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STRATIGRAPHIC SUMMARY OF PENNSYLVANIAN AND LOWER PERMIAN ROCKS, MANZANO MOUNTAINS, NEW MEXICO

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INTRODUCTION

The Manzano Mountains (fig. 1) are east of the Rio Grande Valley between 1-40 and U.S. 60. The Manzano Mountains are a fault-block range about 16 km wide and 72 km long. The western part of the range has been uplifted along mostly concealed north-trending faults to expose a core of Precambrian metasedimentary, metavolcanic, and crystalline rocks. The Albuquerque basin is downfaulted relative to the uplift.

The eastern part of the range is a gently sloping surface formed by Pennsylvanian rocks that dip eastward beneath overlying surficial deposits. The Pennsylvanian rocks, at most places, overlie the Precambrian; however, at a few localities, remnants of Mississippian rocks that are less than 4 m thick rest on the Precambrian.

The Pennsylvanian and Lower Permian marine, marginal marine, and terriginous rocks (fig. 2) have been subdivided into the Sandia Formation (Atokan) and the overlying Madera Group. The Madera Group is subdivided, in ascending order, into the Los Moyos Limestone (Des Moinesian and Missourian), the Wild Cow Formation (Missourian, Virgilian, and Wolfcampian), and the Bursum Formation (Wolfcampian).

SANDIA FORMATION

The Sandia Formation is a slope-forming sequence of olive-drab micaceous siltstone, sandstone, and conglomerate; it also contains a few discontinuous thin beds of marine limestone. The Sandia lies on Precambrian rocks except at Bosque Peak and at the southern side of Tijeras Canyon where less than 4 m of Mississippian limestone belonging to the Arroyo Pefiasco Group intervenes locally. The average thickness of the Sandia is about 61 m; however, the thickness ranges from less than 15 m to about 92 m. The differences in thickness are the results of pre-Sandia erosional relief on the Precambrian.

At most localities the basal beds of the Sandia are conglomerate or coarse-grained sandstone, derived from nearby Precambrian rocks. The basal beds are overlain by olive-drab sandstone, siltstone, and shale that contains fossil wood and plant impressions; thin beds of carbonaceous shale and lenticular beds of coaly shale are present locally. Lenticular beds of impure silty limestone that contain the fusulinid *Fusulinella* and a few brachiopods are present.

Overlying these basal beds is a medial sequence of micaceous, olive-gray to yellowish-brown sandstone and siltstone that contains a few thin, lenticular beds of gray calcarenite. Dark-gray to brownish-gray carbonaceous shale, locally gypsiferous, occurs at some places. Plant impressions are common. At the top of these medial beds is a persistent zone of calcareous sandstone that contains casts and molds of brachiopods, crinoid-stem segments, clams, and other marine fossils.

The upper beds of the Sandia, a total of about 21 m thick, are transitional upward from dominantly terriginous deposition to dominantly marine deposition. In these beds, there is a gradual upward increase in the proportion of shale versus sandstone and siltstone, and a concurrent increase in the amount of calcareous material. Marine fossils are common in the upper 9-12 m; chert is an important constituent in the upper 6 m. The uppermost beds are medium- to dark-gray shaly and sandy limestone with partings of calcareous shale and siltstone; lenses of brown chert are common. The fusulinid *Fusulinella famula* is common in the uppermost beds of the Sandia.

On the basis of the contained fusulinids, the age of the Sandia is Atokan. There is no evidence that the Sandia includes rocks of Morrowan age in the Manzano Mountains.

MADERA GROUP

The Madera Group (Myers, 1973) in the Manzano Mountains includes rocks tht were formerly assigned to the Madera Limestone of Read and others (1944) and to the Bursum Formation. The Madera Group, as now defined for this region (fig. 2), includes the Los Moyos Limestone, mostly cliff-forming beds of limestone; the Wild Cow Formation, a sequence of alternating beds of sandstone, shale, and limestone; and the Bursum Formation, a sequence of red beds and marine limestone at the southern end of the mountains. The Madera Group ranges in age from early Des Moinesian to early Wolfcampian.

Los Moyos Limestone

The Los Moyos Limestone is about 180 m thick, and it forms the prominent white cliffs along the crest of the mountains between Capilla Peak and Guadalupe Peak. The contact of the Los Moyos and the underlying Sandia Formation is gradational; the base of the Los Moyos was mapped at the base of the lowermost ledge-forming, cherty limestone. These lower beds, a total of more than 60 m thick, are medium-gray calcarenite that contains lenses and bands of rusty weathering, dark-gray chert and minor amounts of interbedded calcareous shale. The chert, characteristically a rusty-orange color on weathered surfaces, is typical of the lower beds of the Los Moyos.

Above the cherty limestone is a 1-to-3-m thick zone of conglomerate, sandtone, siltstone, and, locally, silty calcarenite that is persistent throughout the mountains. At some places, rocks of this zone contain silicified logs as long as 2.5 m; at other places, in the northern part of the mountains, there are lenticular beds of limestone conglomerate whose cobbles are well-rounded and have algal coatings as much as 6.5 mm thick. The matrix of the limestone conglomerate contains debris of abraded brachiopods, crinoid-stem segments, and other marine fossils which also have algal coatings; some of the clasts contain *Komia* sp.

The remainder of the Los Moyos above the sandstone-conglomerate zone is medium-gray, cliff-forming, cherty calcarenite that changes upward into light-olive-gray calcarenite. Local beds of sandstone, conglomeratic sandstone, siltstone, and calcareous shale are interbedded with the limestone and become more common toward the top.

The fusulinids *Beedeina arizonensis, Fusulinella famula,* and primitive species of *Wedekindellina* are found in the basal beds of the Los Moyos. These fusulinids are succeeded upward by an assemblage dominated by *Beedeina novamexicana.* The upper beds contain *Beedeina sulphurensis* and related species. Locally, in the uppermost beds of the

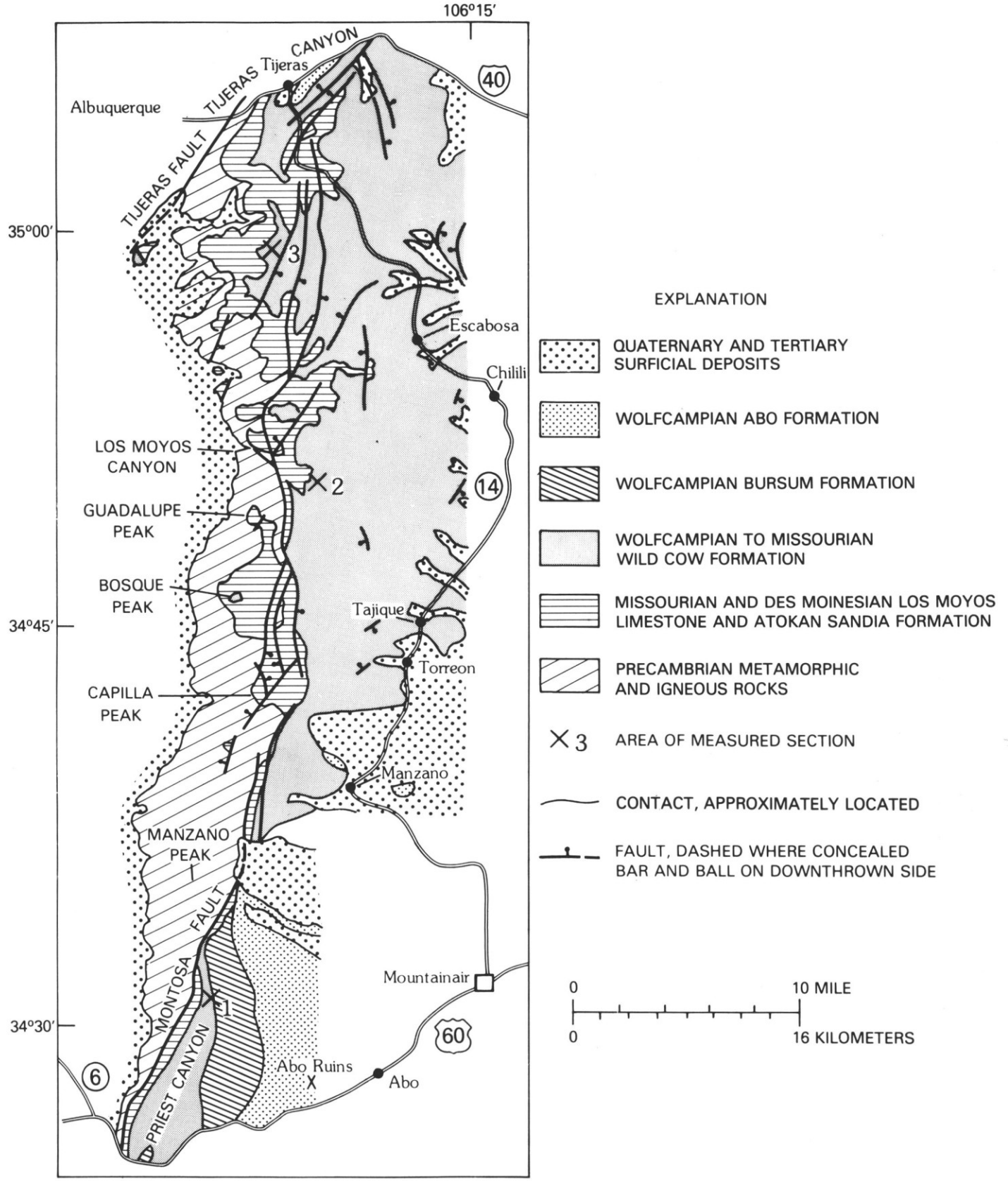

Figure 1. Generalized geologic map of Manzano Mountains, New Mexico. Modified from Myers (1966, 1967a, 1977) and Myers and McKay (1970, 1971, 1972, 1975, 1976).

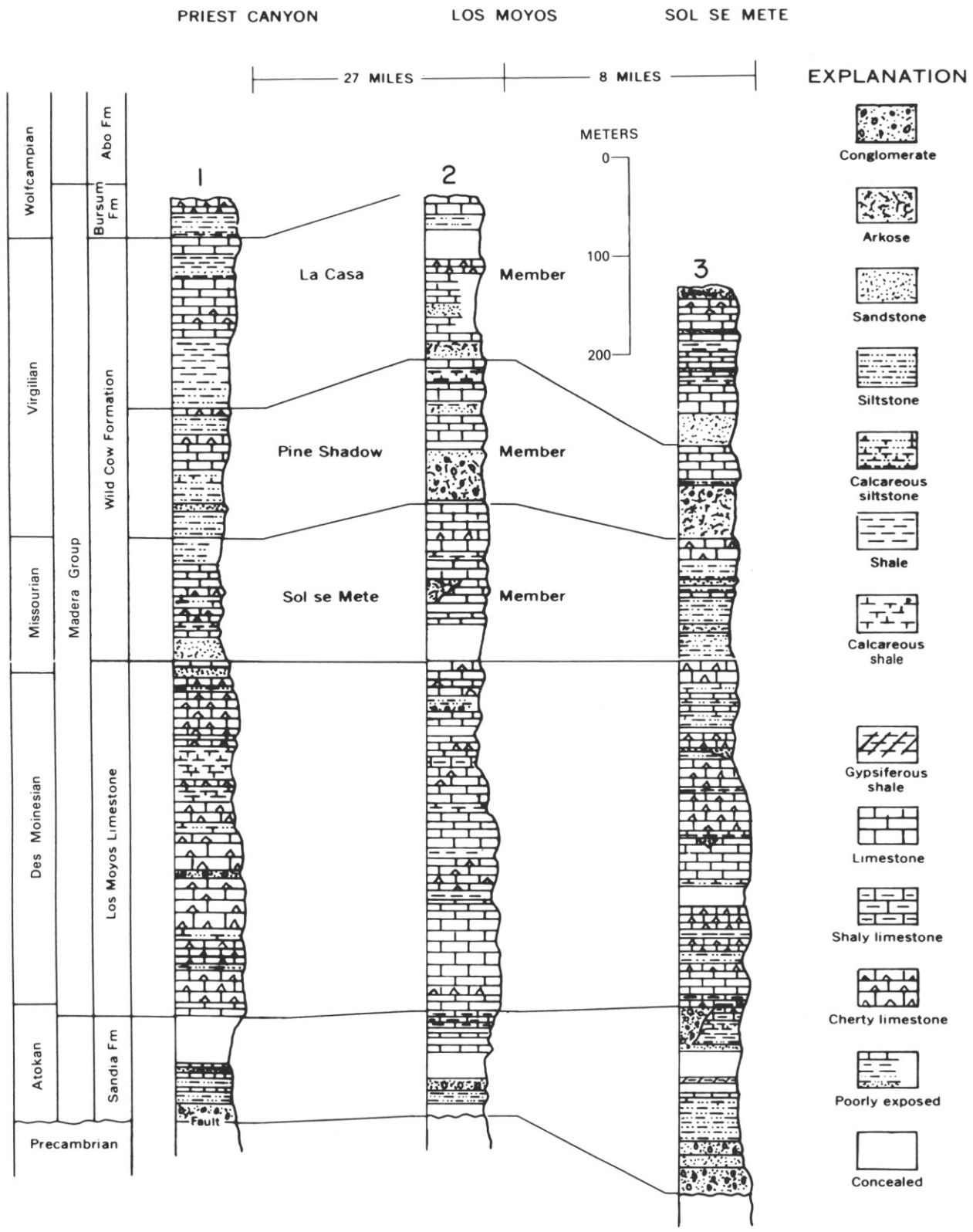

Figure 2. Type and reference sections for the Los Moyos and Wild Cow formations, Madera Group. Section of Wild Cow Formation in Los Moyos area is composite (Myers, 1966, sections, 4, 5, 6). Thickness of concealed basal interval represents maximum possible; minimum is about 15 m (50 ft) less than shown. From Myers (1973).

Los Moyos, *Eowaeringella joyitaensis* has been found. The fusulinids indicate that most of the Los Moyos is of Des Moinesian age, and that the uppermost beds are, at least locally, of early Missourian age.

Wild Cow Formation

The Wild Cow Formation, defined by Myers (1973), consists of alternating sequences of arkosic sandstone, sandstone, conglomerate, gray to yellow siltstone and shale, gray to black calcareous shale, and thin- to thick-bedded calcarenite that is locally cherty. Some of the limestone in the upper part of the formation contains angular megascopic fragments of detrital pink feldspar. The Wild Cow Formation is the arkosic limestone member of the Madera Limestone of Read and others (1944). The formation is subdivided into three members that are, in ascending order: Sol se Mete Member, Pine Shadow Member, and La Casa Member.

Sol se Mete Member

The Sol se Mete Member is unit B of the upper part of the Madera Limestone as previously mapped by Myers (1966, 1967a, 1969) and Myers and McKay (1970, 1971, 1972).

The basal beds of the Sol se Mete, from 4 to 30 m thick, are usually conglomerate, coarse- to fine-grained crossbedded sandstone, or siltstone; in places the basal beds are arkosic and contain angular to subrounded fragments of metamorphic rock. Locally, petrified logs are common. In the vicinity of the community of Tijeras at the northern end of the mountains, the basal beds, about 2 m thick, are grayish-brown micaceous siltstone and fissile claystone that weathers red. These beds may represent a paleosoil that developed on the surface of the Los Moyos; they are overlain by the usual sequence of crossbedded sandstone and conglomerate.

The basal beds are overlain at most places by a poorly exposed succession of calcareous gray shale and nodular limestone. The upper part of the member is 9-18 m of gray calcarenite, locally cherty, that forms a cliff. The thickness of the member averages about 60 m, ranging from about 45 m at the southern end of the mountains to about 90 m in the central part of the mountains. At the southern end of the mountains, much of the limestone grades laterally into stratigraphically equivalent siltstone and fine-grained sandstone.

The Sol se Mete contains fusulinids related to *Triticites irregularis* and *Triticites ohioensis.* These, and other fusulinids in the Sol se Mete, indicate that the member was deposited during Missourian time. They resemble fusulinids from the Canyon Group of north-central Texas (Myers, 1960, 1967b) and from the Missourian Series of the Midcontinent region.

Pine Shadow Member

The Pine Shadow Member is unit C of the upper part of the upper Madera Limestone as previously mapped by Myers (1966, 1967a, 1969) and Myers and McKay (1970, 1971, 1972). It is the middle member of the Wild Cow Formation. Throughout most of the Manzano Mountains, the basal beds are crossbedded arkosic conglomerate. The conglomerate is composed of pebble- to cobble-size, rounded to subrounded fragments of metamorphic rock in a poorly sorted arkosic matrix. Fragments of fossil wood are common in the conglomerate; bedding planes are commonly ripple-marked. At the top of the conglomeratic sequence, in the northern part of the mountains, fossil-tree stumps in position of growth have been found. At the type section (fig. 2) and elsewhere in the southern part of the mountains, the basal beds are yellow to brown micaceous siltstone and fine-grained sandstone; these beds contain fragments of carbonized plant debris and fossil wood. The basal unit is generally 15-27 m thick; however, it is locally as thin as 1.5 m or more than 30 m thick. The basal unit is overlain by thinly-bedded yellow to gray siltstone and calcareous shale.

The uppermost part of the Pine Shadow Member is ledge- or cliff-forming. Near Sol se Mete, the upper beds are 15 m of calcarenite; in the Tajique area, there are 3 beds of calcarenite separated by sandstone and calcareous shale; at the type section, 2 beds of limestone are separated by siltstone. The limestone is mostly light-olive gray calcarenite that is locally cherty. It is generally from 15 to 21 m thick but may be as much as 40 m thick.

Algal colonies about the size and shape of golf balls weather into relief and are prominent at the top of the upper limestone beds in the central part of the mountains; an elongated species of *Triticites* is associated with these colonies of algae.

Fusulinids from the Pine Shadow Member belong to various species of *Triticites* that indicate deposition during early Virgilian time. They have affinities to *Triticites* spp. from the Graham Formation in north-central Texas (Myers, 1960), to the faunas from the lower part of the Earp Formation in the Whetstone Mountains in southeastern Arizona (Ross and Tyrrell, 1965), and to the faunas from the Gaptank Formation of west Texas (Ross, 1965, beds G, **H,** and I).

La Casa Member

The La Casa Member is unit D of the upper part of the upper Madera Limestone as mapped by Myers (1966, 1967a, 1969) and Myers and McKay (1970, 1971, 1972). The La Casa is the uppermost member of the Wild Cow Formation. At the type section of the member (fig. 2), the lower part is about 37 m of poorly exposed siltstone and shale. This is overlain by about 30 m of light gray calcarenite, the lower 21 m of which forms a pronounced ridge, and by an overlying thin sequence of red and gray shale and yellowish-green calcareous sandstone. The upper part of the member is 9 m of cherty gray calcarenite. North of the type section, the lower part becomes arkosic and, locally, conglomeratic. In the Tajique area, the basal beds of the member consist of about 9 m of arkose and conglomerate; in the vicinity of Sol se Mete, basal beds of similar lithology are about 15 m thick. The 30-m-thick sequence of limestone at the type section in Priest Canyon grades northward into alternating beds of limestone, siltstone, sandstone, and shale. Locally, some of these upper limestone beds contain megascopic angular fragments of detrital pink feldspar.

The La Casa Member appears to thicken northward from the type section and, in the vicinity of Sol se Mete, if the pre-Cenozoic surface were restored, the member probably would be about 98 to 105 m thick.

Fusulinids from the La Casa Member belong to the genera *Dunbarinella, Schubertella, Leptotriticites,* and to various species of *Triticites.* They have affinities to fusulinids from the uppermost Graham and Thrifty formations in north-central Texas, to the uppermost part of the Gaptank Formation in west Texas, and to the lower member of the Earp Formation in the Whetstone Mountains of Arizona. The presence of fusulinids similar to *Triticites creekensis,* and *Leptotriticites* indicates that the youngest beds of the La Casa were deposited during early Wolfcampian time.

BURSUM FORMATION

The Bursum Formation, of Early Permian age, gradationally overlies the La Casa Member in the southern part of the Manzano Mountains. It represents the last phase of the mainly marine environment in which the underlying Pennsylvanian formations were deposited.

In the Priest Canyon area, the Bursum Formation consists of more than 30 m of lenticular beds of red arkosic hematitic sandstone, red and locally green shale and siltstone, and greenish-gray calcarenite. For the most part, it underlies a gently sloping alluvium-covered surface

that slopes east and southeast. The top of the Bursum is the highest marine limestone that underlies the nonmarine Abo Formation.

North of Priest Canyon, the Bursum thins and the upper beds may be replaced laterally by the Abo Formation, or they may have been removed by erosion that accompanied deposition of the Abo. The Bursum is not a mappable unit north of Priest Canyon. The northernmost exposures of the Bursum are west of Manzano where about 12 m of red beds and limestone crop out in the town dump. In the northern half of the mountains, the Bursum is absent. Geologic mapping suggests that many of the Bursum red beds grade into gray shale and limestone in the northern part of the mountains. If so, the uppermost beds of the La Casa Member include equivalents of the Bursum Formation.

Fusulinids from the Bursum include *Triticites creekensis, Leptotriticites,* and *Schwagerina pinosensis.*

ABO FORMATION

Needham and Bates (1943) redescribed the Abo Formation from Lee's (1909) original description. They designated a type section for the Abo to be the exposures extending east from Priest Canyon to a hill east of Abo Ruins, north of U.S. 60. The formation consists of about 280 m of nonmarine, crossbedded, hematitic, locally arkosic conglomerate, sandstone, siltstone, and shale, with the finer textured rocks predominant. Thin lenses of nodular, fresh-water limestone are present but uncommon in the lower part. Impressions of plants and fragments of fossil wood are common in the lower part; tracks of vertebrate animals have been reported; burrows and other trace fossils are common in some places. Copper is present in the lower 116 m and is associated with fossil-plant debris in light-bluish-gray and pinkish-white sandstone and pebble conglomerate (Myers, 1977; Myers and McKay, 1974; Hatchell and others, this guidebook). Excellent exposures of the Abo may be seen in roadcuts along U.S. 60 between Priest Canyon and the vicinity of Abo Ruins.

YESO FORMATION

The Yeso Formation is intermittently exposed in roadcuts along U.S. 60 between Mountainair and the top of the Abo Formation. Myers (1977) mapped the formation in the Scholle area, but the part of the area that contains the Yeso lies south of the area of Figure 1. The Yeso Formation gradationally overlies the Abo Formation; the contact was mapped on a change in color from the dominant deep reds of the Abo to the orange-reds of the Yeso. The lower part of the Yeso, the Meseta Blanca Sandstone Member, is about 76 m of pinkish-gray, pale-red, moderate-reddish-brown, thin-bedded, ripple-marked, crossbedded, fine-grained sandstone and siltstone (Myers, 1977). Some bedding surfaces are burrowed. The soil which forms on the Yeso is orange to pink.

The upper part of the Yeso, the Torres Member, is poorly exposed, light-gray, bedded gypsum, yellowish-gray gypsiferous sandstone and siltstone, and a few thin beds of medium- to light-olive-gray gypsiferous limestone. The uppermost beds of the Yeso crop out south of U.S. 60.

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