with the limestone; these beds become more common toward the top of the formation. Fusulinids from the Los Moyos are referred to various species of *Beedeina* and *Wedekindellina* and indicate Desmoinesian age (Myers, chapter A). The uppermost beds of the Los Moyos Limestone contain rare specimens of *Eowaeringella*; this fusulinid indicates earliest

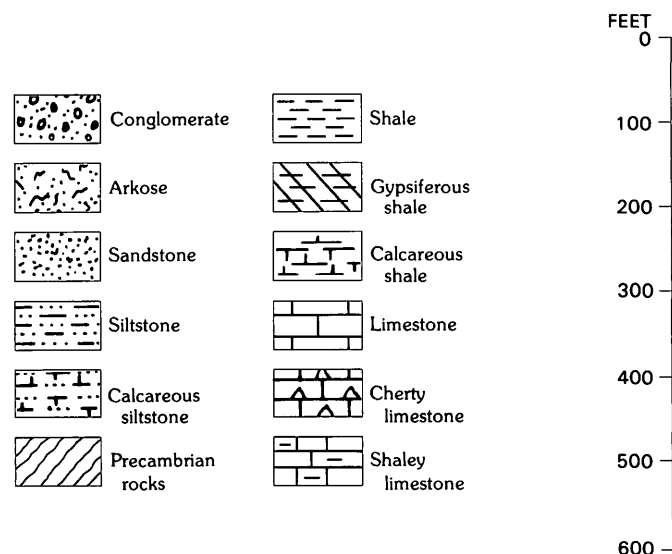


FIGURE 3.—Explanation of graphic sections on figure 2 and plates 1–13. Scale applies to plates 1–13 only.

Missourian age for the top few feet of the Los Moyos (chapter A). The contact between the Los Moyos and the overlying Wild Cow Formation is erosional.

The Wild Cow Formation, the middle formation of the Madera Group (Myers, 1973) is the arkosic limestone member of the Madera Limestone of Read and others (1944), and it lies entirely within the zone of *Triticites*. The Wild Cow has an average thickness of about 600 ft and contains a rhythmically-deposited sequence of conglomerate, sandstone, siltstone, shale, and limestone (Myers, 1973). The conglomerate and sandstone are commonly arkosic, mostly nonmarine and contain debris of fossil plants in places; the siltstone and shale are both marine and nonmarine; the limestone is mostly marine shelf deposits. The Wild Cow has been subdivided into three members, from oldest to youngest: Sol se Mete, Pine Shadow, and La Casa. The formation disconformably overlies the Los Moyos Limestone of mostly Desmoinesian age and is gradationally overlain by the Wolfcampian Bursum Formation in the southern part of the mountains; it is disconformably overlain by the Permian Abo Formation in the northern part of the mountains.

Fusulinids in the Wild Cow Formation are most commonly found in medium- to light-gray calcarenite and calcareous shale; they are less commonly found in algal micrites; rarely are they found in calcareous sandstone where their tests are usually abraded, broken, and may show evidence of reworking.

Reworked fusulinid faunas have been noted in the Wild Cow. At USGS locality f10276, the Pine Shadow Member of the Wild Cow Formation contains reworked late Desmoinesian fusulinids in a limestone-pebble conglomerate (pl. 13, figs. 19–22).

| SYSTEM | SERIES | STRATIGRAPHIC UNIT | Fusulinid zones (and assemblage subzones) |
|----------------------|------------------|---------------------|---|
| PERMIAN (part) | Wolfcampian part | Abo Formation | ? |
| | | Bursum Formation | Zone of <i>Schwagerina</i> |
| PENNSYLVANIAN (part) | Virgilian | La Casa Member | <i>T. creekensis</i> (H) |
| | | | <i>T. whetstonensis</i> (G) |
| | | | <i>T. beedei</i> (F) |
| | | | <i>T. cullomensis</i> (E) |
| | Missourian | Pine Shadow Member | <i>T. bensonensis</i> (D) |
| | | | <i>T. asperoides</i> (C) |
| PENNSYLVANIAN (part) | Desmoinesian | Sol se Mete Member | <i>T. ohioensis</i> (B) |
| | | | <i>T. nebraskensis</i> (A) |
| | | | <i>B. sulphurensis</i> * |
| | | | <i>B. rockymontana</i> * |
| | Atokan part | Los Moyos Limestone | <i>B. novamexicana</i> * |
| | | | <i>B. insolita</i> * |
| | | Sandia Formation | <i>F. whitensis</i> * |
| | | | <i>F. devexa</i> * |

* Myers, this paper, pt. A, fig. 2

FIGURE 4.—Summary of fusulinid zones and assemblage subzones, Manzano Mountains, New Mexico. Assemblage subzones: A, *Triticites nebraskensis*; B, *T. ohioensis*; C, *T. asperoides*; D, *T. bensonensis*; E, *T. cullomensis*; F, *T. beedei*; G, *T. whetstonensis*; H, *T. creekensis*.

The Bursum Formation gradationally overlies the Wild Cow Formation in the southern part of the mountains and consists of 100 ft or more of lenticular beds of red, arkosic, hematitic sandstone; red and locally green mudstone and siltstone; and greenish-gray marine limestone. The Bursum mostly underlies gently sloping alluvium-covered surfaces. The top of the formation is the highest marine limestone that underlies the nonmarine Abo Formation. The Bursum thins to the north and may have been either replaced laterally by redbeds of the Abo Formation, or it may have been removed by erosion that accompanied deposition of the Abo. In the northern part of the mountains, the formation is absent. Field evidence suggests that many of the Bursum red beds grade into gray shale and limestone of the upper part of the La Casa Member of the Wild Cow Formation. The Bursum contains fusulinids of Early Permian age.

Fusulinid faunas from the Wild Cow and Bursum Formations have been assigned to the zones of *Triticites* and *Schwagerina*. The zone of *Triticites* has been subdivided into eight assemblage subzones: *Triticites*

nebraskensis, *T. ohioensis*, *T. asperoides*, *T. bensonensis*, *T. cullomensis*, *T. beedei*, *T. whetstonesis*, and *T. creekensis* (figs. 2 and 3).

The Abo Formation, of Permian age, consists of about 800 ft (Hatchell and others, 1982) of nonmarine, cross-bedded, hematitic, locally arkosic conglomerate, sandstone, siltstone, and mudstone. The rocks are mostly dark red in the lower part, grading up into light red at the top. Thin lenses of nodular freshwater limestone are present locally in the lower part. Impressions of plants and fragments are common in the lower part; burrows and other trace fossils are common.

STRATIGRAPHIC DISTRIBUTION OF THE FUSULINIDS

The upper part of the Madera Group, in ascending order, includes the Wild Cow Formation and the Bursum Formation. The Wild Cow Formation, of Late Pennsylvanian and Early Permian age, is subdivided, in ascending order, into the Sol se Mete, Pine Shadow, and La Casa Members. The Bursum Formation, of Early Permian age, has not been subdivided into members. Fusulinid faunas are distributed throughout the upper part of the Madera Group. Eight assemblage subzones have been recognized in the Wild Cow Formation.

WILD COW FORMATION

SOL SE METE MEMBER

The Sol se Mete Member, from 150 ft to 300 ft thick, has an average thickness of about 200 ft, and it represents nonmarine to marine depositional cycles of early Missourian age. The basal beds consist of conglomerate, sandstone, siltstone and minor arkose, commonly containing petrified logs. The basal beds range in thickness from about 15 ft to 100 ft or more and are gradationally overlain by 30–70 ft of calcareous gray shale and nodular limestone. The top of the member is 30–60 ft of locally cherty gray limestone that forms cliffs or ledges. The member is thinnest at the south end of the mountains and thickest in the central part of the mountains.

Fusulinids are sparse in the southern part of the mountains; they are common in the central and northern parts.

ASSEMBLAGE SUBZONE OF *TRITICITES NEBRASKENSIS*

The oldest fusulinids from the Sol se Mete Member are referred to the assemblage subzone of *Triticites nebraskensis* (A, on fig. 2). *Triticites nebraskensis* Thompson, 1934 is found in the lower 25 ft of the

member in the southern part of the mountains (pl. 1, figs. 22–24) and in the central and northern part of the mountains it is found in the lower 100 ft (pl. 3, figs. 15–25).

The middle part of the member does not contain fusulinids in the southern and northern parts of the mountains. *Triticites* cf. *T. celebroides* Ross, 1965 (pl. 2, figs. 10–12) is found at about the middle of the member in the central part of the mountains. *T. celebroides* appears to be intermediate in evolutionary development between *T. nebraskensis* and the younger *T. ohioensis*, and is here included in the assemblage subzone of *T. nebraskensis*.

ASSEMBLAGE SUBZONE OF *TRITICITES OHIOENSIS*

The youngest fusulinids from the member are referred to as the assemblage subzone of *Triticites ohioensis* (B, on fig. 2). Fusulinids are sparse in the upper part of the member in the southern part of the mountains; however, the genus *Kansanella* sp. (pl. 1, figs. 18–21) has been found at one locality, about 40 ft below the top. In the central part of the mountains, *Triticites* cf. *T. ohioensis* Thompson, 1936 (pl. 2, figs. 1–9) dominates the fusulinid fauna where it first appears about 20 ft below the top of the member. In the northern part of the mountains, *T. ohioensis*, (pl. 3, figs. 11–14), and *T. aff. T. ohioensis* (pl. 3, figs. 7–10) are common in the limestone in the upper 60 ft of the section.

PINE SHADOW MEMBER

The Pine Shadow Member, of early Virgilian age, is from 200 ft to 250 ft thick and has an average thickness of about 225 ft. The basal beds of the member throughout most of the mountains are arkosic conglomerate; however, in the southern part of the mountains they are micaceous siltstone and fine-grained sandstone. Fragments of fossil wood and carbonized plant debris are common. Thickness of the basal beds ranges from 5 ft to more than 100 ft, but is generally 50–90 ft. These basal beds, in most places, are overlain by less than 10 ft to about 60 ft of yellow to gray siltstone and minor amounts of shale that become calcareous toward the top. The upper part of the member is mostly ledge- to cliff-forming limestone containing minor amounts of sandstone, siltstone, and calcareous shale. The upper beds of limestone are generally 50–70 ft thick, but locally may be as much as 130 ft thick.

There are no fusulinid-bearing beds in the lower half of the Pine Shadow Member in the southern part of the mountains; they are common in the limestone beds in the upper half. Fusulinids are common throughout the

member in the central and northern parts of the mountains. There are relatively few distinctive species that are common to the southern, central, and northern parts of the mountains; therefore, assignment of faunas to the following assemblage subzones is uncertain.

ASSEMBLAGE SUBZONE OF *TRITICITES ASPEROIDES*

The interval representing this assemblage subzone in the southern part of the mountains is barren of fusulinids and probably contains no marine fossils. In the central part of the mountains, the assemblage subzone of *Triticites asperoides* (C, on fig. 2) is represented in two thin beds of limestone between 50 and 75 ft above the base of the member. Fusulinids from these two limestone beds are *Millerella?* sp. (pl. 4, fig. 17), *Triticites gilaensis* Ross, 1969 (pl. 4, figs. 18–20), and *Triticites* sp. (pl. 4, figs. 15, 16). In the northern part of the mountains, the assemblage subzone is represented in a limestone sequence about 55–60 ft above the base of the member. The fusulinids from this limestone sequence are *Triticites* aff. *T. asperoides* Ross, 1965 (pl. 3, figs. 4–6), and *Triticites* aff. *T. primarius* Merchant and Keroher, 1939 (pl. 3, figs. 1–3).

ASSEMBLAGE SUBZONE OF *TRITICITES BENSONENSIS*

The interval representing this subzone in the southern part of the mountains is barren of fusulinids and no marine fossils have been recognized. In the central part of the mountains, the assemblage subzone of *Triticites bensonensis* (D, on fig. 2) is represented in a thick sequence of limestone at about the middle of the member. The fusulinids from this limestone sequence are *Triticites* sp. (pl. 4, figs. 12–14) and *Triticites secalicus* (Say), 1823 (pl. 4, figs. 5–11). In the northern part of the mountains, the assemblage subzone is represented in an 80-ft-thick sequence of limestone and shale at about the middle of the member. Near the base of this sequence, *Oketaella?* sp. (pl. 6, figs. 12–15) has been found. Near the middle of the unit, in a limestone quarry, numerous specimens of *Triticites bensonensis* Ross and Tyrrell, 1965 (pl. 6, figs. 9–11) and *Dunbarinella* aff. *D. wildei* Kauffman and Roth, 1966 (pl. 6, figs. 4–8) occur. The top of this sequence contains a large, slender, subcylindrical *Triticites* sp. (pl. 6, figs. 1–3) in calcareous shale.

ASSEMBLAGE SUBZONE OF *TRITICITES CULLOMENSIS*

This assemblage subzone (E, on fig. 2) is present in the uppermost limestone beds of the member in the southern part of the mountains. *Triticites collus?*

Burma, 1942 (pl. 1, figs. 14–17) is found at the base of the uppermost limestone sequence. Between about 30 ft and 55 ft above the base of the sequence, *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927 is found (pl. 1, figs. 6–13); this species (pl. 1, figs. 1–5) is also present at the top of the Pine Shadow.

In the central part of the mountains, the assemblage subzone of *T. cullomensis* is marked by the first occurrence of *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927 (pl. 4, figs. 1–4). Fusulinids at the top of the Pine Shadow consist of *Triticites* aff. *T. acutuloides* Ross, 1965 (pl. 5, figs. 18–20), and *Triticites* aff. *T. confertoides* Ross, 1965 (pl. 5, figs. 15–17). *T. aff. T. confertoides*, in the central part of the mountains and is often associated with hemispherical to lenticular colonies of cryptozoon-like bodies at the top of the uppermost bed (Myers and McKay, 1972, as algal balls in map unit C). The average diameter of these colonies is 1.5–2 inches.

In the northern part of the mountains, the assemblage subzone is found in the upper 120 ft of the member where the rocks are mostly limestone and calcareous shale. Fusulinids are abundant in the lower half of the interval; they have not been found in the upper half. The oldest fusulinid from this subzone is *Triticites* cf. *T. turgidus* Dunbar and Henbest, 1942 (pl. 7, figs. 20–22), which is common near the base. The middle of the interval is characterized by numerous specimens of *Triticites* aff. *T. confertoides* Ross, 1965 (pl. 7, figs. 17–19).

LA CASA MEMBER

The La Casa Member, of late Virgilian and early Wolfcampian age, is the uppermost member of the Wild Cow Formation. It is about 290 ft thick at the type section in the southern part of the mountains. The upper beds of the member have been removed by late Tertiary or Holocene erosion in the central and most of the northern parts of the mountains. In Tijeras Canyon, in roadcuts along Interstate Highway 40, the member is about 335 ft thick (Myers and McKay, 1976, section 2).

In the southern part of the mountains, the member consists of about 120 ft of poorly exposed siltstone and shale at the base; about 100 ft of ridge-forming, light-gray calcarenite; as much as 40 ft of red and gray shale and yellowish-green calcareous sandstone; and, at the top, about 30 ft of light-olive-gray calcarenite. Farther north the basal beds of the member are arkosic, and locally conglomeratic; these beds are about 30 ft thick in the Tajique area and, in the Sol se Mete area, are about 50 ft thick. In both the Tajique and Sol se Mete areas, the medial 100-ft-thick bed of calcarenite in the southern part of the mountains has been replaced by alternating beds of limestone, siltstone, sandstone, and

shale. Northeast of Tijeras, the upper limestone beds of the member have been replaced by red beds and a few thin beds of gray calcarenite (Myers and McKay, 1976). Three assemblage subzones have been recognized in the La Casa Member: *Triticites beedei*, *T. whetstonensis*, and *Triticites creekensis* (fig. 2).

ASSEMBLAGE SUBZONE OF *TRITICITES BEEDEI*

This assemblage subzone (F, on fig. 2) is represented throughout the Manzano Mountains. In the southern part of the mountains, the interval of rocks that contains the subzone is in the lower 145 ft of the member. The oldest fusulinids in the subzone, *Triticites* cf. *T. arcuosoides* Ross, 1969 (pl. 8, figs. 19–21) are found in nodular limestone about 74 ft above the base of the member. Somewhat higher in the section, a few feet below the thick medial calcarenite, is *Triticites* cf. *T. beedei* Dunbar and Condra, 1927 (pl. 8, figs. 12–18). The basal beds of the thick calcarenite contain *Triticites* aff. *T. birdspringensis* Cassity and Langenheim, 1966 (pl. 8, figs. 9–11). The top of the subzone is marked by *Triticites* cf. *T. callosus* Dunbar and Henbest, 1942 (pl. 8, figs. 5–8) and *Triticites* aff. *T. beedei* Dunbar and Condra, 1927 (pl. 8, figs. 1–4).

In the central part of the mountains, the oldest fusulinids from the assemblage subzone are from thin beds of limestone about 25 ft above the base of the member. An assemblage of fusulinids from this limestone consists of *Triticites* cf. *T. beedei* Dunbar and Condra, 1927 (pl. 5, figs. 12–14); *Millerella?* sp. (pl. 5, figs. 7, 10); *Triticites* aff. *T. confertoides* Ross, 1965 (pl. 5, figs. 9, 11); and *Triticites* aff. *T. nealensis* Ross, 1965 (pl. 5, figs. 5, 6, 8). Another thin bed of limestone, about 45 ft above the base of the member contains *Triticites* aff. *T. beedei* Dunbar and Condra, 1927 (pl. 5, figs. 3, 4). The upper thin bed of limestone whose stratigraphic position is uncertain, but is probably about 55 ft above the base of the member, contains *Oketaella* sp. (pl. 5, figs. 1, 2). In many places the three limestone beds just mentioned have been replaced by channel-fill deposits of conglomerate, sandstone, and siltstone. A thin bed of limestone at the top of these channel-fill deposits, about 92 ft above the base of the member, contains *Triticites* cf. *T. plummeri* Dunbar and Condra, 1927 (pl. 11, figs. 17–19).

The oldest fusulinids from the assemblage subzone in the northern part of the mountains are from calcareous claystone about 40 ft above the base of the member. These fusulinids are *Triticites* cf. *T. beedei* Dunbar and Condra, 1927 (pl. 7, figs. 14–16) and *Dunbarinella* sp. (pl. 7, figs. 12, 13). About 55 ft above the base, in a limestone that caps Cedro Peak, *Triticites* cf. *T. beedei*

(pl. 7, figs. 9–11), *Dunbarinella* sp. (pl. 7, fig. 8), and *Millerella?* sp. (pl. 7, fig. 7) are found. About 60 ft above the base, *Triticites* cf. *T. cuchilloensis* Needham, 1937 (pl. 7, figs. 4–6) is found. *Triticites* sp. (pl. 7, figs. 1–3) is found in nodular limestone about 110 ft above the base.

About 145 ft above the base of the member, the same *Triticites* (pl. 12, figs. 12–15) as on pl. 7 (figs. 1–3) is found. A calcareous shale and nodular limestone about 180 ft above the base contains *Triticites* aff. *T. cameratoides* Ross, 1965 (pl. 12, figs. 10, 11) and *Ozawainella?* sp. (pl. 12, fig. 9). About 240 ft above the base, a massive limestone contains *Triticites* aff. *T. plummeri* Dunbar and Condra, 1927 (pl. 12, figs. 6–8). Exposures in cuts along Interstate Highway 40 (old U.S. Highway 66) have yielded *Dunbarinella* sp. (pl. 12, fig. 4) and *Triticites* aff. *T. plummeri* (pl. 12, figs. 3, 5) from about 64 ft below the base of the Permian Abo Formation.

ASSEMBLAGE SUBZONE OF *TRITICITES WHETSTONENSIS*

This assemblage subzone (G, on fig. 2) includes that part of the La Casa Member that contains the latest Pennsylvanian fusulinids. In the southern part of the mountains, the base of the subzone is marked by the first appearance of *Triticites ventricosus* var. *sacramentoensis* Needham, 1937 (pl. 9, figs. 9–17). *Triticites* aff. *T. beedei* Dunbar and Condra, 1927 (pl. 10, figs. 16–19) has been found near the top of the assemblage subzone.

In the central part of the mountains, the subzone is characterized, near its base, by an obese form of *Triticites* cf. *T. plummeri* Dunbar and Condra, 1927 (pl. 11, figs. 17–19). *Triticites* cf. *T. whetstonensis* Ross and Tyrrell, 1965 (pl. 11, figs. 6–16) is common in many of the upper limestone beds of the member.

In the northern part of the mountains, the sole representative of this assemblage subzone is *Triticites* aff. *T. rhodesi* Needham, 1937 (pl. 12, figs. 1, 2) at the top of the La Casa Member.

ASSEMBLAGE SUBZONE OF *TRITICITES CREEKENSENSIS*

The fusulinids in this assemblage subzone (H, on fig. 2) are all referred to rocks of earliest Permian age. These rocks include the uppermost beds of the La Casa Member of the Wild Cow Formation and part of the overlying Bursum Formation.

In the southern part of the mountains, the base of the uppermost limestone beds of the La Casa Member contains *Triticites* aff. *T. pinguis* Dunbar and Skinner, 1937 (pl. 9, figs. 1, 2, 5), and *Leptotriticites* sp. (pl. 9, figs. 3, 4); also, in these same basal beds, *Triticites* cf. *T. creekensis* Thompson, 1954 (pl. 10, figs. 13–15) is found.

Triticites sp. (pl. 10, figs. 9–12) occurs a few feet above the basal beds. At the top of the member, *Triticites* cf. *T. creekensis* Thompson, 1954 (pl. 10, figs. 6–8), *Triticites pinguis* Dunbar and Skinner, 1937 (pl. 10, figs. 4, 5), *Millerella?* sp. (pl. 10, fig. 3), and *Schubertella* sp. (pl. 10, figs. 1, 2) are found.

In the central part of the mountains, in the uppermost beds of the member, the subzone is marked by *Triticites* sp. (pl. 11, figs. 1–3, 5), and *Leptotriticites* sp. (pl. 11, fig. 4). The assemblage subzone is probably not present in the northern part of the mountains. At one locality in the northern part of the mountains, sparse limestone nodules that weather from red beds beneath the Permian Abo Formation contain rare specimens of *Triticites* cf. *T. nealensis* Ross, 1965 (pl. 13, figs. 13–18) referred to this assemblage subzone. These nodules are from a zone between 3 and 5 ft below the base of the Abo.

The fusulinid faunas of the Wild Cow Formation change significantly from the early Missourian faunas at the base of the formation to the early Wolfcampian faunas at the top. The faunas are similar laterally and mark narrow zones that have been identified as assemblage subzones (fig. 2). Deposition of the carbonate rocks that contain these assemblage subzones was in a marine tropical to subtropical shelf environment of shallow to moderate water depth. Carbonate deposition was repeatedly interrupted by incursions of nearshore and nonmarine terrigenous sediments that disrupted the faunal succession. These disruptions may have been local, as in the southern part of the mountains where the assemblage subzones of *Triticites asperoides* and *T. bensonensis* are not represented in the Pine Shadow Member, or it may have been regional throughout the Manzano Mountains where marine faunas of late Missourian time and parts of Virgilian time are absent (fig. 4). Deposition of marine rocks and succession of fusulinid faunas was apparently continuous or nearly continuous across the boundary between Pennsylvanian and Permian time.

BURSUM FORMATION

The Bursum Formation (fig. 1), the uppermost formation of the Madera Group, is present only in the southern part of the Manzano Mountains. Exposures of the Bursum are generally poor, and no complete section was measured or described. It consists (Myers, 1977) of about 250 ft of reddish-brown, arkosic, hematitic, crossbedded, locally conglomeratic sandstone, red and gray shale, and olive-gray limestone. The base of the formation is gradational from the underlying La Casa Member of the Wild Cow Formation. The

top of the formation is the top of the highest marine limestone. It is disconformably overlain by the Abo Formation. The assemblage subzone of *Triticites creekensis* is present in the lower beds of the Bursum. Limestone and nodular limestone about 50 ft above the base of the formation contain *Triticites creekensis* Thompson, 1954 (pl. 13, figs. 9–12). Still in the lower part of the Bursum, but probably stratigraphically above these fusulinids, *Leptotriticites* sp. (pl. 13, figs. 6, 8) and *Triticites* aff. *T. creekensis* Thompson, 1954 (pl. 13, fig. 7) have been found. Still in the lower part of the formation, *Triticites* aff. *T. creekensis* (pl. 13, figs. 3–5) has been found in algal limestone nodules.

The youngest fusulinids found in the area are *Schwagerina pinosensis* Thompson, 1954 (pl. 13, figs. 1, 2) from a 12-foot-thick bed of brownish-gray, wavy-bedded calcarenite at about the middle of the formation. These fusulinids are from the zone of *Schwagerina*, which is not represented elsewhere in the Manzano Mountains.

FAUNAL CORRELATIONS

Correlations of the fusulinid assemblage subzones with fusulinid assemblages from west Texas, central Texas, the mid-continent region, and parts of the western and southwestern United States are attempted in this chapter. Many of the fusulinid faunas from the mid-continent region, particularly those of Virgilian age, have not been illustrated or described. Where comparisons are made with these faunas, reference is made to unfigured material in my collections. The stratigraphic positions of the various assemblage subzones in the Manzano Mountains are shown on figure 2.

ASSEMBLAGE SUBZONE OF *TRITICITES NEBRASKENSIS*

The assemblage subzone of *Triticites nebraskensis*, of early Missourian age, embraces the lower part of the Sol se Mete Member of the Wild Cow Formation. It is equivalent to the *Triticites celebroides* assemblage subzone of Ross (1965, p. 1159) from the lower part of the Gaptank Formation in west Texas. The fauna is the same as that illustrated by Myers (1960, pl. 16) from the Brownwood Shale Member of the Graford Formation in central Texas.

In the mid-continent region, *T. nebraskensis*, recorded as *T. exiguus* by Dunbar and Condra (1927), is from the Avoca Limestone of Nebraska and the Cherryvale Shale of Missouri.

Thompson and Thomas (1953, p. 31) have reported *T. nebraskensis* from the Casper Formation about 176 ft above its base in Wyoming. In the Wasatch Mountains of Utah, Thompson, Verville, and Bissell (1950) described *T. springvillensis* from about 12,040 ft above the base of the Oquirrh Formation and near the base of the Missourian part of that formation. The evolutionary development of *T. springvillensis* is similar to that of *T. nebraskensis* and the two species may have been contemporaneous. Rich (1961, p. 1170) has recorded *T. springvillensis* from beds 1,975–2,000 ft above the base of the Bird Spring Formation in Clark County, Nevada. *Triticites nebraskensis* is present in a limestone bed 18 ft below the top of the Lead Camp Limestone in the San Andres Mountains, in southern New Mexico (Bachman and Myers, 1969, p. C23).

The Joyita Hills, 23 mi southwest of the Manzano Mountains in Socorro County, contain a short section of Pennsylvanian rocks (Kottowski and Stewart, 1970). At the top of this section, earliest Missourian rocks are found and they contain *Triticites nebraskensis* associated with *T. riograndensis* and *T. liosepta* Stewart, 1970.

Few, if any, species of *Triticites* older than *T. nebraskensis* have been reported from the mid-continent region or western United States. This assemblage subzone appears to define a biostratigraphic position that appeared during early Missourian time.

ASSEMBLAGE SUBZONE OF *TRITICITES OHIOENSIS*

The assemblage subzone of *Triticites ohioensis* lies in the upper part of the Sol se Mete Member of the Wild Cow Formation. In west Texas, in the Gaptank Formation, the assemblage subzone of *T. collus* (Ross, 1965, p. 1162) is probably equivalent to that of *T. ohioensis*, although there are no species in common. In central Texas, the Manzano faunas are equivalent to faunas from the Adams Branch Limestone Member of the Graford Formation where *T. muscerda* Myers, 1967b, a close relative to *T. ohioensis*, and *Kansanella voluminosa* Myers, 1967b are found (Myers, 1960, 1967b). In the mid-continent region, the *T. ohioensis* fauna is found in the Brush Creek and Cambridge Limestone Members of the Conemaugh Formation in Galia County, Ohio (Thompson, 1936, p. 682). Elsewhere, the *T. ohioensis* fauna has been reported from the Livingston Limestone in Edgar County, Illinois (Dunbar and Henbest, 1942, p. 131), and also from the Winterset Limestone Member of the Dennis Limestone in Iowa (Thompson, 1957, p. 314).

In the western part of the United States, *T. cf. T. ohioensis* has been recorded from the Whetstone Mountains, Arizona, in the Horquilla Limestone about 800 ft above the base (Ross, 1965, p. 632).

Field evidence in the Manzano Mountains indicates that younger Missourian strata, if they were deposited, have been removed by erosion. The basal sandstone and conglomerate beds of the overlying Pine Shadow Member represent subaerial erosion and are of probable Virgilian age. Thus, a hiatus, represented by terrigenous rocks in the Manzano Mountains and by the absence of fusulinid faunas that are present in the mid-continent, represents the upper part of the Kansas City Group and all of the Lansing and Pedee Groups in the midcontinent.

ASSEMBLAGE SUBZONE OF *TRITICITES ASPEROIDES*

The assemblage subzone of *Triticites asperoides*, of early Virgilian age, is found in the lower 75 ft of the Pine Shadow Member. The fauna is similar to that described by Ross (1965, p. 1160) from his bed G in the Gaptank Formation, west Texas; it may be approximately equivalent to his assemblage subzone of *T. moorensis*. This fauna, although there are no species in common, has a similar evolutionary development to that figured by Myers (1960) (pl. 18, figs. 10–23) from the Bluff Creek Shale Member of the Graham Formation in central Texas. It resembles material in my collections from the Douglas Group and lower part of the Shawnee Group of early Virgilian age in Kansas. The fauna of this assemblage subzone has not been recognized in Utah, Nevada, or Arizona.

ASSEMBLAGE SUBZONE OF *TRITICITES BENSONENSIS*

The evolutionary development of the various species of fusulinids in the assemblage subzone of *Triticites bensonensis* is similar to that in Ross' (1965, p. 1160) beds H and I in the Gaptank Formation, west Texas. The faunas have a close similarity to that from the Gunsight Limestone Member of the Graham Formation in central Texas (Myers, 1960) (pl. 18, figs. 1–3; pl. 19, figs. 1–15). The fauna resembles material from my collections from the Shawnee Group in Kansas. The species from which the subzone is named was described by Ross and Tyrrell (1965, p. 619) from 50 to 120 ft above the base of the Earp Formation in the Whetstone Mountains, Arizona and has also been recorded from about 100 ft

above the highest Missourian fusulinids in the Gila Mountains, Arizona.

ASSEMBLAGE SUBZONE OF *TRITICITES CULLOMENSIS*

The assemblage subzone of *Triticites cullomensis* is present in the upper beds of the Pine Shadow Member. The presence of *T. aff. T. cullomensis* in the upper part of this assemblage subzone suggests correlation with the fauna between beds I and J in the Gaptank Formation in west Texas (Ross, 1965, p. 1160); it also suggests correlation with the faunas of the Ivan Limestone Member of the Graham Formation in central Texas (Myers, 1960, pl. 21). In the mid-continent region, *T. mediocris angustus* was described from the Greenup Limestone in Illinois (Dunbar and Henbest, 1942, p. 135); *T. cullomensis*, a closely related species, has been found in the Beil Limestone Member of the Lecompton Limestone at about the middle of the Shawnee Group in Kansas. The *T. cullomensis* fauna is in common with the Virgilian part of the Furner Valley Limestone in the East Tintic Mountains, Utah (Morris, Douglass, and Kopf, 1977, fig. 4). *T. muddiensis* Cassity and Langenheim, 1966 was described by them (p. 950) from the Virgilian portion of the Bird Spring Formation in Arrow Canyon, Clark County, Nevada; *T. muddiensis* appears to be closely related to *T. cullomensis* and probably occupies a similar stratigraphic position. *T. cullomensis* has been reported by Sabins and Ross (1963, p. 328) from the Virgilian part of the Horquilla Limestone in the Chiricahua Mountains of southeastern Arizona, and by Ross (1965, p. 632) as *T. cf. T. cullomensis* from the Whetstone Mountains, Ariz.

The fusulinid faunas from the preceding three assemblage subzones represent deposition during early Virgilian time during which the Douglas and lower half of the Shawnee Groups were deposited. A faunal hiatus (fig. 4) is present which represents the time of deposition of the upper part of the Shawnee Group. The sandstone and conglomerate at the base of the overlying La Casa Member represent a period of subaerial erosion in the Manzano Mountains during this time.

ASSEMBLAGE SUBZONE OF *TRITICITES BEEDEI*

The assemblage subzone of *Triticites beedei* is in the lower part of the La Casa Member of the Wild Cow Formation. The base of the assemblage subzone is marked by the appearance of *T. cf. and aff. T. beedei* Dunbar

and Condra, 1927 and *T. cf. T. arcuosoides* Ross, 1969. The fauna of the assemblage subzone has elements in common with those of *T. cameratoides* and *T. nealensis* in bed J of the Gaptank Formation (Ross, 1965, p. 1160, 1165). The fauna resembles material in my collections from the lower part of the Wabaunsee Group in Kansas. It is similar to that reported by Sabins and Ross (1963, p. 328-329) from near the top of the Horquilla Limestone and the lower part of the Earp Formation in southeast Arizona, where species in common with the Manzano Mountains fauna are *T. cuchilloensis* Needham, 1937 and *T. plummeri* Dunbar and Condra, 1927.

ASSEMBLAGE SUBZONE OF *TRITICITES WHETSTONENSIS*

The assemblage subzone of *Triticites whetstonensis* contains the youngest Pennsylvanian fusulinids in the Manzano Mountains. Faunal representatives of this assemblage subzone are not present in the type area of the Gaptank Formation in west Texas. In central Texas, the faunas illustrated by Myers (1960, pl. 22, 23) from the Breckenridge and Chaffin Limestone Members of the Thrifty Formation are similar to those of the assemblage subzone of *T. whetstonensis*. They are at a similar evolutionary stage to those from the upper part of the Wabaunsee Group in Kansas. The *T. whetstonensis* fauna is present in the lower part of the Earp Formation in the Whetstone Mountains (Ross and Tyrrell, 1965, p. 620).

ASSEMBLAGE SUBZONE OF *TRITICITES CREEKENSIS*

The assemblage subzone of *Triticites creekensis*, of early Wolfcampian age, is found in the upper beds of the La Casa Member and in the lower part of the Bursum Formation. *Triticites pinguis*, from this assemblage subzone, has been found in the upper beds of the La Casa Member; this species occurs in the Neal Ranch Formation in the area of the Wolf Camp Hills, west Texas (Ross, 1963, p. 111). The types of *T. creekensis* are from the Camp Creek Shale Member of the Pueblo Formation in central Texas where it is associated with *Schwagerina campensis* (Thompson, 1954, p. 43). *Leprotriticites* sp., which is associated with *T. creekensis* in the Manzano Mountains, is found in the Waldrip Shale Member of the Pueblo Formation in central Texas; it is a common fusulinid in the Council Grove Group in Kansas (Thompson, 1954, as *Dunbarinella*).

T. creekensis has been reported by Cassity and Langenheim (1966, p. 939) from the basal beds of the Wolfcampian portion of the Bird Spring Formation at Arrow Canyon in Clark County, Nevada.

ZONE OF *SCHWAGERINA*

The sole representative of the genus *Schwagerina* in the study area is *Schwagerina pinosensis* Thompson, 1954 from about the middle of the Bursum Formation. *S. pinosensis* is an early species of the genus and, as such, represents early Wolfcampian time. Species of similar evolutionary development have been recorded from the Neal Ranch Formation in west Texas (Ross, 1963); from the Pueblo Formation in central Texas (Thompson, 1954); from the Council Grove Group in Kansas (Thompson, 1954); from the Casper Formation in Wyoming (Thompson and Thomas, 1953); from the Furner Valley Limestone in the East Tintic Mountains in Utah (Morris, Douglass, and Kopf, 1977); from the Bird Spring Formation, Arrow Canyon, Nevada (Cassity and Langenheim, 1966); and from the Oscura and Los Pinos Mountains, New Mexico (Thompson, 1954).

The fusulinid assemblage subzones defined in the preceding chapters have been correlated with similar fusulinid assemblages in west- and north-central Texas, the mid-continent region, parts of Wyoming, Utah, Nevada, southeastern Arizona, and parts of New Mexico south of the Manzano Mountains. The sequence of fusulinid assemblages indicates faunal hiatuses in late Missourian and in early and mid-Virgilian time. These gaps in the faunal record are represented in the Manzano Mountains by terrigenous clastic rocks that suggest nearby uplift and erosion. The fusulinid and stratigraphic field evidence suggests that marine deposition was essentially continuous across the boundary between Pennsylvanian and Permian time.

COLLECTING LOCALITIES

All listed localities are in New Mexico and, unless otherwise indicated, are on U.S. Geological Survey 7½-minute topographic quadrangle maps that were published in 1952 (Mount Washington), 1954 (Capilla Peak, Sedillo, Tajique, Tijeras, Torreon, Torreon 15-minute), and 1972 (Scholle). All collections were made by the author between 1962–1975. Access to collection sites located on Isleta Indian Pueblo land and the Sandia Military reservation may be difficult. Authorization to enter should be obtained from the Isleta Pueblo

government at Isleta, or from military authorities at Sandia Base in Albuquerque.

All members listed are from the Wild Cow Formation. All locality numbers have a USGS prefix. All topographic quadrangles listed are 7½-minute unless otherwise noted.

- f10201. Pine Shadow Member, Tajique quadrangle, Torrance County. From a 12-ft-thick bed of ledge-forming limestone; overlies 63 ft of poorly-exposed arkosic sandstone that is the base of the member. About 210 ft above base of measured section 6 (Myers, 1966). Base of section is in SE1/4, sec. 8, T. 6 N., R. 6 E.; 0.35 mi, S. 17° E. from Tajique Cabin.
- f10202. Sol se Mete Member, Tajique quadrangle, Torrance County. From 3 ft below top of member in section 5 (Myers, 1966). North edge, NW1/4SW1/4, sec. 32, T. 7 N., R. 6 E., in the stream channel of Cañon del Troncon Negro, near junction with tributary canyon from the northwest.
- f10203. Pine Shadow Member, Tajique quadrangle, Torrance County. From 132 ft above base of member. See f10202 for locality.
- f10204. Pine Shadow Member, Tajique quadrangle, Torrance County. From 225 ft above base of member. See f10202 for locality.
- f10205. Pine Shadow Member, Tajique quadrangle, Torrance County. From 156 ft above base of member; 311 ft above base of measured section. Base of section is in the stream channel of a tributary to Cañon de la Perra, about 700 ft north of junction; NW1/4NW1/4, sec. 22 T. 7 N., R. 5 E. Section measured northeast to crest of ridge.
- f10206. Pine Shadow Member, Tajique quadrangle, Torrance County. From about 90 ft above base of member; SE1/4NW1/4SW1/4, sec. 23, T. 7 N., R. 6 E.
- f10207. Sol se Mete Member, Tajique quadrangle, Torrance County. Measured section 10 (Myers, 1966); from 25 ft above base of section. North side of Tajique Canyon; 1.3 mi northwest of Tajique; 0.3 mi. east of Cibola National Forest boundary.
- f10208. Sol se Mete Member, Tajique quadrangle, Torrance County. See f10207 for locality. About 60 ft above base of section.
- f10209. Sol se Mete Member, Tajique quadrangle, Torrance County. See f10207 for locality. About 17 ft below top of member.
- f10210. Sol se Mete Member, Tajique quadrangle, Torrance County. From yellowish-brown sandy limestone about 25 ft above base of member. In roadcut 0.7 mi due west from southwest corner, sec. 5, T. 7 N., R. 6 E., on north side Los Moyos Canyon. Isleta Pueblo.
- f10211. Pine Shadow Member, Tajique quadrangle, Torrance County. From 5-ft-thick bed of medium-dark-gray calcarenite in Canyon Largo, about 1/2 mi west of junction with Canyon de Chilli.
- f10212. La Casa Member, Tajique quadrangle, Torrance County. From northeast corner, SW1/4SW1/4, sec. 8, T. 7 N., R. 6 E.
- f10213. La Casa Member, Tajique quadrangle, Torrance County. From medium-gray, hackley-fractured, well-jointed calcarenite near top of hill 7780; northwest corner, sec. 1, T. 6 N., R. 5 E.
- f10214. Pine Shadow Member, Tajique quadrangle, Torrance County. From medium- to light-gray calcarenite, 12 ft below top of member; measured section 6 (Myers, 1966).
- f10215. La Casa Member, Sedillo quadrangle, Bernalillo County. Highway cut on U.S. Highway 66 (destroyed by more recent cuts along Interstate Highway 40), 4.2 mi east of junction with New Mexico Highway 14 at Tijeras. From SE1/4SW1/4, sec. 5, T. 10 N., R. 6 E. From 64 ft below base of Abo Formation.
- f10216. La Casa Member, Sedillo quadrangle, Bernalillo County. See f10215 for location. Top of member; overlain by red beds of Abo Formation.

- f10217. La Casa Member, Torreon quadrangle, Torrance County. About 15 ft below base of Abo Formation; at head of south-draining ravine into Canyon Nuevo; 1.28 mi N. 30° W. from church at Manzano; 0.43 mi N. 82° W. from junction with road to Candelaria Place. Top of section 6 (Myers, 1967a).
- f10218. La Casa Member, Torreon quadrangle, Torrance County. From section 2 (Myers, 1967a), 25 ft above base of member.
- f10219. La Casa Member, Torreon quadrangle, Torrance County. From section 2 (Myers, 1967a), 43 ft above base of member.
- f10220. La Casa Member, Torreon quadrangle, Torrance County. From section 2 (Myers, 1967a), 92 ft above base of member.
- f10221. La Casa Member, Torreon quadrangle, Torrance County. Top of section 1 (Myers, 1967a); 1.9 mi N. 60° W. from church at Manzano; about 500 ft east of west edge of quadrangle; from nodular arkosic limestone that caps hill.
- f10222. La Casa Member, Torreon quadrangle, Torrance County. From an estimated 10 ft below base of Abo Formation; in bed of Canyon Nuevo, 0.7 mi N. 27° W. from church at Manzano; 0.45 mi S. 16° W. from road junction to Candelaria Place.
- f10223. La Casa Member, Torreon quadrangle, Torrance County. From calcareous sandstone in bed of Canyon Nuevo about 20–25 ft below base of Abo Formation; 1.1 mi N. 34° W. from church at Manzano.
- f10224. Sol se Mete Member, Torreon quadrangle, Torrance County. Lower part of uppermost 42-ft-thick bed of limestone. From section 3 (Myers, 1967a).
- f10225. La Casa Member, Sedillo quadrangle, Bernalillo County. In quarry on south side of hill 7758 where power line meets road to abandoned building site, NE1/4NE1/4, sec. 17, T. 9 N., T. 6 E.
- f10226. Sol se Mete Member, Torreon 15-minute quadrangle, Valencia County. Top of member from light-olive-gray calcarenite. From section 2 (Myers and McKay, 1974).
- f10227. Pine Shadow Member, Torreon 15-minute quadrangle, Valencia County. Medium- to dark-gray, weathers yellowish-brown, calcarenite, 5 ft thick; 140 ft above base of member. Section 2 (Myers and McKay, 1974).
- f10228. Pine Shadow Member, Torreon 15-minute quadrangle, Valencia County. About 180 ft above base of member from top of 25-ft-thick bed of cliff-forming limestone. Section 2 (Myers and McKay, 1974).
- f10229. La Casa Member, Torreon 15-minute quadrangle, Valencia County. From 53 ft above base of member. Section 2 (Myers and McKay, 1974).
- f10230. La Casa Member, Torreon 15-minute quadrangle, Valencia County. From 72 ft below top of member. Section 2 (Myers and McKay, 1974).
- f10231. La Casa Member, Torreon 15-minute quadrangle, Valencia County. From 13 ft below top of member. Section 2 (Myers and McKay, 1974).
- f10232. La Casa Member, Mount Washington quadrangle, Bernalillo County. From limestone nodules about 300 ft N. 10° W. from Manzano Lookout Tower; SE1/4NE1/4NW1/4, sec. 34, T. 9 N., R. 5 E. Sandia Military Base.
- f10233. Pine Shadow Member, Torreon 15-minute quadrangle, Valencia County. From 5 ft below top of member in a 64-ft-thick sequence of calcarenite; from section 3 (Myers and McKay, 1974).
- f10234. La Casa Member, Torreon 15-minute quadrangle, Valencia County. About 74 ft above base of member in poorly exposed sequence of sandstone, red shale, and nodular limestone. Section 3 (Myers and McKay, 1974).
- f10235. La Casa Member, Torreon 15-minute quadrangle, Valencia County. In 25-ft-thick bed of light-olive to medium-gray, cherty calcarenite, that is about 112 ft below top of member. Section 3 (Myers and McKay, 1974).
- f10236. La Casa Member, Torreon 15-minute quadrangle, Valencia County. From base of uppermost limestone bed of member, 32 ft below base of Bursum Formation in cherty calcarenite. Section 3 (Myers and McKay, 1974).
- f10237. Pine Shadow Member, Mount Washington quadrangle, Bernalillo County. About 25 ft below basal sandstone of La Casa Member. Section 3 (Myers and McKay, 1970).
- f10238. La Casa Member, Mount Washington quadrangle, Bernalillo County. About 60 ft above base of member in poorly exposed limestone. Section 3 (Myers and McKay, 1970).
- f10239. La Casa Member, Mount Washington quadrangle, Bernalillo County. Nodular limestone about 110 ft above base of member. Section 3 (Myers and McKay, 1970).
- f10240. La Casa Member, Mount Washington quadrangle, Bernalillo County. Nodular limestone about 145 ft above base of member. Section 3 (Myers and McKay, 1970).
- f10241. Sol se Mete Member, Mount Washington quadrangle, Bernalillo County. Above 35 ft below top of member. Section 3 (Myers and McKay, 1970).
- f10242. La Casa Member, Capilla Peak quadrangle, Torrance County. South side of Bartolo Canyon at approximate elevation 7,950 ft; 600 ft N. 40° W. from hill 8066; small, rare fusulinids in light-olive-gray to yellowish-gray calcarenite.
- f10243. Pine Shadow Member, Capilla Peak quadrangle, Torrance County. Top of member in bed that contains balls of *Cryptozoon*-like algae. About 2.3 mi S. 27° E. from lookout tower on Capilla Peak.
- f10244. La Casa Member, Torreon 15-minute quadrangle, Torrance County. About 3 ft above bottom of ravine in poorly exposed medium-gray calcarenite. North side of Red Canyon, 3,200 ft due south of hill 8061; approximate elevation 7,820 ft.
- f10245. Sol se Mete Member, Torreon 15-minute quadrangle, Torrance County. Dark-gray calcarenite about 25 ft above top of Los Moyos Limestone; SW1/4SW1/4SW1/4, sec. 20, T. 4 N., R. 5 E., in bottom of ravine at approximate elevation 7,180 ft.
- f10246. La Casa Member, Torreon 15-minute quadrangle, Torrance County. Light-olive-gray, cherty calcarenite contains large ventricose fusulinids; northeast corner sec. 31, T. 4 N., R. 5 E., at approximate elevation 6,900 ft.
- f10247. Bursum Formation, Torreon 15-minute quadrangle, Torrance County. Algal limestone nodules in pink and red shale on north bank of east-draining ravine; southwest corner NW1/4, sec. 29, T. 4 N., R. 5 E. at approximate elevation 6,960 ft.
- f10248. La Casa Member, Torreon 15-minute quadrangle, Torrance County. Basal part of limestone that caps upper part of southeast-trending nose; NW1/4SW1/4NW1/4, sec. 32 T. 4 N., R. 5 E.; about 300 ft southeast of saddle.
- f10249. La Casa Member, Torreon 15-minute quadrangle, Torrance County. Shaley interbeds in limestone, at base of outcrop on north edge of arroyo channel; southwest corner NW1/4SW1/4, sec. 32, T. 4 N., R. 5 E.
- f10250. La Casa Member, Torreon 15-minute quadrangle, Torrance County. For locality, see f10249. Shaley interval 2 ft above base of outcrop.
- f10251. La Casa Member, Torreon 15-minute quadrangle, Torrance County. For locality see f10249. From shaley interval 8 ft above base of outcrop.
- f10252. La Casa Member, Torreon 15-minute quadrangle, Torrance County. For locality see f10249. From shaley interval 17 ft above base of outcrop.
- f10253. Pine Shadow Member, Torreon 15-minute quadrangle, Valencia County. Top of 58-ft-thick, ridge-forming, yellowish-gray calcarenite with minor amounts of chert in upper 20 ft, 173 ft above base of member; type section of member. Section 1 (Myers and McKay, 1974); also fig. 2 (Myers, 1973).

- f10254. La Casa Member, Torreon 15-minute quadrangle, Valencia County. For locality, see f10253. Type section of member. From 20 ft above base of 30-ft-thick, thinly bedded, light-olive-gray calcarenite that is 208 ft above base of member.
- f10255. La Casa Member, Scholle quadrangle, Valencia County. For locality see f10253. From 30-ft-thick, ledge-forming, light-olive-gray calcarenite at top of member; collection from 5 ft above base of calcarenite.
- f10256. La Casa Member, Scholle quadrangle, Valencia County. For locality, see f10253. From 5 ft below top of member.
- f10257. Pine Shadow Member, Sedillo quadrangle, Bernalillo County. Calcareous claystone contains large, slender fusulinids in ditch and cuts on road to Cedro Peak; NW1/4, sec. 36, T. 10 N., R. 5 E., approximate elevation 7,590 ft.
- f10258. Sol se Mete Member, Sedillo quadrangle, Bernalillo County. From top of lowermost limestone, 33 ft above base of member. Section 1 (Myers and McKay, 1976).
- f10259. Sol se Mete Member, Sedillo quadrangle, Bernalillo County. From middle of 22-ft-thick, cherty, ledge-forming limestone that contains green micaceous siltstone partings; 55 ft below top of member. For locality, see f10258.
- f10260. Pine Shadow Member, Sedillo quadrangle, Bernalillo County. From 7-ft-thick bed of yellowish-gray limestone and interbedded claystone that is 170 ft above base of member. For locality, see f10258.
- f10261. Pine Shadow Member, Sedillo quadrangle, Bernalillo County. From 93 ft below top of member at top of 22-ft-thick sequence of argillaceous nodular limestone and calcareous claystone. For locality, see f10258.
- f10262. La Casa Member, Sedillo quadrangle, Bernalillo County. From white calcareous claystone at top of sequence of red beds, 40 ft above base of member. For locality, see f10258.
- f10263. La Casa Member, Sedillo quadrangle, Bernalillo County. Base of 14 ft limestone that caps Cedro Peak. For locality, see f10258.
- f10264. Sol se Mete Member, Tijeras quadrangle, Bernalillo County. Fusulinid bed about 5 ft above basal sandstone of member. NW1/4NE1/4, sec. 33, T. 10 N., R. 5 E., elevation about 6,700 ft.
- f10265. Sol se Mete Member, Tijeras quadrangle, Bernalillo County. Pale to grayish-orange, weathering medium-dark-gray calcarenite about 5 ft above basal sandstone of member. West side of Corral Canyon, SE1/4NE1/4, sec. 28, T. 10 N., R. 5 E., approximate elevation 6,430 ft.
- f10266. Pine Shadow Member, Tijeras quadrangle, Bernalillo County. On south wall of abandoned segment of Ideal Cement Co. quarry, about 8 ft above floor of quarry. Interbedded, olive-brown, calcareous siltstone and light-gray, bioclastic calcarenite that lies near base of mostly medium-dark-gray, fine-grained calcarenite. NW1/4NW1/4, sec. 27, T. 10 N., R. 5 E.
- f10267. Sol se Mete Member, Tijeras quadrangle, Bernalillo County. Rare fusulinids in light-olive-gray, weathers yellowish gray, silty limestone, NE1/4SW1/4NW1/4, sec. 34, T. 10 N., R. 5 E., at top of cut in primitive road where road reaches top of east-trending spur at elevation 6,780 ft.
- f10268. Pine Shadow Member, Sedillo quadrangle, Bernalillo County. Ant hill in saddle on north side of primitive road, about 55 ft above base of member. North edge, northwest corner, NW1/4, sec. 31, T. 10 N., R. 6 E.
- f10269. La Casa Member, Tijeras quadrangle, Bernalillo County. Rare nodules, dusky yellow-green and dark-gray limestone on covered slope 35 ft below Abo Formation. Rare fusulinids found in dark-gray nodules. SW1/4, sec. 23, T. 10 N., R. 5 E., 2,200 ft N. 34° E. from section corner 6440 at approximate elevation 6,410 ft.
- f10270. Bursum Formation, Scholle quadrangle, Socorro County. Nodular, lenticular limestone about 50 ft above base of formation in shallow ravine where it crosses abandoned segment of old U.S. Highway 60; about 200 ft north of current U.S. Highway 60; SE1/4SW1/4, sec. 11, T. 2 N., R. 4 E., elevation approximately 6,020 ft.
- f10271. Bursum Formation, Scholle quadrangle, Socorro County. About 12 ft of brownish-gray, weathers light olive-gray, calcarenite; overlies greenish to yellowish-gray shale and red shale. Limestone is wavy bedded and has thin interbeds of calcareous shale. Sparse *Schwagerina* on bedding plane surfaces about 4 ft above base of limestone. In El Paso Natural Gas Co. pipeline cut, 1,250 ft southeast of U.S. Highway 60, NE1/4SE1/4, sec. 24, T. 2 N., R. 4 E.
- f10272. Pine Shadow Member, Sedillo quadrangle, Bernalillo County. About 60 ft above base of member, 0.31 mi southwest of Cedro Peak in clearing for power lines; SW1/4NE1/4, sec. 36, T. 10 N., R. 5 E.
- f10273. La Casa Member, Torreon 15-minute quadrangle, Valencia County. This is the same locality as f10229.
- f10276. Pine Shadow Member, Mount Washington quadrangle, Bernalillo County. Reworked Desmoinesian fusulinids in 6-in.-thick bed of crinoidal-pebble conglomerate in roadbed; about 30 ft above base of member. SE1/4NW1/4, sec. 33, T. 9 N., R. 5 E., at approximate elevation 7,610 ft; about 50 ft southwest of road junction to observation cabin on Mount Washington. Sandia Military Base.
- f10279. Pine Shadow Member, Tajique quadrangle, Torrance County. About 43 ft above base of member on east side of Terrero Canyon at approximate elevation 7,380 ft; SW1/4SW1/4SW1/4, sec. 28, T. 7 N., R. 6 E.

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Plates 1-13 follow

Contact photographs of these plates are available, at cost, from the U.S. Geological Survey Photographic Library, Box 25046, Denver Federal Center, Denver, Colorado 80225

PLATE 1

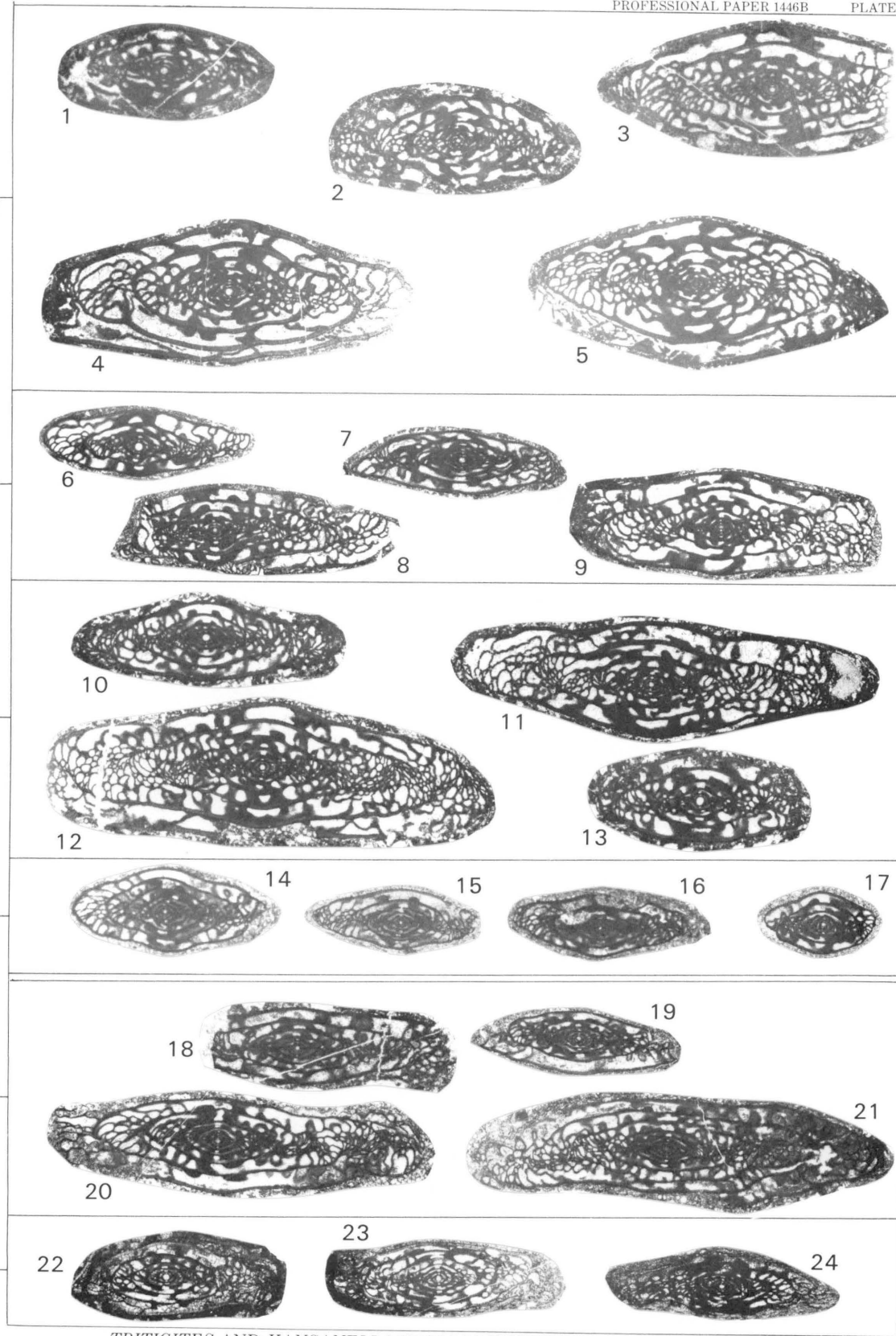
Fusulinids from the Sol se Mete and Pine Shadow Members of the Wild
Cow Formation in the southern part of the Manzano Mountains.

[All unretouched photographs; $\times 10$]

For explanation and scale of graphic section see figure 3.

- FIGURES 1-5. USGS f10233, *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927. Axial sections, slides 15, 11, 14, 5, 10; USNM 375190, 375191, 375192, 375193, 375194.
- 6-9. USGS f10253, *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927. Axial sections, slides 8, 1, 12, 9; USNM 375195, 375196, 375197, 375198.
- 10-13. USGS f10228, *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927. Axial sections, slides 3, 4, 1, 5; USNM 375199, 375200, 375201, 375202.
- 14-17. USGS f10227, *Triticites collus?* Burma, 1942. Axial sections, slides 10, 2, 4, 3; USNM 375203, 375204, 375205, 375206.
- 18-21. USGS f10226, *Kansanella* sp. Axial sections, slides 8, 4, 3, 2; USNM 375207, 375208, 375209, 375210.
- 22-24. USGS f10245, *Triticites* cf. *T. nebraskensis* Thompson, 1934. Axial sections, slides 6, 15, 8; USNM 375211, 375212, 375213.

| AGE | UNIT |
|--------------|---------------------|
| WOLFCAMPIAN | Bursum Fm |
| VIRGILIAN | La Casa Member |
| MISSOURIAN | Wild Cow Formation |
| | Pine Shadow Member |
| | Sol se Mete Member |
| DESMOINESIAN | Los Moyos Limestone |
| ATOKAN | Sandia Formation |
| PRECAMBRIAN | |



TRITICITES AND KANSANELLA FROM SOUTHERN MANZANO MOUNTAINS

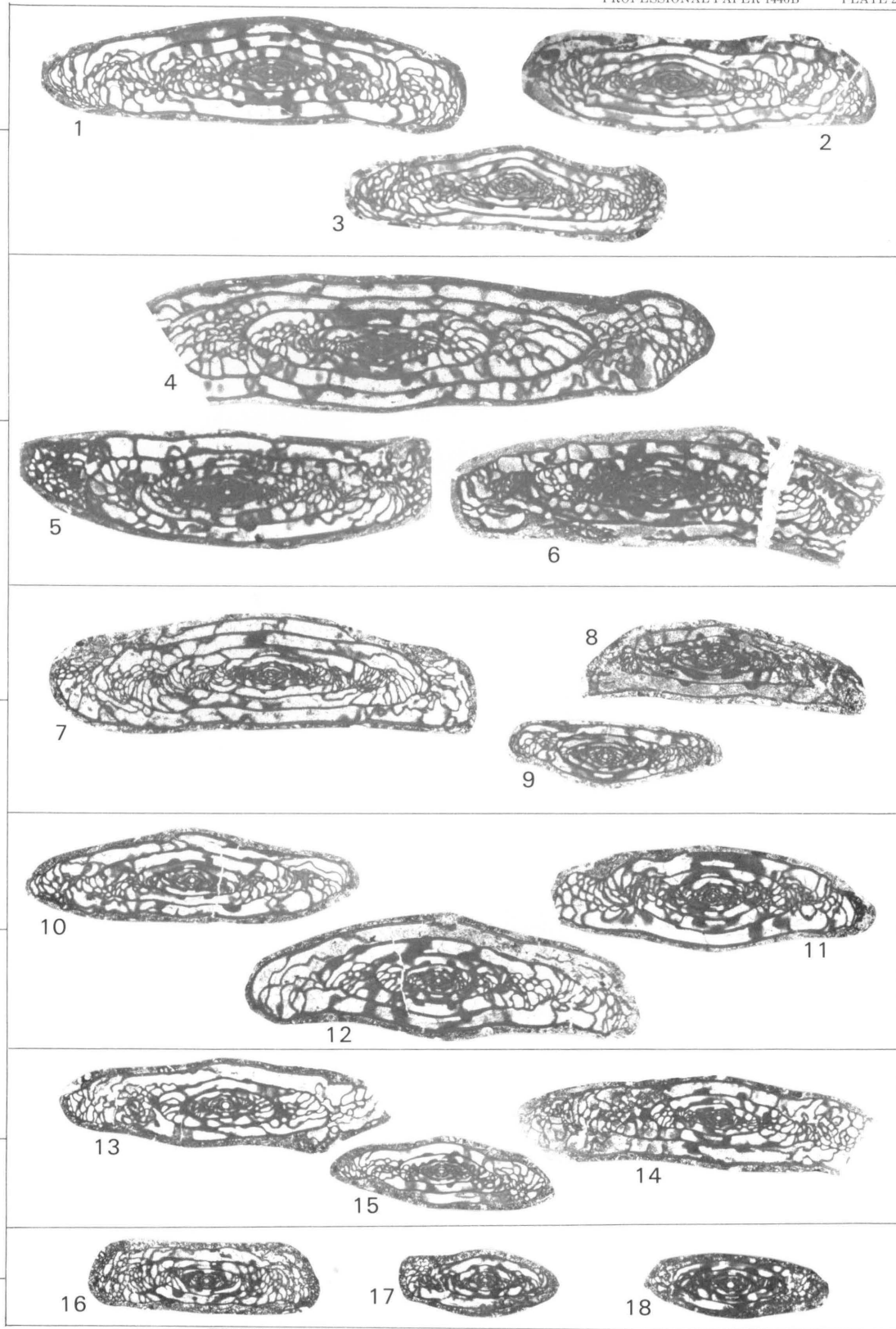
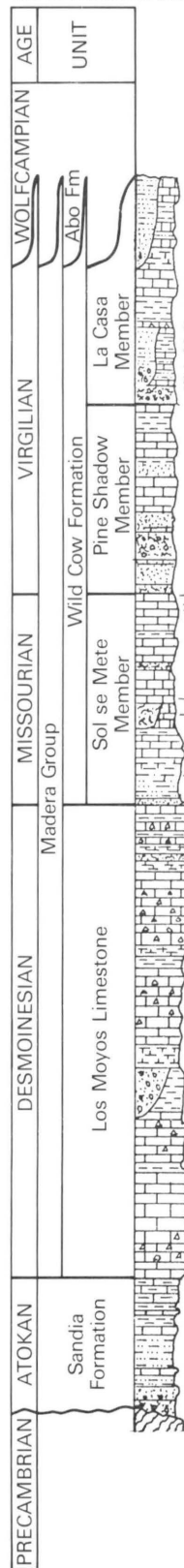
PLATE 2

Fusulinids from the Sol se Mete Member of the Wild Cow Formation in the central part of the Manzano Mountains.

[All unretouched photographs; $\times 10$]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-3. USGS f10202, *Triticites* cf. *T. ohioensis* Thompson, 1936. Axial sections, slides 2, 4, 3; USNM 375214, 375215, 375216.
- 4-6. USGS f10209, *Triticites* cf. *T. ohioensis* Thompson, 1936; Axial sections, slides 7, 5, 3; USNM 375217, 375218, 375219.
- 7-9. USGS f10224, *Triticites* cf. *T. ohioensis* Thompson, 1936. Axial sections, slides 3, 10, 4; USNM 375220, 375221, 375222.
- 10-12. USGS f10208, *Triticites* cf. *T. celebroides* Ross, 1965. Axial sections, slides 3, 2, 1; USNM 375223, 375224, 375225.
- 13-15. USGS f10207, *Triticites* cf. *T. nebraskensis* Thompson, 1934. Axial sections, slides 1, 3, 8; USNM 375226, 375227, 375228.
- 16-18. USGS f10210, *Triticites nebraskensis* Thompson, 1934. Axial sections, slides 3, 4, 2; USNM 375229, 375230, 375231.



TRITICITES FROM CENTRAL MANZANO MOUNTAINS

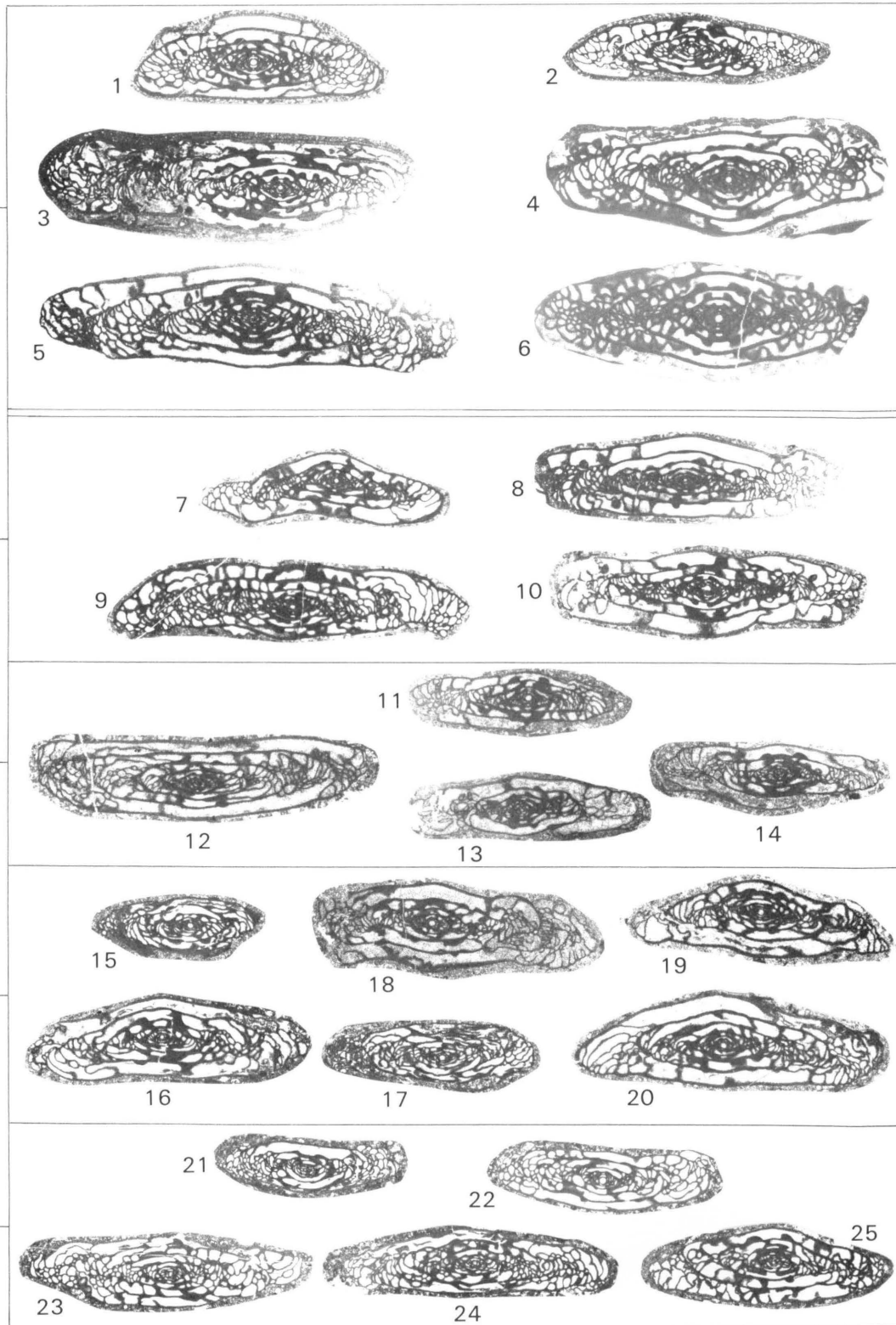
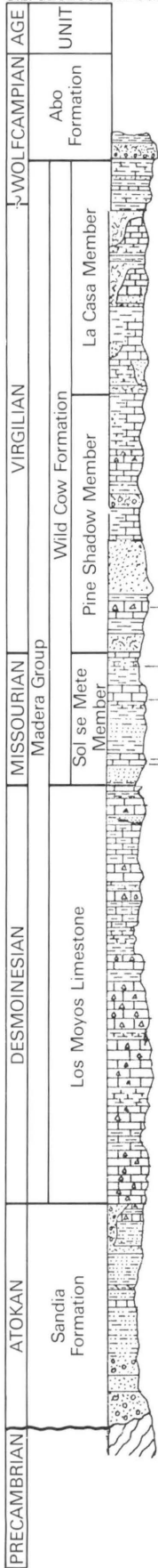
PLATE 3

Fusulinids from the Sol se Mete and Pine Shadow Members of the Wild
Cow Formation in the northern part of the Manzano Mountains.

[All unretouched photographs; $\times 10$]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-3. USGS f10272, *Triticites* aff. *T. primarius* Burma, 1942. Axial sections, slides 1, 4, 3; USNM 375232, 375233, 375234.
- 4-6. USGS f10268, *Triticites* aff. *T. asperoides* Ross, 1965. Axial sections, slides 1, 8, 6; USNM 375235, 375236, 375237.
- 7-10. USGS f10241, Axial sections, slides 3, 1, 6, 2; USNM 375238, 375239, 375240, 375241.
- 11-14. USGS f10259, *Triticites ohioensis* Thompson, 1936. Axial sections, slides 7, 1, 5, 4; USNM 375242, 375243, 375244, 375245.
- 15-17. USGS f10264, *Triticites nebraskensis* Thompson, 1934. Axial sections, slides 4, 2, 1; USNM 375246, 375247, 375248.
- 18-20. USGS f10265, *Triticites nebraskensis* Thompson, 1934. Axial sections, slides 2, 4, 1; USNM 375249, 375250, 375251.
- 21-25. USGS f10258, *Triticites nebraskensis* Thompson, 1934. Axial sections, slides 4, 2, 3, 5, 8; USNM 375252, 375253, 375254, 375255, 375256.



TRITICITES FROM NORTHERN MANZANO MOUNTAINS

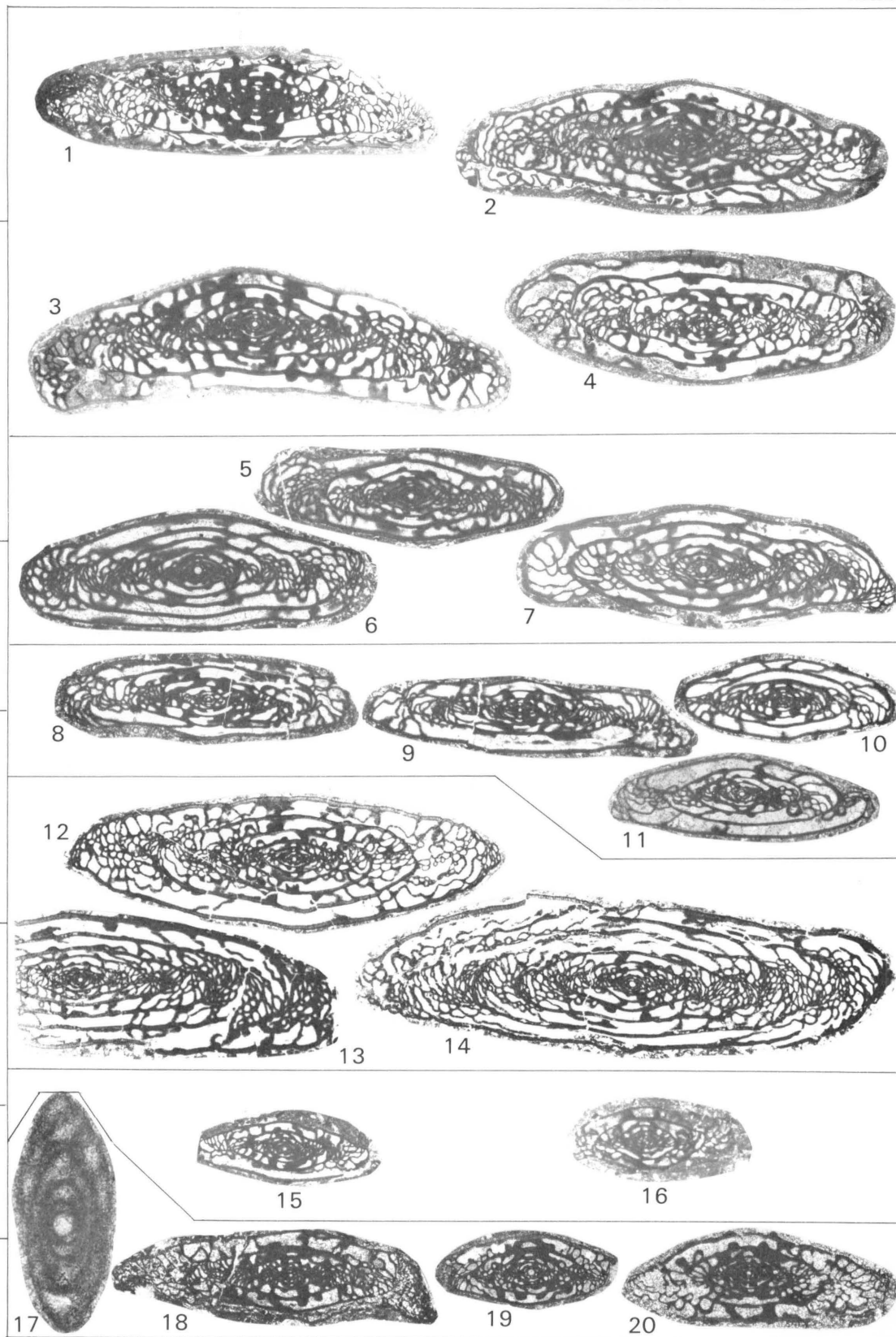
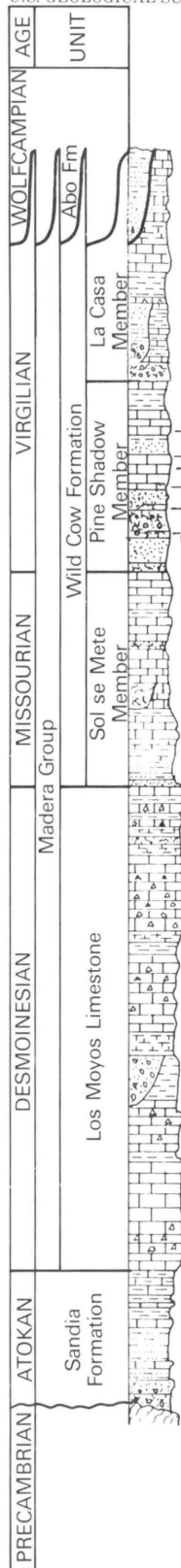
PLATE 4

Fusulinids from the Pine Shadow Member of the Wild Cow Formation in the central Manzano Mountains.

[All unretouched photographs; $\times 10$ unless otherwise indicated]

For explanation and scale of graphic section see figure 3.

- FIGURES 1-4. USGS f10214, *Triticites* aff. *T. cullomensis* Dunbar and Condra, 1927. Axial sections, slides 4, 9, 1, 6; USNM 375257, 375258, 375259, 375260.
- 5-7. USGS f10205, *Triticites secalicus* (Say), 1823. Axial sections, slides 3, 4, 1; USNM 375261, 375262, 375263.
- 8-11. USGS f10203, *Triticites secalicus* (Say), 1823. Axial sections, slides 9, 13, 8, 15; USNM 375264, 375265, 375266, 375267.
- 12-14. USGS f10206, *Triticites* sp. Axial sections, slides 1, 2, 5; USNM 375268, 375269, 375270.
- 15-16. USGS f10201, *Triticites* sp. Axial sections, slides 11, 5; USNM 375271, 375272.
17. USGS f10279, *Millerella?* sp. ($\times 100$). Axial section, slide 1; USNM 375273.
- 18-20. USGS f10211, *Triticites gilaensis?* Ross, 1969. Axial sections, slides 8, 9, 10; USNM 375274, 375275, 375276.



TRITICITES AND MILLERELLA? FROM CENTRAL MANZANO MOUNTAINS

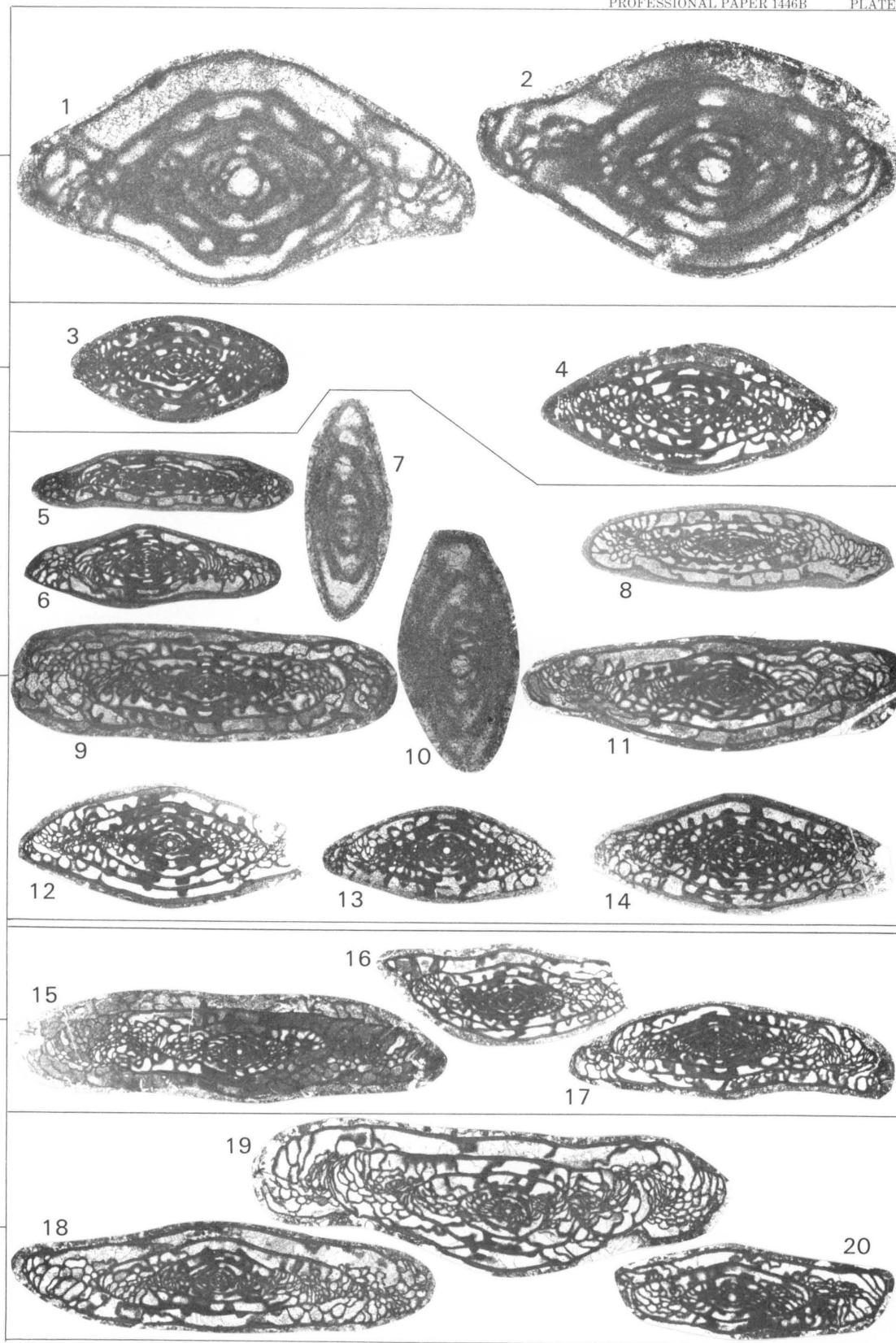
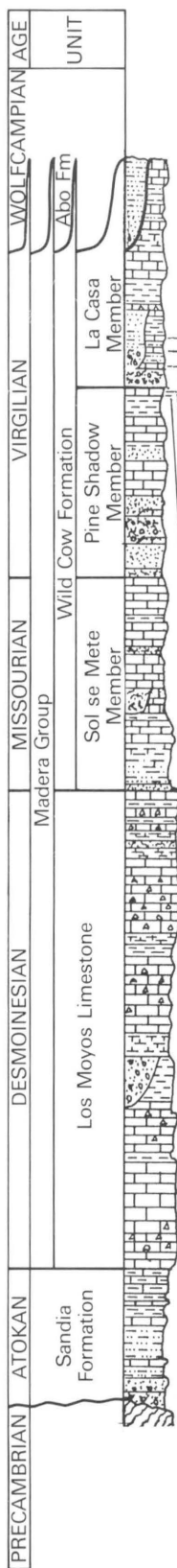
PLATE 5

Fusulinids from the Pine Shadow and La Casa Members of the Wild Cow Formation in the central Manzano Mountains.

[All unretouched photographs; $\times 10$ unless otherwise indicated]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1, 2. USGS f10242, *Oketaella* sp. ($\times 50$). Axial sections, slides 5, 2; USNM 395849, 375277.
- 3, 4. USGS f10219, *Triticites* aff. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 1, 3; USNM 375278, 375279.
- 5, 6, 8. USGS f10212, *Triticites* aff. *T. nealensis* Ross, 1965. Axial sections, slides 1, 5, 4; USNM 375280, 375281, 375282.
7. USGS f10212, *Millerella*? sp. ($\times 100$). Axial section, slide 9; USNM 375283.
- 9, 11. USGS f10213, *Triticites* aff. *T. confertoides* Ross, 1965. Axial sections, slides 5, 2; USNM 375284, 375285.
10. USGS f10213, *Millerella* sp. ($\times 100$). Axial section, slide 6; USNM 375286.
- 12-14. USGS f10218, *Triticites* cf. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 1, 5, 4; USNM 375287, 375288, 375289.
- 15-17. USGS f10243, *Triticites* aff. *T. confertoides* Ross, 1965. Axial sections, slides 3, 2, 4; USNM 375290, 375291, 375292.
- 18-20. USGS f10204, *Triticites* aff. *T. acutuloides* Ross, 1965. Axial sections, slides 10, 7, 3; USNM 375293, 373294, 375295.



OKETAELLA, TRITICITES, AND MILLERELLA FROM CENTRAL MANZANO MOUNTAINS

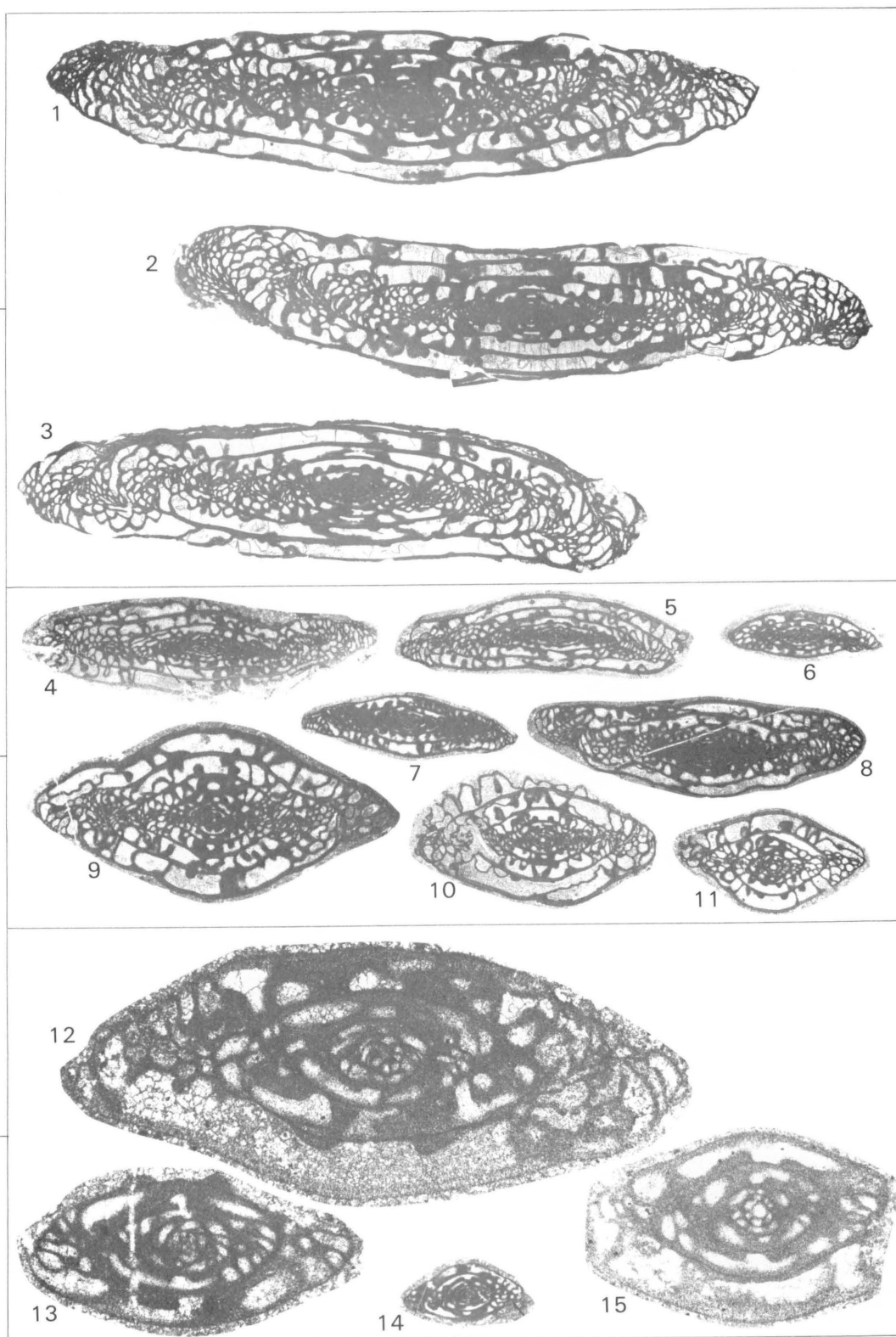
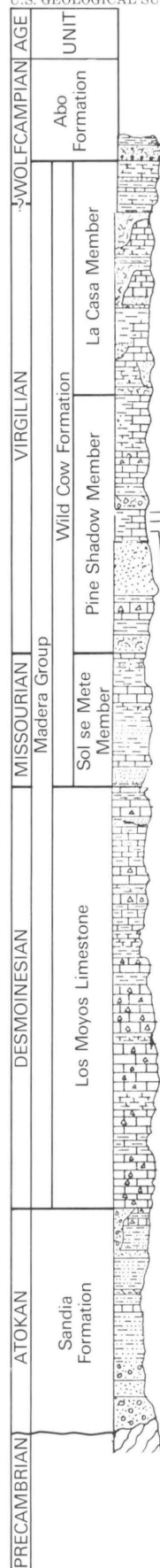
PLATE 6

Fusulinids from the middle part of the Pine Shadow Member of the
Wild Cow Formation in the northern Manzano Mountains.

[All unretouched photographs; $\times 10$, unless otherwise indicated]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-3. USGS f10257, *Triticites* sp. Axial sections, slides 4, 1, 3; USNM 375296, 375297, 375298.
- 4-8. USGS f10266, *Dunbarinella* aff. *D. wildei* Kauffman and Roth, 1966. Axial sections, slides 4, 26, 11, 10, 3; USNM 375299, 375300, 375301, 375302, 375303.
- 9-11. USGS f10266, *Triticites bensonensis* Ross and Tyrrell, 1965. Axial sections, slides 14, 1, 8; USNM 375304, 375305, 375306.
- 12-15. USGS f10260, *Oketaella?* sp. ($\times 50$). Axial sections, slides 6, 5, 11, 10; USNM 375307, 375308, 375309, 375310.



TRITICITES, DUNBARINELLA, AND OKETAELLA? FROM
NORTHERN MANZANO MOUNTAINS

PLATE 7

Fusulinids from the Pine Shadow and La Casa Members of the Wild Cow Formation in the northern Manzano Mountains.

[All unretouched photographs; $\times 10$ unless otherwise indicated]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-3. USGS f10239, *Triticites* sp. Axial sections, slides 4, 1, 2; USNM 375311, 375312, 375313.
- 4-6. USGS f10238, *Triticites* cf. *T. cuchilloensis* Needham, 1937. Axial sections, slides 5, 4, 2; USNM 375314, 373315, 373316.
7. USGS f10263, *Ozawainella?* sp. ($\times 100$). Tangential section, slide 9; USNM 375317.
8. USGS f10263, *Dunbarinella* sp. Axial section, slide 8; USNM 375318.
- 9-11. USGS f10263, *Triticites* cf. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 7, 5, 1; USNM 375319, 375320, 375321.
- 12, 13. USGS f10262, *Dunbarinella* sp. Axial sections, slides 15, 18; USNM 375322, 375323.
- 14-16. USGS f10262, *Triticites* cf. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 9, 13, 1; USNM 375324, 375325, 375326.
- 17-19. USGS f10237, *Triticites* aff. *T. confertoides* Ross, 1965. Axial sections, slides 4, 6, 1; USNM 375327, 375328, 375329.
- 20-22. USGS f10261, *Triticites* cf. *T. turgidus* Dunbar and Henbest, 1942. Axial sections, slides 5, 11, 9; USNM 375330, 375331, 375332.

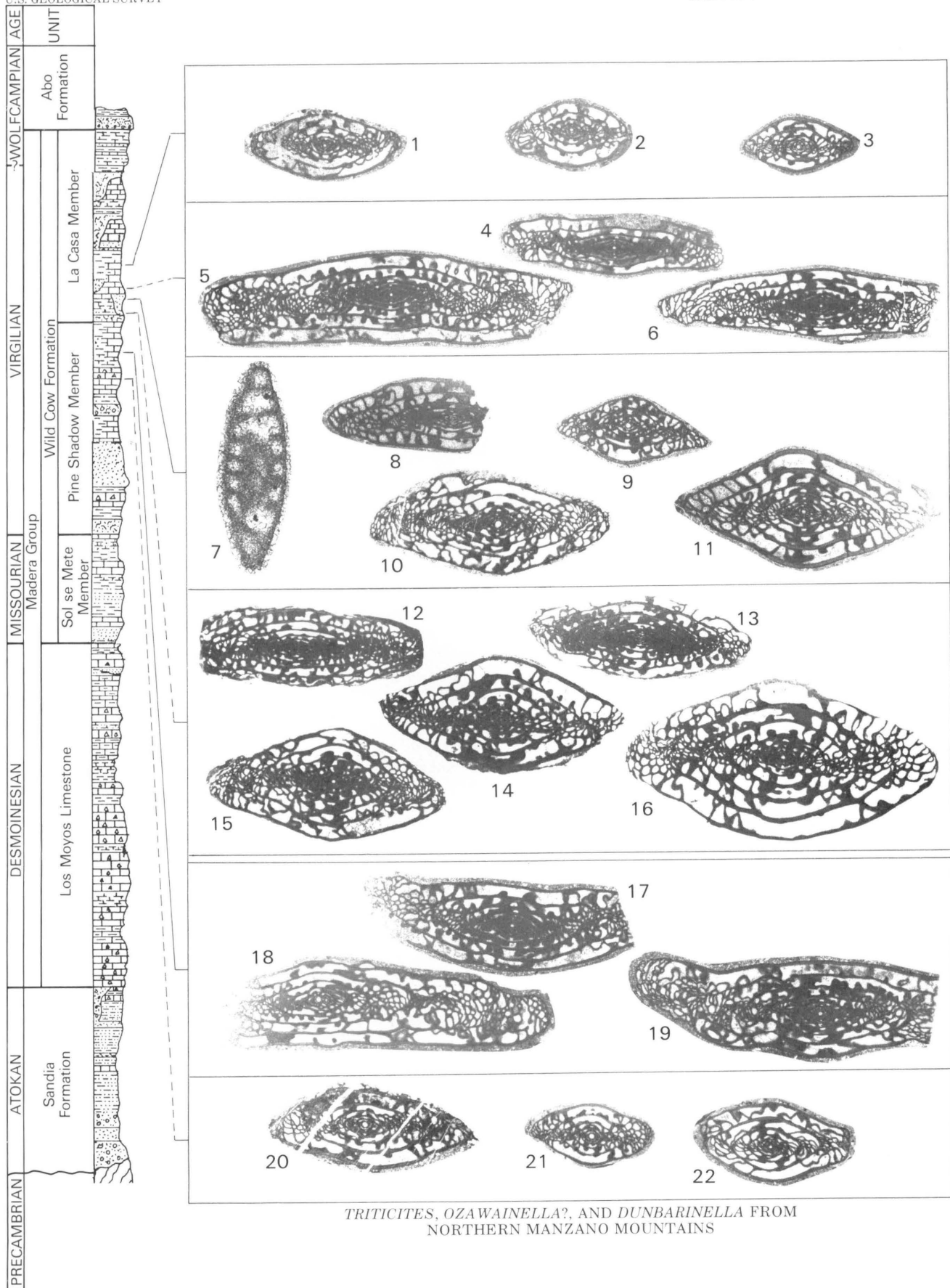


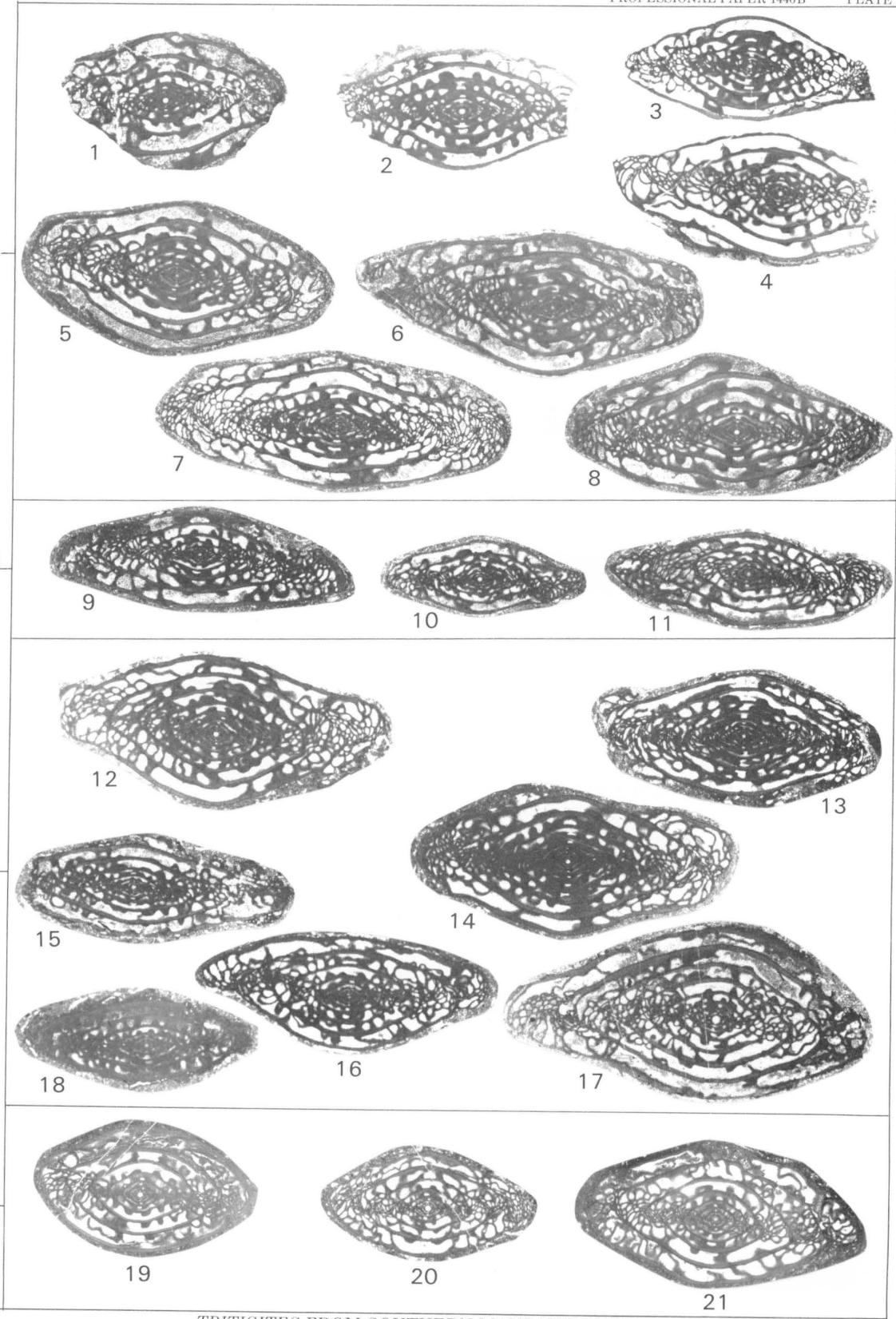
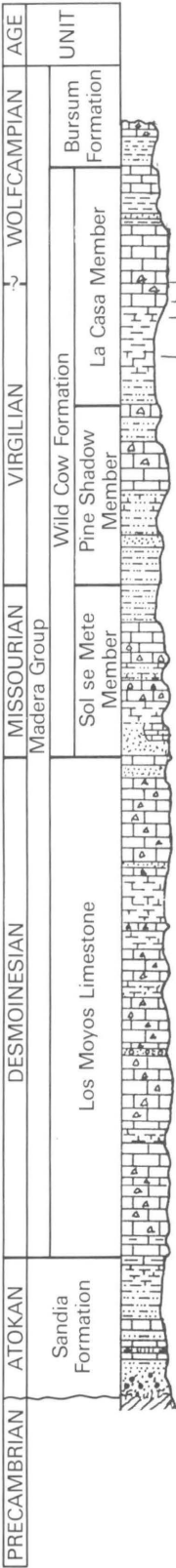
PLATE 8

Fusulinids from the lower part of the La Casa Member of the Wild Cow Formation in the southern Manzano Mountains.

[All unretouched photographs; $\times 10$]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-4. USGS f10249, *Triticites* aff. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 6, 7, 1, 4; USNM 375333, 375334, 375335, 375336.
- 5-8. USGS f10235, *Triticites* cf. *T. callosus* Dunbar and Henbest, 1942. Axial sections, slides 2, 3, 1, 5; USNM 375337, 375338, 375339, 375340.
- 9-11. USGS f10230, *Triticites* aff. *T. birdspringensis* Cassity and Langenheim, 1966. Axial sections, slides 5, 6, 1; USNM 375341, 375342, 375343.
- 12-14. USGS f10229, *Triticites* cf. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 4, 1, 2; USNM 375344, 375345, 375346.
- 15-18. USGS f10273, *Triticites* cf. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 2, 3, 4, 10; USNM 375347, 375348, 375349, 375350.
- 19-21. USGS f10234, *Triticites* cf. *T. arcuosoides* Ross, 1969. Axial sections, slides 5, 3, 1; USNM 375351, 375352, 375353.



TRITICITES FROM SOUTHERN MANZANO MOUNTAINS

PLATE 9

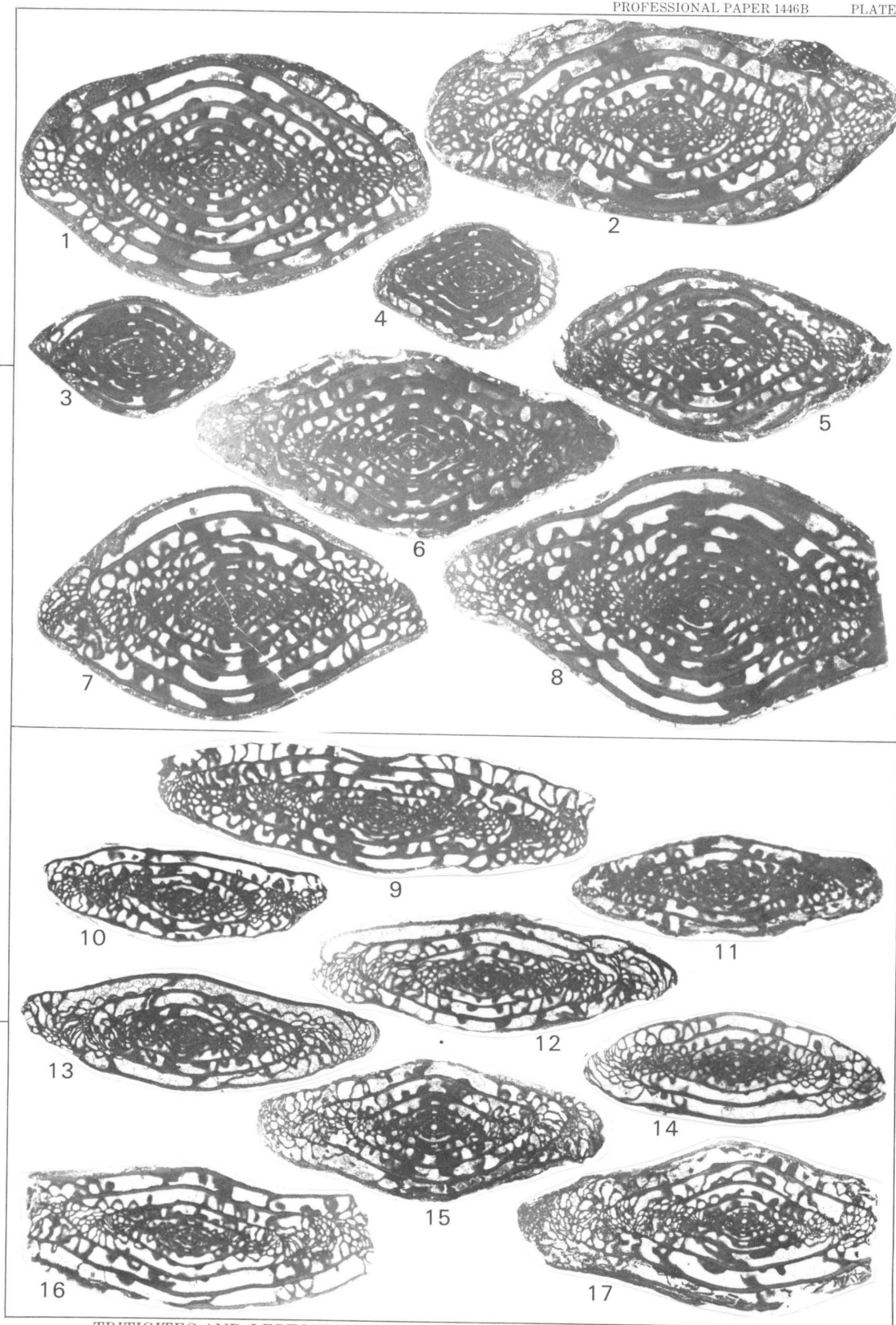
Fusulinids from the middle part of the La Casa Member of the Wild
Cow Formation, southern Manzano Mountains.

[All unretouched photographs; $\times 10$]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1, 2, 5. USGS f10246, *Triticites* aff. *T. pinguis* Dunbar and Skinner, 1937. Axial sections, slides 8, 4, 6; USNM 375354, 375355, 375356.
- 3, 4. USGS f10246, *Leptotriticites* sp. Axial sections, slides 11, 9; USNM 375357, 375358.
- 6-8. USGS f10231, *Triticites* cf. *T. pinguis* Dunbar and Skinner, 1937. Axial sections, slides 5, 1, 2; USNM 375359, 375360, 375361.
- 9-11. USGS f10252, *Triticites* sp. Axial sections D3, D5, D6; USNM 375362, 375363, 375364.
- 12-14. USGS f10251, *Triticites* cf. *T. ventricosus* var. *sacramentoensis* Needham, 1937. Axial sections, slides C7, C3, C5; USNM 375365, 375366, 375367.
- 15-17. USGS f10250, *Triticites* cf. *T. ventricosus* var. *sacramentoensis* Needham, 1937. Axial sections, slides B4, B5, B10; USNM 375368, 375369, 375370.

| AGE | UNIT |
|--------------|---------------------|
| WOLFCAMP | Bursum Formation |
| VIRGILIAN | Wild Cow Formation |
| | Pine Shadow Member |
| | La Casa Member |
| MISSOURIAN | Sol se Mete Member |
| | Madera Group |
| DESMOINESIAN | Los Moyos Limestone |
| ATOKAN | Sandia Formation |
| PRECAMBRIAN | |



TRITICITES AND LEPTOTRITICITES FROM SOUTHERN MANZANO MOUNTAINS

PLATE 10

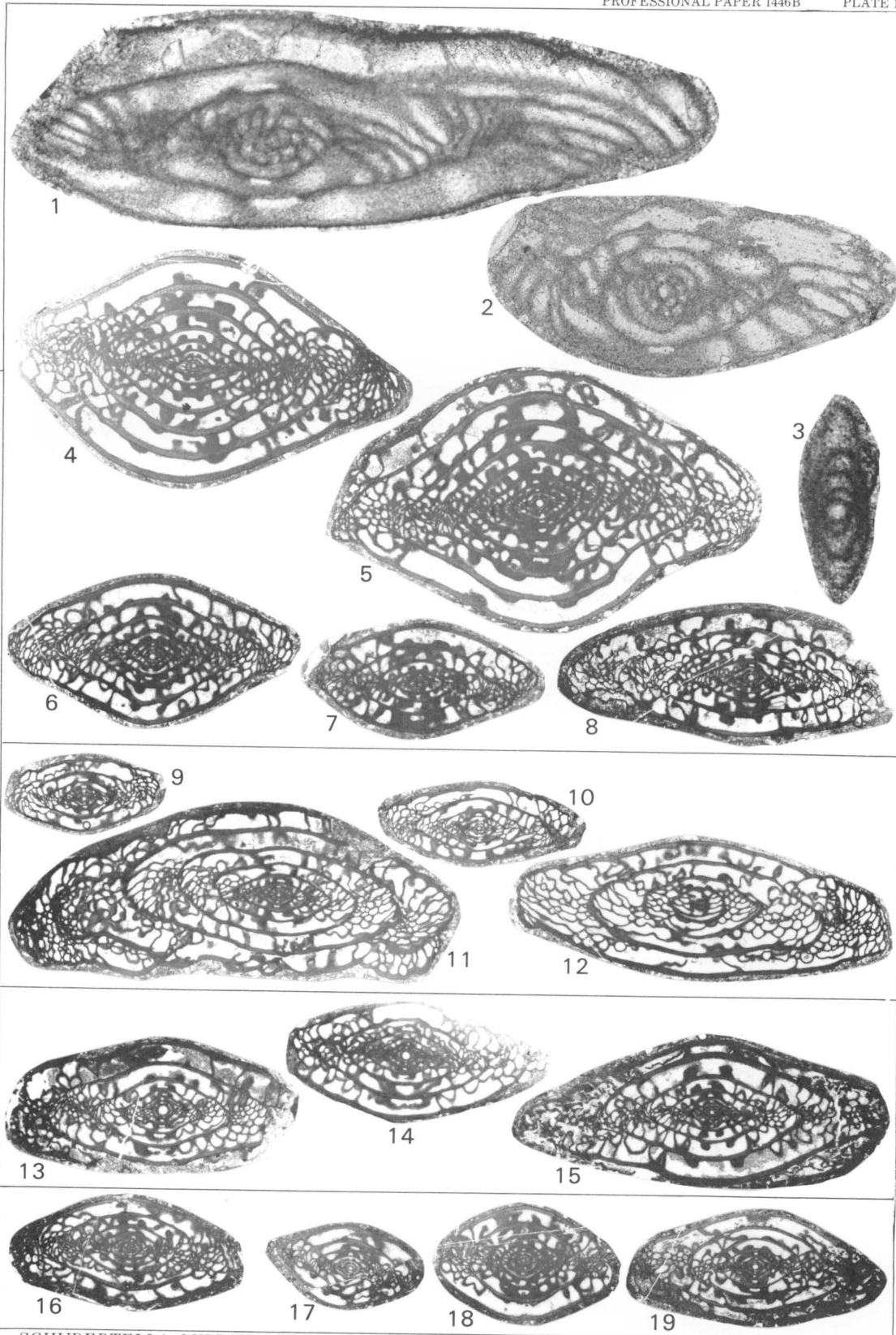
Fusulinids from the upper part of the La Casa Member of the Wild Cow Formation in the southern Manzano Mountains.

[All unretouched photographs; $\times 10$, unless otherwise indicated]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1, 2. USGS f10244, *Schubertella* sp. ($\times 100$). Axial sections, slides 14b, 13; USNM 375371, 375372.
3. USGS f10244, *Millerella?* sp. ($\times 100$). Axial sections, slide 14a; USNM 375373.
- 4, 5. USGS f10244, *Triticites pinguis* Dunbar and Skinner, 1937. Axial sections, slides 5, 4; USNM 375374, 375375.
6. USGS f10244, *Triticites* cf. *T. creekensis* Thompson, 1954. Axial section, slide 1, USNM 375376.
- 7, 8. USGS f10256, *Triticites* cf. *T. creekensis* Thompson, 1954. Axial sections, slides 3, 2; USNM 375377, 375378.
- 9-12. USGS f10255, *Triticites* sp. Axial sections, slides 2, 1, 6, 7; USNM 375379, 375380, 375381, 375382.
- 13-15. USGS f10236, *Triticites* cf. *T. creekensis* Thompson, 1954. Axial sections, slides 5, 6, 7; USNM 375383, 375384, 375385.
- 16-19. USGS f10254, *Triticites* aff. *T. beedei* Dunbar and Condra, 1927. Axial sections, slides 7, 1, 6, 5; USNM 375386, 375387, 375388, 375389.

| PRECAMBRIAN | ATOKAN | DESMOINESIAN | MISSOURIAN | VIRGILIAN | WOLFCAMPIAN | AGE |
|-------------|------------------|---------------------|--------------------|--------------------|------------------|------|
| | Sandia Formation | Los Moyos Limestone | Madera Group | Wild Cow Formation | Bursum Formation | UNIT |
| | | | Sol se Mete Member | Pine Shadow Member | La Casa Member | |



SCHUBERTELLA, MILLERELLA?, AND TRITICITES FROM SOUTHERN MANZANO MOUNTAINS

PLATE 11

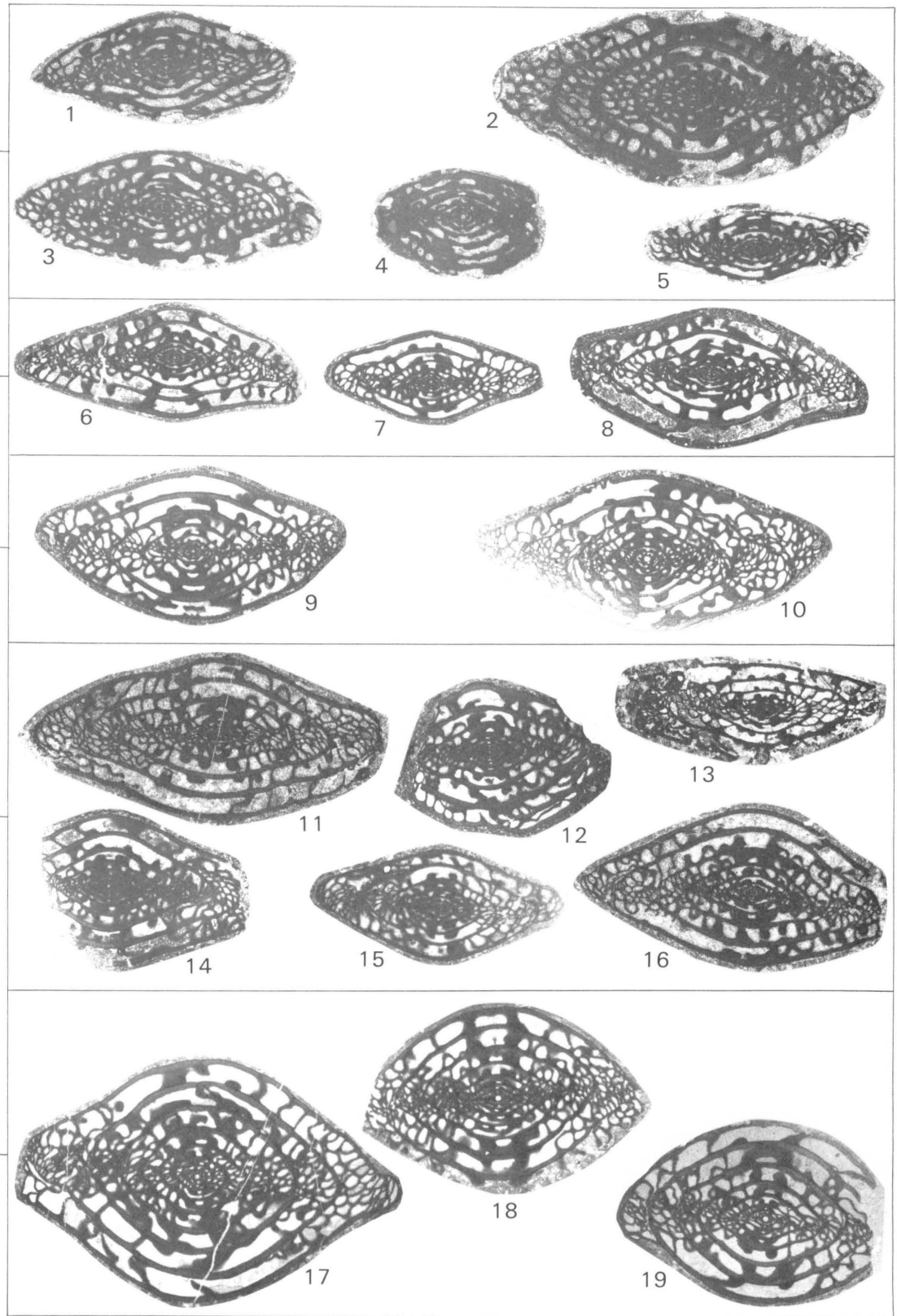
Fusulinids from the upper part of the La Casa member of the Wild Cow Formation, central Manzano Mountains.

[All unretouched photographs: $\times 10$]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1-3. USGS f10223, *Triticites* sp. Axial sections, slides 6, 5, 8; USNM 375390, 375391, 375392.
4. USGS f10223, *Leptotriticites* sp. Axial section, slide 7; USNM 375393.
5. USGS f10223, *Triticites* sp. Axial section, slide 4; USNM 375394.
- 6-8. USGS f10222, *Triticites* cf. *T. whetstonensis* Ross and Tyrrell, 1965. Axial sections, slides 4, 2, 3; USNM 375395, 375396, 375397.
- 9, 10. USGS f10221, *Triticites* cf. *T. whetstonensis* Ross and Tyrrell, 1965. Axial sections, slides 4, 3; USNM 375398, 375399.
- 11-16. USGS f10217, *Triticites* aff. *T. whetstonensis* Ross and Tyrrell, 1965. Axial sections, slides 7, 1, 8, 2, 3, 10; USNM 375400, 375401, 375402, 375403, 375404, 375405.
- 17-19. USGS f10220, *Triticites* cf. *T. plummeri* Dunbar and Condra, 1927. Axial sections, slides 4, 1, 3; USNM 375406, 375407, 375408.

| PRECAMBRIAN | ATOKAN | DESMOINESIAN | MISSOURIAN | VIRGILIAN | WOLFCAMPIAN | AGE |
|-------------|------------------|---------------------|--------------|--|--------------------------|------|
| | Sandia Formation | Los Moyos Limestone | Madera Group | Wild Cow Formation Pine Shadow Member Sol se Mete Member | La Casa Member Abo Fm | UNIT |



TRITICITES AND LEPTOTRITICITES FROM CENTRAL MANZANO MOUNTAINS

PLATE 12

Fusulinids from the La Casa Member of the Wild Cow Formation in the northern Manzano Mountains.

[All unretouched photographs; $\times 10$, unless otherwise indicated]

For explanation and scale of graphic section, see figure 3.

- FIGURES 1, 2. USGS f10216, *Triticites* aff. *T. rhodesi* Needham, 1937. Axial sections, slides 4, 1; USNM 375409, 375410.
- 3, 5. USGS f10215, *Triticites* aff. *T. plummeri* Dunbar and Condra, 1927. Axial sections, slides 3, 1; USNM 375411, 375412.
4. USGS f10215, *Dunbarinella*, sp. Axial section, slide 5; USNM 375413.
- 6-8. USGS f10232, *Triticites* aff. *T. plummeri* Dunbar and Condra, 1927. Axial sections, slides 3, 1, 6; USNM 375414, 375415, 375416.
9. USGS f10225, *Ozawainella* sp. ($\times 100$). Axial section, slide 6; USNM 375417.
- 10, 11. USGS f10225, *Triticites* aff. *T. cameratoides* Ross, 1965. Axial sections, slides 1, 2; USNM 375418, 375419.
- 12-15. USGS f10240, *Triticites* sp. Axial sections, slides 7, 6, 4, 1; USNM 375420, 375421, 375422, 375423.

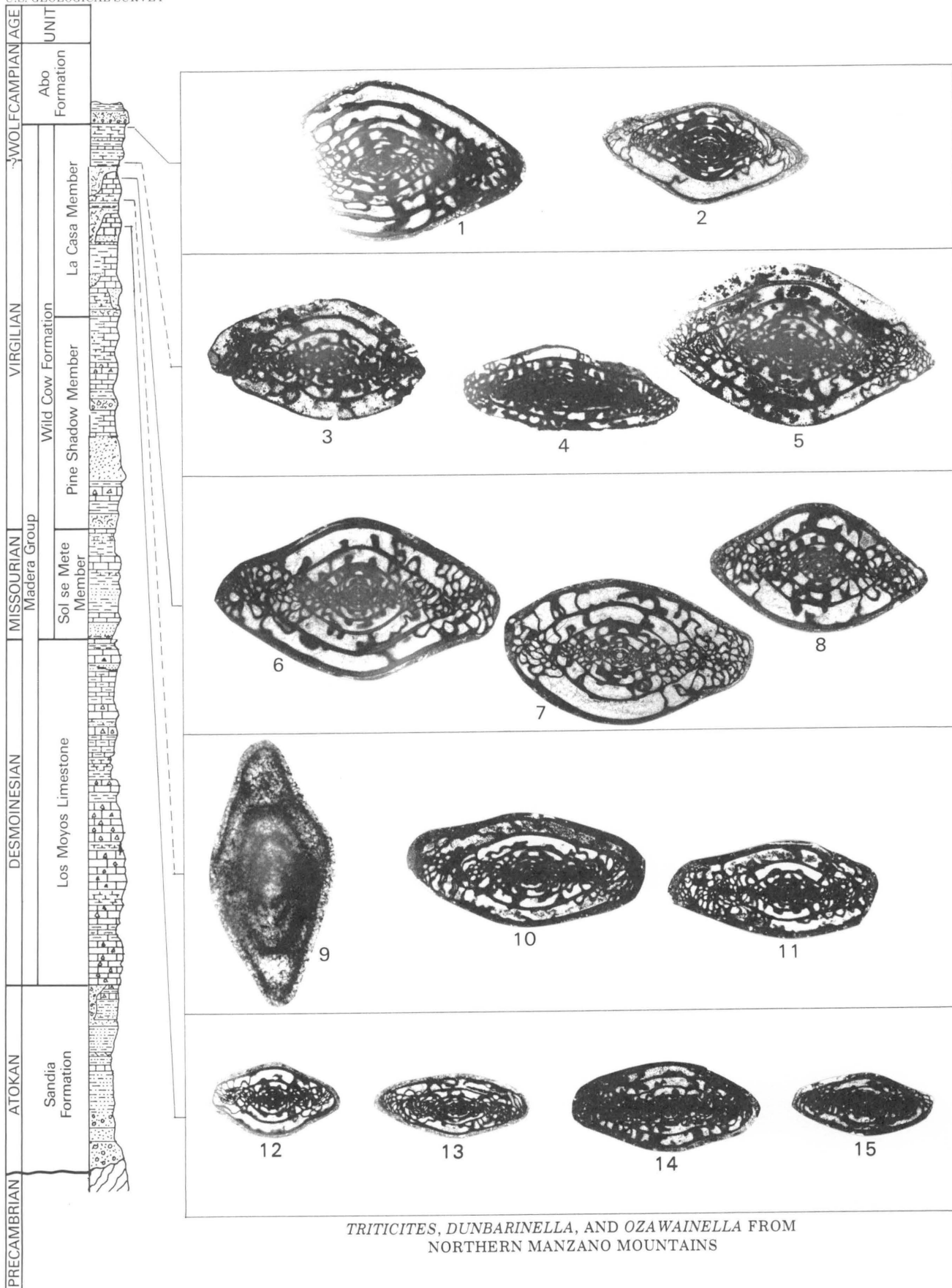


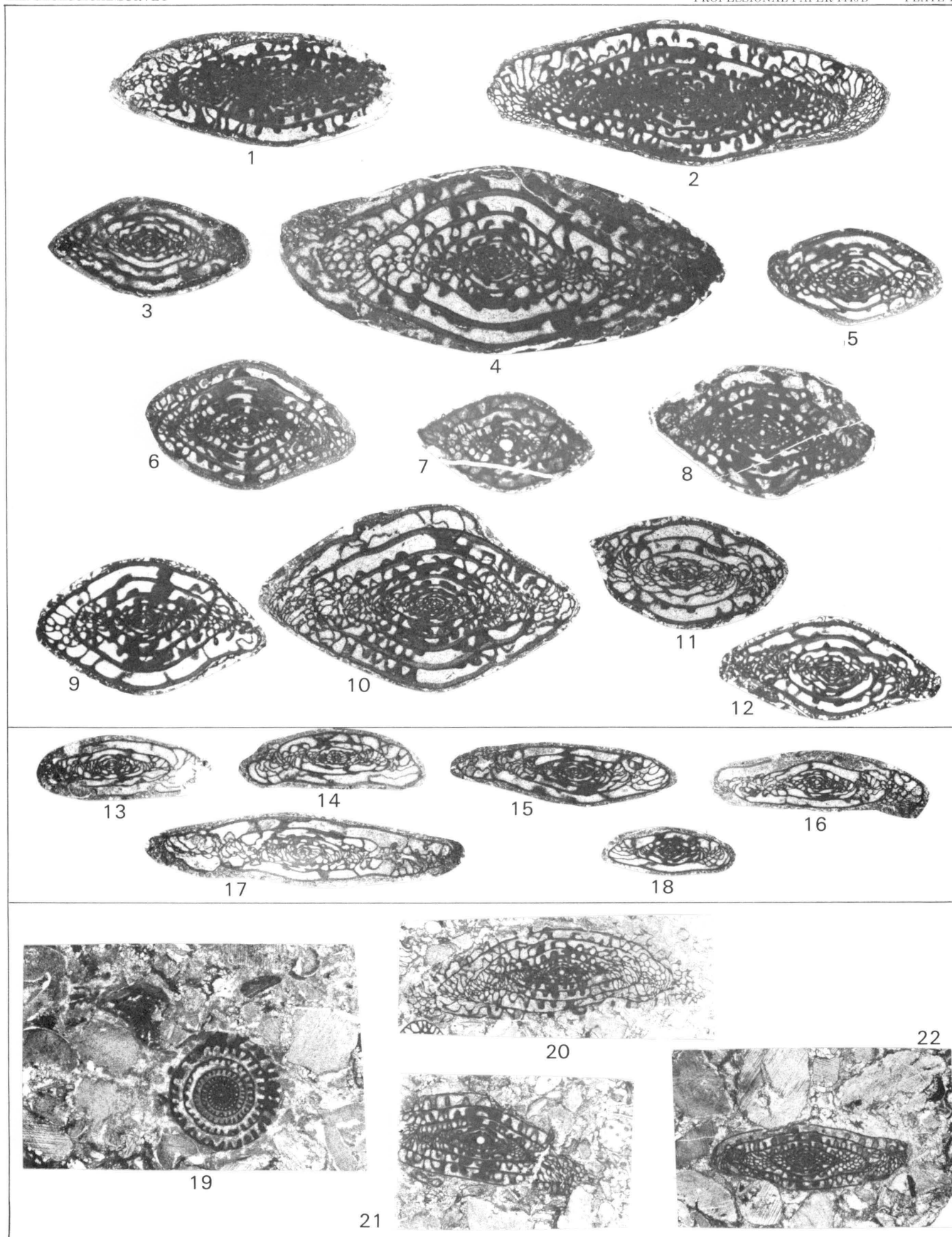
PLATE 13

Fusulinids from the Bursum Formation, southern Manzano Mountains, and miscellaneous fusulinids, Manzano Mountains.

[All unretouched photographs; $\times 10$]

FIGURES 1-12. Fusulinids from the Bursum Formation.

- 1, 2. USGS f10271, *Schwagerina pinosensis* Thompson, 1954. Axial sections, slides 7, 6; USNM 375424, 375425.
- 3-5. USGS f10247, *Triticites* aff. *T. creekensis* Thompson, 1954. Axial sections, slides 4, 3, 5; USNM 375426, 375427, 375428.
- 6, 8. USGS f10248, *Leptotriticites* sp. Axial sections, slides 3, 5; USNM 375429, 375430.
7. USGS f10248, *Triticites* aff. *T. creekensis* Thompson, 1954. Axial section, slide 10; USNM 375431.
- 9-12. USGS f10270, *Triticites creekensis* Thompson, 1954. Axial sections, slides 21, 10, 15, 8; USNM 375432, 375433, 375434, 375435.
- 13-18. Fusulinids from the La Casa Member of the Wild Cow Formation.
- 13-18. USGS f10269, *Triticites* cf. *T. nealensis* Ross, 1965. Axial sections, slides 2, 3, 5, 7, 11, 4; USNM 375436, 375437, 375438, 375439, 375440, 375441.
- 19-22. Reworked fusulinids in the Pine Shadow Member of the Wild Cow Formation.
- 19-22. USGS f10276, *Beedeina* sp. Axial sections, slides 5, 1, 3, 4; USNM 375442, 375443, 375476, 375477. Late Desmoinesian fusulinids that have been reworked into a crinoid-pellet conglomerate in the Pine Shadow Member.



SCHWAGERINA, TRITICITES, LEPTOTRITICITES, AND BEEDEINA FROM MANZANO MOUNTAINS