GEOLOGY OF THE RANCHO DE LOPEZ AREA
EAST OF SOCORRO, NEW MEXICO

by

Joe Maulsby

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science in Geology

New Mexico Institute of Mining and Technology

Socorro, New Mexico

December 1981

Table of Contents

List of Figures

List of Plates

ACKNOWLEDGEMENTS

I am grateful to my thesis advisor, Dr. David Johnson, for his guidance and suggestions in the field and in the classroom. Special thanks is extended to John Dooley for his help with the infrared spectrometer, x-ray diffractometer, and field assistance on several interesting road trips.

I would like to thank Donald Myers of the United States Geological Survey, Denver Colorado, for prompt fusulinid identification. The task would have been much more difficult without suggestions and help from Dr. Clay Smith, Dr. Antonius Budding, and other colleagues at the New Mexico Institute of Mining and Technology.

Many thanks to the taxpayers of the United States for the H. E. W. Research Fellowship which provided funding for every aspect of this thesis. Last, but not least, I am grateful for the support my family has given me through good times and bad.

ABSTRACT

The Rancho de Lopez area is located nine miles east-northeast of Socorro, New Mexico (Socorro County). The majority of the field is located on the Lomas de las Cañas Quandrangle. This field area forms the eastern flank of the Rio Grande Rift.

The rocks exposed in the area range from Pennsylvanian (Missourian) to Permian (Leonardian). An incomplete Pennsylvanian section is present due to normal faulting.

The landmass responsible for the majority of clastics was probably the Pedernal Landmass to the northeast. Clastic content increases toward the east.

Pennsylvanian strata in this field area are represented by limestones, shales, arkose and fine-grained sandstones. Pennsylvanian rocks are not conformable with the overlying Permian strata.

Permian rocks are variable in lithology. Marine and continental sedimentary structures are preserved in the strata. Permian strata in the Rancho de Lopez area, consist of mudstone, limestone, sandstones, siltstones, and gypsum.

The structural style of the area is dominated by extensional tectonics (normal faulting). A subordinate amount of gentle folding is present. Stratigraphic throw ranges from a few meters to 36.4 meters. Major faults trend roughly north-south.

Stratigraphic nomenclature used herein is essentially that of Thompson (1942). The only deviation is use of Bursum Formation (Wilpolt and Wanek, 1946) instead of Bruton Formation.

INTRODUCTION

Location, Size, and Accessibility

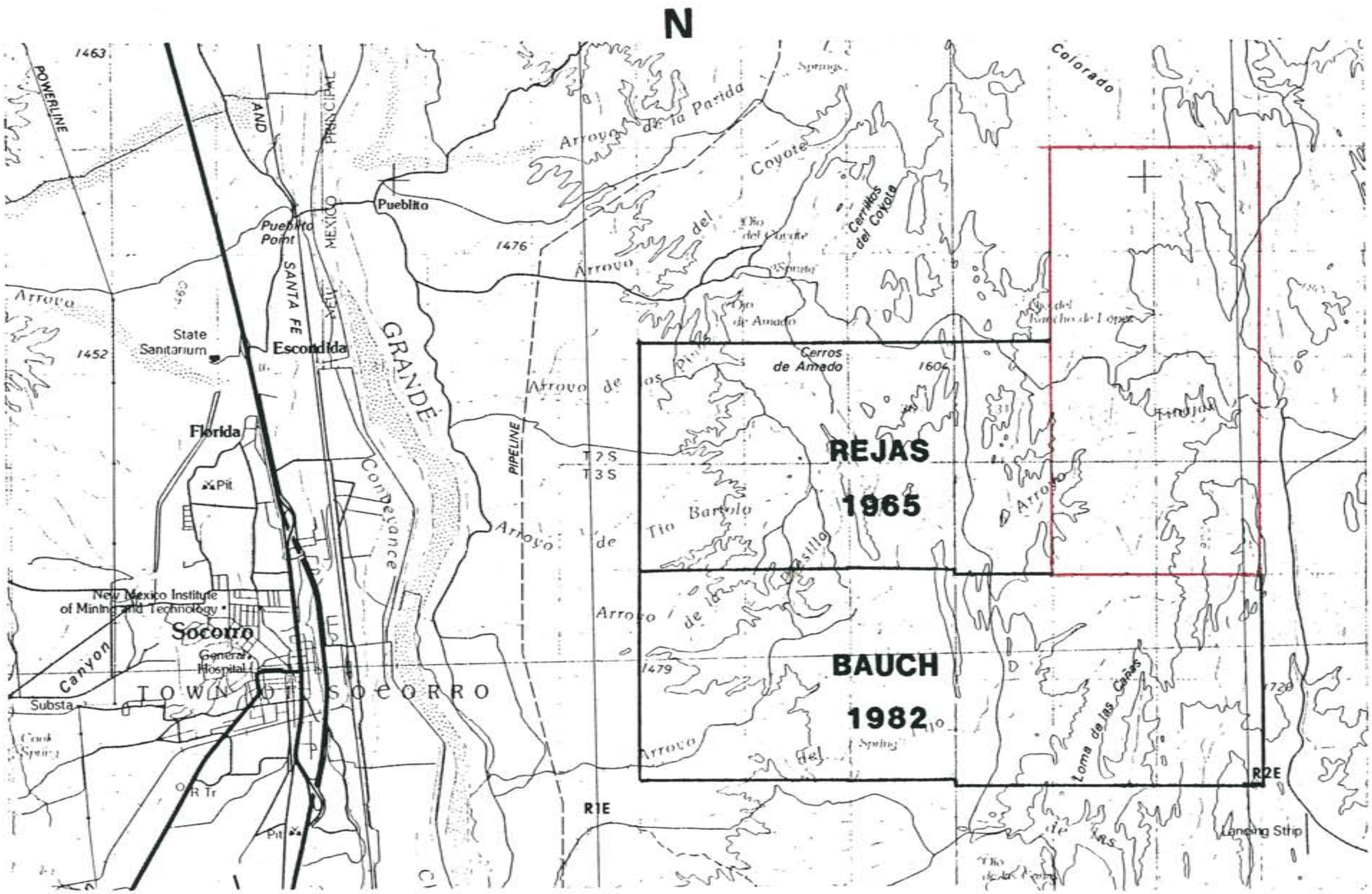
The study area is located along the east flank of the Rio Grande Rift, nine miles east-northeast of Socorro, New Mexico (Figure 1). The majority of this area is located on the Lomas de las Cañas Quandrangle. Remaining field area is contained on the following quadrangle maps: Bustos Well, Mesa del Yeso, and Sierra de la Cruz. Coordinates involved are: 106° 45′ 6" E and 106° 42′ 37" E longitude; 34° 7′ 32" N and 34° 4′ 25" N latitude.

Study area encompasses approximately ten square miles. Sections included are: 19, 20, 21, 22, 27, 28, 29, 32, and 33 in T. 2 S., R. 2 E.,; 3, 4, 5, and 6 in T. 3 S., R. 2 E.

Gravel roads along west and east borders provide access to the area studied. These roads are maintained by the Bureau of Land Management.

Purpose

The purpose of this project is three-fold. One is to generate a detailed, lithostratigraphic map. A second is to construct geologic cross-sections which delineate tectonic-produced structural features. Third, to postulate possible, depositional environments which might have been active in the Rancho de Lopez area.



SCALE 1:100,000

CONTOUR INTERVAL 20 METERS

KILOMETERS 0 1 2 3 4 5

MILES 0 1 2 3

Study area index map

Figure 1

Methods of Investigation

Before detailed mapping began, a reconnaissance of the study area was completed. Aerial photographs (1:31,500) were used for field reference. Data obtained from field mapping is plotted on topographic maps enlarged to final map scale (1:12,000).

The thickness of rock units comprising the stratigraphic section was determined using a pocket transit and Jacob staff. When possible, a steel tape was used to measure thickness. Bedding classification of Mckee and Weir (1953) is used throughout this thesis.

Rock samples were primarily collected at the site of the measured section. These samples were taken at important changes in lithology. The "average" lithotype is represented by these samples. Other samples were collected throughout the field area if unusual sedimentary structures or paleontological horizons were discovered. Grain size scale of Wentworth (in Pettijohn et al., page 72, 1972) is used throughout this paper.

Thin sections were made from most hand samples and stained with Alizarin red S (stains calcite, but not dolomite). Two sections of Pennsylvanian strata were measured in T. 2 S., R. 2 E. The west section location is : W/2, W/2, W/2, section 29 (Plate 1). Approximately 2.6 kilometers northeast of this section is the location of the east measured section. Its location is: SE/4, NW/4, section 21.

Rock descriptions included in this report will follow the classification scheme of Pettijohn et al. (1972) for carbonates and Dunham (1962) for clastics. The term "carbonate mudstone" will replace Dunham's mudstone to avoid confusion with clastic mudstones.

Previous Work

A detailed geological map of this study area has never been produced. Wilpolt and Wanek (1951) drafted a preliminary reconnaissance map (1:62,500), but good detail is lacking. Angel Rejas (1965) mapped twelve square miles west of this study area. John Bauch is mapping ten square miles south of this study (see figure 1). William Siemers (1978) completed an interpretation of depositional environments for upper Paleozoic strata around Socorro, New Mexico. Siemers did not compile a lithostratigraphic map. Published work by Thompson (1942) and Kottlowski (1960) describes strata encompassed by this field study.

Topography, Relief, and Drainage

Topography is dominated by long (up to 4.8 km.) fault scarps produced by normal faulting (Figure 2). Topographic relief increases from west to east. Elevation ranges from 1581 meters (5200 feet) to a maximum of 1886.6 meters (6206 feet) above sea level.

Figure 2 Long fault scarp produced by normal faulting between Pennsylvanian and Permian strata. Section 5, T. 2 S., R. 2 E.

Subsequent streams predominate in the drainage patterns. Small tributaries appear to be controlled by faulting. Several large tributaries, trending east-west, feed the Rio Grande River.

Vegetation

Vegetation is sparse, due to the semi-arid climate. The dominant plants include: mesquite, ocotillo, creosote bush, numerous cacti, wild flowers, and varieties of gramma grass. Few trees are able to survive. Junipers are the exception. Vegetation does not seem to prefer any particular lithology. Enough grass is available to run two to three head of cattle per section of land.

Wildlife

Mammals and reptiles are quite abundant in this desert environment. Numerous deer, rabbits, and ground squirrels are observed throughout the field season.

Reptiles are represented by lizards, and rattlesnakes. Western Diamond-back and prairie rattlesnakes are the main species in this area.

Climate

A semi-arid environment prevails in the study area most of the year. July and August are the wet months of the year. Fifty percent of the yearly rainfall usually occurs during this sixty day interval. The average yearly rainfall in Socorro is less than nine inches (22.9 cm.). This precipitation is probably close to the amount received by this field area.

In the summer, temperatures climb as high as 110° F. January average, maximum temperature is 52° F. January average, minimum temperature is 23° F. In the winter, a few, light snowfalls will occur.

GEOLOGY

Rocks in the study area range in age from Pennsylvanian (Late Missourian) to Permian (Middle Leonardian). Emphasis of this study is on the Pennsylvanian System. Most of the area is covered by a veneer of Quaternary alluvium. Outcrops of igneous rocks (pre-Cambrian) can be found two miles west of this study area.

STRATIGRAPHY

Stratigraphic units described by Thompson (1942) were used for this study (Figure 3). These same stratigraphic units were used by Rejas in 1965 in an adjacent field area. A much more simplified stratigraphic column was used by Wilpolt and Wanek in 1951. Greater stratigraphic detail was recognized and needed, than could be provided by Wilpolt and Wanek.

Thompson (1942) named the unit located between the Abo Formation (Permian) and Moya Formation (Pennsylvanian), the Bruton Formation. The Bruton was decribed from exposures in the Oscura Mountains. Bruton type section was not observed

PENNSYLVANIAN STRATIGRAPHIC CLASSIFICATION

SERIES	GROUP	Thompson (1942) and This Study (1981) FORMATIONS and MEMBERS		Wilpolt and Wanek (1951) FORMATION	Wilpolt and Wanek (1951) MEMBER
Virgil	Fresnal	Bruton Formation[1]			
Virgil	Keller	Moya Formation	upper member lower member	Madera Limestone	Arkosic limestone member
Virgil	Keller	Del Cuerto Formation		Madera Limestone	Arkosic limestone member
Missouri	Hansonburg	Story Formation	upper member lower member	Madera Limestone	Arkosic limestone member
Missouri	Hansonburg	Burrego Formation		Madera Limestone	Lower gray limestone member
Missouri	Veredas	Council Springs Form.[1]		Madera Limestone	Lower gray limestone member
Missouri	Veredas	Adobe Formation[1]		Madera Limestone	Lower gray limestone member
Missouri	Veredas	Coane Formation[1]		Madera Limestone	Lower gray limestone member
Des Moines	Bolander[1]			Madera Limestone	Lower gray limestone member
Des Moines	Armendaris	Garcia Formation[1]		Madera Limestone	Lower gray limestone member
Des Moines	Armendaris	Whiskey Canyon Form.[1]		Madera Limestone	Lower gray limestone member
Des Moines	Armendaris	Elephant Butte Form.[1]	Warmington member	Sandia Formation	
Derry	Mud Springs	Cuchillo Negro Form.[1]		Sandia Formation	
Derry	Mud Springs	Hot Springs Formation[1]		Sandia Formation	
Derry	Green Canyon	Apodaca Formation[1]		Sandia Formation	
Derry	Green Canyon	Arrey Formation[1]		Sandia Formation	

[1] not present in Rancho de Lopez area

Figure 3

by this writer.

Wilpolt and others (1946) named the unit between the Moya and Abo Formations the Bursum Formation. The type section is west of the Bursum triangulation point in the SE/4, Section 1, T. 6 S., R. 2 E., Socorro County, New Mexico. Since this type section is closer to the Rancho de Lopez Area than the Bruton type section, this writer favors use of Bursum Formation for red arkosic sands, conglomerate and interbedded, nodular limestones between the Moya and Abo Formations.

Reasonably good lithologic correlation, with stratigraphic units recognized by Rejas, is achieved herein. The major difference seems to be increasing clastics eastward (this report). The Del Cuerto Formation is not differentiated into lower, middle, and upper members in this report due to poor exposure.

The Moya and Story Formations provide easily recognizable marker beds throughout the field area. Lower Moya Formation is usually found capping cuestas when the Moya is present. The Story Formation comprises the lower prominent ledge of a "double ledge" display (Figure 4).

The Joyita, Cañas, and Torres Members of the Yeso Formation are mapped together as Torres Member, but differentiated in measured sections.

Figure 4A Prominent double ledge found in the upper Pennsylvanian strata in New Mexico. Looking northward; section 32, T. 2 S., R. 2 E.

Figure 4B Same double ledge observed from measured section 2. Looking eastward; section 21, T. 2 S., R. 2 E.

DESCRIPTIVE SEDIMENTOLOGY

Pennsylvanian Rocks

Hansonburg Group

Burrego Formation

The term Burrego was proposed by Thompson in 1942 for a group of massive to massively bedded and nodular limestones directly above the Council Springs Limestone. The type section is found north of Burrego Spring on the northeast side of the Oscura Mountains. This is also coincident with the type locality for the complete Hansonburg Group.

At the type locality (Figure 5), the Burrego Formation is 16 meters thick (Thompson, 1942). South and northwest of the type section, the Burrego is much thicker due to increased clastic material.

Burrego Formation measured for this study is thicker than Thompson (1942) or Rejas (1965) recorded. Burrego in both measured sections is not complete due to faulting. In the west, 81.1 meters is recorded. Northeast of this section, 102.4 meters of Burrego is present. Rejas measured a Burrego section 2.4 km. west of this writer's section 1. Rejas recorded 11.3 meters. Burrego Formation appears to conformably underlie the Story Formation.

Section 1 (west) is predominantly light olive-brown, fissile shales and carbonate mudstones (Figure 6). Shales and mudstones are silty and micaceous (see complete

Figure 5 Type section for Burrego, Story, Del Cuerto, and Moya Formations in the Oscuras. Looking northward; section 31, T. 5 S., R. 6 E.

Figure 6 Burrego Formation carbonate mudstone and shale (App. A, unit 1).

descriptions in Appendix A and B). Only seven percent of the exposed section is sandstone. The sandstone is fine- to medium-grained sand; subrounded, moderately sorted. The sand body is lenticular (Figure 7) and exhibits planar crossbedding. Localized occurrences of limestone cobble conglomerate are located at the base of this sand unit (Figure 8). Limonite-stained concretions are present within some shale intervals. Pelmatozoan stems are abundant in several carbonate intervals. Productid brachiopods are also observed. All fossil material is highly abraded. In thin sections, Triticites spp. similar to those from the lower half of the Pine Shadow Member of the Wild Cow Formation (Early Virgillian) is recognized. The Wild Cow Formation is located in the southern part of the Manzano Mountains. The lithology described above, corresponds with the western measured section of Rejas (1965). Major difference between the two is thickness of strata.

Burrego Formation in section 2 is dominated by clastics (33%). Again, a complete section of Burrego is lacking due to faulting. Clastics are primarily arkosic sandstones (Figure 9A). Color of arkose ranges from yellowish-brown to olive gray. Coarse silt to fine sand dominates clastic grain size. Several arkosic sandstones contain as much as 5% micaceous material. Small-scale planar crossbedding dominates sedimentary structures (Figure 9B). Distorted bedding was also observed at the top of two fine grained sandstone units(Figure 10). An imprint of plant material

Figure 7 Lenticular, channel sand (App. A, unit 8) within the upper Burrego. Looking eastward.

Figure 8 Channel lag gravels and cobbles in Burrego.

Figure 9A Burrego, arkosic sandstone from measured section 2. Scale is 30.5 cm. in length.

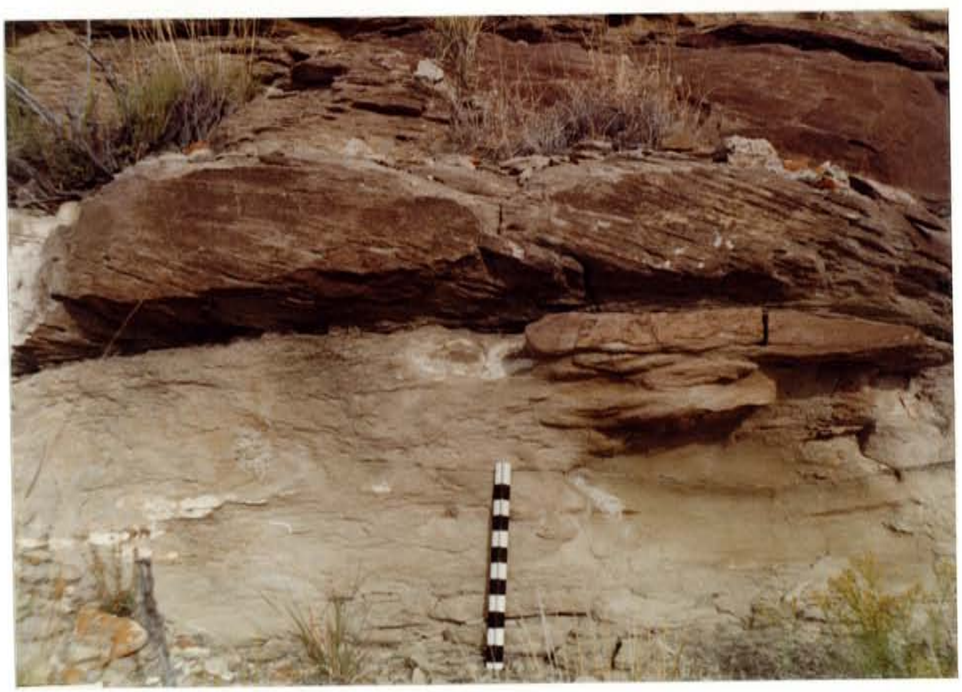


Figure 9B Small-scale, planar crossbedding within a Burrego arkosic sandstone (App. A, unit 26). Scale is same as above.

Figure 10A

Figure 10B

Figure 10 A and B Distorted bedding displayed in a Burrego sandstone (App. A, unit 12).

was found on one of the thin, arkosic sandstones. The plant fragment is identified as Calamites sp. Most of the arkosic intervals are interbedded with laminated carbonate mudstones and shales (Figure 11A).

Calcareous siltstones and shales are light to dark gray (Figure 11B). These rock types are most abundant in the lower half of measured section 2. Clastic units display very thin to thick tabular bedding.

Limestones within this interval are wackestones, with an occasional packstone. Fossils include pelecypods, fenestrate bryozoans, and pelmatozoan fragments. Most skeletal grains are abraded. Thin section analysis reveals ostracods throughout most of the Burrego Formation. There is also evidence of bioturbation in two carbonate mudstone thin sections.

Story Formation

The term Story Formation was proposed for the upper 17.7 meters of the Hansonburg Group (Thompson, 1942). Thompson described a lower unit (6 meters) of reddish-brown shale, arkosic and micaceous sandstone and gray shale, and an upper unit (11.5 meters) composed of light gray, massive to massively bedded and highly fossiliferous limestone (Figure 5). This formation has been recognized throughout most of central New Mexico (Thompson, 1942). The Story Formation appears to comformably overlie

Figure 11A Carbonate mudstone and gray, fissile shale (App. B, unit 6) found within the Burrego Formation. Scale is 30.5 cm. in length.

Figure 11B Burrego siltstones and shales (App. B, unit 8) from measured section 2.

the Burrego Formation, and conformably underlie the Del Cuerto Formation.

lower clastic unit

In section 1 this unit is represented by 9.5 meters of grayish-red, micaceous, thin bedded, arkosic siltstone (Figure 12). Section 2 unit is similar, but thicker (13.2 meters). This unit is best described as an arkosic sandstone (fine sand-size quartz). It too is micaceous, and thin bedded.

upper limestone unit

Section 1 contains about 6.8 meters of fossiliferous, carbonate mudstone (Figure 13). Both contacts are sharp. From outctop observation, pelmatozoan stems (up to 19 cm. long), solitary rugose corals, phylloid algae, and fenestrate bryozoans are common. Thin section analysis yields pelecypod valves, forams, calcispheres (algal reproductive structures), and ostracods. Bedding is very poor to massive. The light brownish-gray limestone is one of two prominent and easily traceable ledge-formers.

Section 2 (east) contains 6.4 meters of light yellowish-brown carbonate mudstone (Figure 14). The mudstone is massively bedded. Similar fossils to those in section 1 were noted. Here too, the upper Story Formation forms a prominent ledge. Lithology is constant between the two sections.

Figure 12 Arkosic siltstone characteristic of the lower unit of the Story Formation (App. B, unit 27). Scale is 30.5 cm. in length.

Figure 13 Upper limestone unit of Story Formation from measured section 1. Looking northeastward; section 29, T. 2 S., R. 2 E.

Figure 14 Upper limestone unit of Story Formation from measured section 2. Looking eastward; section 21, T. 2 S., R. 2 E.

KELLER GROUP

Del Cuerto Formation

As a result of extensive work throughout New Mexico, Thompson (1942) states that "... the Virgillian Series lithology in New Mexico varies more markedly geographically than the lithology of any other Pennsylvanian Series. Lithology varies from marine limestone to deltaic to brackish water silts and silty limestones to sandstones."

The terms Keller and Del Cuerto were first used by Thompson in 1942. Type locality is at the north end of the Oscura Mountains. The predominant lithology at the type section is limestone. Twenty-five meters of Del Cuerto Formation was recognized by Thompson. Although dominant lithology is limestone, interbedded arkosic sandstones, red to gray shales, and limestone conglomerate are present.

Rejas (1965) divided the Del Cuerto Formation into three members. Due to poor outcrop exposure in both measured sections of this study, the Del Cuerto Formation is described as a single unit. Rejas measured 17.3 meters of Del Cuerto.

In section 1 (west), Del Cuerto attains a thickness of 11.8 meters. Lithology is characterized by light gray carbonate mudstones, sandy packstones, and cherty, carbonate mudstones (near its contact with overlying Moya Formation). The fossiliferous packstones contain abraded pelmatozoan debris. This unit weathers back beneath the Moya Formation.

Section 2 contains about fifty percent less section (6.2 meters). Outcrop exposure is poor. Lithology here is characterized by light gray, fossiliferous wackestone. Upper contact is gradational with overlying Moya Formation. It appears upper and lower contacts are conformable. At the outcrop, brachiopods and pelmatozoan debris is common. Bedding is wavy. The top one meter is a thin bedded, pelecypod packstone.

Moya Formation

Thompson (1942) proposed the term Moya Formation for the massive to massively bedded and irregularly bedded to nodular limestone between the top of the Del Cuerto Formation below and the base of the Bruton Formation above. Thompson recognized the Moya throughout central New Mexico. The type locality is found on the northeast side of the Oscura Mountains. When the upper limestone unit of the Moya Formation is present, it forms the caprock on cuesta ridges. Most east dip-slopes throughout the Oscura Mountains are Moya Formation.

At the type locality, the Moya Formation is 15.5 meters thick (Figure 5). Thompson (1942) did note an increasing thickness toward the north and south. Total Moya thickness in this study (measured section 1) is 26.8 meters. At measured section 2, the upper Moya is not present due to erosion on the dip slope. Thickness for the lower limestone is 10.6 meters. Rejas (1965) measured 23.3 meters of Moya. His section is located approximately 4.8 km. west of this writer's measured section 1. In the Rancho de Lopez area, it was possible to divide the Moya into an upper and lower limestone unit.

lower limestone unit

Measured section 1 contains 15.9 meters of light gray carbonate mudstone (Figure 15). The lower one meter contains large nodules of chert (Figure 16). Location of this chert within the member is fairly constant throughout the study area. Medium to thick bedding predominates in this poorly bedded unit (Figure 17). Pelmatozoan stems and brachiopods (disarticulated) are also abundant. Phylloid algae are abundant.

Petrographic analysis yields further faunal information. In addition to fauna mentioned above, ostracods, encrusting bryozoans, and encrusting, red algae are observed. Mineralogy is mostly calcite.

upper limestone unit

Total thickness of the upper unit from measured section 1 is 10.9 meters. Lithology is quite similar to the lower unit. Wackestone comprises most of this unit, but packstones are observed. Wackestone is medium to thick bedded, light gray, and poorly bedded. Disarticulated

Figure 15 Lower limestone unit of Moya Formation near measured section 1. Looking northward.

Figure 16 Chert nodules in the basal one meter of lower Moya Formation. Scale is 30.5 cm. in length.

Figure 17 Closeup of bedding characteristic of the lower Moya Formation. Scale is 15 cm. long; section 29, T. 2 S., R. 2 E.

pelmatozoan stems are common at outcrops. Phylloid algae are common (Figure 18).

Petrographic analysis yielded further fauna present. Foraminifera and fusilinids, bryozoa, ostracods, molluscs, punctate brachiopods, and encrusting, red algae can be identified. One thin section shows evidence of burrowing. Mineralogy is predominantly calcite. This limestone is dense.

At most localities throughout this study area, the transition between upper and lower Moya Formation is subtle. In some locations, a thin bedded, brown, arkosic sandstone separates the two units (Figure 19). This sandy interval is usually covered. Where the sandstone is covered, a slight break in slope is arbitrarily used as the contact between the two limestone units of the Moya.

Permian Strata

Bursum Formation

The type section of the Bursum Formation, named by Wilpolt and others (1946), is west of the Bursum triangulation point in the SE 1/4, section 1, T. 6 S., R. 4 E., Socorro County, New Mexico. At the type locality, the Bursum Formation consists of thick beds of dark purplish-red and green shale separated by thinner beds of arkose, arkosic conglomerate, and gray limestone. A thin, rubbly, nodular, purplish-gray limestone consisting of material possibly

Figure 18A Phylloid algae found in the Moya Formation (App. A, unit 27).

Figure 18B Remains of phylloid algae now filled with sparry calcite in the Moya Formation.

Figure 19A

Figure 19B

Figure 19 A and B Thin bedded, fine grained, arkosic sandstone unit between the upper and lower Moya limestone units. Looking eastward. Scale is 15 cm. in length.

derived from the underlying Moya Formation occurs locally at the base (Wilpolt and Wanek, 1951). They considered the Bursum Formation to be Wolfcampian in age, as determined by fusilinid identification. This age is supported by fusilinid data obtained from the current study area. _Triticites creekensis_ is the most abundant fusilinid identified in this area. _Bradyina_ sp. is also noted, but may be detrital (Myers, personal communication, 1981). _T. creekensis_ was described by Thompson (1964) from material in the Camp Creek Shale of north-central Texas, where it is associated with _Schwagerina campensis_. Thompson (1964) also described specimens _T. creekensis_ from the Bursum Formation in the Oscura Mountains, and from the southern part of the Los Piños Mountains, in New Mexico. Maximum thickness at the type locality is 75.6 meters.

Rejas (1965) measured 60.6 meters of Bursum Formation in the Cerros de Amado area. In the Rancho de Lopez area, 76.7 meters of Bursum is present. Rock type is dominated by conglomerates (see Appendix C). At most outcrops viewed in this study area, a basal, limestone, pebble conglomerate is located above the Moya Formation (Figure 20). This conglomerate is very poorly bedded (wavy) and weathers into talus piles of limestone pebbles. The other type of conglomerate observed is a quartz and pink feldspar pebble conglomerate (Figure 21). Quartz pebbles and feldspar grains are in a calcareous, sandy matrix. Hematite staining of grains and matrix is abundant.

Figure 20A Basal, nodular, limestone conglomerate (App. C, unit 1) in the Bursum Formation. Upper unit is one meter thick. Upper unit is quartz-feldspar pebble conglomerate.

Figure 20B Closeup of Bursum basal conglomerate. Section 5, T. 2 S., R. 2 E.

Figure 21 Quartz-feldspar conglomerate in the Bursum Formation (App. C, unit 2). Unit length of grasshopper = 2.54 cm.

Two intervals of quartz and limestone pebble conglomerate exhibit a fining-upward sequence. Poorly developed crossbedding (planar) can also be recognized. Limestone clasts range in size from coarse sand to pebbles. Quartz clasts fall in the same size range. Most clasts are poorly sorted and subrounded. Thin beds of very light gray mudstone are interbedded with the conglomerates. Bursum Formation upper contact is gradational (conformable) with the overlying Abo Formation.

Abo Formation

W. T. Lee named the Abo Sandstone in 1909. The type section is located in Abo Canyon, Torrance County, New Mexico. There, the total thickness is 242 meters and consists of sixty percent red shales and forty percent sandstone, arkose, and conglomerate (Needham and Bates, 1943). Rejas (1965) measured 139.4 meters of reddish-brown, slightly massive, calcareous shale and carbonate mudstone interbedded with quartz siltstones and sandstones. He also noted occasional beds of pebbly conglomerate up to 3/10 meter thick. Pebbles are subrounded limestone clasts in the Rancho de Lopez area.

In this study area, the Abo Formation is 187 meters thick. It is approximately 67 percent sandstones and siltstones, and 33 percent mudstones and shales. Lithology remains fairly constant throughout the field area. Dark reddish-brown siltstones dominate the clastic intervals

(Figure 22). Near the top of the Abo, there is a thick (20.3 m.) light brown sandstone containing very fine to fine quartz sand. The sand is moderately sorted; subrounded; and exhibits small-scale planar crossbedding. Mudstones are also dark, reddish-brown. Most are silty and similar to the siltstones mentioned above. Some mudstone and siltstone intervals contain white spots on weathered surfaces. Many of these spots are circular. Rejas (1965) and others have referred to these patches as "reduction spots". These spots are not uniformly distributed and a wide variety of sizes is present (Figure 23).

The Abo Formation does not contain limestones or marine fossils, but burrows are present (Figure 24). Leaf casts were found in collections made for this study (Figure 25). Besides plant remains, numerous mud cracks (Figure 26), ripple marks (both wave and current), and low angle planar crossbedding are observed. At the Chupadera Mine (4 km. west), tracks of reptiles have been recovered (Rejas, 1965). These tracks are found in association with plant remains preserved as casts. Numerous fluvial channels (Figure 27) can be observed in the Rancho de Lopez area. A brecciated unit was also observed (Figure 28).

In the Rancho de Lopez area, the lower contact with the Bursum Formation is gradational, but at other localities, around the state, this lower contact suggests an unconformity. Abo rests on beds spanning a broad range of

Figure 22 Dark, red siltstones characteristic of the Abo Formation. Vertical relief is 30 meters. Looking northward; section 32, T. 2 S., R. 2 E.

Figure 23A "Reduction spots" in the Abo Formation. Spot on right side of photo is 4 cm. in diameter. Section 30, T. 2 S., R 2 E.

Figure 23B Similar Abo "reduction spots" showing circular nature of many spots. Largest spot on photo is 2.5 cm. in diameter. Section 30., T. 2 S., R. 2 E.

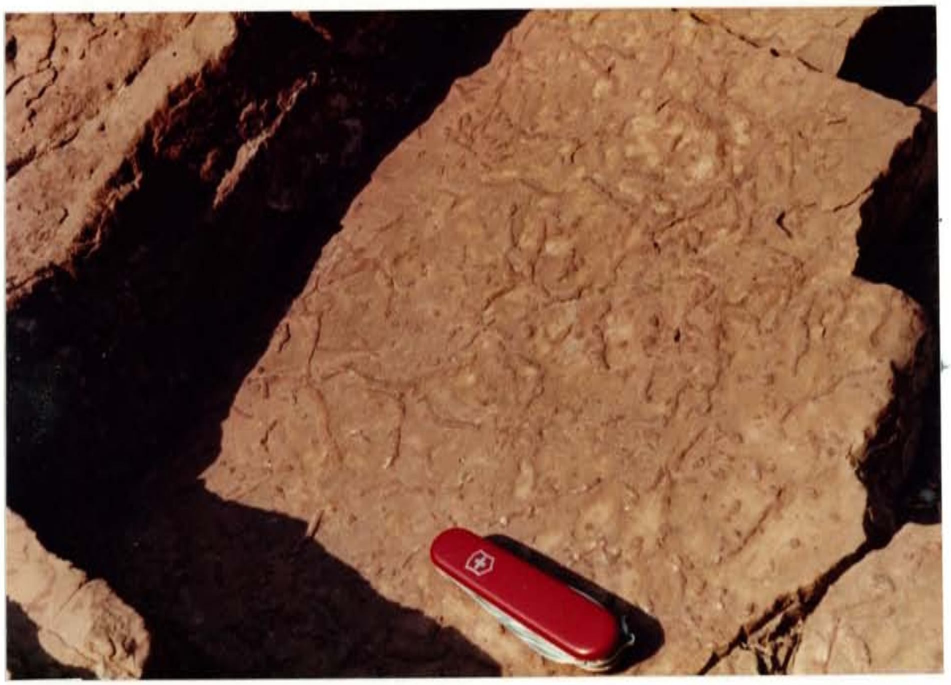


Figure 24 Burrows noted on Abo bedding surface. Section 4, T. 2 S., R. 2 E. Photo by D. B. Johnson

Figure 25A Conifer(?) casts found on Abo bedding surface. Section 30, T. 2 S., R. 2 E.

Figure 25B Abo conifer imprints. Same location as above.

Figure 26A Mud cracks preserved on Abo bedding surfaces. Section 4, T. 2 S., R. 2 E. Keys are 5 cm. in length.

Figure 26B Abo mud cracks. Section 30, T. 2 S., R. 2 E. Same scale as above.

Figure 27A Lenticular, Abo channel. Channel height is 3.6 meters. Looking westward; section 32, T. 2 S., R. 2 E.

Figure 27B Closeup of Abo channel showing lenticular shape. Vertical scale and location same as above.

Figure 28 Abo Formation breccia. Section 5, T. 2 S., R. 2 E. Clasts are actual size.

geologic time throughout New Mexico.

The Abo-Yeso contact is also gradational (Rancho de Lopez). The transition from reddish-brown Abo siltstones and mudstones to buff-colored siltstones and sandstones is taken as the upper contact. At some localities, Abo-Yeso contact is placed at the first siltstone below a thin bedded mudstone (containing halite casts). In strata studied herein, the mudstone (Figure 29) with halite casts is found much higher in the section. A thin basal limestone separates the Yeso and Abo Formations at the Yeso type locality (16 km. northeast of Socorro, N. M.).

Alternating beds of shales and siltstones produce a topographic expression similar to valley and ridge topography. Vegetative cover on the Abo Formation is sparse; consequently, the distinct red color can be observed for long distances.

Yeso Formation

Rocks designated as Yeso Formation were introduced by Lee in 1909. The name was derived from Mesa del Yeso located 19.2 km. north of Socorro, New Mexico; however, exposures at the mesa are poor. Needham and Bates (1943) remeasured and described the Yeso section 3.2 km. southeast of the mesa. The Yeso Formation can be divided into four members in the Rancho de Lopez area. These members in ascending order are: Meseta Blanca, Torres, Cañas, and

Figure 29 Halite casts found in upper Meseta Blanca mudstone. Section 4, T. 2 S., R. 2 E.

Joyita.

Meseta Blanca Member

The Meseta Blanca Member was named by Wood and Northrop in 1946. This member is composed entirely of buff, reddish-brown, brown, and red siltstones and sandstones. The Meseta Blanca, at the type locality, is characterized by pink, orange, and white sandstones. Erosion usually produces mesas supported by Meseta Blanca Member (Figure 30). These mesas are capped by the lowest limestone unit of the Torres Member.

Quartz grains ranging in size from coarse silt to fine sand are subangular to subrounded and moderately sorted. Several units cemented by calcium carbonate are friable. The majority of the Meseta Blanca is cemented with silica, with subordinate amounts of carbonate cement. Bedding ranges from thin to medium. Sandstones are well-bedded. Planar crossbedding (small-scale) is common. A small channel (1.5 m. long by .6 m. deep) is noted at the top of the member. Total thickness in this field area is 71.1 meters.

The lower contact with the Abo Formation is gradational. Upper contact throughout the field area is sharp. The upper contact in this field area, is mapped between the lowest limestone unit of the Torres Member and the upper sandstone interval of the Meseta Blanca Member.

Figure 30 Mesa supported by flat-lying Meseta Blanca Member of the Yeso Formation. Caprock is the lowest limestone in Torres Member (Yeso Formation). Looking eastward; section 5, T. 2 S., R. 2 E.

Rejas (1965) estimated Meseta Blanca thickness in his area to be 97 meters.

Torres Member

Wilpolt and others (1946) named the Torres Member from a type section found 11.2 km. south of Black Butte, Socorro County. The member is 181.8 meters thick and composed of interbedded orange-red and buff sandstone and siltstone, gray limestone, and gypsum. Rejas reconstructed a thickness of 66.7 meters based on structural cross sections.

In the Rancho de Lopez area, the Torres Member is incomplete due to faulting. An incomplete thickness in section four (east side) is 52.1 meters. On the west side of section four, gypsum is present above the lowest limestone ledge. A fault appears to coincide with this gypsum unit. One stratigraphic section bounded by faults, contains at least four limestone beds interbedded with orange-red sandstones. If this section is not repeated by faulting, the multiple limestone beds seem to indicate cyclic sedimentation.

Cañas Member

Needham and Bates (1943) named the middle evaporites of the Yeso Formation. The Cañas Member is 29.1 meters thick at its type section, but is quite variable in thickness elsewhere; ranging from 34.8 meters in the south part of New Mexico, to 24.2 meters in the northern part.

Twenty-nine kilometers north of Socorro, the Cañas Member is not present in a fully exposed Yeso Formation section.

In the Rancho de Lopez area, 29.3 meters of gypsum is measured. This gypsum is light gray on weathered and fresh surfaces. Bedding is massive. Several very thin bedded, brown siltstones are found interbedded with Cañas gypsum. Rejas (1965) estimated 12.1 meters of Cañas gypsum from his cross sections.

Joyita Member

La Joyita Hills contain 48.5 meters of pink, orange, and yellow thin bedded sandstone (Needham and Bates, 1943). In the Rancho de Lopez area, Joyita Member is approximately 18 meters thick. At most exposures, the Joyita is missing due to faulting. The lower 12.1 meters is a gypsiferous, pale red, siltstone. Pale red to red sandstone comprises the upper unit. This sandstone is poorly indurated, poorly sorted, and subrounded quartz grains are dominant. In this study area, the upper contact with the Glorieta Sandstone is distinct.

Glorieta Sandstone

Keyes (1915) was the first geologist to use the name Glorieta (Needham and Bates, 1943). From 1944 to the late 1950's, the sandstone was considered to be the lower member of the San Andres Formation by the United States Geological Survey. The United States Geological Survey adopted

Glorieta Sandstone as a formation in 1957 (Borton, 1972). Keyes did not designate a type section. Needham and Bates designated the type section at Glorieta Mesa (1.6 km. west of Rowe, New Mexico, San Miguel County). In this study area, the Glorieta Sandstone attains a thickness of 41.2 meters (Figure 31). West of Rancho de Lopez area, Rejas (1965) measured an incomplete thickness of 33.3 meters. Essentially, the same lithology is described by Rejas.

In this study area, the Glorieta is pale red, yellowish-brown, or white quartz sandstone. The quartz is subrounded, and poorly to well-sorted. Thin to medium bedding prevails. In the Rancho de Lopez area, the Glorieta weathers into alternating rounded and vertical-faced ledges. Sandstones producing rounded ledges are not as well-indurated and seem to contain more calcareous cement. Several units exhibit small-scale, planar crossbedding. Five intervals can be classified quartz arenites. Quartz grains are fine sand-size, well-rounded, well-sorted, well-indurated, and are bonded together with siliceous cement. It is these quartz arenites that produce the prominent, vertical-faced ledges.

The lower contact with the Yeso Formation (Rancho de Lopez area) is sharp (Figure 32). This lower contact is mapped at the first buff-colored sandstone. This buff-colored sandstone is better indurated and more mature than the underlying Joyita Member. The upper Joyita is

Figure 31 Westward view of Torres, Cañas, Joyita Members of Yeso Formation and Glorieta Sandstone and San Andres Formation. Section 3 and 4, T. 2 S., R. 2 E. Vertical height is 100 meters.

Figure 32 Westward view of contact between Permian Yeso Formation, Glorieta Sandstone, and San Andres Formation. Section 4, T. 2 S., R. 2 E. Vertical height of outcrop is 67 meters.

friable and pale red. The upper contact with San Andres Formation in this study area, is sharp. The upper contact is placed at the base of the first San Andres limestone ledge. Glorieta Sandstone is placed in the Leonardian Series by Dunbar (1960).

San Andres Formation

Lee named the San Andres Limestone in 1909. This name was derived from the San Andres Mountains in southern Socorro County (Needham and Bates, 1943). Total thickness of the San Andres Formation at the type locality is 179.8 meters. In the northern part of the state, the San Andres is thin and outcrops are discontinuous. Moving south and east, San Andres thickens and crops out over 5,000 square miles.

On paleontological grounds, the San Andres Formation is correlated with the Bone Springs Limestone in the Delaware Basin (Lang, 1937). San Andres is considered to be Upper Leonardian in age (Adams, 1939 and Dunbar, 1960). The San Andres Limestone, in the Rancho de Lopez area is incomplete due to erosion. Partial thickness measured is 21.7 meters.

The main lithotypes are calcareous mudstones, wackestones, and packstones. One sandstone unit (6.2 m.) is interbedded with limestone. This sandstone is a buff-colored quartz arenite. Quartz grains are fine sand-sized, well-sorted and rounded. Silica cement is dominant. A striking similarity is recognized between this sandstone and highly resistant sandstone within the Glorieta Sandstone.

Quaternary System

Rocks younger than San Andres Formation are not present in the Rancho de Lopez area due to erosion or nondepositon. The only strata younger than Leonardian Age are represented by recent alluvial deposits. This alluvium is composed of unconsolidated gravels, pebbles, cobbles, and sand derived from Pennsylvanian and Permian strata in the area. Several of the largest accumulations are shown on the geologic map (Plate 1). Thin veneers of alluvium blanket many flat, low-lying areas. These are not all shown on the geologic map.

STRUCTURAL GEOLOGY

Folding

Folded strata due to compressional forces, are not abundant in the Rancho de Lopez area. Gentle folding, probably predates faulting, as shown by the faulted, west side of the syncline in the center of Section 32, T. 2 S., R. 2 E. No evidence of drag folding along the faulted west side of the syncline was found. Dip measured on flanks of these and other folds is less than twenty-five degrees.

Rejas (1965) mapped an intensely folded area with fold axes trending NW-SE in the center of SE/4, section 6, T. 2 S., R. 2 E. Some his folds are overturned with axial planes dipping 45 to 70 degrees to the west. This type of tight folding can also be observed in the area to the south and west mapped by Bauch. Tightly folded strata are not present in the Rancho de Lopez area.

Conclusions on Field Area Folding

On the basis of stratigraphic evidence available within this area of study, the deformation can be dated only as post-Permian. The major faults in this field area, may have been localized in the weakened limbs of the folds.

Faulting

The Rancho de Lopez study area is dissected by numerous faults. Stratigraphic throw ranges from less than 3.0 meters to 36.4 meters. Two longer north-trending faults can be traced for several kilometers. These major faults generally trend parallel to the direction of the Rio Grande Rift in this area.

A majority of the faults are normal faults with the downthrown side on the west. Dipping beds produced by fault "drag" are common (Figure 33).

Numerous smaller faults intersect major faults at random orientations. A relationship between the large and small fault trends is not recognized. In one area (center of NE/4, section 29, T. 2 S., R. 2 E.) of closely spaced, short "faults", there is a distinct possibility that movement of these small blocks resulted from slumping. An

Figure 33A Fault produced bed "drag" between the Pennsylvanian Moya Formation and Permian Abo Formation. Looking eastward; section 34, T. 2 S., R. 2 E.

Figure 33B Similar "drag" produced by normal faulting. Looking northward; section 29, T. 2 S., R. 2 E.

interesting pair of "faults" (N/2, NE 1/4, section 4, T. 2 S., R. 2 E.) which seem to curve around in an arcuate shape, may have been a result of low angle reverse faulting or gravity gliding. This structural discontinuity is coincident with a thick unit of gypsum in the Yeso Formation (Torres Member).

Most if not all arroyos in this field area, owe their position to faults. Tracing many of the faults for several kilometers was made possible by the striking lithologic differences between Permian rocks (usually on downthrown side) and Pennsylvanian strata (upthrown side). A "hinge" fault (near junction of Sections 20, 21, 28, and 29, T. 2 S., R. 2 E.) can be traced from the area of maximum throw, to the site of negligable offset.

Conclusions on Faulting Based on Field Data

Rejas (1965) defined three fault systems in his adjacent field area. The major faults between Pennsylvanian and Permian rocks probably correspond to his fault system number two (high angle, normal faults trending north-south).

These faults, which were produced by extensional tectonics, are probably a result of Rio Grande Rifting (Late Tertiary). If this is true, then the greatest principal stress would have been oriented east-west; intermediate principal stress was north-south; and the least principal stress was vertical. It is possible that much of the major faulting is initiated during the Laramide Orogeny (Cretaceous to early Tertiary).

Structural Events During Pennsylvanian Time

Positive and negative elements active in pre-Pennsylvanian time (Figure 34) were modified during the Pennsylvanian (Armstrong and others, 1979). The regional depositional surface in Early Pennsylvanian time was tilted down to the south and general northward thinning resulted from the overlap of that surface by Pennsylvanian rocks (Armstrong and others, 1979). Most geologists agree that the Pedernal Uplift was initiated in Pennsylvanian time. This uplift probably remained as a positive area until Middle Permian time. Judging from east-west sections measured in the Rancho de Lopez area, the Pedernal Landmass probably contributed most of the clastic material found in this area. Clastic material in measured sections decreases from east to west.

ECONOMIC GEOLOGY

Several small prospects are located along the eastern border of this study area. Apparently, these claims were filed with the intent of mining red bed copper deposits associated with Permian (Bursum) and Pennsylvanian (Moya) strata. These prospects contain subeconomic deposits at this time (1981).

Two samples from the Burrego Formation were tested to determine if organic material is present. Thin sections appear to contain intergranular bitumens. Using a mull technique (Conley, 1972) on an infrared, grating spectrometer, the presence of aliphatic (straight-chain) and

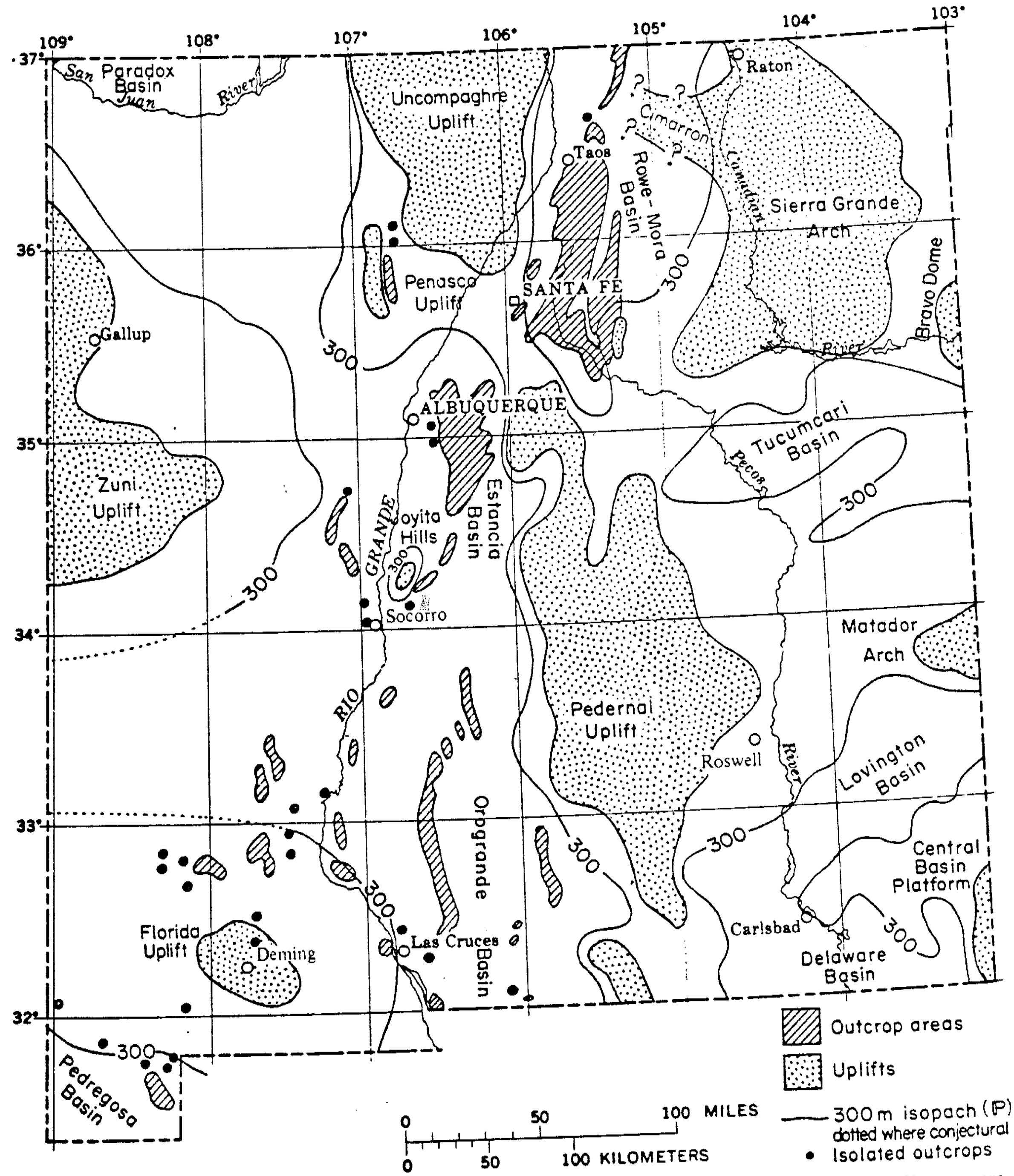


FIGURE 34—Map of New Mexico showing areas where Mississippian and Pennsylvanian rocks (1) crop out, (2) are more than 300 m thick, and (3) are absent. Positive areas are labeled. Armstrong 1979

aromatic (ring-structure) hydrocarbons was confirmed in one of the samples.

A substantial amount of insoluble residue remained from the samples tested above. The residue was powdered, and passed through a 200-mesh sieve. A smear mount of this powder was made. X-ray diffraction was then performed on both samples. Fluorite is the dominant mineralogy detected by X R D.

Bituminous material in Upper Pennsylvanian wackestones from this study area suggest that organic material was present. It is difficult to determine whether this bituminous material is residual hydrocarbons (a source rock?), or remains of hydrocarbons which migrated out of the Rancho de Lopez area. Environmental and diagenetic conditions may have been similar for the Pennsylvanian strata located in the southern part of New Mexico (subsurface). Further geochemical testing is needed to substantiate this.

DEPOSITIONAL HISTORY

During Burrego deposition, an uplifted source area (Pedernal?) to the east was providing abundant silt-laden muds and fine grained clastics. Evidence for the transport direction of Burrego clastics comes from paleocurrent analysis by Siemers (1978). His data was obtained 5 kilometers west of the Rancho de Lopez area. Paucity of marine fossils associated with this mud (now shale) suggests a marginal marine origin. Discovery and identification of Calamites sp. further supports this origin. Fine grained clastics are predominantly feldspathic arenites. Due to lack of continuity of outcrops, it is difficult to determine, with reasonable accuracy, the geometry of these sand bodies. It is quite possible that the arenites were part of a fluvial-dominated delta front sequence. The data obtained from a field area limited to ten square miles suggests a possible deltaic environment.

Thick, uniform sequences of shale, mudstone, and siltstone were probably deposited out of suspension at the base of the delta front. Paucity of marine fauna could be explained by continuous fallout of sediment from suspension, or freshwater influence disrupting water salinity. Plant debris is common in this lower facies. Carbonaceous material from plants is present in the lower Burrego carbonate mudstones and siltstones.

Several siltstone units exhibit distorted bedding (Figure 10). This structure could be a product of tectonics, loading, or a thin (20 cm.), fine-grained turbidite.

Due to lack of distortion of the contact with similar fine grained sediments below, tectonic deformation is not likely. Soft sediment deformation produced by loading does not seem reasonable. This is usually observed between sediments of two different size distributions (muds and fine grained clastics). Grain size is equivalent between deformed and undeformed intervals. Therefore, field evidence suggests this distorted bedding may be the product of a turbidity current.

The medium grained, lenticular sandstone unit noted from measured section 1 probably represents the distributary channel of a delta lobe. Channel lag (pebbles and gravels) can be observed at the base of this sandstone unit (Figure 8) Similar depositional sequences are described by Reading (1978).

Carbonate mudstones and wackestones (bearing marine fossils) in the Burrego suggest clastic influx decreased at various times. With the clastic supply temporarily interrupted, a marine transgression proceeded over the clastic interval. Most fossils are abraded indicating periods of more turbulent sea water movement.

Two sites where mud supported sediments accuvmulate are: below marine-wave base; and behind a shelf margin where wave action is subdued.

If these carbonate mudstones and wackestones mentioned above were deposited below wave base, abraded fossils throughout the section would be unlikely. This could be possible if burrowing organisms throughly mixed the mud.

The vertical succession should yield packstones and grainstones if these mud supported rocks formed below wave base. Grain supported rocks are not observed in the vertical succession. Deposition above wave base is favored. Storm waves may have washed the abraded fossils back into the lagoonal area. Lack of bedding here could be caused by bioturbation.

Thinning of clastic units from east to west may indicate increasing distance from clastic sources to the east and northeast (Pedernal landmass?). Further work east of this study area is needed to test this hypothesis.

Renewed uplift and subsequent erosion at the end of Burrego time, produced the grayish-red arkose and silty shale of the lower Story Formation.

After the lower unit of the Story Formation was deposited, clastic input was interrupted. A marine transgression again proceeded over the clastic interval. As a result of this proposed, northward transgression (Thompson, 1942), the thick carbonate mudstone unit of the Story Formation was produced. Localized occurrences of phylloid algae suggest deposition within the photic zone. The widespread occurrence and uniform thickness of this carbonate mudstone seems to indicate deposition occurred behind the shelf margin. This depositional surface was probably relatively flat and covered by a shallow sea. The shallow nature of this sea would allow open marine muds to accumulate without generation of much wave or tidal energy.

Massive nature of bedding suggests constant, uniform carbonate mud deposition.

Carbonate deposition continued to be the dominant process during accumulation of the Del Cuerto Formation. Interruptions of this deposition may be responsible for the thin to medium bedding present in the Del Cuerto. Paucity of fauna provides little insight into marine water conditions. Lack of preservation or restricted marine water conditions could account for this paucity of fauna. A minor amount of sand (fine sand) was introduced into a middle carbonate mudstone unit suggesting a brief influx of terrigenous clastics. Sand grains do not appear to be mature enough to have a near-shore, beach or dune origin.

When a source of clastics was reduced carbonate accumulation was once again favored. The result is the lower unit of the Moya Formation. Faunal diversity and abundance suggests normal marine conditions. Common occurrence of phylloid algae implies shallow, sea water in the range of the photic zone. Quiet water conditions must have prevailed for the calcareous mud to accumulate.

Upper Moya lithology indicates marine conditions similar to lower Moya precipitation were repeated. Diversity and abundance of fauna in the upper Moya appear to be greater than in the lower Moya Formation. This may be due to methods of sampling. This carbonate precipitation (upper Moya) marked the last significant carbonate accumulation until the Permian Yeso Formation was deposited.

Deposition of Bursum Formation was dominated by fluvial processes. This is suggested by subordinate amounts of limestone present. A thin bedded carbonate mudstone interval indicates an interruption of clastics for a short period of time. Evidence for a depositional hiatus between the underlying Moya Formation and the Bursum is found at the base of the Bursum Formation throughout this study area. These pebbles appear to be lithologically equivalent to the underlying Moya Formation. Renewed or more intense uplift of an igneous or metamorphic source provided the quartz and feldspar pebbles composing the bulk of the Bursum Formation. This igneous or metamorphic source was probably a different source than the area providing the majority of the Pennsylvanian clastics (silts and fine sand-sized quartz). The upper arkosic beds do not contain carbonates. This was probably the beginning of fluviatile, depositional dominance. This dominance lasted until the end of Abo Formation sedimentation.

Numerous lines of evidence point to fluvial deposition of the Abo Formation (See figures 26-28). The depositional environments suggested by fine grained clastics, mudcracks, current ripple marks, and plant fragments could be an alluvial fan (temperate to semi-arid climate), fluvial overbank, or deltaic. If indeed the Abo is part of an alluvial fan, the presence of conifers (Figure 26) indicates a temperate to semi-arid environment.

Judging from the thickness of the Abo (187 meters), a continuous clastic influx of long duration must have been supplied. Increasing thickness further north suggests a northerly clastic source area.

The presence of wave ripple marks, salt casts, low angle crossbedding, and mature sand sized quartz, within the Meseta Blanca Member (Yeso Formation), suggests a near shore depositional environment. Superimposed wave ripple marks indicate a bimodal direction (tidal flat?) of wave energy.

Salt casts and mud cracks in silty mudstone intervals suggest the sea was shallow. Some type of barrier must have been present to restrict circulation of sea water. Low angle cross-stratified, mature, quartz sandstone suggests a barrier beach. These barrier beaches or possibly the shallowness of the sea provided the elevated salinities necessary for halite crystal growth.

Environmental conditions during Torres Member deposition favored sulfate accumulation and preservation. Lithology and vertical succession of strata suggest a coastal sabkha was present in this area. Cyclic sedimentation is indicated by the repeated sequences of interlaminated gypsum and carbonate mudstone. It is possible, that the mudstone unit below each gypsum interval represents a tidal flat accumulation. The only observed fauna was a thin bedded pelecypod packstone. The pelecypod shells exhibit a bimodal size distribution. All valves are disarticulated and abraded, suggesting transportation after death. The low diversity and high numbers of individuals in the fauna, associated with the evaporite sequence, confirms a restricted environment. Due to the limited exposure of the Joyita sandstone, one can only speculate that the sands may represent the eolian interval which usually caps a sabkha sequence.

The mature nature of the Glorieta Sandstone implies a near shore or beach environment. Due to the limited analysis of the formation by this writer, a well written and documented circular published by the New Mexico Bureau of Mines and Mineral resources is recommended (Milner, 1978).

A marine transgression was probably occurring throughout San Andres Formation deposition. It was only during times of clastic supply interruption that thick limestone units could accumulate. Brachiopods are the only fauna visible at the outcrop. Carbonate mudstone, indicating quiet, water deposition, is the dominant lithotype. Sandstone interbedded with this carbonate mudstone is similar to Glorieta Sandstone. These sandstone intervals are composed of well rounded, well sorted, low angle cross-stratified quartz sand. The mature nature of this sandstone implies a beach sand origin.

Permian strata younger than the San Andres Formation is not present in this study area. These younger, Permian rocks are located farther north and south.

REFERENCES

Adams, J. E., and others, 1939, "Standard Permian of North America": A. A. P. G. Bull., Vol. 23, Bull. 11, p. 1677

Armstrong, A. K., and others, 1979, "The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States--New Mexico": U. S. Geol. Surv. Prof. Paper, No. 1110-W, 27 p.

Bauch, J., 1981, personal communication

Borton, R. L., 1972, "Structure of Glorieta Sandstone in Northwest Chaves County New Mexico": New Mexico State Bureau of Mines and Mineral Resources, Cir. 122, 25 p.

Conley, R. T., 1972, Infrared Spectroscopy, 2nd ed., Boston: Allyn and Bacon, Inc., p. 48-50

Dunbar, C. O., and others, 1960, "Correlation of the Permian formations of North America": Geol. Soc. Am. Bull., Vol. 71, No. 12, part 1, p. 1776

Dunham, R. J., 1962, "Classification of carbonate rocks according to depositional texture", in Ham, W. E., editor, Classification of carbonate rocks: A. A. P. G., Mem. 1, p. 108-121

Kottlowski, F. E., 1960, "Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona": New Mexico State Bureau of Mines and Mineral Resources Bull., No. 66, 187 p.

Lang, W. T. B., 1937, "The Permian Formations of the Pecos Valley of New Mexico and Texas": A. A. P. G. Bull., Vol. 21, No. 7, p. 833-898

Lee, W. T., and Girty, G. H., 1909, "The Manzano Group of the Rio Grande Valley, New Mexico": U. S. Geol. Surv. Bull., No. 389, 141 pages

Milner, S., 1978, "Genesis, provenance, and petrography of the Glorieta Sandstone of eastern New Mexico": New Mexico State Bureau of Mines and Mineral Resources, Cir. 165, 25 p.

McKee, E. D., and Weir, G. W., 1953, "Terminology for stratification and cross stratification in sedimentary rocks": Geol. Soc. Am. Bull., Vol. 64, p. 381-390

Myers, D. A., 1981, personal communication

Needham, C. E., and Bates, R. L., 1943, "Permian type section in central New Mexico": Geol. Soc. Am. Bull., Vol. 54, p. 1653-1668

Pettijohn, F. J., Potter, P. E., Siever, R., 1972, Sand and Sandstones, Heidelberg: Springer-Verlag, 618 p.

Reading, W. G., 1978, Sedimentary Environments and Facies, New York: Elsevier, 557p.

Rejas, A., 1965, "Geology of the Cerros de Amado Area, Socorro County, New Mexico", New Mexico Institute of Mining and Technology, 128 p.

Siemers, W. T. 1978, "Pennsylvanian System of the Socorro Region; West-Central New Mexico", New Mexico Institute of Mining and Technology, Ph. D. dissertation , 259 p.

Thompson, M. L., 1942, "Pennsylvanian System in New Mexico", New Mexico State Bureau of Mines and Mineral Resources, Bull. 17, 92 p.

______________, 1964, "Fusilinacea", in Moore, R. C., editor, Geol. Soc. Am. Treatise on invertebrate paleontology, Part C, Vol. 1, p. C358-C436

Wilpolt, R. H., MacAlpin, A. J., Bates, R. L., and Vorbe, G., 1946, "Geologic map and stratigraphic sections of Paleozoic rocks of Joyita Hills, Los Piños Mountains, and northern Chupadera Mesa, Valencia, Torrance, and Socorro Counties, New Mexico": U. S. Geol. Surv. Oil and Gas Prelim. Inv. Map No. 61 (2 sheets)

Wilpolt, R. H., and Wanek, A. A., 1951, "Geology of the region from Socorro and San Antonio east to Chupadera Mesa, Socorro County, New Mexico": U. S. Geol. Surv. Oil and Gas Prelim. Inv. Map No. 121

Wood, G. H., and Northrop, W. A., 1946, "Geology of the Nacimiento Mountains, and adjacent plateaus, in parts of Sandoval and Rio Arriba Counties, New Mexico": U. S. Geol. Surv. Oil and Gas Inv. Prelim. Map No. 57

APPENDIX A through APPENDIX D

EXPLANATION: (w)-- color of rock on a weathered surface

(f)-- color of rock on a fresh surface

Grain size scale from Wentworth (Pettijohn et al., page 72, 1972)

Colors used to describe strata are from the Munsell Color chart.

Pelmatozoans are sessile echinoderms (blastoids, crinoids, cystoids).

APPENDIX A

Pennsylvanian Measured Section One (West)

W/2, W/2, W/2, Section 29

UNIT	THICKNESS (METERS)	DESCRIPTION
Top of upper unit-- Moya Formation		
27.	10.9	LIMESTONE--mudstone; medium light gray (w); medium gray (f); lower one meter contains gray "mottled" patches of wackestone; slight break in slope taken arbitrarily as contact between upper and lower Moya Formation; disarticulated pelmatozoans common; phylloid algae common
Top of lower unit		
26.	15.	LIMESTONE--mudstone; medium light gray (w); gray (f); phylloid algae common; disarticulated pelmatozoans and small brachiopods abundant; lower contact gradational, upper contact sharp; chert nodules in lower one-third meter.
25.	.9	LIMESTONE--mudstone; light gray (w) ; gray (f); lower one meter conains nodular chert; top and bottom contacts covered; medium to thick bedding; pelmatozoans abundant; phylloid algae common.
Top of Del Cuerto Formation		
24.	1.4	Covered
23.	1.8	LIMESTONE--mudstone; light gray (w); dark gray (f); large chert nodules dissimenated; medium to thick bedding; top and bottom contacts covered; sl'

UNIT	THICKNESS (METERS)	DESCRIPTION
22.	.9	LIMESTONE-- packstone; sandy (fine sand); disarticulated pelmatozoans; all fossils less than one cm.; recrystallized carbonate; light gray (w); dark gray (f); trace of chert; medium bedded.
21.	1.4	LIMESTONE--mudstone; light yellowish-gray (w); gray (f); top of unit covered; thin to medium bedding.
20.	4.5	Covered
19.	.9	LIMESTONE--mudstone; light gray (w); dark gray (f); thin to medium bedding; weathers back under overlying Moya.
Top of upper unit-- Story Formation		
18.	6.8	LIMESTONE--mudstone; light brownish-gray (w); light gray (f); massive bedded; cliff former; articulated pelmatozoans stalks abundant; phylloid algae common.
Top of lower unit		
17.	9.6	SILTSTONE--grayish-red (w) and (f); thin bedded; micaceous; planar bedding surfaces; upper six meters covered.
Top of Burrego Formation		
16.	2.7	LIMESTONE--mudstone; brownish-gray (w) dark gray (f); poorly bedded; thin to thick bedding; numerous fractures; upper contact sharp; silty; abraded pelmatozoans; ridge-former.
15.	11.6	Covered

UNIT	THICKNESS (METERS)	DESCRIPTION
14.	.73	MUDSTONE--terrigenous; dark grayish-brown (w) light gray (f); silty; distorted bedding; medium to thick bedding; upper contact covered; planar crossbedding (small-scale); slight ridge former.
13.	2.5	SHALE--fissile; olive-brown (w) and (f); some laminated siltstones interbedded.
12.	1.8	SANDSTONE--dark grayish-brown (w); light gray (f); micaceous; silt to very fine sand; medium to thick bedding; distorted bedding; some shale interbedded.
11.	1.8	SHALES--interbedded with terrigenous mudstones; grayish-brown (w); light gray (f); abundant mica; wavy laminae; contains more silt at the top.
10.	.45	LIMESTONE--mudstone; olive brown (w); light gray (f); silty; thin bedded.
9.	19.5	SHALE--interbedded with limonite-stained, calcareous mudstone; shale is gray on (w) and (f); silty near top.
8.	3.6	SANDSTONE--moderate brown (w); light gray (f); well indurated; planar crossbedding; medium sand-sized quartz; moderately sorted; subrounded; lenticular sand body; basal limestone cobble conglomerate; pelmatozoans rare; ridge former.
7.	16.	SHALE--fissile; moderate yellow-gray (w) and (f).

UNIT	THICKNESS (METERS)	DESCRIPTION
6.	.45	LIMESTONE--olive brown (w); light yellow-gray (f); upper and lower contacts sharp; slightly fossiliferous (marine) mudstone; thin to medium bedded; very fine sand-size quartz, subangular, poorly sorted.
5.	.91	SHALE--moderate yellowish-gray (w and f); fissile.
4.	1.4	LIMESTONE--packstone; moderate yellowish-brown (w); medium dark brown (f); abraded pelmatozoan and brachiopod debris; thick bedded; slight ridge former; both contacts sharp.
3.	8.6	SHALE--olive brown (w and f); fissile; upper contact sharp.
2.	.9	LIMESTONE--mudstone; olive brown (w); dark gray (f); micaceous; silty; thin bedded.
1.	6.8	SHALE--fissile; moderate yellowish-gray (w and f).

APPENDIX B

Pennsylvanian Measured Section Two (East)

SE, NW, Section 21

UNIT	THICKNESS (METERS)	DESCRIPTION
Top of lower unit -- Moya Formation		
30.	10.6	LIMESTONE--wackestone; light gray (w); medium gray (f); medium to thick bedding; tabular beds; disarticulated crinoids common; phylloid algae common; bryozoans rare; nodular chert in the lower 1.75 meters.
Top of Del Cuerto Formation		
29.	6.1	LIMESTONE--wackestone; light gray (w); medium gray (f); wavy bedding; upper one meter is a thin bedded pelecypod packstone; brachiopods and pelmatozoans are common.
Top of upper unit - Story Formation		
28.	6.4	LIMESTONE--wackestone; light yellowish-brown (w); medium gray (f); massive bedded; corals (rugose) common; bryozoans and pelmatozoans abundant; phylloid algae rare; upper contact covered;
Top of lower unit - Story Formation		
27.	13.2	ARKOSE--grayish-red (w and f); thin bedded ; micaceous; planar bedding surfaces; fine sand-sized quartz; upper two thirds is covered.
Top of Burrego Formation		
26.	12.2	ARKOSE--pale yellowish-brown (w); light pale yellowish-brown (f); thick bedding; lower contact sharp; poorly indurated on weathered surface; coarse silt-sized quartz; subangular, well sorted; trace of biotite and chlorite; porous.

UNIT	THICKNESS (METERS)	DESCRIPTION
25.	2.3	LIMESTONE--wackestone; medium light gray (w); medium gray (f); weathers to a nodular texture; abraded fossil debris; wavy bedding; medium bedding; brachiopods and pelmatozoans common; gastropods, pelecypods, and corals rare.
24.	2.3	SHALES, SILTSTONES, & CLAY--very light gray (w and f); top contact sharp.
23.	1.0	SANDSTONE--pale yellowish-brown (w); medium dark gray (f); fine sand sized quartz, moderately sorted; thin to medium bedded; symmetric ripple marks; small-scale planar crossbedding; upper contact covered lower contact sharp.
22.	8.2	SHALES--light gray (w and f); interbedded with carbonate mudstones and silty mudstones.
21.	.4	LIMESTONE--mudstone; dark yellowish-orange (w); medium dark gray (f); gastropods abundant; brachiopods and pelecypods rare; thick bedded; trace of fine sand-sized, subangular quartz.
20.	3.0	LIMESTONE--wackestone; light brownish-gray (w); medium gray (f); fossils weather dark gray; pelecypods common; gastropods rare; lower meter is is medium bedded; upper 40 cm. is fissile shale.
19.	10.9	SANDSTONE--pale yellowish-brown (w & f); micaceous; fine to medium sand-size quartz, subangular, poorly sorted; planar crossbedding (small-scale); thin to thick bedding; mudstone laminae near top of unit.
18.	8.5	SANDSTONE--light brownish-gray (w and f); fine sand, moderately sorted; micaceous; limonite specks on fresh surface; tabular beds; very thin bedded at the top of unit; medium bedded at bottom; FeO staining on (w); some distorted bedding at top of unit.

UNIT	THICKNESS (METERS)	DESCRIPTION
17.	2.4	SANDSTONE--light brownish-gray (w and f); micaceous; interbedded with fissile shale; medium bedded; carbonaceous material present; weathered surface contains hematite-limonite spots; brachiopods are rare; angular to subangular, coarse silt to fine sand-sized quartz, poorly sorted.
16.	14.3	SILTSTONES & SHALES--light olive gray (w); light gray (f); siltstones are thin bedded; shales are fissile.
15.	1.8	LIMESTONE--packstone; moderate yellow-brown (w); medium yellowish-gray (f); brachiopods, and pelmatozoans abundant, bryozoans, fusilinids, and rugose corals rare; medium to thick bedding; tabular beds; trace of coarse silt; most brachiopods are still articulated.
14.	12.5	SHALES & SILTSTONES--interbedded; light olive-gray (w and f); siltstones in lower two meters; shale becomes dark gray near the top.
13.	2.4	SANDSTONE--light olive-gray (w and f); micaceous; medium to thick bedded; some laminated siltstones interbedded; fine sand-size quartz, well sorted, subrounded.
12.	5.5	SHALES--light olive-gray (w); light gray (f); micaceous; interbedded with micaceous siltstones (light olive gray on (w) and (f)); siltstone in lower two meters.
11.	2.0	ARKOSE--olive-gray (w); gray (f); slightly crossbedded (planar); lower one meter is limestone pebble conglomerate; quartz and feldspar up to .5 cm. long; pebbles are gray and limonite stained; wavy bedding planes.

UNIT	THICKNESS (METERS)	DESCRIPTION
10.	2.6	SHALE--light gray; fissile.
9.	.55	ARKOSE--pale yellowish-brown (w and f); thick bedded; basal 8 cm. contains limestone cobble conglomerate; tabular bedding; graded bedding; subrounded, poorly sorted, medium to coarse quartz sand.
8.	8.2	SHALES & SILTSTONES--interbedded; light olive gray (w); greenish-gray (siltstones, w and f); micaceous; thin to medium bedded.
7.	.45	SHALE--light gray (w); medium gray (f); nodular carbonate mudstone interbedded; medium bedded.
6.	.48	LIMESTONE--wackestone; light yellowish-orange (w); olive gray (f); rugose corals, pelecypods, and brachiopods are common; thick bedded; lower ten cm. is pelecypod-rich packstone.
5.	.42	SHALE--dark gray (w and f); fissile
4.	.66	LIMESTONE--medium dark gray (w); medium gray (f); mudstone; medium bedded.
3.	.27	LIMESTONE--packstone; yellowish-gray (w); medium gray (f); pelmatozoans, brachiopods, rugose corals, and bryozoans are abundant; thin bedded.
2.	.42	LIMESTONE--silty mudstone; limonite stained (w); light gray (f).
1.	1.4	SHALE--light olive gray (w and f); fissile.

Older Pennsylvanian Strata is Faulted Out of this Section

APPENDIX C

Permian Measured Section One

UNIT	THICKNESS (METERS)	DESCRIPTION
Top of Meseta Blanca Member- Yeso Formation		
38.	1.4	SANDSTONE--calcareous cement; medium dark gray (w); dark gray (f); thin bedded; small-scale planar crossbedding; ridge former; fine sand-sized quartz.
37.	2.3	SANDSTONE--light brown to buff (w); white (f); orthoquartzite; medium to thick bedding; slightly wavy bedding.
36.	2.7	SANDSTONE--pale reddish-brown (w and f); fine sand-sized quartz; thin bedded; planar bedding surfaces; noted a 1.5 meter by .6 meter deep fluvial channel at the top of unit.
35.	.94	SILTSTONE--dark reddish-brown (w and f); very thin to medium bedding; planar bedding surfaces.
34.	.96	SANDSTONE--brown (w); light brown (f); fine to medium quartz grains; poorly sorted; subrounded; medium bedded; poorly preserved low angle, planar crossbedding (small-scale).
33.	2.5	SANDSTONE--same as above except thin bedded.
32.	6.7	SILTSTONE--dark reddish-brown (w); reddish-brown (f); thin bedded; planar bedding; upper contact gradational; fine silt.
31.	3.7	SANDSTONE--brown (w); light brown (f); fine to medium quartz grains, poorly sorted; subrounded; medium bedding; poorly preserved low angle, planar crossbedding (small-scale).
30.	1.1	SANDSTONE--lower .7 meter is reddish-brown (w and f); remainder is buff (f); grayish-brown (w); poorly indurated; very fine sand-size quartz; upper .67 meter is well indurated orthoquartzite; thin bedding; planar bedding; top covered.

UNIT	THICKNESS (METERS)	DESCRIPTION
29.	21.8	SILTSTONE--buff (w and f) for lower 8 cm.; dark brownish-red color on remainder; very thin bedded; planar bedding.
28.	10.2	MUDSTONE--silty; laminated; alternating white and red (w and f); planar bedding surfaces; terrigenous mudstone.
27.	16.3	SANDSTONE--alternating white, red, and yellowish-brown (w and f); very fine sand-size quartz; thin bedded, planar bedding surfaces; poorly indurated.
26.	0.66	SANDSTONE--buff (w and f); thin bedded; friable; very fine sand-size quartz, well sorted, subrounded; upper contact covered.
25.	2.9	SANDSTONE--light brown (w and f); very fine sand-size quartz; planar bedding surfaces; thin bedded.
Top of Abo Formation		
24.	3.2	MUDSTONE--terrigenous; calcareous; light gray (w and f); very thin bedded; bottom contact sharp; top contact is gradational; planar bedding surfaces.
23.	20.4	SANDSTONE--light brown (w and f); very fine to fine quartz; moderately sorted, subangular; small-scale planar cross-bedding.
22.	1.8	MUDSTONE--terrigenous; silty; brownish-gray (w); very light gray (f); thin bedded.
21.	2.2	Covered
20.	1.7	MUDSTONE--terrigenous; silty; brownish-gray (w); very light gray (f); medium to thick bedding; abundant dendritic pyrolusite on weathered surfaces.
19.	5.9	Covered
18.	1.4	MUDSTONE--terrigenous; dark brown (w); brown (f); silty; medium bedded; poorly developed planar cross-

UNIT	THICKNESS (METERS)	DESCRIPTION
18. (continued)		bedding; bottom and top of interval is covered;
17.	16.3	MUDSTONE--terrigenous; dark reddish-brown (w); reddish-brown (f); thin bedded; planar bedding surfaces; upper surfaces contain abundant burrows.
16.	29.0	Covered
15.	1.4	SILTSTONE--yellowish-brown (w); light grayish-red (f); thin bedded.
14.	17.7	SILTSTONE--yellowish-brown (w); grayish-red (f); planar bedding surfaces; planar crossbedding (small-scale); thin to medium bedding.
13.	6.1	SILTSTONE--same as above, but with numerous "reduction spots".
12.	3.7	SILTSTONE--same as unit 14; ridge former.
11.	1.7	SILTSTONE--same as unit 14 with very thin bedding.
10.	3.4	SILTSTONE--yellowish-brown (w); grayish-red (f); planar bedding surfaces; small-scale, planar crossbedding; thin to medium bedding.
9.	44.2	SILTSTONE--dark reddish brown (w); reddish-brown (f); very thin to thick bedding.
8.	.94	SILTSTONE--dark reddish brown (w); reddish brown (f); thick bedded; few scattered "reduction spots"; five cm. of limestone pebble conglomerate at the top of the unit.
7.	25.6	SILTSTONE--dark reddish-brown (w); reddish-brown (f); very thin bedded; planar bedding surfaces.

Top of the Bursum Formation

UNIT	THICKNESS (METERS)	DESCRIPTION
6.	2.7	CONGLOMERATE--light grayish-red (w); dark grayish-red (f); hematite staining throughout; calcareous cement; gray limestone pebbles;

UNIT	THICKNESS (METERS)	DESCRIPTION
6. (continued)		pebbles fine upward; limestone ranges from very coarse sand to 7 cm.; thin bedded; top of unit exhibits trough crossbedding; abundant subrounded pink orthoclase.
5.	44.3	QUARTZ PEBBLE CONGLOMERATE--grayish-red (w); dark grayish-red (f); upper contact covered; quartz and orthoclase are coarse sand-sized; carbonate cement; medium bedded; FeO staining throughout; normal graded bedding; some pebbles up to 4 cm. in diameter; poorly developed planar crossbedding; quartz subangular to subrounded and poorly sorted.
4.	1.2	LIMESTONE PEBBLE CONGLOMERATE--very light gray (w); medium gray (f); weathers into piles of limestone pebbles; very poor, wavy bedding; thin bedded; lower contact covered.
3.	.25	LIMESTONE AND QUARTZ PEBBLE CONGLOMERATE--grayish-red matrix; matrix contains fine sand-size quartz; well indurated with carbonate cement; pebbles are light gray (w); medium gray (f); pebbles are poorly rounded and sorted.
2.	.91	QUARTZ PEBBLE CONGLOMERATE--same as unit 5 above.
1.	23.2	LIMESTONE PEBBLE CONGLOMERATE--same as unit 4 above.

Pennsylvanian Moya Formation

APPENDIX D

Permian Measured Section Two

UNIT	THICKNESS (METERS)	DESCRIPTION
Top of San Andres Formation		
33.	incomplete	LIMESTONE--mudstone; light gray (w); medium gray (f); thin to thick bedded; thin bedded units concentrated at base of unit; bottom contact covered; disseminated chert nodules; poorly bedded; brachiopods are common; ridge former; not a full section due to erosion.
32.	6.2	SANDSTONE--buff to light brown (w); white (f); orthoquartzite; fine sand, well sorted and rounded; thin to medium bedded; similar to well indurated orthoquartzite units of Glorieta Sandstone.
31.	5.2	LIMESTONE--packstone; sandy; fine sand; rounded and moderately sorted; disseminated chert nodules; massive bedded; medium dark gray (f); light olive gray (w); pelmatozoans (disarticulated) are common; sharp upper contact; lower contact gradational; cliff former.
30.	9.1	LIMESTONE--mudstone; medium dark gray (f); light olive gray (w); mumerous layers of 1-3 cm. (diameter) brachiopods, many still articulated; medium bedded; silty; scattered chert nodules; smells slightly petroliferous on (f); brachiopod molds are filled with sparry calcite.
29.	1.3	Covered
Top of Glorieta Sandstone		
28.	7.3	SANDSTONE--alternating pale red and light yellow (w and f); quartzite; some beds not well indurated; majority are well indurated; well indurated beds seem to be much cleaner (less clay "matrix"); low angle, planar, cross-

UNIT	THICKNESS (METERS)	DESCRIPTION
28. (continued)		bedded(small-scale) sand; fine sand, well sorted, well rounded; top and bottom contacts are covered; medium bedding.
27.	3.6	SANDSTONE--buff (w and f); poorly indurated; thin bedded; moderately sorted; subrounded; fine sand-size quartz; weathers back.
26.	1.5	SANDSTONE--grayish-pink (w); white (f); orthoquartzite; predominantly siliceous cement; well rounded, sorted; small-scale, planar crossbedding; medium bedded; lower contact gradational; upper contact covered; fine sand-size quartz; slight cliff-former.
25.	7.1	SANDSTONE--pale red (w and f); poorly bedded; thin to medium bedding; lower contact gradational; not well indurated.
24.	24.5	SANDSTONE--buff (w); white (f); lower one meter well indurated orthoquartzite; subrounded, well sorted, fine sand-size quartz; cliff former (flat faced); remaining sandstone is not well indurated; forms rounded cliffs; medium bedded.
23.	7.6	SANDSTONE--yellowish-brown (w); light yellowish-brown (f); thin to medium bedding; poorly bedded; weathers back more than the sand above or below; poorly sorted, subrounded, fine sand; grades upward into buff sandstone with planar crossbedding.
22.	9.8	SANDSTONE--light yellowish-brown (w); white (f); medium to thick bedding; small-scale planar crossbedding; fine sand-sized quartz grains, moderately sorted, subrounded; lower contact gradational; weathers to rounded cliffs; poorly bedded.
21.	1.4	SANDSTONE--same as unit 22 above, except buff on (w).

UNIT	THICKNESS (METERS)	DESCRIPTION
20.	1.9	SANDSTONE--yellowish-brown (w and f); very fine sand; thin bedded; poorly indurated; wavy bedding; upper contact gradational.
19.	.64	SANDSTONE--moderate yellowish-brown (w); white (f); orthoquartzite; fine sand-size quartz, well rounded, sorted, and indurated; thick bedded; weathers to a flat ledge.
18.	1.8	SANDSTONE--yellowish-brown (w and f); very fine sand-size quartz, poorly indurated; poorly bedded; wavy bedding; upper contact gradational; limonite stained patches.
17.	1.6	SANDSTONE--light yellowish-brown (w); yellowish-brown (f); fine sand; well indurated; medium bedded; rounded, well sorted quartz grains; upper contact gradational.
16.	6.5	SANDSTONE--light yellowish-white (w); pinkish-gray (f); thick bedded; not well indurated; very fine sand; subrounded, moderately sorted; both contacts are sharp; calcareous cement; weathers into rounded ledges.
Top of Joyita Member- Yeso Formation		
15.	5.9	SANDSTONE--pale red to red (w and f); poorly indurated; fine sand, poorly sorted, subrounded; lower contact gradational with siltstone; poorly bedded; thin bedding; becomes thick bedded at upper contact.
14.	12.1	SILTSTONE--pale red (w and f); gypsiferous; poorly bedded; thin bedded.
Top of Cañas Member		
13.	29.3	GYPSUM--light gray (w and f); massive bedding; weathers back from units above and below; contains several siltstone laminae interbedded.
Top of Torres Member		
12.	3.9	LIMESTONE--mudstone; light olive-gray (w); medium dark gray (f); smells petroliferous on (f); thin bedded;

UNIT	THICKNESS (METERS)	DESCRIPTION
12. (continued)		well bedded; ridge former; top contact covered.
11.	.25	LIMESTONE--medium dark gray (w); dark gray (f); packstone; abundant pelecypod shells, many articulated, shells exhibit a bimodal size distribution, and are parallel to bedding; medium bedding; upper contact gradational; good marker bed.
10.	1.2	LIMESTONE--mudstone; light gray (w); medium light gray (f); silty; thin bedded; lower contact covered.
9.	3.4	SANDSTONE--light yellowish-brown (w); white with yellow "specks" (f); rounded, well sorted, fine sand; poorly sorted; thin bedded.
8.	10.3	GYPSUM--buff to light gray (w and f); weathers back; massive bedding; upper contact covered.
7.	.53	LIMESTONE--light olive-gray (w); light yellowish-gray (f); mudstone; thin to medium bedding; both contacts covered; slight ridge former.
6.	7.7	GYPSUM--yellowish-brown (w and f); massive bedding; weathers back from the units above and below; both contacts are sharp.
5.	3.2	LIMESTONE--mudstone; light olive-gray (w); medium gray (f); thin to medium bedding; chert filled solution channels near top of unit; smells slightly petroliferous; upper contact covered; ridge former.
4.	5.9	SANDSTONE--yellowish-brown (w and f); fine sand-size quartz, subrounded, moderately sorted, thin bedded; small-scale, planar crossbedding; upper contact covered.
3.	.91	LIMESTONE--light olive gray (w); medium dark gray (f); mudstone; thin bedded; slightly wavy bedding; top is covered.

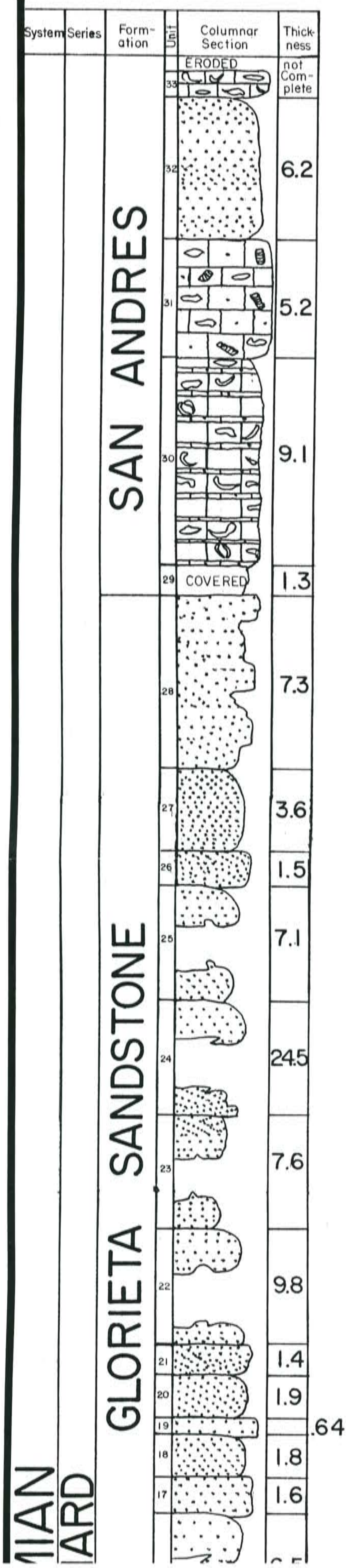
UNIT	THICKNESS (METERS)	DESCRIPTION
2.	10.4	LIMESTONE--mudstone; silty; yellowish-brown, pale red, and buff alternating throughout the interval; poorly bedded; thin bedded.
1.	2.7	LIMESTONE--mudstone; light olive-gray (w); light gray (f); medium bedding; becomes sandy (very fine sand) at top; subangular; moderately sorted quartz grains.

Incomplete Yeso Formation section due to faulting

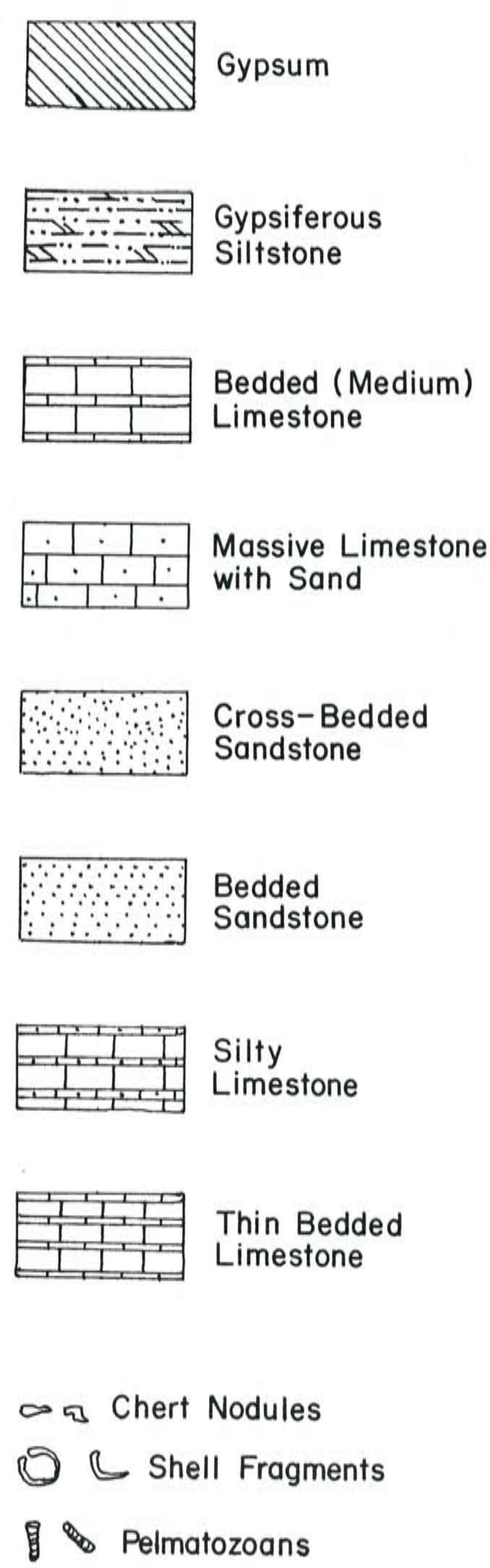
PLATE 6

Permian Measured Section Two

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



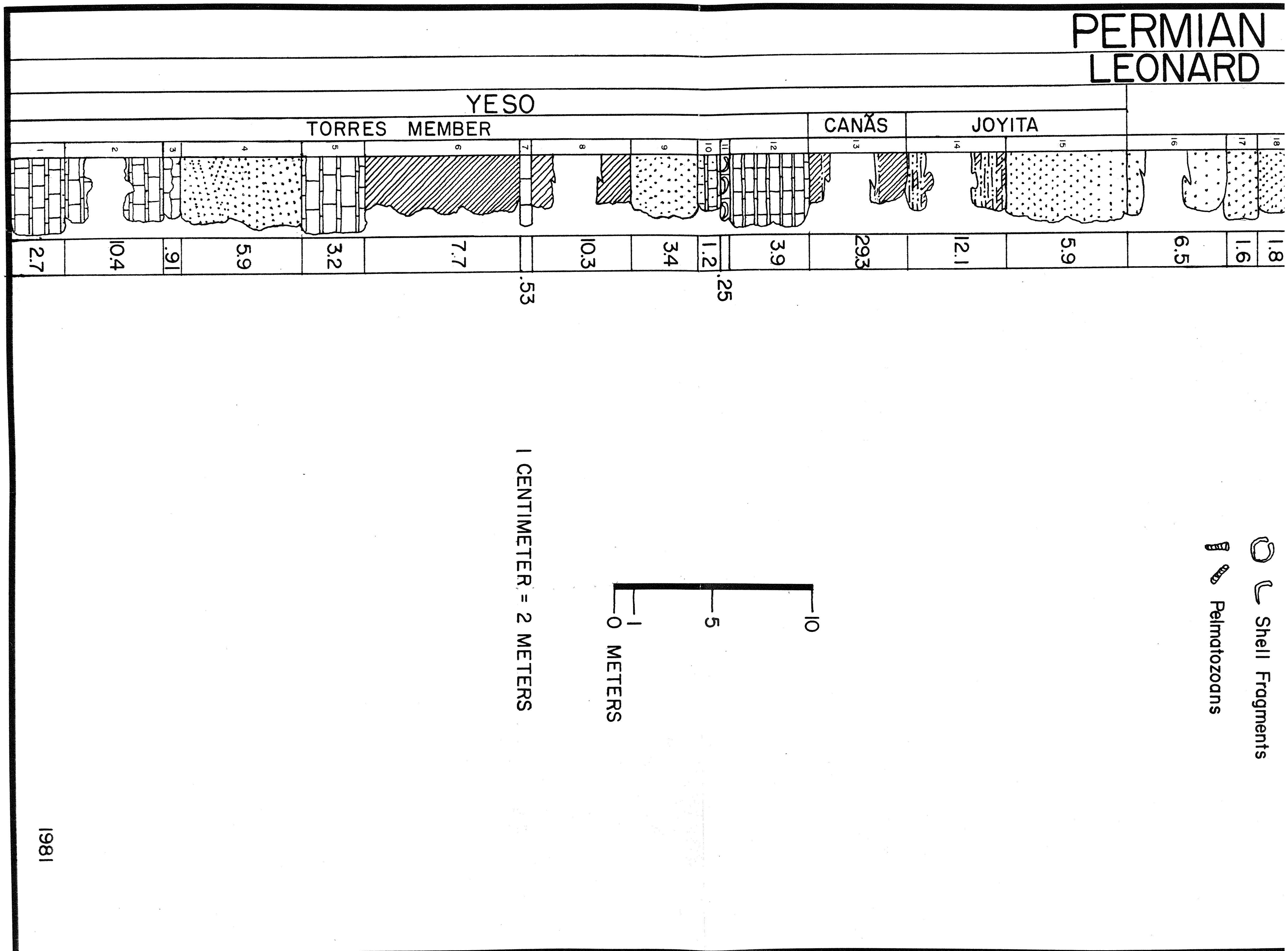
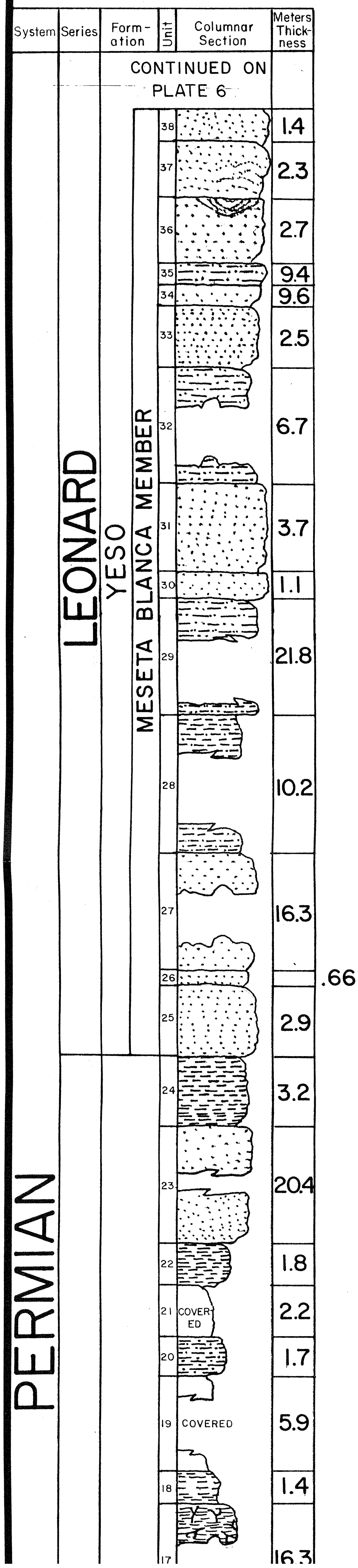

PERMIAN
LEONARD
YESO
TORRES MEMBER
CAÑAS
JOYITA
2.7
10.4
.91
5.9
3.2
7.7
.53
10.3
3.4
1.2
.25
3.9
29.3
12.1
5.9
6.5
1.6
1.8
Shell Fragments
Pelmatozoans
0 1 5 10
METERS
1 CENTIMETER = 2 METERS
1981

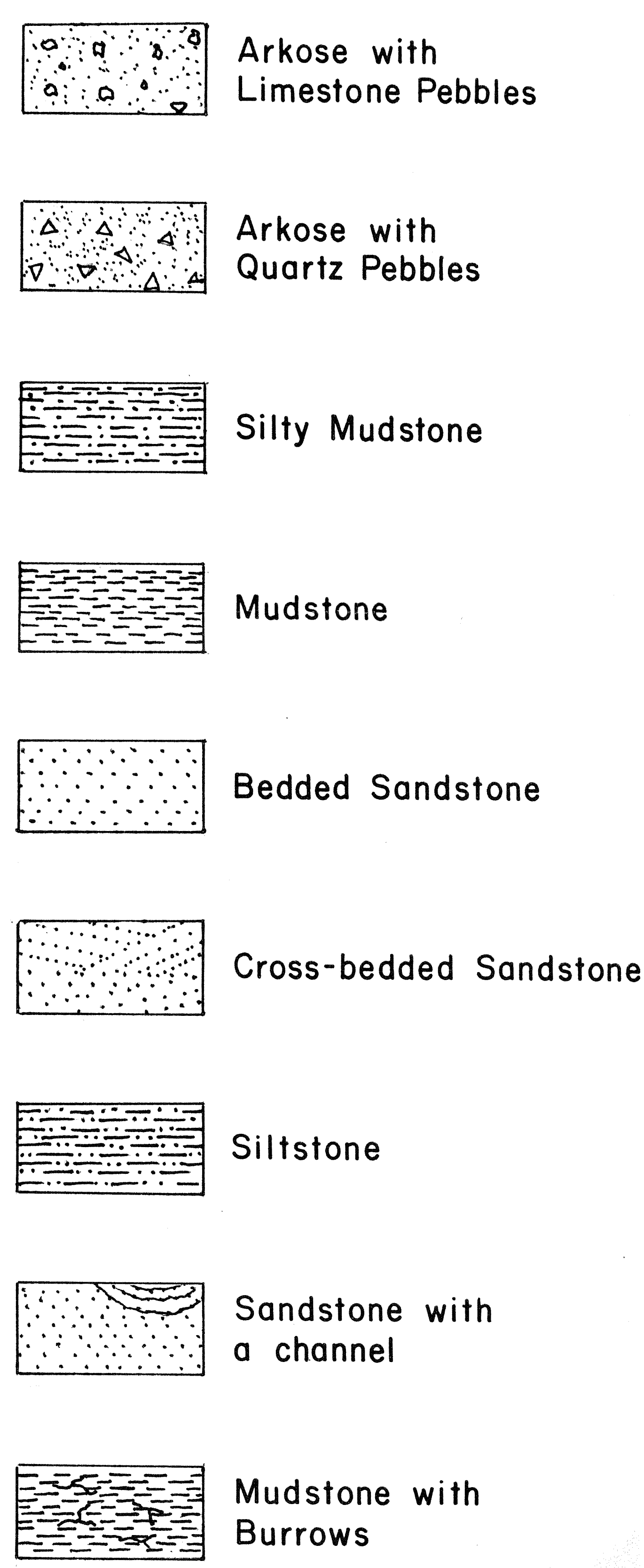
PLATE 5

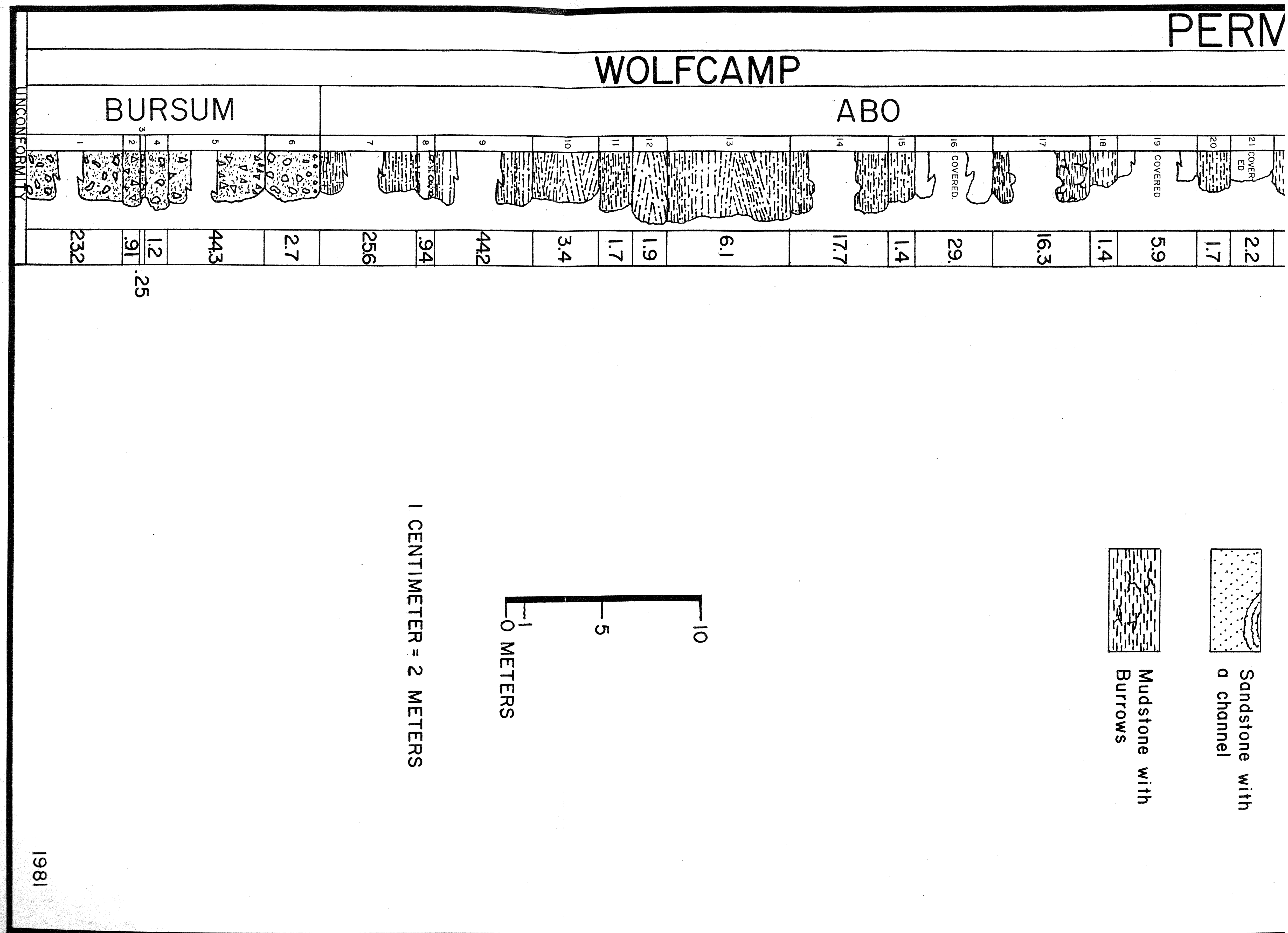
Permian Measured Section One

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



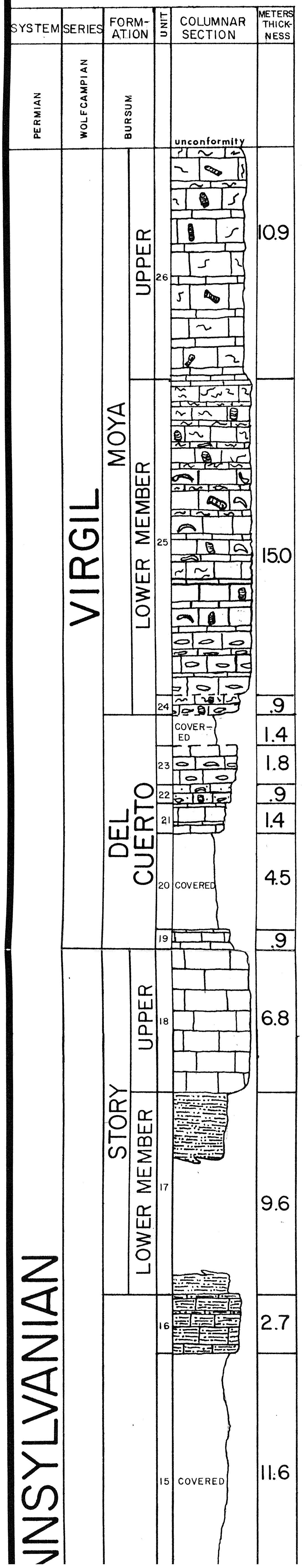


PERM
WOLFCAMP
BURSUM
ABO
UNCONFORMITY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
COVERED
COVERED
COVERED
23.2 .91 .25 1.2 44.3 2.7 25.6 .94 44.2 3.4 1.7 1.9 6.1 17.7 1.4 29. 16.3 1.4 5.9 1.7 2.2
Sandstone with a channel
Mudstone with Burrows
10
5
1
0 METERS
1 CENTIMETER = 2 METERS
1981

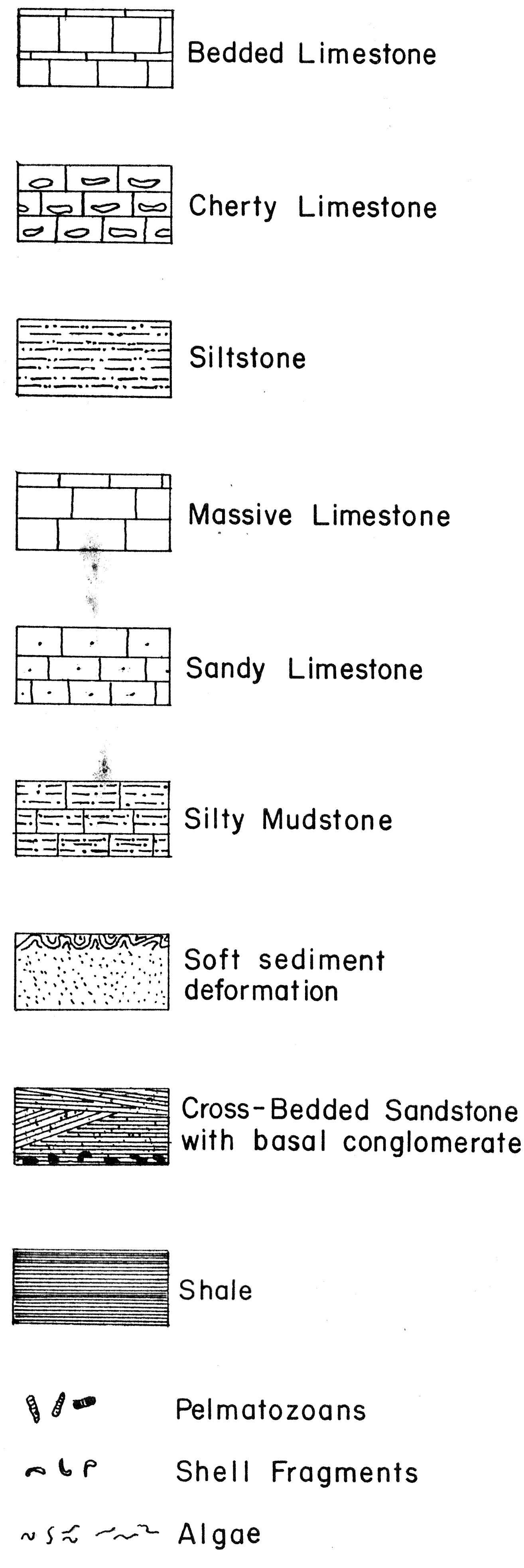
PLATE 3

Pennsylvanian Measured Section Number One

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



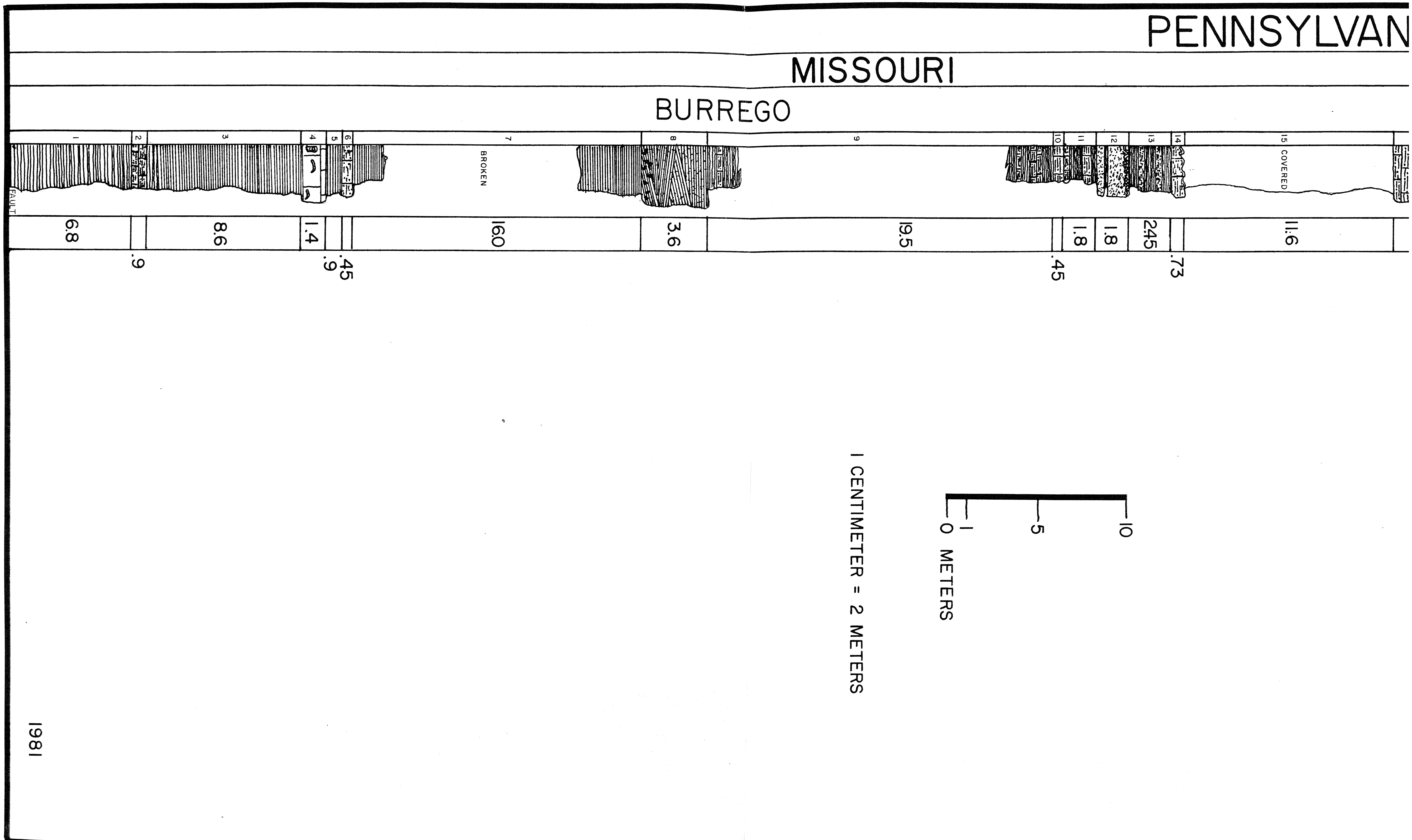
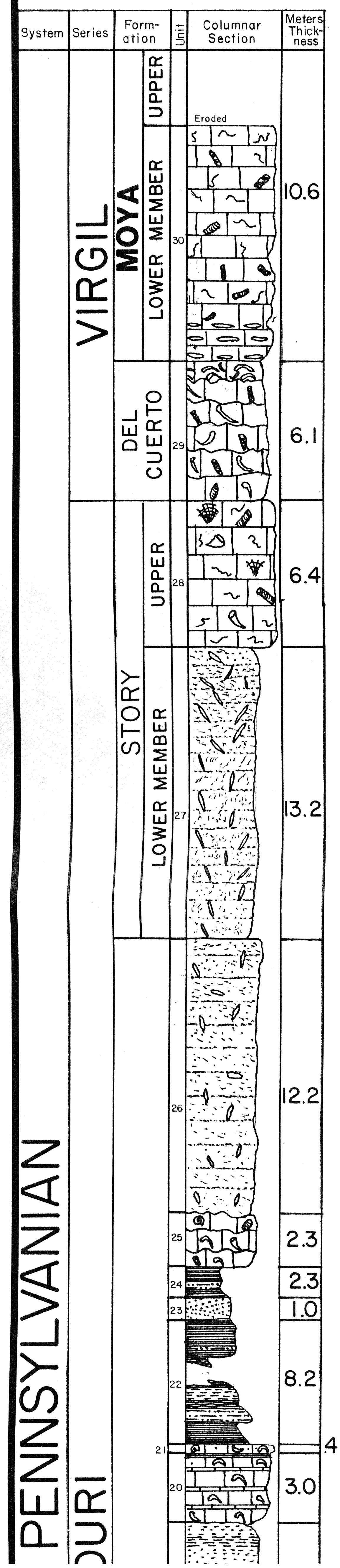

PENNSYLVAN
MISSOURI
BURREGO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
BROKEN
COVERED
FAULT
6.8
.9
8.6
1.4
.9
.45
16.0
3.6
19.5
.45
1.8
1.8
2.45
.73
11.6
0 1 5 10
METERS
1 CENTIMETER = 2 METERS
1981

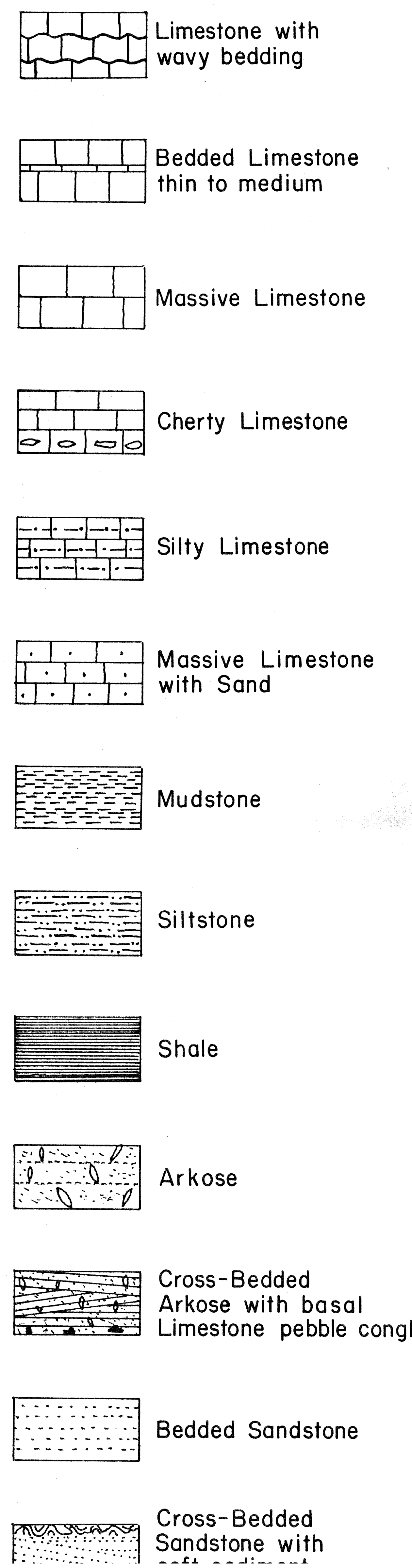
PLATE 4

Pennsylvanian Measured Section Number Two

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



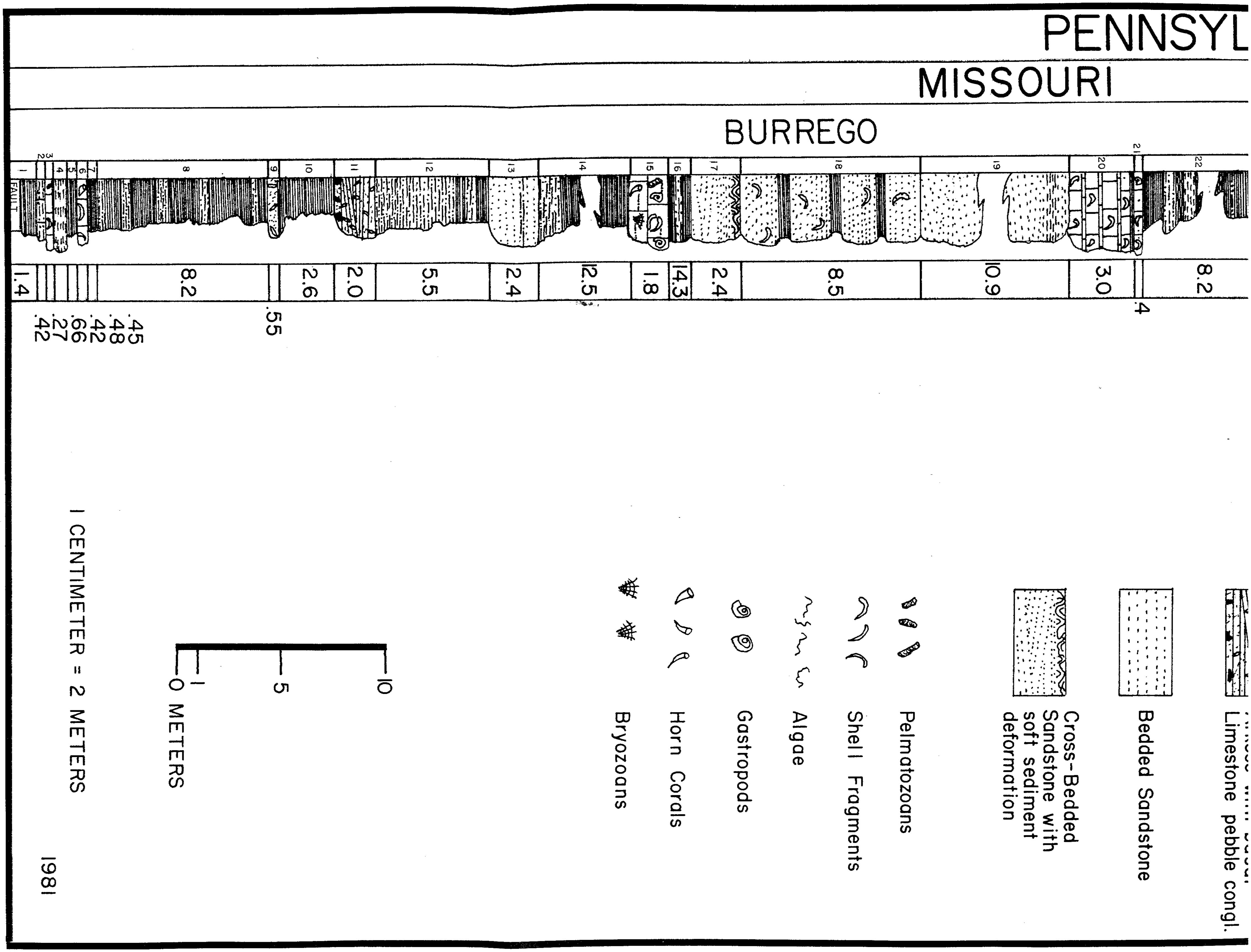
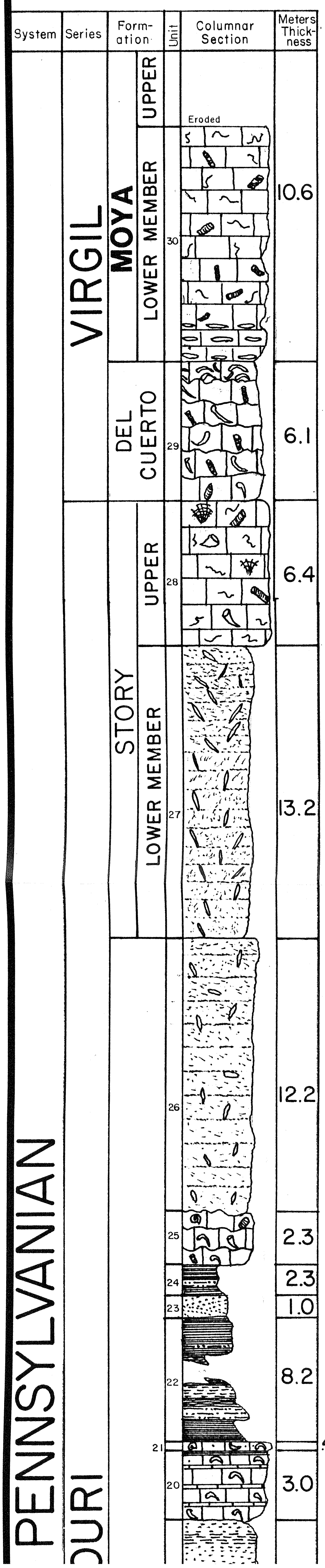

PENNSYL
MISSOURI
BURREGO
FAULT
1.4
8.2
2.6
2.0
5.5
2.4
12.5
1.8
14.3
2.4
8.5
10.9
3.0
8.2
.4
.42
.27
.66
.42
.48
.45
.55
Limestone pebble congl.
Bedded Sandstone
Cross-Bedded Sandstone with soft sediment deformation
Pelmatozoans
Shell Fragments
Algae
Gastropods
Horn Corals
Bryozoans
0 METERS
1
5
10
1 CENTIMETER = 2 METERS
1981

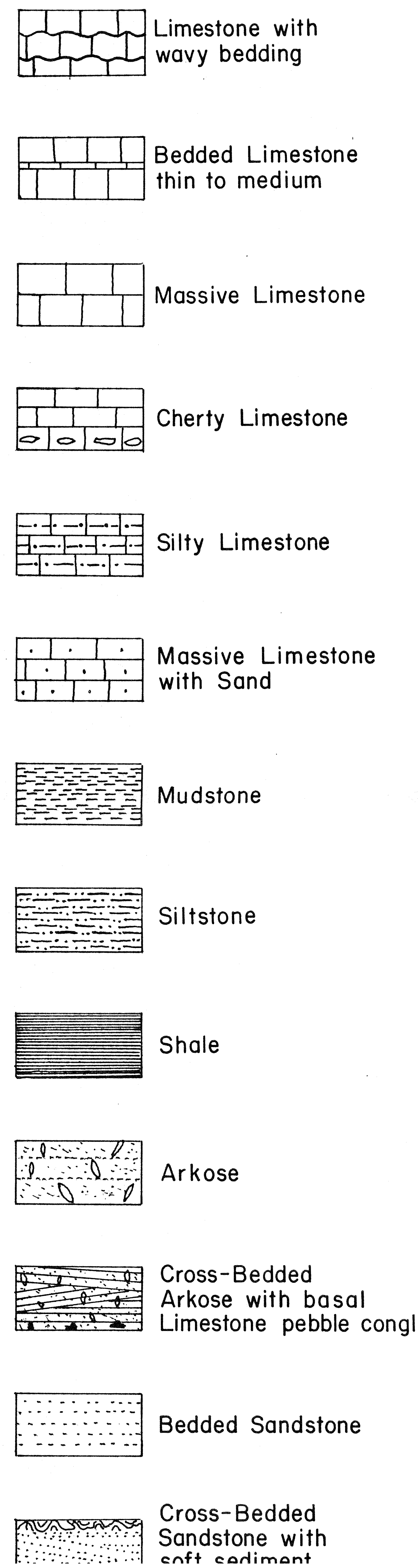
PLATE 4

Pennsylvanian Measured Section Number Two

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



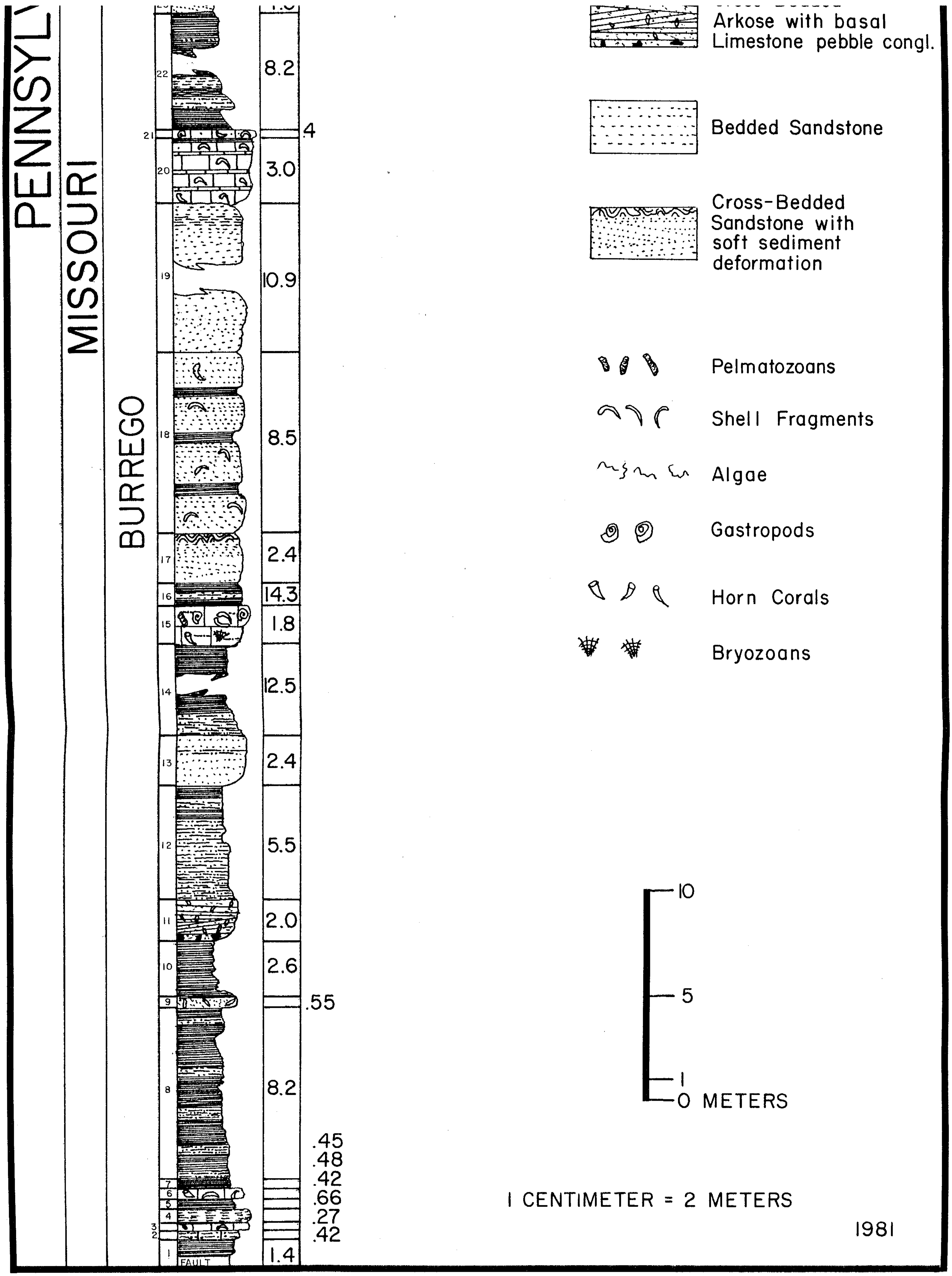
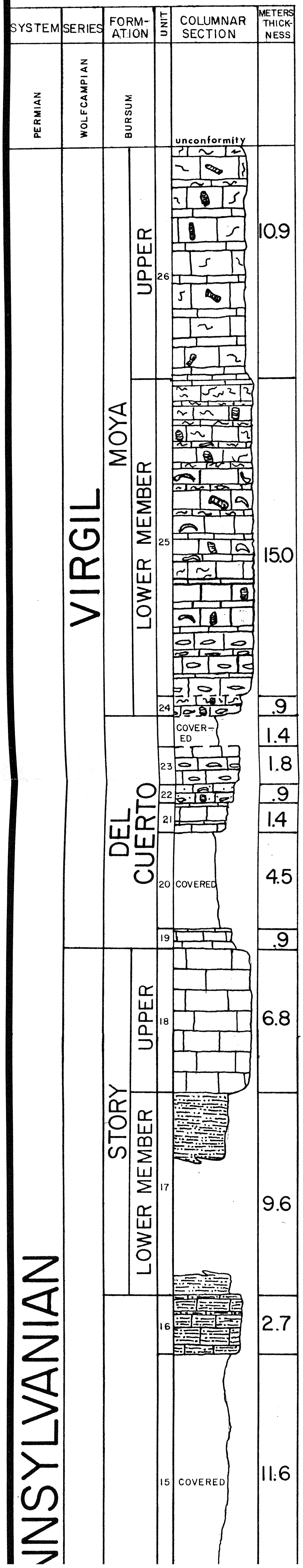
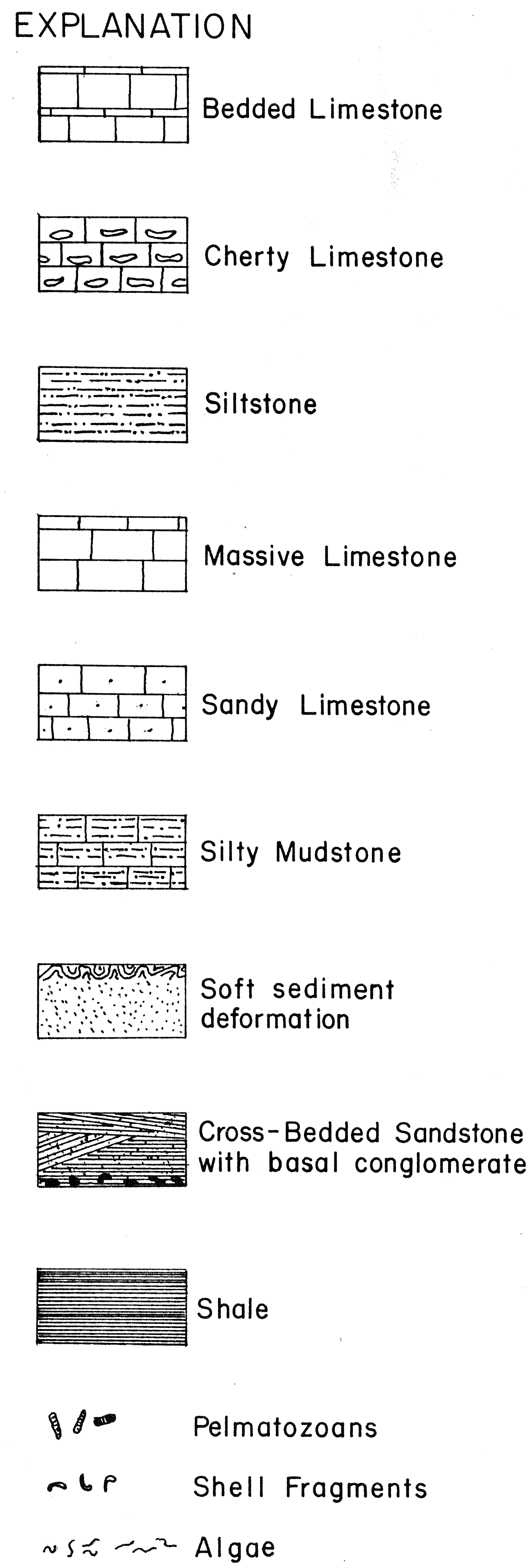

PENNSYLV
MISSOURI
BURREGO
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
FAULT
1.4
.42
.27
.66
.42
.48
.45
8.2
.55
2.6
2.0
5.5
2.4
12.5
1.8
14.3
2.4
8.5
10.9
3.0
.4
8.2
Arkose with basal Limestone pebble congl.
Bedded Sandstone
Cross-Bedded Sandstone with soft sediment deformation
Pelmatozoans
Shell Fragments
Algae
Gastropods
Horn Corals
Bryozoans
10
5
1
0 METERS
1 CENTIMETER = 2 METERS
1981

PLATE 3

Pennsylvanian Measured Section Number One

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY

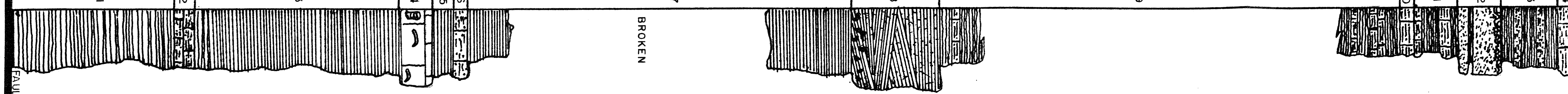




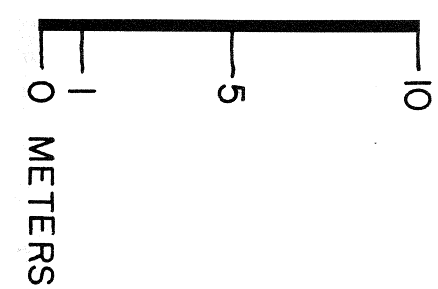
PENNS

MISSOURI

BURREGO



6.8 .9 8.6 1.4 .9 .45 16.0 3.6 19.5 .45 1.8 1.8 2.45 .73



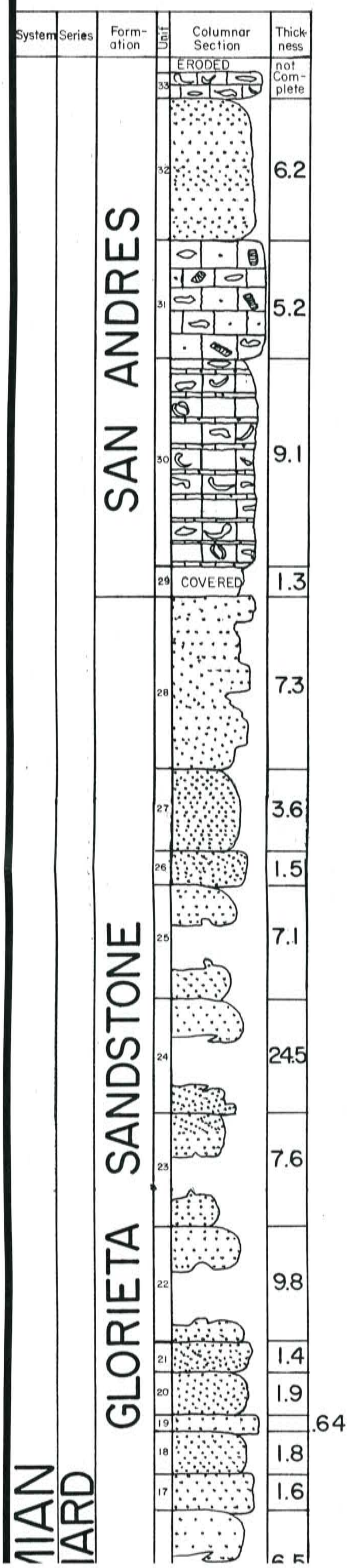
1 CENTIMETER = 2 METERS

1981

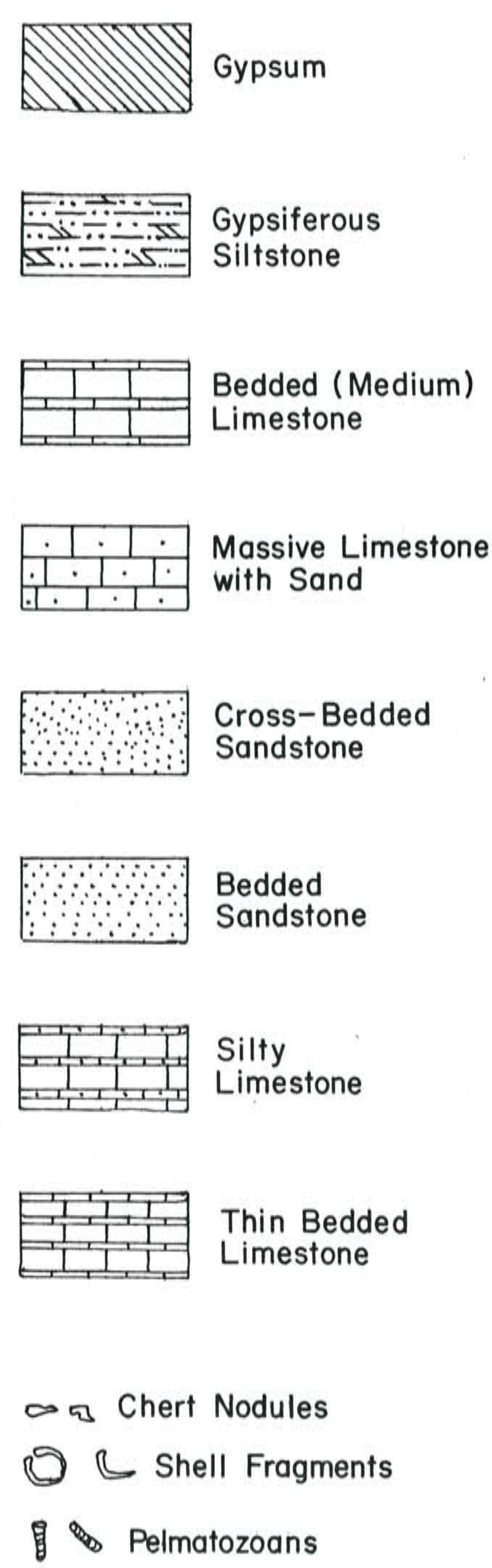
PLATE 6

Permian Measured Section Two

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



EXPLANATION



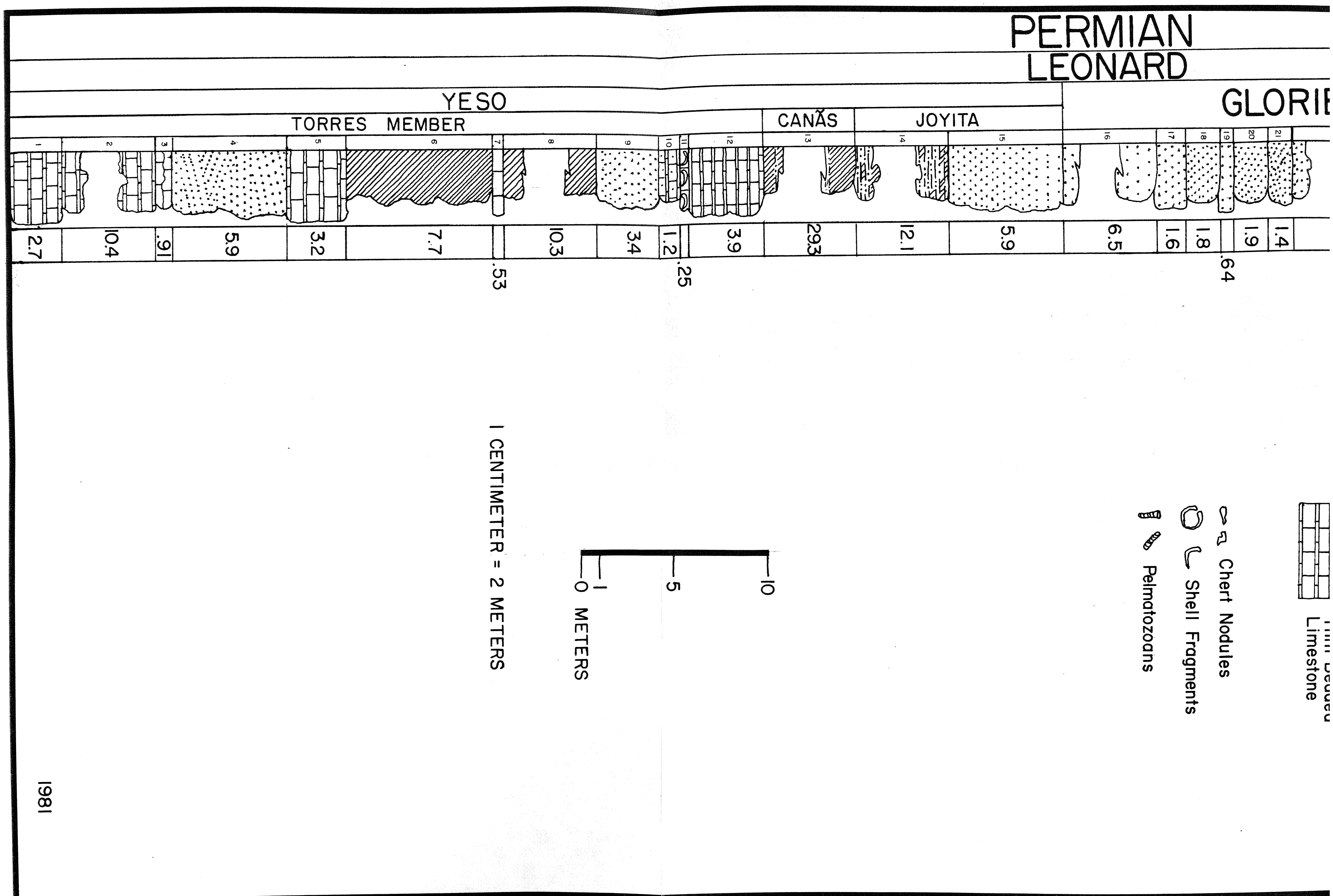
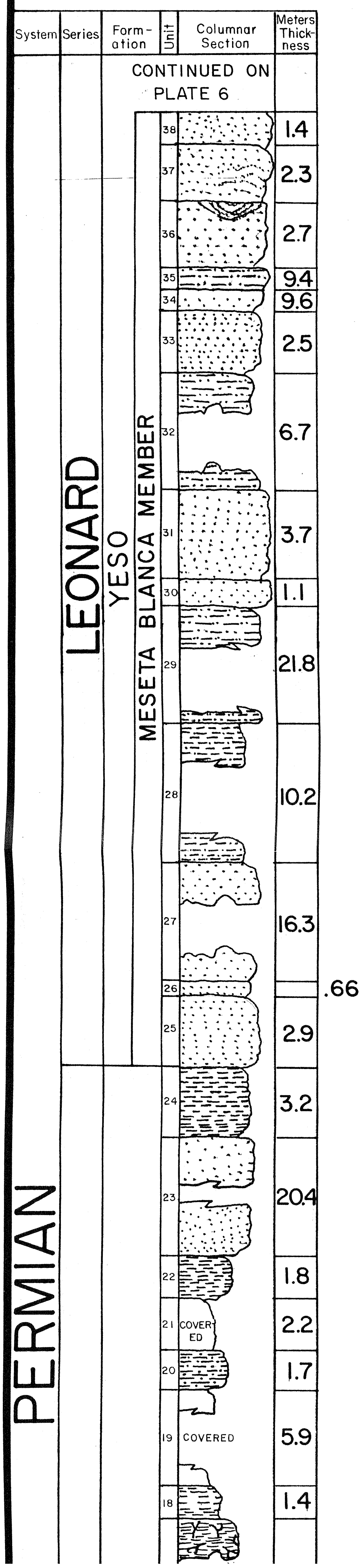

PERMIAN
LEONARD
YESO
TORRES MEMBER
CAÑAS
JOYITA
GLORIE
2.7
10.4
.91
5.9
3.2
7.7
.53
10.3
3.4
1.2
.25
3.9
29.3
12.1
5.9
6.5
1.6
1.8
.64
1.9
1.4
Limestone
Chert Nodules
Shell Fragments
Pelmatozoans
0 1 5 10
METERS
1 CENTIMETER = 2 METERS
1981

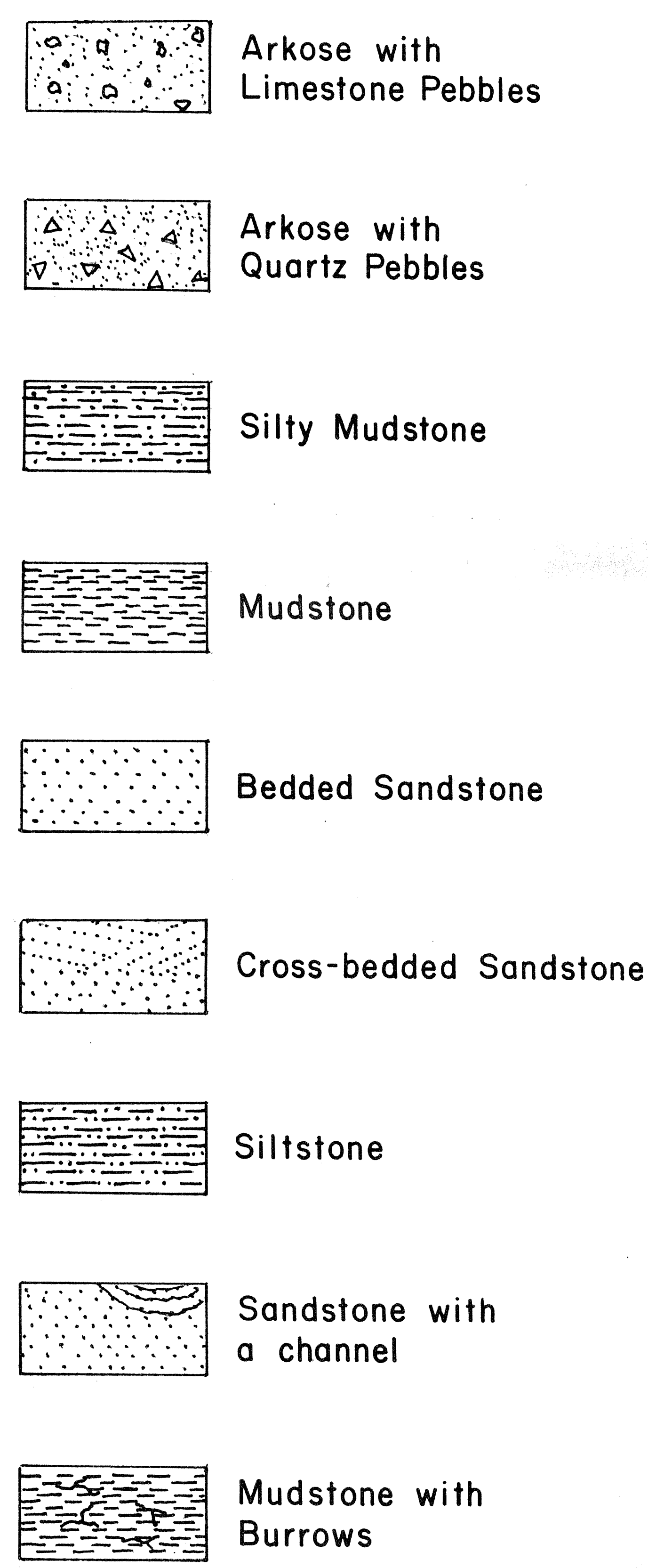
PLATE 5

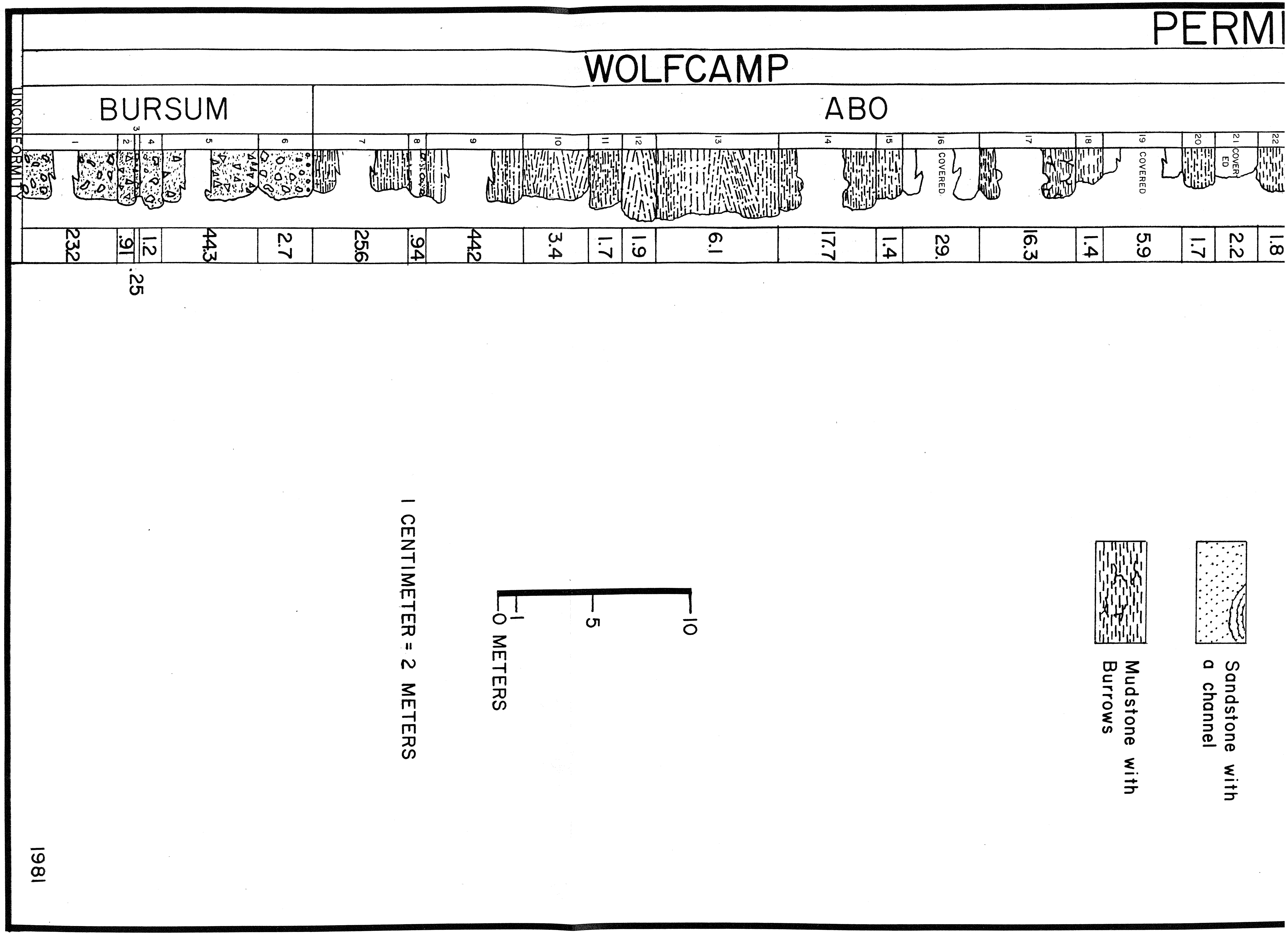
Permian Measured Section One

RANCHO DEL LOPEZ AREA — SOCORRO COUNTY



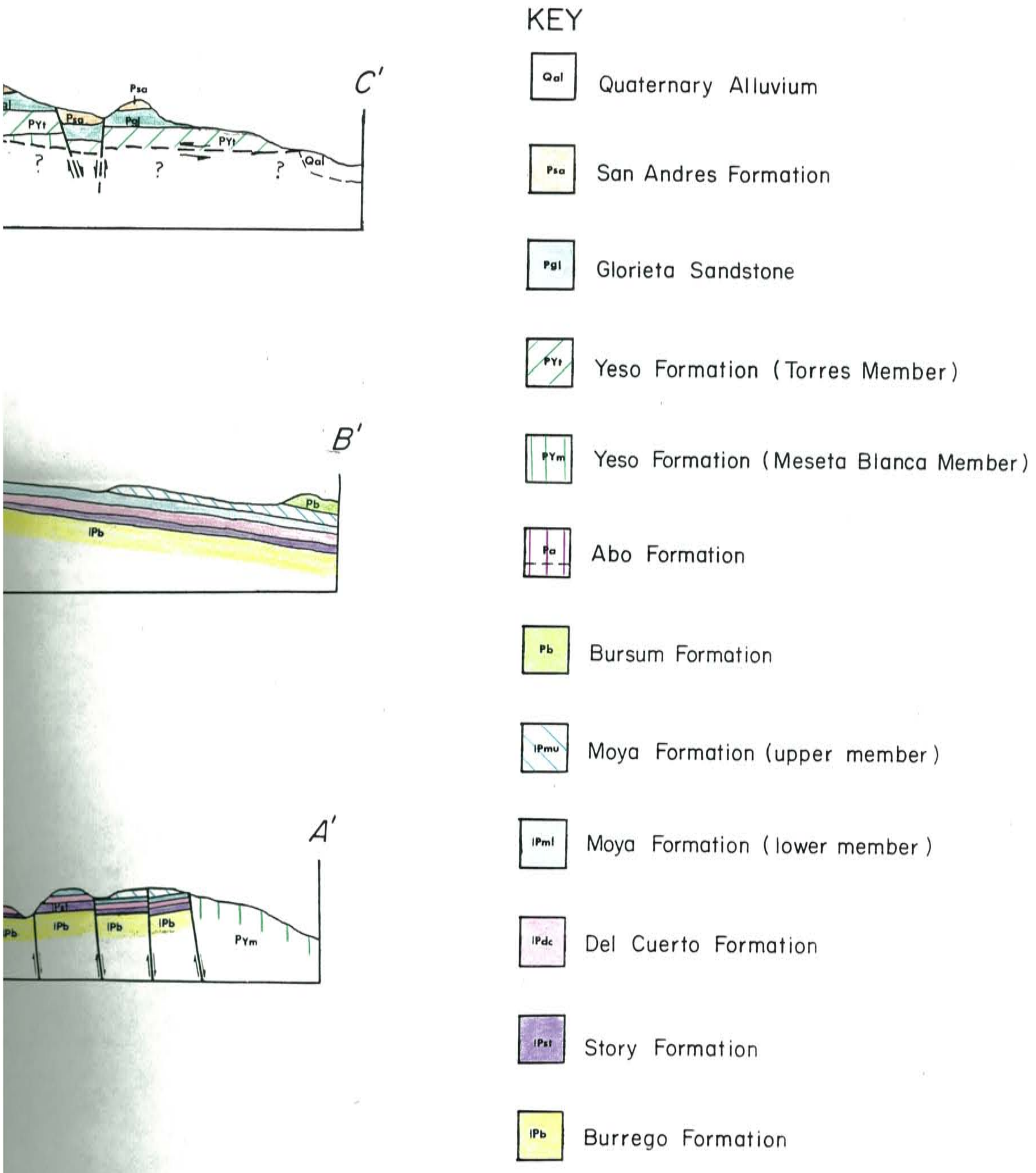
EXPLANATION





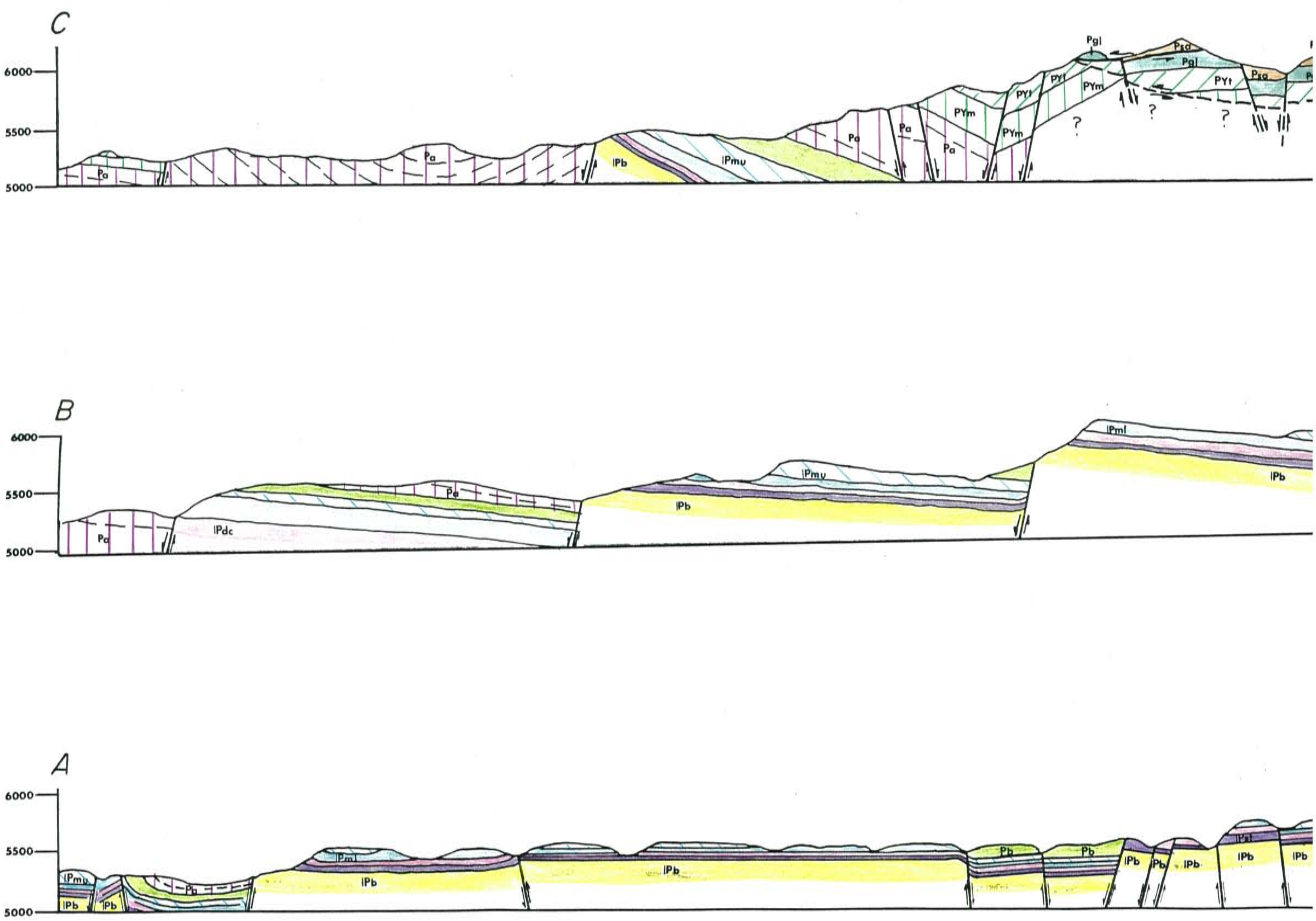
PERMI
WOLFCAMP
BURSUM
ABO
UNCONFORMITY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
COVERED
COVERED
COVERED
23.2
.91
1.2
.25
44.3
2.7
25.6
.94
44.2
3.4
1.7
1.9
6.1
17.7
1.4
29.
16.3
1.4
5.9
1.7
2.2
1.8
0 1 5 10
METERS
1 CENTIMETER = 2 METERS
Sandstone with a channel
Mudstone with Burrows
1981

E 2

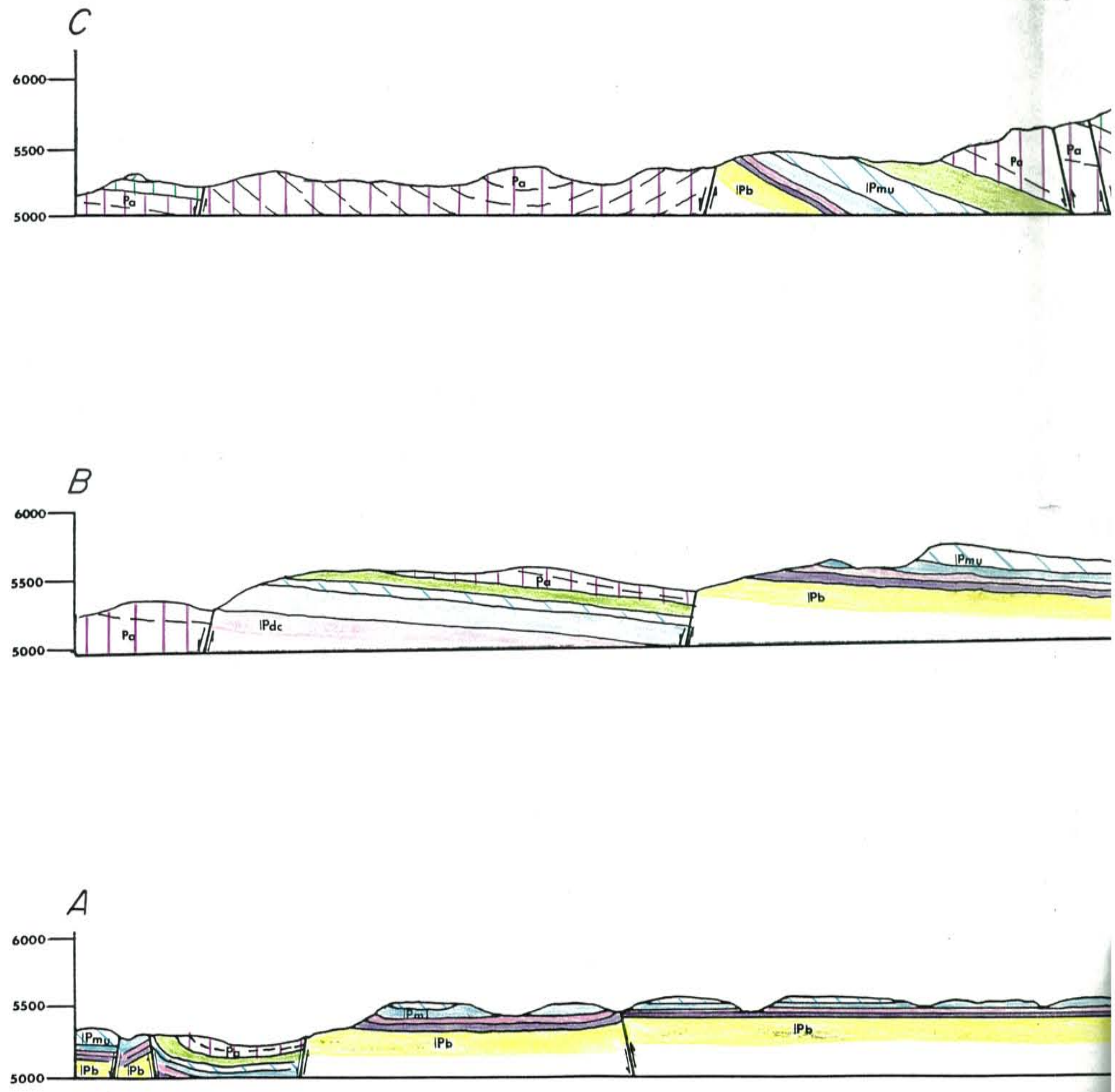

C'
B'
A'
Psa
Pgl
PYt
Qal
Pb
IPb
PYm
IPst
KEY
Qal Quaternary Alluvium
Psa San Andres Formation
Pgl Glorieta Sandstone
PYt Yeso Formation (Torres Member)
PYm Yeso Formation (Meseta Blanca Member)
Pa Abo Formation
Pb Bursum Formation
IPmu Moya Formation (upper member)
IPml Moya Formation (lower member)
IPdc Del Cuerto Formation
IPst Story Formation
IPb Burrego Formation

1981

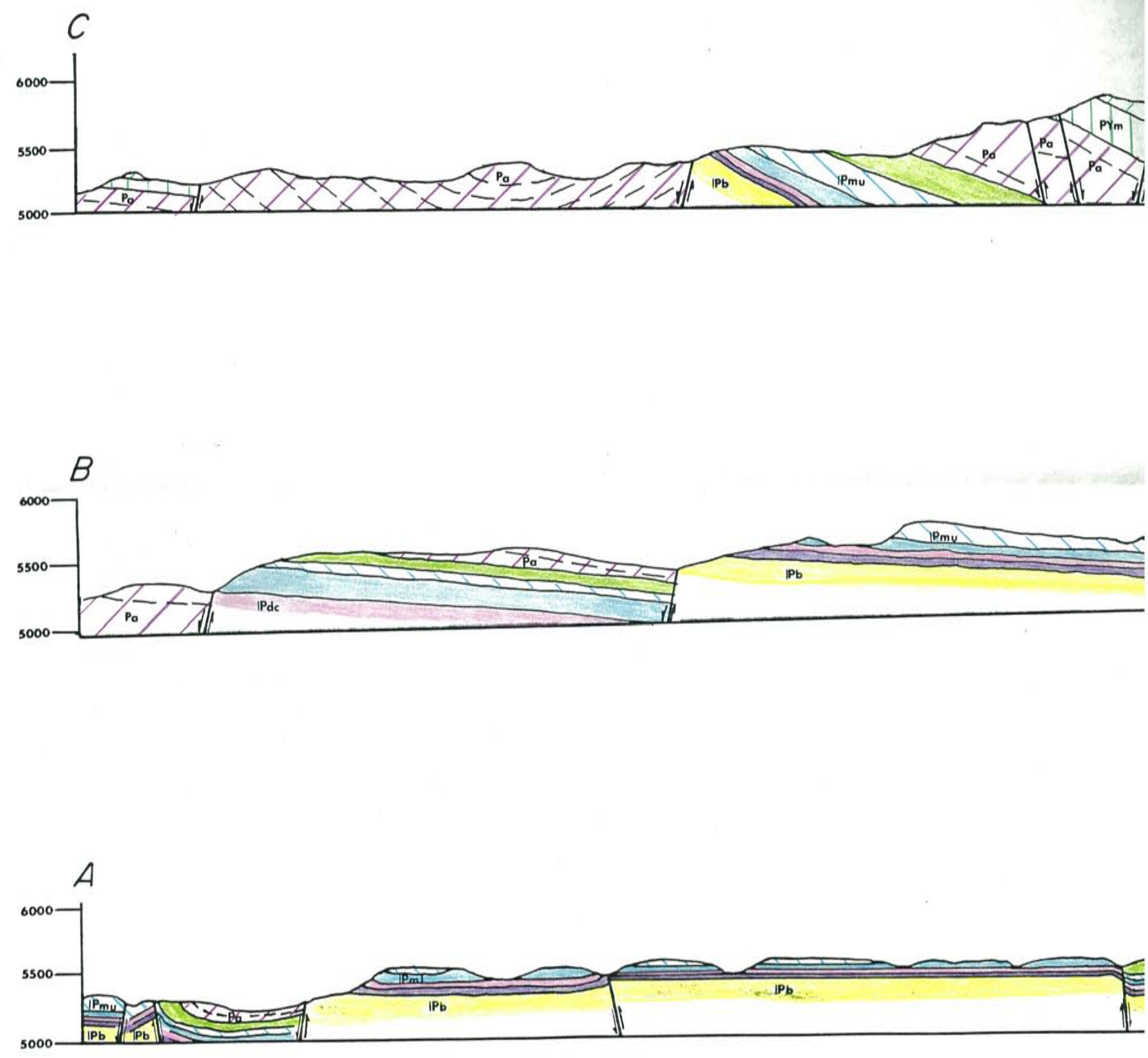
PLATE 2



VERTICAL and HORIZONTAL SCALE: 1 INCH = 1,000 FEET

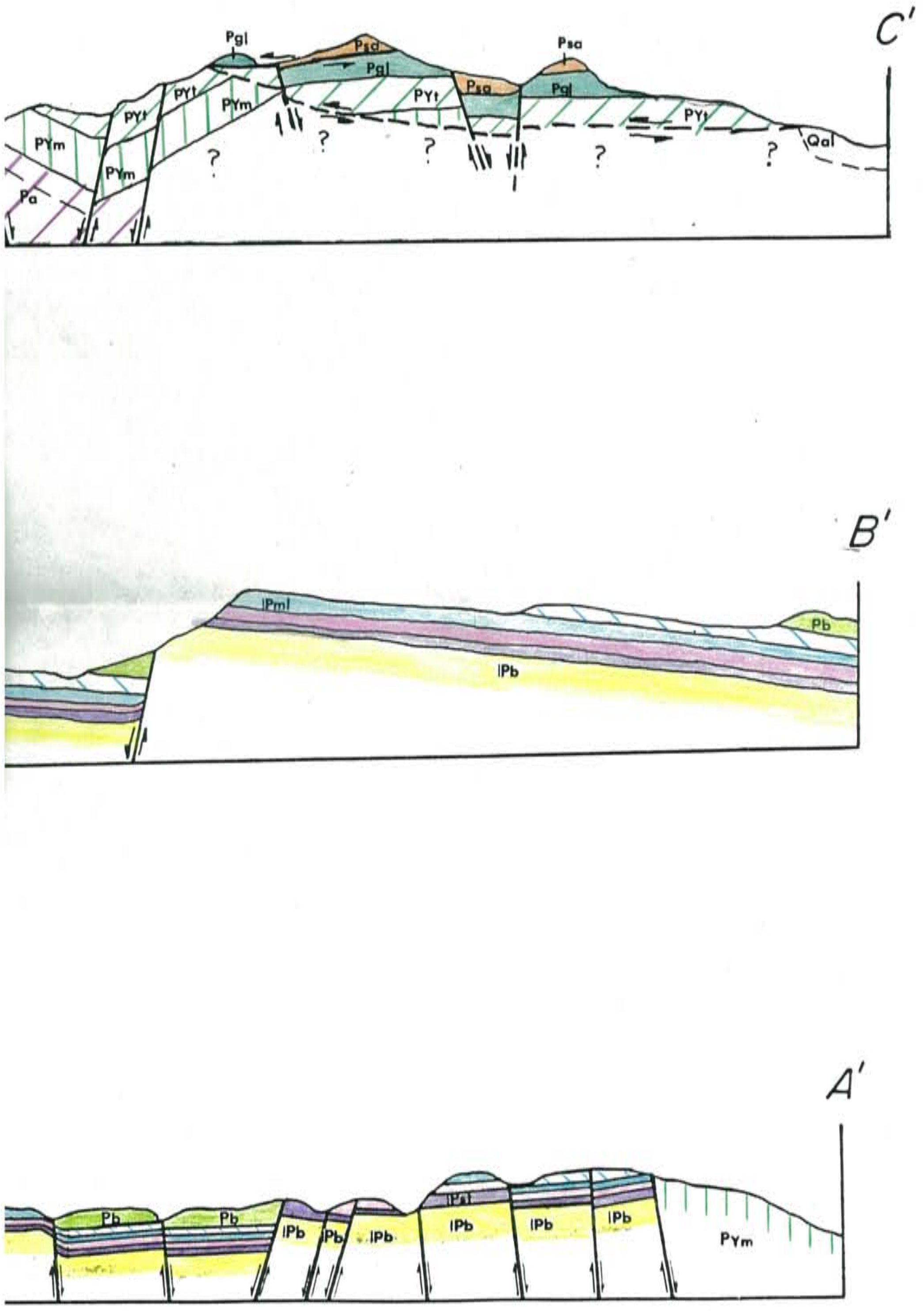


VERTICAL and HORIZONTAL SCALE: 1 INCH = 1,000 FEET



VERTICAL and HORIZONTAL SCALE: 1 INCH = 1,000 FEET

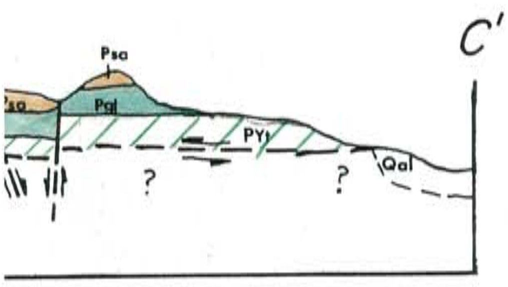
PLATE 2

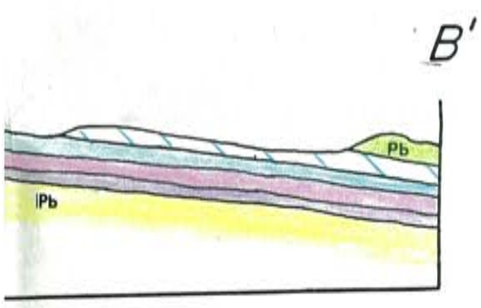


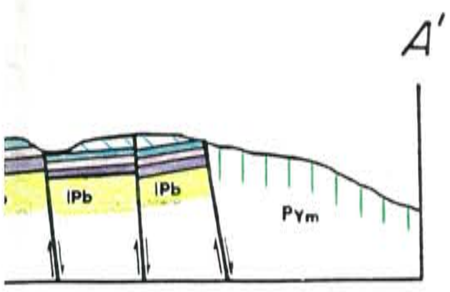
KEY

- Qal — Quaternary Alluvium
- Psa — San Andres Formation
- Pgl — Glorieta Sandstone
- PYt — Yeso Formation (Torres Member)
- PYm — Yeso Formation (Meseta Blanca Member)
- Pa — Abo Formation
- Pb — Bursum Formation
- IPmu — Moya Formation (upper member)
- IPml — Moya Formation (lower member)
- IPdc — Del Cuerto Formation
- IPst — Story Formation
- IPb — Burrego Formation

1981







KEY

- Qal — Quaternary Alluvium
- Psa — San Andres Formation
- Pgl — Glorieta Sandstone
- PYt — Yeso Formation (Torres Member)
- PYm — Yeso Formation (Meseta Blanca Member)
- Pa — Abo Formation
- Pb — Bursum Formation
- IPmu — Moya Formation (upper member)
- IPml — Moya Formation (lower member)
- IPdc — Del Cuerto Formation
- IPst — Story Formation
- IPb — Burrego Formation

1981