Circular 189 1984

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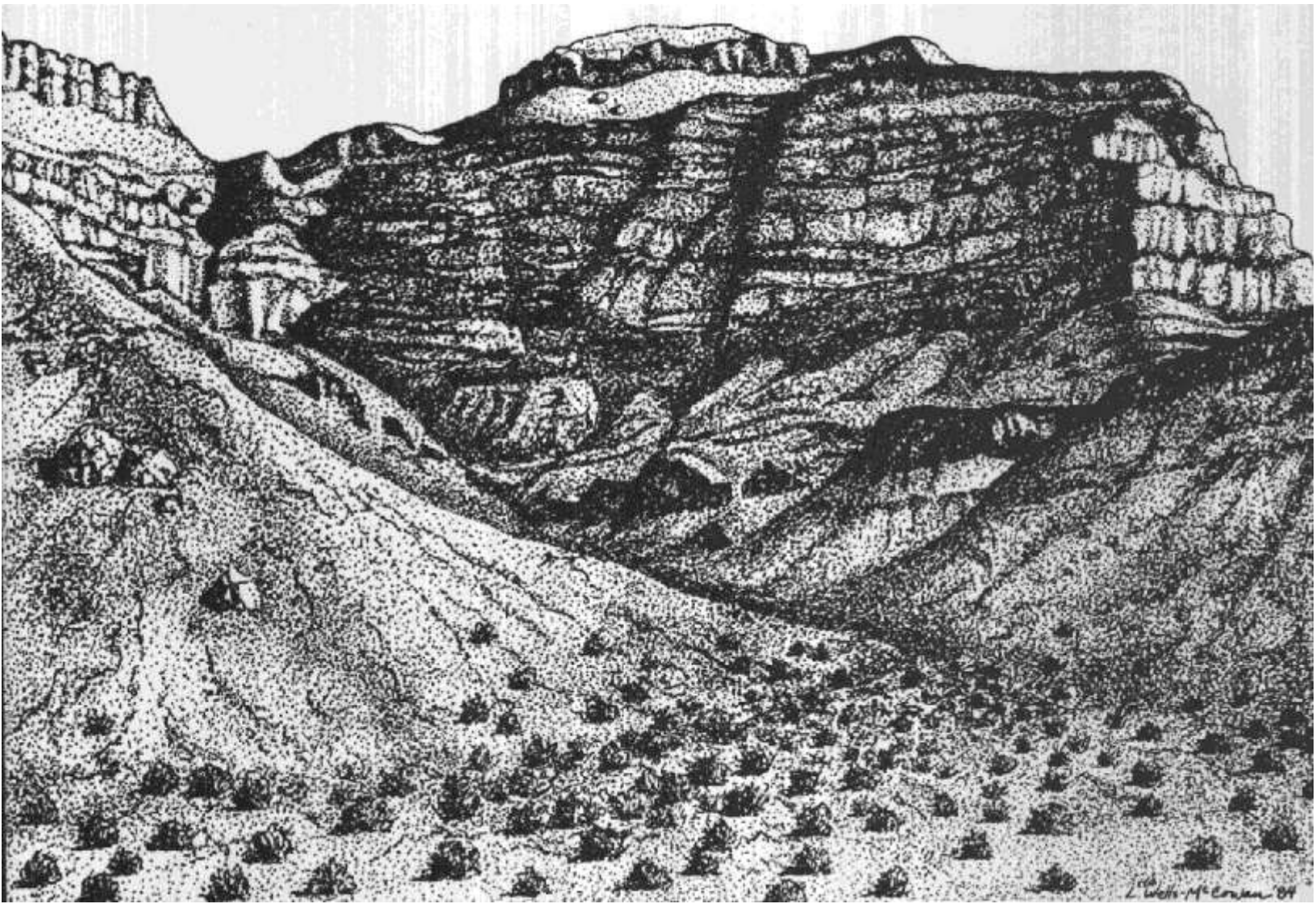
by James E. Sorauf



New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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COVER-Type locality of the Sly Gap Formation and Thurgood Sandstone Member at Sheep Mountain. See Fig. 16 (Drawing by Linda Wells-McCowan).

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# Preface

**This study evolved from beginning investigations of the Frasnian coral faunas of southern New Mexico. As part of these studies, I was in the San Andres Mountains in the summers of 1977 and 1978, in the area north of, and including, Cottonwood Canyon, where excellent development of platform fades of the Sly Gap and Contadero Formation results in the occurrence of abundant and varied Frasnian coral faunas. In addition to collecting coral faunas, I described stratigraphic sections for the Sly Gap and Contadero rocks at the Sheep Mountain and Rhodes Canyon localities. My growing awareness of stratigraphic problems regarding lateral fades equivalence and age of lithic sequences led in 1982 to further study focused more directly on Devonian strata throughout the San Andres Mountains, on exposures to the west in the Mud Springs Mountains, and at Hermosa, New Mexico.**

**Both phases of this study have been carried out with the generous and efficacious support of the New Mexico Bureau of Mines and Mineral Resources, which provided vehicles, personnel, financial support, and assistance in obtaining access to the restricted field area on White Sands Missile Range. My field work in 1977 was carried out in the company of Richard Campbell, Robert Coughlin, and James Howard, then students at the State University of New York at Binghamton. The 1978 field studies benefited greatly from the companionship of Stephen Hook, then paleontologist of the New Mexico Bureau of Mines and Mineral Resources, who, along with Frank Kottlowski, Director of the Bureau, arranged all necessary financial and logistical support for the study.**

**In January and June of 1982, an aggregate month of field days was spent specifically studying the Devonian strata and stratal relationships within the San Andres Mountains, with field assistance from Stanley Krukowski and Frank Timbalier of the New Mexico Institute of Mining and Technology; finances and logistics were kindly arranged by Frank Kottlowski, George Austin, and Donald Wolberg of the New Mexico Bureau of Mines and Mineral Resources.**

**Permission to work on the White Sands Missile Range was arranged by the Engineering Plans and Services Division, by James Kilcrease of the Master Plans and Programs Branch and his staff, John Diaz, Fred Janer, Jon Hubbard, and Len Wallace, all of whom accompanied me in the field. Moise Nevarez and John Vallejos also provided company in the field. Field guidance and security were provided by Tom Emmanuel and Bill Bates, Range Riders of the White Sands Missile Range.**

**G. A. Cooper and J. T. Dutro Jr. kindly allowed me access to their study, while still in manuscript form, of the Devonian brachiopods and stratigraphy of New Mexico.**

**Binghamton, New York**
**October, 1983**

***James E. Sorauf,*** **State University of New York at Binghamton**

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## Abstract

Devonian strata in the San Andres Mountains comprise a thin (25-50 m or 60-170 ft), unconformity-bounded sequence, commonly with diastemic formation or member boundaries. The formations recognized throughout most of the area are the Oñate, Sly Gap, and Contadero Formations of Givetian, Frasnian, and Famennian ages, respectively. The setting during Devonian time was a shelf area characterized by calcareous, argillaceous, and sandy sediments, grading into dark basinal shales at the south end of the range. Over most of the area, the Oñate Formation is characterized by brown, silty, dolomitic rocks overlain by shales and argillaceous limestones of the Sly Gap Formation. The overlying Contadero Formation, mostly consisting of shales and fine sandstones, can be subdivided into members in the northernmost quarter of the area. These units are the basal Salinas Peak Member (proposed herein), the middle Thurgood Sandstone Member, and the upper Rhodes Canyon Member of interbedded tan shale and sandstone. These units cannot be identified south of Cottonwood Canyon, and the Sly Gap and Contadero Formations can be differentiated only as far south as San Andres Canyon. South of San Andres Canyon, dark shales comprise the Devonian rocks above much-thinned Oñate Formation dolomites.

All units are fossiliferous, with excellent brachiopod faunas providing ages of each. Corals that are present throughout the Frasnian part of the section are extremely rare in older rocks and absent in the Famennian rocks. Faunal elements are recognizable to the west in outcrops examined at the Mud Springs Mountains and at Hermosa, New Mexico. Both the Oñate and Sly Gap beds are demonstrably present to the west, and at Hermosa they occur beneath typical Percha Shale.


# Introduction

The San Andres Mountains are among the most scenic and prominent of the north-south-trending mountain ranges of south-central New Mexico. Because they lie totally within the restricted White Sands Missile Range, only limited studies have been carried out on most stratigraphic units. However, outcrops of Devonian rocks in the San Andres Mountains are of critical importance in understanding Devonian fades relationships and depositional history of the strata. Devonian units not developed elsewhere are exposed within the San Andres Mountains, and the mountains lie in a critical position with respect to east-west facies changes in Devonian formations. Calcareous platform deposits, which originated near a Devonian shoreline, are found in the northernmost outcrops within the San Andres Mountains. Facies change to deeper water, basinal shales at the latitude of the southern portion of the range. Some Devonian units are more fossiliferous in the San Andres Mountains than elsewhere. For example, excellent Upper Devonian (Frasnian) colonial-coral faunas of the Sly Gap Formation and large solitary-coral faunas of the Contadero Formation are not developed outside of the San Andres Mountains.

## Areas of study

This study focuses on the San Andres Mountains (Fig. 1), with supplementary sections measured and described for the Devonian strata of the Mud Springs Mountains (west of Truth or Consequences, New Mexico) and the Palomas mining district of Hermosa, New Mexico.

Research on Devonian stratigraphy in the San Andres Mountains began in the north-central part of the range, as part of a program to study the Devonian coral faunas of the area, and was later expanded both north and south to provide coverage from Bear Canyon at the south end of the range to Johnson Park near the northern end. The 16 stratigraphic sections described were chosen for optimal spacing and/or wherever access was permitted (Fig. 1).

The San Andres Mountains are a west-dipping monoclinal fault block modified by transverse faults and several igneous intrusives. Devonian strata are exposed on the east-facing flank of the range and are generally accessible by canyons opening to the east, towards the Tularosa Valley. The San Andres Mountains measure approximately 78 mi (125 km) from north to south and are incised by 17 or 18 major east-facing canyons. The areas between Cottonwood and Hembrillo Canyons and between San Andres and Ash Canyons were inaccessible during this study. These appear to be areas of rapid and pronounced fades change (Fig. 2) where obtaining more data would be. desirable.

Roads are maintained by White Sands Missile Range personnel into the San Andres Mountains to recover ordnance. During 1978-1982, roads in the northern part of the range (Cottonwood Canyon to Johnson Park) were better maintained, while the southern part (Hembrillo Canyon to Ash Canyon) had poor accessibility. Much of the San Andres Mountains will be accessible only by helicopter in the future.

The 16 sections described can be divided readily into northern and southern areas of study (Fig. 1). In

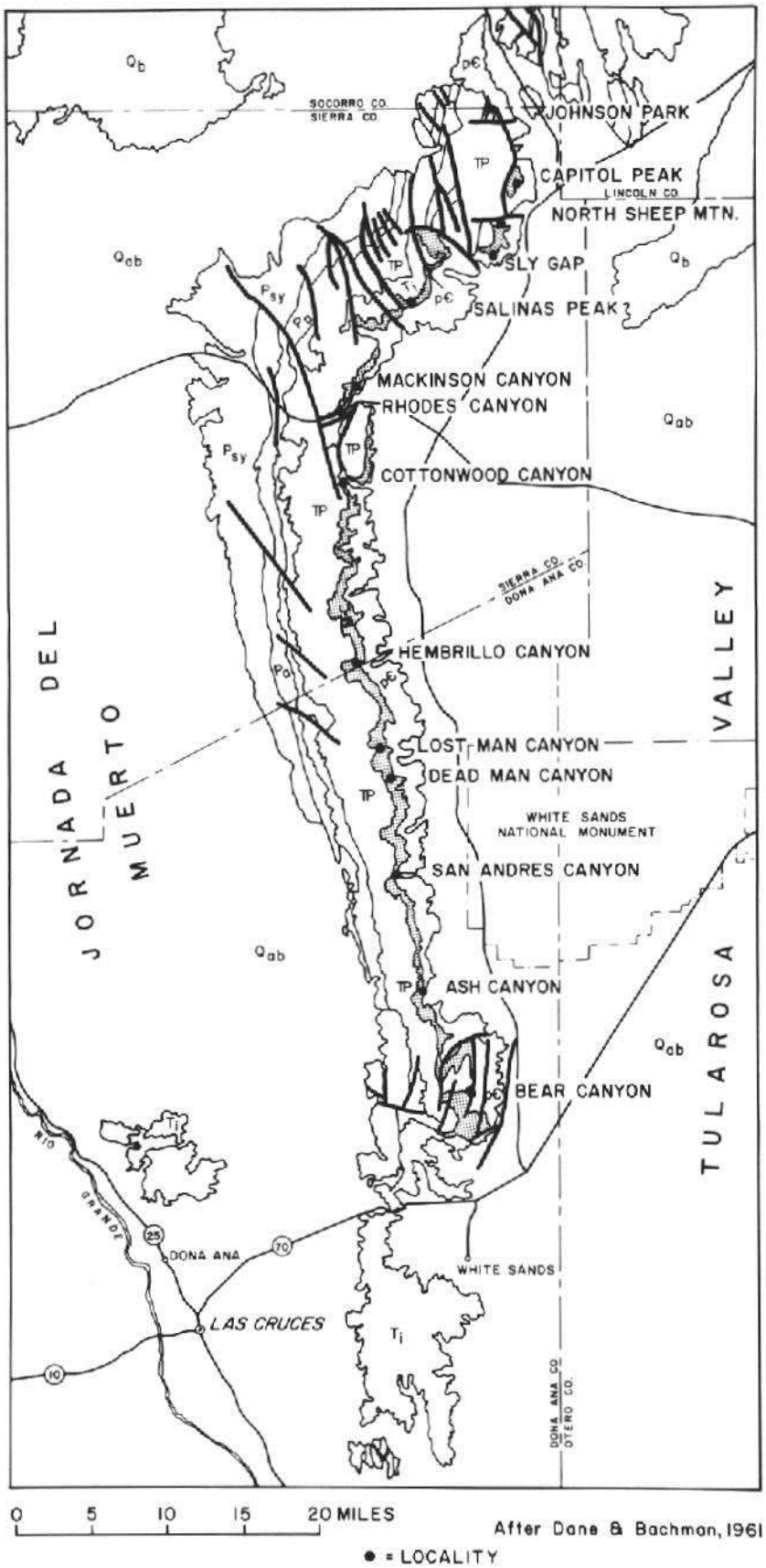


FIGURE 1—Index map of the San Andres Mountains, New Mexico, showing location of stratigraphic sections. Position of localities is indicated by solid black circles; exact locality descriptions are noted in Appendix. Map symbols are as follows: **Qb** = Quaternary basalt, **Qab** = Quaternary alluvium & bolson, **Ti** = Tertiary intrusives, **Psy** = Permian San Andres & Yeso Formations, **Pa** = Permian Abo Formation, **PP** = Pennsylvanian, **pC** = Precambrian. Stippled outcrop belt is rocks of Cambrian through Mississippian age. Thick black lines are faults; thinner lines are contacts.

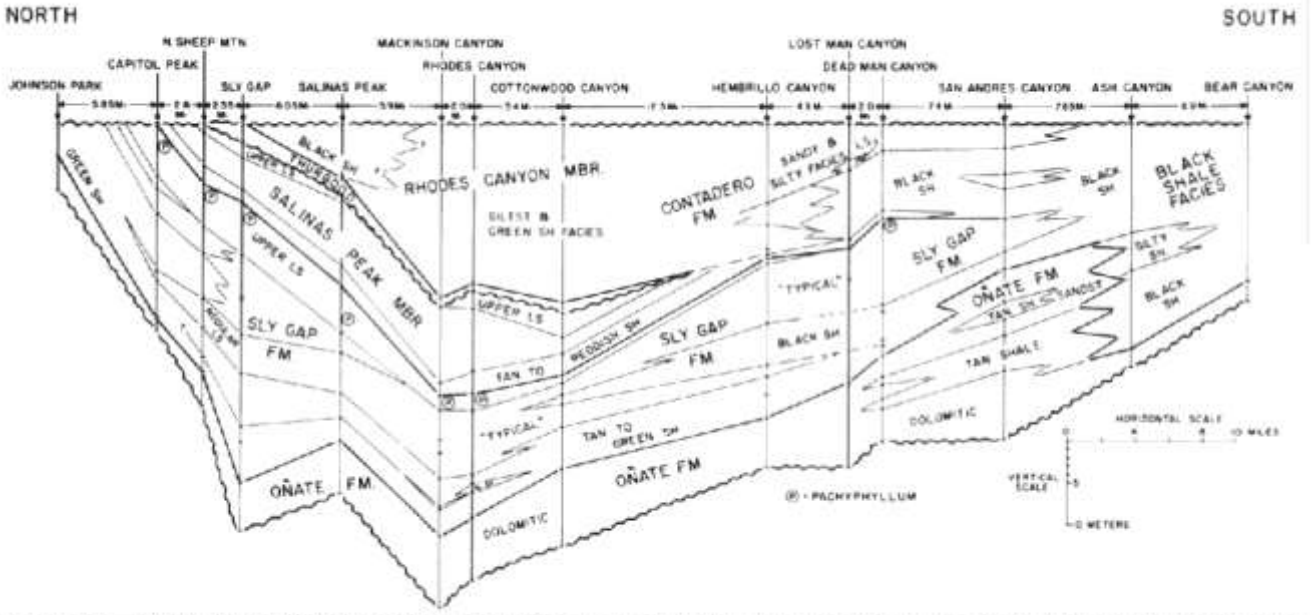


FIGURE 2—North–south cross section of Devonian strata of the San Andres Mountains, New Mexico. Datum plane is the pre-Mississippian unconformity. Locations of sections are shown on Fig. 1. Black-shale facies at south end of cross section is unnamed.

**the northern area (Cottonwood Canyon to Johnson Park), Devonian strata are easily differentiated into a number of stratigraphic units, each abundantly fossiliferous, that represent more shelfward environments of deposition. In the southern area (Hembrillo Canyon to Bear Canyon), depositional environments represented are progressively more influenced by basinal conditions and are not as fossiliferous as those to the north.**

## Previous work

**Table 1 summarizes the history of nomenclature for Devonian rocks in the central and northern San Andres Mountains. Gordon (1907) noted the occurrence of fossiliferous Devonian shales in the mining districts of Lake Valley, Hillsboro, and Kingston, New Mexico. Gordon referred to the unit as the Percha Shale but did not treat it as anything other than a shale sequence underlying the Mississippian rocks of the region, the focal point of his research.**

**Darton, in a pair of remarkable papers on the stratigraphy and regional geology of New Mexico (1918; 1928), outlined the geology of the San Andres Mountains and published an excellent reconnaissance geologic map of the range (1928). This map illustrates the generally homoclinal structure of the range and describes some of the structural complications at both the south and north ends. The map is also an excellent source for some place names no longer in common use. In 1918 and again in 1928, Darton discussed the Devonian strata, all placed within the Percha Shale, and noted faunas collected from Capitol Park and Lava Gap in the north part of the range. Lava Gap is presently shown on the 1981 Sheep Mountain 7[1]/2-min quadrangle, but was named Thoroughgood Canyon on the 1947 Capitol Peak 15-min quadrangle and, more recently, Thurgood Canyon on the 1981 version of the Salinas Peak 7[1]/2-min quadrangle. Darton noted that the Devonian faunas collected in the San Andres Mountains differed from those collected farther west in the Percha Shale, with fewer elements in common with the fauna of the Ouray Limestone of Colorado and "more of the forms characteristic of the Martin limestone and Nevada limestone" (1918, p. 46).**

**Stevenson proposed the name "Sly Gap Formation" in an abstract (1941). In a major paper (1945), he discussed all Devonian units of New Mexico and proposed, clearly defined, illustrated, measured, and described type sections for the Oñate, Sly Gap, and Contadero Formations, and for the Ready Pay and Box Members of the Percha Shale. Thus, Stevenson did more than any other geologist to clarify the Devonian strata, their dominant faunas, and their mutual relationships. He established a stratigraphic framework that can be utilized essentially as he defined it, although minor modifications have been made. Stevenson showed remarkable insight into the faunal zonation, physical stratigraphy, and correlation of his units.**

**Stainbrook (1935, 1947, 1948) described brachiopods and solitary corals from exposures of the Sly Gap Formation in the Sacramento Mountains (1935, 1948) and brachiopods from the Percha Shale (1947). In the 1947 paper, he included Contadero brachiopods from Rhodes Canyon, which he mistakenly ascribed to the Percha Shale. The Contadero faunas are considerably older than the upper Percha brachiopod faunas described by Stainbrook. In general, his reporting is marred by field collections that included both Devonian and Mississippian float specimens in the Percha fauna and by insufficient attention to Stevenson's stratigraphic framework for Devonian beds in the San Andres Mountains.**

**Fritz (1944) reported on Devonian bryozoans, including some from the Sly Gap and Oñate Forma-**

TABLE 1—Evolution of stratigraphic nomenclature of Devonian rocks in the northern San Andres Mountains.

| Stage | System | Darton, 1928 San Andres Mountains | Stevenson, 1945 Northern San Andres Mountains | Kottlowski and others, 1955 Northern San Andres Mountains | Flower, 1958 Northern San Andres Mountains | Bowsher, 1967 San Andres Mountains | Cooper & Dutro, 1982 Northern San Andres Mountains | Sorauf, this paper Northern San Andres Mountains | |
|---|---|---|---|---|---|---|---|---|---|
| Famennian | Upper Devonian | Percha Formation | Contadero Formation | Percha Formation | Rhodes Canyon Formation | Rhodes Canyon Formation | Rhodes Canyon Formation | Rhodes Canyon Member | Contadero Formation |
| | | | | | Thoroughgood Formation | Thorogood Formation | Thoroughgood Formation | Thurgood Member | |
| Frasnian | | | Sly Gap Formation | Contadero Formation | Contadero Formation | Contadero Formation | Contadero Formation | Salinas Peak Member | |
| | | | | Sly Gap Formation | Sly Gap Formation | Sly Gap Formation | Sly Gap Formation | Sly Gap Formation | |
| Givetian | Middle Devonian | | Oñate Formation | Oñate Formation | Oñate Formation | Oñate Formation | Oñate Formation | Oñate Formation | |
| | | | | | | | | | |

tions. Especially important is the common bryozoan of the Oñate named *Sulcoreteopora anomalotruncata* by Fritz, but referred to as *Cystodictya* by Cooper and Dutro (1982).

Laudon and Bowsher, in their excellent study of the Mississippian formations of southern New Mexico (1949), also included considerable data on the Devonian strata, largely as graphic presentations of these rocks where they occur with the Mississippian formations. They measured sections of the Devonian from the Sacramento and Franklin Mountains and from 10 localities in the San Andres Mountains. These data constitute an important source of information on the Devonian strata of the San Andres Mountains.

Kottlowski (1955) presented a synopsis of the geology of the San Andres Mountains with a major emphasis on stratigraphy, including a resume of the Devonian stratigraphy as known at that time. A year later, Kottlowski and others (1956) published a memoir on stratigraphic studies of the complete sedimentary sequence of the San Andres Mountains and included measured sections of Devonian strata in Rhodes, Hembrillo, and Ash Canyons. This study remains a basic reference on the geology of the San Andres Mountains. Kottlowski (1963) summarized the extent and fades of Devonian rocks of southern New Mexico and presented an isopach and lithofacies map of the Devonian strata.

Flower, in a series of short papers (1955, 1958, 1959, 1965, 1969), did much to increase understanding of the Devonian stratigraphy of southern New Mexico by clarifying age relationships of stratigraphic units. He restricted the Contadero Formation of Stevenson and proposed the Thoroughgood and Rhodes Canyon Formations for overlying late Late Devonian (Famennian) beds. These last two units are regarded herein as members of the Contadero Formation.

Bowsher (1967) also reported on the general geology, thickness, and fades distribution of the Devonian rocks of New Mexico, summarizing his understanding of these strata gained through field studies over a period of 30 yrs in the company of Laudon, Stevenson, Cooper, and others.

Two regional studies in neighboring areas that have shed further light on Devonian rocks of the San Andres Mountains are descriptions by Pray (1961) of the Paleozoic stratigraphy of the Sacramento Mountains and mapping by Seager (1981) of the general geology of the southernmost San Andres Mountains and more southerly ranges. Pray described north—south regional variations of Devonian strata along the front of the Sacramento Mountains as being similar to those seen in the San Andres Mountains to the west.

The latest study dealing with Devonian strata and faunas of southern New Mexico is the excellent report by Cooper and Dutro (1982), who thoroughly examined and elucidated regional aspects of the strata, determined their detailed megafossil biostratigraphy, and introduced much conodont information in their paleontologic study of the Givetian, Frasnian, and Famennian brachiopod faunas. They also correlated the New Mexico rocks with all major North American Devonian sequences. Anyone wishing to gain an overall knowledge of the Devonian strata and faunas of New Mexico is encouraged to consult this monograph.

# Stratigraphy

**The Devonian sequence in the San Andres Mountains is a slope-forming succession of shaly rocks, occurring between older Paleozoic cliff-forming carbonates below (Fusselman and/or Montoya Dolomite) and Mississippian cliff- and slope-forming rocks above. The Devonian sequence is best studied in gullies in the overall receding slope. This thin sequence, ranging from 21-28 m (69-92 ft) thick in the south to 4555 m (148-180 ft) thick in the north, is interesting because of excellent faunas and highly variable strati-graphic units.**

**In the northern and central San Andres Mountains, the following lithostratigraphic units are recognized (in ascending order): Oñate Formation, Sly Gap Formation, and Contadero Formation. Of these, only the Contadero is divided into members that, however, are recognizable only in the northern part of the range. They are (in ascending order): Salinas Peak Member, Thurgood Sandstone Member, and Rhodes Canyon Member. In the southern part of the San Andres Mountains, shallow-water, carbonate-rich fades change into basinal, black shales that overlie reduced thicknesses of Oñate Formation.**

## Oñate Formation

**Stevenson (1945, p. 222) named the Oñate Formation for 26 m (85 ft) of siltstones, shale, very fine sandstone, and limestone exposed in San Andres Canyon in the south-central San Andres Mountains (SW 1/4 sec. 18, T. 18 S., R. 4 E., Bear Peak 15-min quadrangle). At the type section, this sequence is characterized by abundant bryozoan and brachiopod faunas and contains more limestone beds than do outcrops of the Oñate Formation either north or south of San Andres Canyon. The Oñate Formation, thickest at San Andres Canyon, was measured for this study as 21 m (69 ft), with measurements by others somewhat thicker; it thins in all directions, with thicknesses slightly in excess of 10 m (33 ft) at Dead Man and Lost Man Canyons and from 6 to 9.5 m (20-31 ft) in the area to the north within the San Andres Mountains. South of San Andres Canyon, thicknesses are 2.25-2.5 m (7.4-8.2 ft) in Ash and Bear Canyons (Fig. 1). Where the Oñate is less than 10 m (33 ft) thick, more uniform lithologies consist of brown-weathering, angular beds of flaggy, dolomitic silt-stones, very fine sandstones, and silty dolomites that form stair-step outcrops in gullies above the massive dolomites of the Fusselman or Montoya Dolomite. Subordinate amounts of silty shale in the lower Oñate increase upward toward the contact with the overlying Sly Gap Formation (Fig. 3).**

**Oñate Formation beds have been recognized throughout the San Andres Mountains. Stevenson (1945, p. 230) failed to recognize the Oñate dolomites north of Rhodes Canyon; instead, he noted a 5-ft- (1.5-m-) thick "porphyritic sill," which is the Oñate Formation, between the Sly Gap and Montoya Formations at Sly Gap. Kottlowski (1955, p. 140) recognized that the Oñate is the most extensive of the Devonian units and, in fact, is the unit of Devonian age comprising the 5 ft- (1.5m-) thick sandy interval in the Oscura Mountains just northeast of the San Andres Mountains. In the same paper, Kottlowski (1955, p. 140) stated that the Oñate rests on older units with marked regional unconformity, a fact recognized by geologists since the time of Darton (1928). Kottlowski also noted that the base of the Oñate is commonly marked by an undulating, silicified, ferruginous surface. This siliceous and ferruginous crust was noted in Ash, Salt, and Bear Canyons at the south end of the San Andres Mountains (Fig. 2), while iron staining or measurable relief was noted on the pre-Devonian surface in all sections to the north where suitable exposures were present (Fig. 4). At Salinas Peak, a 42-cm (17-inch)-thick bed of black, chert-pebble conglomerate that occurs at the base of the Mate lies directly on Montoya Dolomite and is characterized by a medium-grained, quartzose-sandstone matrix. The upper limit of the formation is drawn at the highest**

FIGURE 3—Oñate Formation, showing complete section of brown-weathering dolomites and siltstones, with Sly Gap strata beginning at shoulder level of the geologist. Sly Gap locality on the south flank of Sheep Mountain.

FIGURE 4—Basal dolomites of the Oñate Formation showing relief on top of Montoya Group below hammer level. Photo taken on north side of Sheep Mountain.

FIGURE 5—Upper siltstone and shale sequence of the Oñate Formation, with basal Sly Gap beds above step-forming siltstone at upper left of photo. Rhodes Canyon locality.

**occurrence of dolomitic siltstones or sandstone of Oñate lithology and beneath tan- or greenish-weathering shales that yield the typical Sly Gap faunas of brachiopods and the solitary coral *Pterorhiza* (formerly *Macgeea).***

## Lithology

**Oñate Formation lithologies are generally carbonate-rich, fine-quartzose clastics that range from silty, dolomitic limestones through silty dolomites and fine sandstone to silty shales. In the northern part of the San Andres Mountains, the Oñate generally is characterized by a lower, angular, rusty brown-weathering unit of either silty dolomite or dolomitic siltstones and by an upper unit containing silty shales with interbedded sandstone, as shown by the upper Oñate in Rhodes Canyon (Fig. 5) and on Sheep Mountain at Sly Gap (Fig. 3). In this section, the thicker beds are generally coarse siltstones with dolomitic cement, occasional brachiopod fragments, and obvious burrows (Fig. 6). Throughout the study area, Oñate Formation sandstones and mudstones are commonly burrowed (Fig. 7); silt-sized quartz grains are commonly absent, but silt- or fine-sand-sized dolomite rhombs are present instead (Fig. 8). Dolomites, where present in rock-forming proportions, commonly consist of silt-sized, rhomb-shaped crystals (Fig. 6). The coarse siltstones also commonly contain feldspar grains that are fresh in appearance but have corroded margins.**

**In San Andres Canyon, the Oñate is anomalously rich in limestone. This section is not only the thickest in the San Andres Mountains, but also has much more limestone and interbedded shale than do other areas of the range. The limestones, rich in crinoidal debris and bryozoans, are classified as skeletal wackestones (Figs. 9 and 10). The calcareous-argillaceous nature of the lower part of this sequence is reminiscent of more westerly outcrops of the Oñate, such as those in the Mud Springs Mountains discussed below. The upper 4 m (13 ft) of the type section in San Andres Canyon is very fine, brown-weathering sandstone; some is massive and some has ripple laminations. This unit is much less fossiliferous than those below.**

## Fauna

**The Oñate Formation has three major faunas at its type section. The basal beds (5-6 m; 16-19 ft) yield very abundant, small brachiopods belonging to the genera *Rhyssochonetes, Echinocoelia,* and *Emanuella.* The large rhynchonellid *Platyterorhynchus* and the bryozoan *Cystodictya* occur above the small brachiopods.**

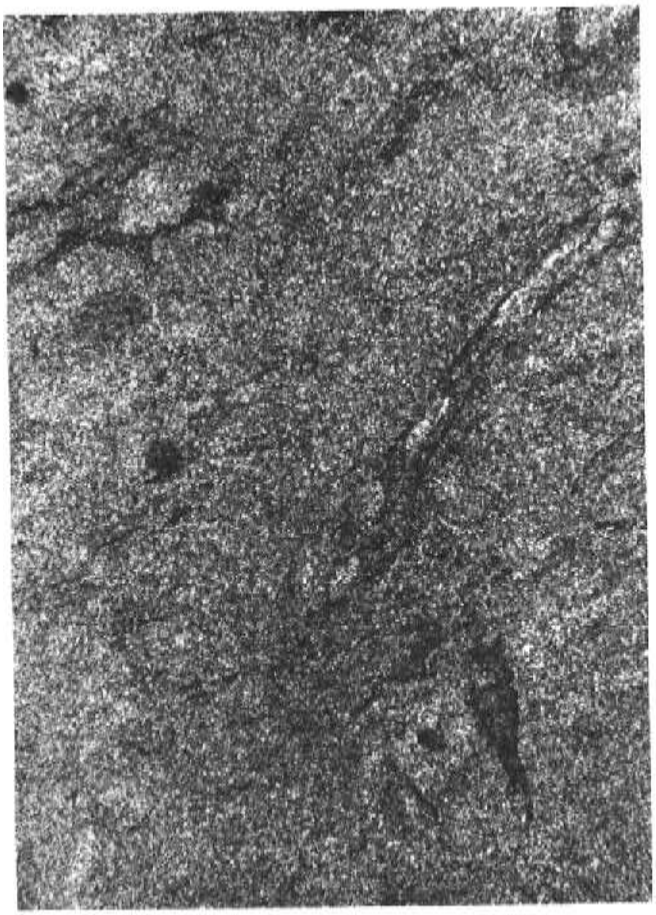

FIGURE 6—Burrowed, coarse siltstone of the Oñate Formation, 1 m (3.3 ft) above base of formation. Sample from Sly Gap, on the south flank of Sheep Mountain. Non-polarized light, ×5.

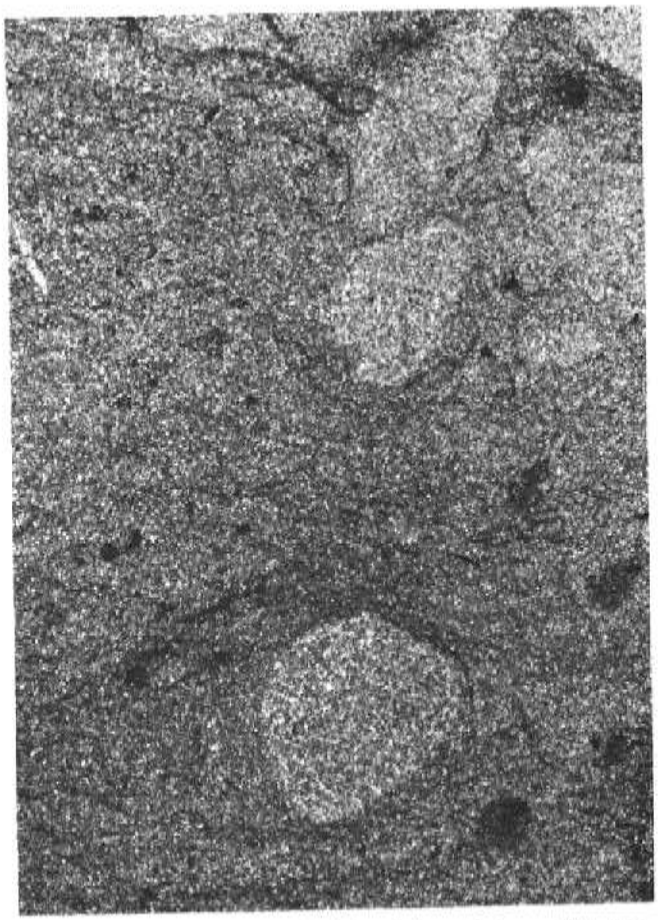

FIGURE 7—Silty, burrowed, dolomitic mudstone of the Oñate Formation, 2.3 m (7.5 ft) above base of formation. Non-polarized light, ×7.5. Hembrillo Canyon locality.

**The upper fossiliferous beds at the San Andres Canyon section are characterized by the atrypids *Desquamatia* and *Atryparia,* as well as abundant *Schizophoria* and less abundant *Warrenella.* Bryozoans, especially *Cystodictya,* are present throughout, becoming more abundant upwards within the zone. The uppermost part of the formation is apparently barren of macro-fauna. A number of other brachiopods, crinoids, bryozoans, and the tabulate coral *Aulopora* occur along with those genera noted above. The named genera are useful for recognition of informal biostratigraphic units within the Oñate Formation, as indicated by Cooper and Dutro (1982, p. 10).**

**As I traced the Oñate Formation south of the type area, I noted only the brachiopods *Echinocoelia* and *Emanuella* of the basal unit (without *Rhyssochonetes)* in the uppermost beds of the Oñate at Bear Canyon, although Cooper and Dutra also report *Platyterorhynchus* at Bear Canyon (1982, p. 141). To the north in the San Andres Mountains, the *Platyterorhynchus fauna* was seen in Dead Man, Hembrillo, and Cottonwood Canyons, but not farther north. More northerly exposures proved to be much more sparsely fossiliferous or unfossiliferous, with the exception of Capitol Peak where the genus *Tropidoleptus* is found, as previously reported by Darton (1928) and by Cooper and Dutro (1982, p. 11). Kottlowski and others (1956, p. 29) reported the occurrence of a number of brachiopods at Hembrillo and Rhodes Canyons and at Sly Gap. The Oñate Formation at Hembrillo Canyon and Sly Gap also yielded the characteristic bryozoan *Sulcoreteopora* (now referred to as *Cystodictya).***

**The section in the Mud Springs Mountains west of Truth or Consequences (Figs. 1 and 11), which has a shalier facies than is typical of the Oñate Formation in the San Andres Mountains, was studied in order to understand regional variation. The Oñate fauna in the Mud Springs Mountains is also characterized by the small brachiopod *Rhyssochonetes* in the basal 2-3 m (6.5-10 ft), followed by remarkably abundant and well-preserved faunas of large brachiopods, crinoids, corals, and receptaculitids throughout the remaining 10 m (33 ft) of the Oñate sequence. The lower portion of this fauna is characterized by abundant occurrences of the receptaculitid genus *Sphaerospongia* in the so-called "sponge beds," mistakenly regarded as Sly Gap by Stevenson (1945, p. 237). This abundant fauna also contains the brachiopods *Schizophoria, Desquamatia, Dichacaenia,* and *Nervostrophia,* and the crinoid *Melocrinites* sp., along with the bryozoan *Cystodictya,* among others. A new species of the rugose coral *Tabulophyllum* is also present. The brachiopod fauna has been fully described by Cooper and Dutro (1982).**

**Still farther west, at Hermosa, the Oñate (Fig. 11)**

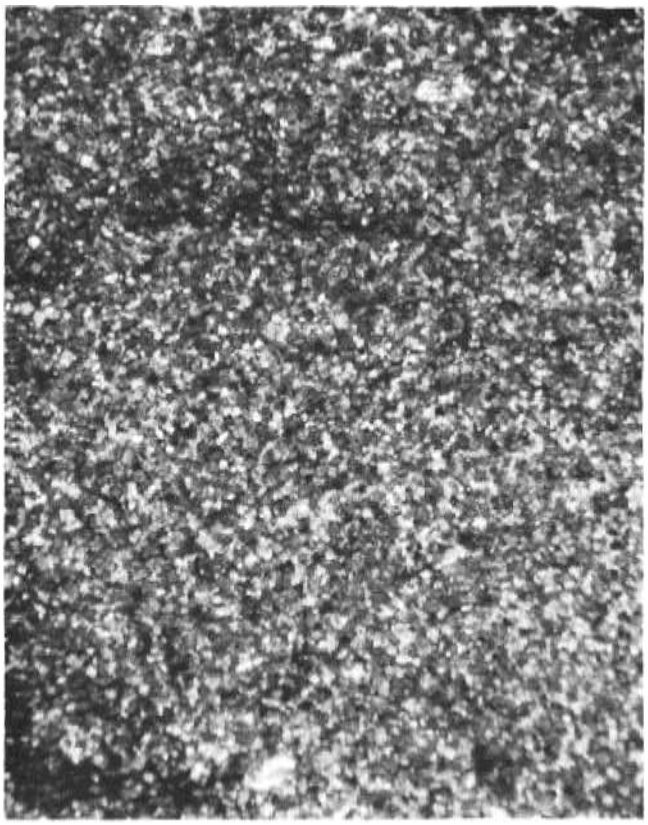

FIGURE 8—Sand grains and dolomite rhombs in dolostone in lower part of Oñate Formation. Partly cross-polarized light, ×24. Hembrillo Canyon locality.

FIGURE 10—Oñate Formation wackestone (same sample as Fig. 9), with the bryozoan *Cystodictya*. Partly crossed polarizers, ×25. San Andres Canyon locality.

FIGURE 9—Medial skeletal wackestone of the Oñate Formation containing abundant crinoid columnals and bryozoans. Plane-polarized light, ×15. San Andres Canyon locality.

**is characterized by the presence of *Rhyssochonetes* in its basal 2 m (6.5 ft), with *Cystodictya* and several brachiopod genera occurring above (Cooper and Dutro, 1982, p. 11).**

## Regional variation

**The stratigraphic correlation diagram (Fig. 2) summarizes the primary changes within the silty and dolomitic Oñate Formation in the San Andres Mountains. In the northern part of the San Andres Mountains, from Sheep Mountain (Sly Gap) to Cottonwood Canyon, the thickness of the formation ranges from 5.5 to 9.5 m (18-31 ft), gradually thickening to the south, but several depositional units can be traced throughout. The formation in this area is characterized by burrowed, dolomitic, fine sandstone and siltstones, with shales subordinate in the lower part, but increasingly dominant in the upper part. North of Sheep Mountain, the Oñate is poorly exposed, but apparently thins as far as Johnson Park (Fig. 1) where it contains bivalves in the upper beds. The Oñate has been partially removed by pre-Mississippian erosion northeast of the San Andres Mountains in the nearby Oscura Mountains.**

**The Oñate, which thickens greatly from Hembrillo Canyon southward to San Andres Canyon (the type section of Stevenson, 1945), also becomes more calcareous, with shale intercalated between silty, sandy,**

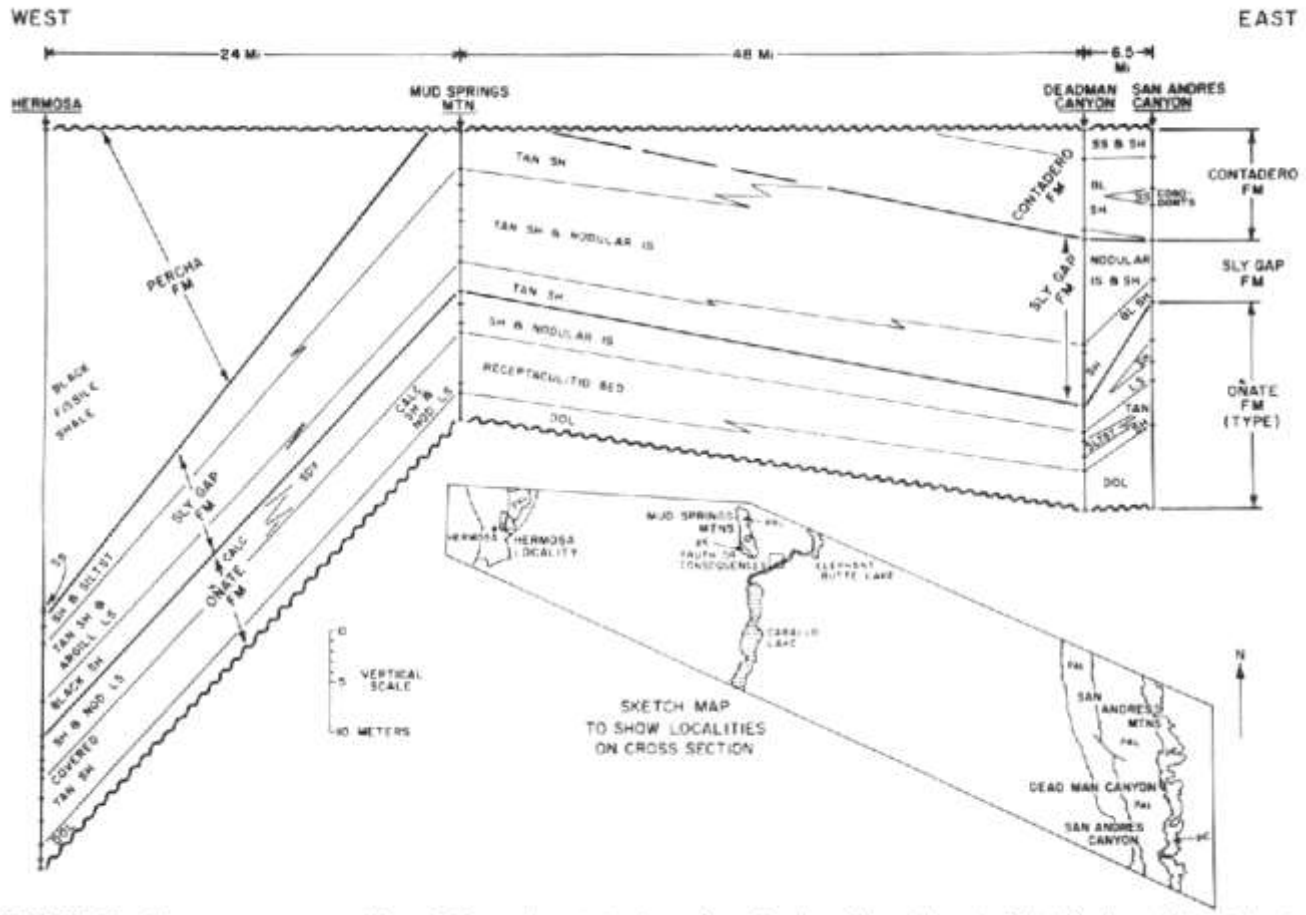


FIGURE 11—East–west cross section of Devonian strata from San Andres Mountains to Mud Springs Mountains to Hermosa, New Mexico.

and limy beds. Faunas are concurrently more abundant to the south.

At the south end of the San Andres Mountains, the Oñate is only a thin 2.5-3-m (8-10-ft)-thick remnant of the dolomitic and silty facies beneath a black-shale sequence.

The north-south variation in thickness and fades of the Oñate shown on the north-south cross section (Fig. 12) suggests the following interpretation. This section is constructed using the top of the Oñate as a datum as far south as San Andres Canyon, based on the assumption that dolomitic, quartzose, terrigenous sediments accumulated on a relatively shallow shelf and that the shelf sequence was prograding to the south where it bordered a euxinic basin during much of Oñate time. This interpretation is corroborated by the occurrence of *Platyterorhynchus* (as plotted in Fig. 12), which is progressively lower in the Oñate when traced from Cottonwood and Hembrillo Canyons to San Andres Canyon, with San Andres Canyon being close to the south margin of the constructional platform formed by the upper Oñate beds. This platform was characterized by abundant faunas of large brachiopods and abundant and varied bryozoans. South of this margin, the Oñate shallow-water sediments largely grade into euxinic, shaly, basinal sediments. Only the lower unit of the Oñate *(Rhyssochonetes* and *Echinocoelia* beds) extends as far south as Ash and Bear Canyons, while younger Mate beds have been replaced by the dark-shale facies. Evidence of this facies change, in addition to the faunal evidence just noted, consists of the presence of silty shales within the black-shale sequence at Ash Canyon (Fig. 2) and the presence of black shales within the Oñate sequence at Bear Canyon.

To the east, a similar north-south fades progression may be present in the Sacramento Mountains. Pray (1961, p. 50) measured 18-18.5 in (60 ft) of Oñate Formation in the vicinity of Dog and Escondido Canyons in the Sacramento Mountains; this thickness is less than, but similar to, the 20.5 m (67 ft) in San Andres Canyon to the west. The north-south section in Pray's figure is similar to the diagram in this report (Fig. 12); the top of the Oñate to the north of its maximum thickness appears to coincide with a rather planar Givetian-Frasnian boundary, but south of its maximum thickness, interfingering with black-shale facies may occur. Pray (1961, p. 56) did not interpret the upper Oñate boundary in this way, although he suggested that the black shale might be a lateral equivalent of both the Sly Gap and Oñate Formations in the southern Sacramento Mountains.

West of the San Andres Mountains, the Oñate Formation changes considerably, as demonstrated in sections studied in the Mud Springs Mountains and in the Palomas (Hermosa) mining district of Sierra County, New Mexico (Fig. 11).

The Oñate Formation in the Mud Springs Moun-

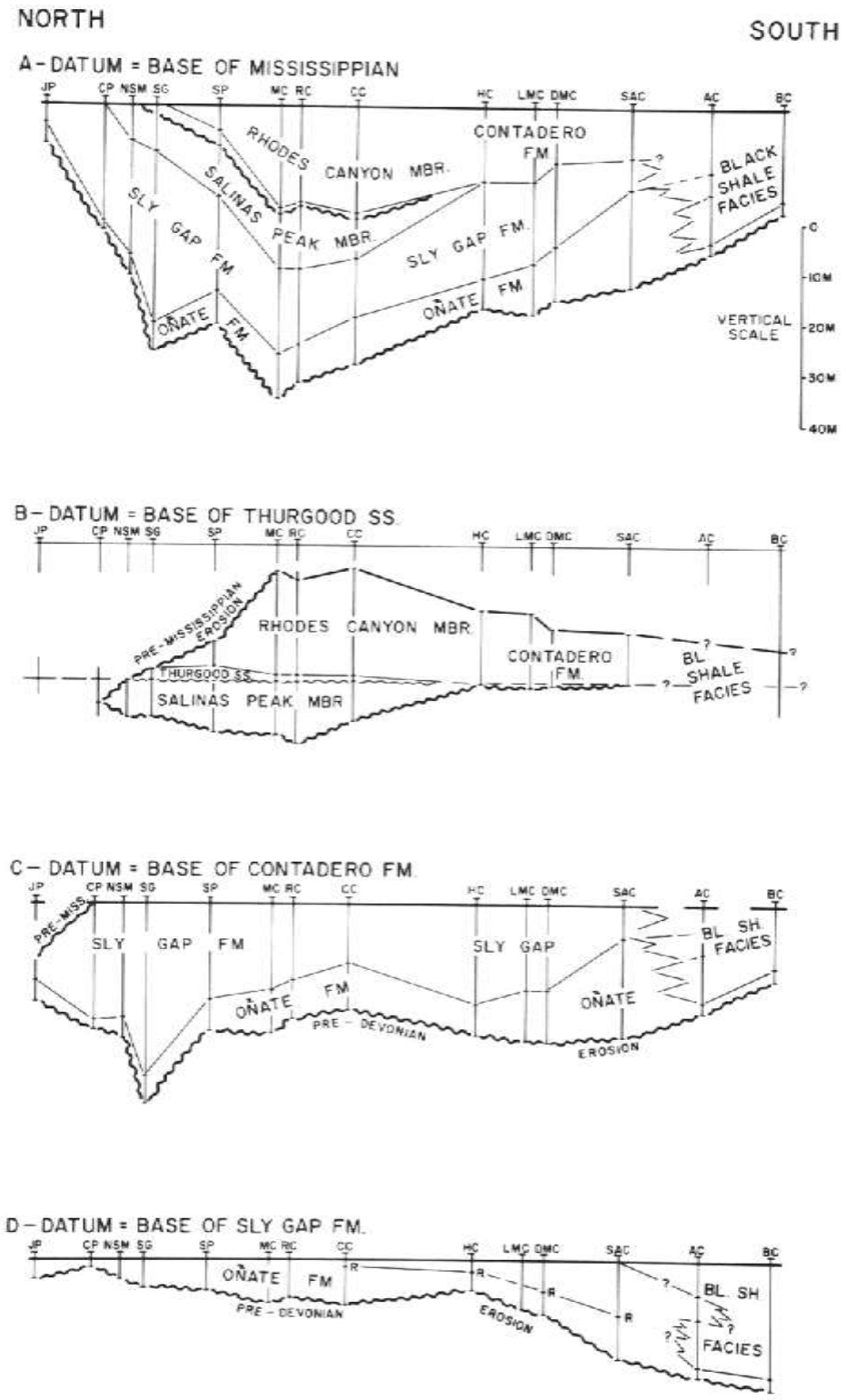


FIGURE 12—North–south summary cross sections, showing thicknesses and unconformities of Devonian strata, San Andres Mountains, New Mexico. Abbreviations for localities given in Appendix. a) Datum is base of Mississippian. Section provides summary of entire sequence; with datum chosen at top of sequence, cross section shows area of maximum development of Rhodes Canyon, Thurgood, and Salinas Peak Members of the Contadero Formation, as well as general relationship of southerly black-shale facies with stratigraphic units to the north. b) Datum is base of Thurgood Sandstone. Section illustrates subdivisions and spatial relationships of the member within the Contadero Formation. Exact relation of black-shale (southerly) facies to individual members of the Contadero is known only in general terms. c) Datum is base of Contadero Formation. Section illustrates areas of maximum development of Sly Gap beds and general equivalence between Sly Gap Formation and portion of the black-shale sequence. d) Datum is base of Sly Gap. Section illustrates southward progradational deposition of Oñate shelf carbonates, as indicated by progressively lower top of *Rhyssochonetes* occurrence. Relationships between Oñate beds and southerly black-shale facies are known only generally and need refinement.

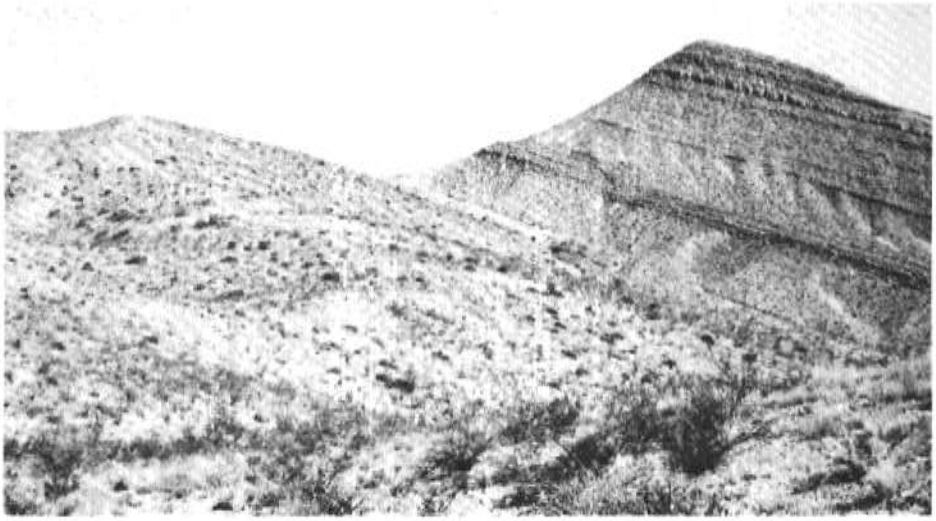

FIGURE 13—Devonian locality in Mud Springs Mountains. Peak at right is 5,505 ft elevation noted on Cuchillo 7½-min quadrangle. Slope extending from left (southwest) to right (northeast) is developed on top of Silurian carbonates. Shale slope at notch is composed of Oñate and Sly Gap Formations.

**tains is much more argillaceous than that of the San Andres Mountains. Above the basal dolomitic fades, it is largely an argillaceous, nodular limestone that is similar to the characteristic facies of the Sly Gap Formation (Figs. 13, 14, and 15). The outcrop shown in Fig. 13 is in the western part of the Mud Springs Mountains; closer to Truth or Consequences, the formation is partially or completely removed by pre-Pennsylvanian erosion. This nodular-limestone sequence within the Oñate is extremely fossiliferous and, in fact, was mistaken by Stevenson for the Sly Gap Formation (1945, p. 237). He noted that receptaculitids are found here in large numbers and that *Sphaerospongia* is abundant. In addition, the characteristic Oñate bryozoan *Cystodictya* and brachiopod fauna, with *Schizophoria, Desquamatia,* and *Dichacaenia,* are abundant. The crinoid *Melocrinites* sp., which had been reported previously from the Onate in San Andres Canyon and near Derry by Bowsher (1%7, p. 266), was also found here.**

**At Hermosa (Fig. 11), in northwest Sierra County, the Oñate again has the typical dolomitic 1.9-m (6.5-ft)-thick basal sequence containing abundant *Rhyssochonetes,* just as in the Mud Springs Mountains and throughout the southern part of the San Andres Mountains to the east. Above this basal unit, the 10-**

FIGURE 14—Closeup of Devonian section in the Mud Springs Mountains. Shaly beds forming slope below road level belong to the Oñate Formation; beds above the road are in the Sly Gap Formation. The Devonian sequence is overlain unconformably by Pennsylvanian strata forming prominent outcrop.

FIGURE 15—Oñate Formation in the Mud Springs Mountains (outcrop shown in Fig. 14), with midpoint of Jacobs staff marking horizon of receptaculitids. Extremely fossiliferous, calcareous shales and nodular limestones predominate.

**m (33-ft)-thick, brown-shale and nodular-limestone sequence lacks an abundant fauna, but contains** *Cysfodictya* **and** *Desquamatia* **noted by me, and** *Schizophoria* **and other Oñate brachiopods noted by Cooper and Dutro (1982, p. 11). The western outcrops of the Oñate are** illustrated **in Fig. 11.**

## Sly Gap Formation

**The Sly Gap Formation, which is the most widely recognized Devonian unit in the San Andres Mountains, is well known because of its superb Frasnian faunas. This richly fossiliferous formation is easily recognized in its usual facies by fossiliferous and nodular limestones interbedded with green, tan, and gray shales, many of which contain calcareous nodules.**

**The Sly Gap Formation, named in 1941 by Stevenson, is best defined in his 1945 paper on Devonian formations of New Mexico. Stevenson clearly defined the unit, presented a columnar section of the type Sly Gap, and discussed its regional variations within the Sacramento, San Andres, Caballo, and Mud Springs Mountains (1945, pp. 227-237). At the type section on Sheep Mountain on the north side of Sly Gap (Figs. 16 and 17), Stevenson (1945, p. 230, Fig. 9) divided the Sly Gap Formation into the following units:**

**L:** *Spirifer* **zone-10.5 ft (3.2 m)**
**K: Fish zone-8.4 ft (2.6 m)**
**J: Coral zone-14.8 ft (4.5 m)**
**I: Laminated brown shale-6 ft (1.8 in)**
**H: Extremely fossiliferous-35.7 ft (10.6 m)**
**G: Extremely fossiliferous (in lower 2/3)-9 ft (2.7 m)**
**F: Brown siltstone-3 ft (0.9 m)**
**E: Atrypa zone-11 ft (3.35 m)**
**D:** *Macgeea* **zone-8 ft (2.4 m)**

FIGURE 16—View from the south of Sheep Mountain. The type locality of the Sly Gap Formation and Thurgood Sandstone Member is directly above the notch in the center of the photo. In the foreground are Precambrian crystalline rocks, with the Bliss Sandstone and Montoya Group forming lower, prominent cliff at right side of photo.

FIGURE 17—Type locality of the Sly Gap Formation. The Sly Gap and Contadero Formations are well exposed in this gully on the south flank of Sheep Mountain, with Oñate Formation and Montoya Group carbonates below.

C: Brown siltstones with fragmentary fossils-9.5 ft (2.9 m)
B: Porphyritic sill-5 ft (1.5 m)
**A:** Montoya Limestone (Ordovician)

Kottlowski and others (1956, p. 29) and Cooper and Dutro (1982, p. 15) have noted that the B and C divisions of Stevenson represent the Oñate Formation, **I** and **J** may be regarded as the basal Contadero Formation, and K and **L** together probably represent the Thurgood Sandstone Member, although discrepancies and confusion exist. Units K and **L** are considerably thicker than the amount of Thurgood actually present in this section (5.8 m or 19 ft, reported thickness, versus 2.1 m or 6.9 ft, actual thickness), and unit **K** is reported by Stevenson to be unfossiliferous and shaly. Stevenson also reported that unit **J** is characterized by the presence of *Alveolites, Hexagonaria,* and *Phillipsastrea,* all colonial corals. These corals mark the uppermost unit of the Sly Gap and were likely confused by Stevenson with the abundant solitary rugose corals belonging to the genus *Tabulophyllum,* present in limestones above the barren, basal, brown shales of the Contadero at this locality. Thus, I do not regard the upper part of Stevenson's section as being correlative with the stratigraphic units recognized today. Measurements, lithologies, and faunas were apparently mixed up in reproducing this section and are not directly applicable to what can be seen on the outcrop today. Cooper and Dutro (1982, p. 15) regard the proper position of the colonial corals as being in the uppermost part of Stevenson's unit H, and this assignment seems logical. However, other problems that still exist include recognizing the older Sly Gap units **(D** through **G** of Stevenson), reconciling his published thicknesses of Sly Gap units with those measured at the outcrop, and especially recognizing units such as the well-bedded limestone of the uppermost Sly Gap in Stevenson's (1945, p. 230) published description of unit H. At this stratigraphic horizon of Stevenson's unit H, I recognized several shaly units with limestone nodules, not a well-bedded limestone.

## Lithology

The base of the Sly Gap is taken to coincide with the base of Stevenson's unit **D,** the *Macgeea* zone, which is uniformly developed with tan or green shales commonly containing small, calcareous nodules, and with the lowest occurrence of the typically Sly Gap fauna, here characterized by the presence of *Pterorhiza* (formerly referred to as *Macgeea). Pterorhiza,* a small, solitary rugose coral characterized by a crown of septa extending above the outer wall to form a ring around the calyx, is easily recognized in the field. In the San Andres Mountains, this basal shaly zone commonly has a rather abundant fauna of atrypid brachiopods, as well as the coral *Pterorhiza* that is seen throughout the entire Sly Gap Formation and is present, although rarely, in the overlying Contadero.

In the more northerly part of the San Andres Mountains (north of Cottonwood Canyon; Figs. 2 and 5), the Sly Gap Formation can be subdivided into the following lithic units (in ascending order): a basal, tan to green shale, sometimes with calcareous nodules; a medial, nodular limestone and limy shale; and an upper argillaceous and nodular limestone.

These units correspond to Stevenson's units **D** and **E** (basal shaly); **F, G,** and lower H (medial, nodular limestone and shale); and upper H (upper nodular and uppermost bedded limestone). As is shown in the cross section (Fig. 2), these units tend to vary somewhat in the northern area, especially in the middle nodular limestone and calcareous shale (Fig. 18) that varies at each locality as the limestone content of the section changes. The uppermost limestone unit is present throughout the northern half of the range, where it characteristically consists of a well-bedded sequence of limestones (Fig. 19) that contains a colonial-coral fauna in addition to the abundant upper Sly Gap brachiopod faunas. The upper limestone is generally composed of well-bedded, burrowed, crinoidal, and bioclastic wackestones (Figs. 20 and 21), with much of the rock composed of finely comminuted biodastic debris. This limestone was traced from Capitol Peak southward to Hembrillo Canyon and contained colonial corals in all sections north of Cottonwood Canyon (Fig. 2). The effects of post-Devonian erosion are seen in the northern San Andres

FIGURE 18—Sly Gap Formation. Upper shales, interbedded, thin limestones, and uppermost limestones with colonial corals at top of photo. Rhodes Canyon locality.

FIGURE 19—Uppermost, nodular limestone of the Sly Gap Formation, with colonial corals and interbedded, calcareous shales. Basal Contadero shales are present in upper one-fifth of photo. Sly Gap locality on Sheep Mountain.

Mountains at Capitol Peak, where Mississippian beds lie directly on this upper limestone of the Sly Gap (Fig. 22); farther north, at Johnson Park, only lower Sly Gap beds are preserved below the Mississippian unconformity.

South of Hembrillo Canyon, the Sly Gap Formation thins and fades change from limestones to black shales. Typical nodular limestones and shales that are noted in the upper Sly Gap are extremely fossiliferous in Dead Man Canyon (Fig. 2), where nodular limestones also contain colonial rugose corals in the upper part of the Sly Gap. San Andres Canyon is the southernmost locality where the Sly Gap nodular-carbonate facies was seen; however, although the typical Sly Gap brachiopod faunas are present, they are not as abundant as is usual. **I** did not recognize the Sly Gap Formation in the southernmost San Andres Mountains, but instead consider part of the black-shale lithosome at Ash Canyon and Bear Canyon as equivalent in age to the Sly Gap (Figs. 2 and 12).

Thickness of the Sly Gap is greatest in the northern part of the San Andres Mountains and normally approaches 20 m (65 ft), with 22.9 m (75 ft) at Capitol Peak, 22.5 m (74 ft) at North Sheep Mountain, and 18.9 m (61.8 ft) at Salinas Peak, thinning to 16.8 m (55 ft) at Mackinson Canyon and 15 m (49 ft) at Rhodes Canyon. Cooper and Dutro (1982) report thicknesses of approximately 20 m (65 ft) at Sly Gap, on the south flank of Sheep Mountain, while the section there, measured twice during this study, was over 30 m (96 ft) thick (Fig. 2). Possibly this section was measured across an unrecognized area of slumping or faulting in the middle part of the Sly Gap. However, all units are present, whether overly thick or not.

The contact of the Sly Gap Formation with the overlying Contadero Formation is easy to recognize because the limestones of the Sly Gap are overlain by tan, fissile shales that are sometimes sandy at the base and weather red. The contact shows no erosional features and apparently represents a planar surface developed on calcareous shelf sediments. As the Sly Gap is traced south from Hembrillo Canyon, the calcareous nature of its uppermost unit vanishes, with well-bedded limestone no longer present. Instead, dark shales of Contadero age first rest directly on nodular limestones of the Sly Gap, and then the limy fades disappears completely in the basin filling of dark mud.

## Fauna

The brachiopod fauna of the Sly Gap has been exhaustively studied and reported by Cooper and Dutro (1982). This fauna consists of 66 species of brachiopods belonging to 38 genera described and **illustrated**

FIGURE 20—Burrowed crinoidal wackestone of the Sly Gap Formation, approximately 3.3 m (11 ft) below top of formation. Non-polarized light, ×7.5.

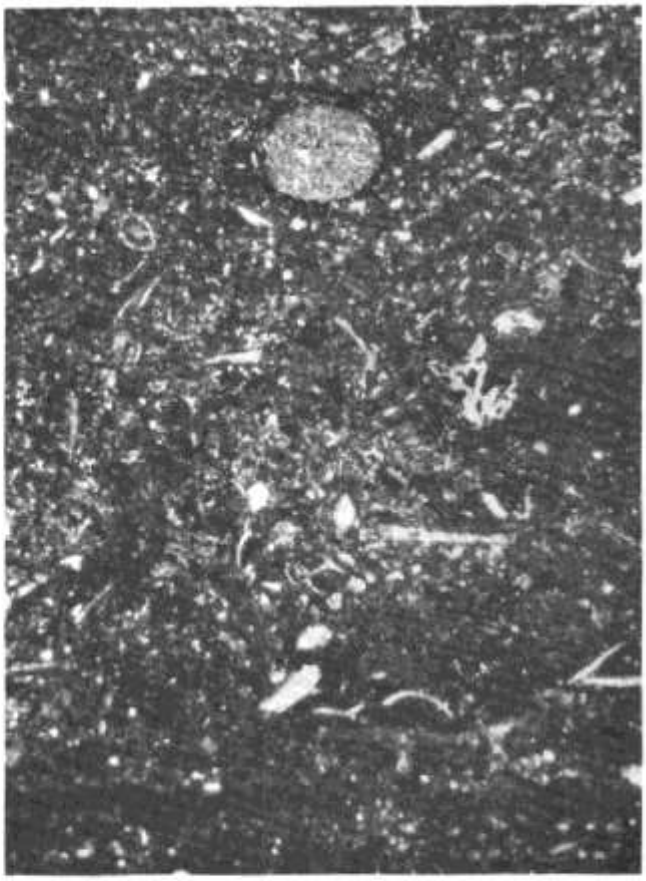

FIGURE 21—Uppermost limestone of the Sly Gap Formation, composed of burrowed lime mudstone with scattered *Tentaculites*, finely comminuted brachiopod fragments, and crinoidal debris. Burrows are horizontal. Partly crossed polarizers, ×10. Cottonwood Canyon locality.

**by these authors, making this the best known Frasnian brachiopod fauna in the world.**

**Cooper and Dutro (1982) recognized five faunal zones of the Sly Gap in the northern San Andres Mountains, with each zone roughly corresponding to the zones of Stevenson (1945). They are, in ascending order: the *Macgeea* zone, *Atrypa* zone, lower brachiopod zone, upper brachiopod zone, and colonial-coral zone.**

**The uppermost Sly Gap Formation, the colonial-coral zone, contains massive colonial rugose corals belonging to the genera *Phillipsastrea* (or *Pachyphyllum?), Hexagonaria,* and *Iowaphyllum.* The first two are noted at most localities in the northern San Andres Mountains, while *Iowaphyllum* was collected only on Capitol Peak, at the northernmost outcrop seen of the colonial-coral zone. *Phillipsastrea* (or *Pachyphyllum?)* was found as far south as Dead Man Canyon (Fig. 2), where the species shows colonial shapes that are exceedingly thin and saucer shaped, suggesting that the corals were living at their extreme limits of tolerance to unfavorable environmental conditions. The tabulate coral genus *Alveolites* is also abundant in this uppermost unit and commonly can be found where the colonial rugosans are absent. Several kinds of solitary corals are likewise found at the top of the Sly Gap, including a large *Tabulophyllum* and the common *Pterorhiza.* The latter is generally referred to as *Macgeea* in American literature on Devonian biostratigraphy, although this name is a junior synonym of *Pterorhiza.***

**The upper and lower brachiopod zones contain the rich and varied faunas that are so typical of the Sly Gap Formation. These faunas, beautifully illustrated and described by Cooper and Dutro (1982), contain a wide variety of forms including *Nervostrophia, Douvillina, Costatrypa, Spinatrypa, Pseudatrypa, Productella, Tylothyris, Thomasaria, Indospirifer,* and *Cyrtospirifer,* as well as a variety of rhynchonellids, including *Hypothyridina.* The brachiopods are commonly accompanied by solitary corals belonging to *Pterorhiza* and, more rarely, *Charactophyllum.***

**Two ammonoid cephalopods, identified as *Manticoceras* sp. by Brian Glenister of the University of Iowa (written communication, 1979), were found at two levels within the type section of the Sly Gap by the author and Stephen Hook. They were collected 3 m (10 ft) and 9.75 m (32 ft) above the base of the formation; thus, the two specimens are within the *Macgeea* and *Atrypa* zones of Stevenson (1945) and Cooper and Dutro (1982). The genus is regarded as a reliable indicator of Frasnian age, as are the brachiopods and corals of the Sly Gap Formation. Cooper and Dutro (1982, p.15) reported *Manticoceras* from the upper brachiopod zone of the Sly Gap, as did Kottlowski and others (1956, p. 29).**

FIGURE 22—Sly Gap and Oñate Formations forming slope below Mississippian strata that create low cliff in center of photo. Upper Sly Gap beds with colonial corals are exposed directly beneath the Mississippian carbonates. Capitol Peak locality.

FIGURE 23—Sly Gap Formation, showing typical, nodular, argillaceous limestones interbedded with tan shales containing calcareous nodules. Staff is marked in tenths of meters. Mud Springs Mountains locality.

Underlying the brachiopod zones is a zone containing highly abundant but more restricted faunas characterized by *Costatrypa.* The basal Sly Gap faunas that are characterized by *Pterorhiza* also contain some scattered atrypid and rhynchonellid brachiopods.

As noted by Cooper and Dutro (1982, p. 18), these zones seem to remain fairly constant in the northern and central San Andres Mountains. As the Sly Gap is traced south from Cottonwood Canyon, the distinctions between zones tend to blur as the strata become rather less fossiliferous, but characteristic brachiopod faunas, along with *Pterorhiza,* are found in argillaceous, nodular limestones as far south as Dead Man Canyon.

## Regional variation

The Sly Gap Formation extends both east and west of the San Andres Mountains. It is present in the Sacramento Mountains to the east and in the Caballo Mountains and Mud Springs Mountains to the west and also has been identified in the Hermosa mining district of westernmost Sierra County.

In the Mud Springs Mountains, the Sly Gap Formation is 16.6 m (54 ft) thick, similar in thickness to sections at the same latitude within the San Andres Mountains. Here, the Sly Gap Formation is shalier (Figs. 11 and 23) and less fossiliferous than in the northern San Andres Mountains. Nodular limestones in the upper middle part of the formation yielded *Spinatrypa, Pseudatrypa, Thomasaria, Indospirifer,* and *Productella,* a fauna suggestive of the brachiopod zones for the typical Sly Gap. The coral fauna of the upper Sly Gap is not well developed. Stevenson (1945, p. 237) noted that fine exposures of the Sly Gap are present in the Mud Springs Mountains, but he failed to recognize the (Mate brachiopod faunas and placed the *Receptaculites-bearing* sequence within the Sly Gap. As noted above, this is a shaly western facies of the Oñate Formation.

The farthest westward extension of the Sly Gap Formation is in the Palomas mining district at Hermosa, in westernmost Sierra County, approximately 24 mi (39 km) west of the Mud Springs Mountains locality. The Sly Gap is thin (12 m or 39 ft) and argillaceous here but contains some argillaceous limestones yielding Sly Gap brachiopods. The Sly Gap is overlain by black Percha Shale at Hermosa, with a basal sandstone containing Famennian conodonts (Cooper and Dutro, 1982, p. 26).

The Sly Gap Formation is well exposed in a series of sections in the Sacramento Mountains to the east

of the San Andres Mountains. The unit has been studied here in some detail by Stevenson (1945), Laudon and Bowsher (1948), Pray (1961), and Cooper and Dutro (1982). The fades and faunal zones developed in the Sacramento Mountains are similar to those seen in the San Andres Mountains, except that the upper unit containing colonial corals is not present. Post-Sly Gap erosion has apparently been more severe in the Sacramento Mountains than farther west, and Cooper and Dutro (1982, p. 30) report the presence of Caballero Formation (Mississippian) beds directly overlying the Oñate south of Mule Canyon in the Sacramento Mountains. Pray (1961, p. 50) regarded these beds as Percha Shale, which he showed lying directly on the Oñate in this area. For discussion of facies and zonation of these units in the Sacramento Mountains, the reader is referred to the writers listed above.

# Nomenclature: Post-Sly Gap strata of the San Andres Mountains

This sequence of rocks presents nomenclatural problems for several reasons. The sequence can be divided by age, as it is partly late Frasnian and partly Famennian in age. In the northern San Andres Mountains, the sequence can be subdivided into units traceable from Cottonwood Canyon to Sheep Mountain, where units were removed by pre-Mississippian erosion.

The post-Sly Gap strata of the San Andres Mountains were included in the Contadero Formation by Stevenson (1945, p. 239) and were named for what he called the Contadero political division, which included Rhodes Canyon in the northern San Andres Mountains. The eastern portion of Rhodes Canyon is the location of the Contadero type section, as proposed by Stevenson in sec. 8, T. 13 S., R. 4 E. (1945, p. 239); this is the same locality described by Kottlowski and others (1956, p. 98) and by me in this report. Stevenson (1945, p. 239) included in the Contadero Formation all strata between the Sly Gap Formation below and the Mississippian rocks above.

Flower (in Kottlowski and others, 1956, p. 30) proposed a revision of Stevenson's Contadero Formation so that, at its type section in Rhodes Canyon, the base would be extended downward to include barren, silty shales that were formerly regarded as part of the Sly Gap Formation by Stevenson. The top was lowered to exclude upper beds containing a Famennian fauna. The result was to restrict the name "Contadero" to a unit that has little in common with the Contadero Formation of Stevenson (1945). In reality, only the 2.25-m (7.4-ft)-thick limestone at the base of Stevenson's type section coincides with the same unit at the top of the Contadero Formation as revised by Flower in 1958. Flower (1955, 1958, 1959, 1965) proposed that the Contadero Formation (as restricted) was overlain by younger beds of Percha and Three Forks age; these units were informally named• the Thoroughgood Formation and the overlying Rhodes Canyon Formation. The units have their type sections at Sly Gap and in Rhodes Canyon, respectively. They represent a lower sandstone and an upper siltstone shale sequence and are recognizable only in the northern San Andres Mountains. The sandstone unit is traceable northward from Cottonwood Canyon as far as the north flank of Sheep Mountain, where it is present only as an erosional remnant beneath the Mississippian disconformity. The upper unit, the Rhodes Canyon Formation, can be traced from Cottonwood Canyon north as far as Salinas Peak but is absent north of there as a result of pre-Mississippian erosion.

Flower took the name "Thoroughgood" from the 1947 topographic map of the Capitol Peak 15-min quadrangle. On this map, Thoroughgood Canyon is the east-west-trending canyon on the north side of Sheep Mountain, near the center of the quadrangle. The name was used by Flower in a number of guidebook articles (1955,1958, 1959, 1965) and was also utilized by Cooper and Dutro (1982). Bowsher (1967, p. 259) used another spelling variation "Thorogood" for the same unit. The name is a modification of the family name "Thurgood," taken from Thurgood ranch shown on the geologic map of Darton (1928). The canyon north of Sheep Mountain is labeled Lava Gap on Darton's map. The 1981 topographic map of the Salinas Peak 7 1/2-min quadrangle shows Thurgood well on the old ranch and names the upper reaches of the canyon as "Thurgood Canyon." The 1981 Sheep Mountain 7 1/2-min quadrangle map reverts to Dar-ton's usage of Lava Gap for "Thoroughgood Canyon" on the north side of Sheep Mountain. I am choosing to modify the spelling for the named sandstone in the Contadero Formation, substituting "Thurgood" for the "Thoroughgood" spelling of Flower (1959). This conforms to the earlier usage of Darton (1928) and modern usage by the U.S. Geological Survey.

These two units mark important changes in lithology and reflect major biostratigraphic breaks. I agree with Flower (1958, 1959, 1969) that the units deserve formal differentiation but am not following his usage as to rank. The Thurgood Sandstone Member, traceable for only approximately 18 mi (29 km), is not recognizable in the Devonian sequence east or west of the San Andres Mountains. The Rhodes Canyon For-

FIGURE 24—Middle sandstones of the Salinas Peak Member of Contadero Formation are very fine grained, thinly laminated with ripple laminae and burrows, and interbedded with tan, fissile shales. North Sheep Mountain locality.

FIGURE 25—The Salinas Peak Member of the Contadero Formation is composed of basal, tan, fissile, reddish-weathering shales lying on flaggy Sly Gap limestones in lower part of photo. Rhodes Canyon locality.

**mation can be recognized only as a lithic unit along with the Thurgood Sandstone beneath it. North of Salinas Peak, the Rhodes Canyon Formation is completely removed by pre-Mississippian erosion. Differentiation of these units is useful to emphasize changes in fauna, local erosional breaks, and the differing local character of Famennian strata in the northern San Andres Mountains. Thus, I regard the units as formal but have retained them as members of the Contadero Formation as defined by Stevenson (1945) in most places and as amended by Flower (1955) to include the older beds in the Rhodes Canyon area. The basal member of the Contadero Formation is here named the *Salinas Peak Member* for Frasnian shales, siltstones, and overlying limestones bearing abundant solitary corals. The Salinas Peak, Thurgood, and Rhodes Canyon Members can be recognized as separate units of the Contadero only north of Hembrillo Canyon. In the southern San Andres Mountains, the Contadero Formation can be recognized only as far south as San Andres Canyon, coincident with the southward extent of the Sly Gap lithologies. In sections studied at Ash Canyon and Bear Canyon, differentiating Sly Gap and Contadero beds was not possible because the Upper Devonian sequence is totally composed of dark fissile shales.**

**Thus, formal members of the Contadero Formation recognized from Cottonwood Canyon northward are (in ascending order): Salinas Peak Member, Thurgood Sandstone Member, and Rhodes Canyon Member.**

## Salinas Peak Member

**The Salinas Peak Member is here proposed as a formal name for the lower Contadero Formation in the northern San Andres Mountains. The name is equivalent to the Contadero Formation of Flower (1955, 1958, 1959, 1965) within this northerly area. The type section of the Salinas Peak Member, listed as locality 5 in the Appendix, is located on the southwest flank of Salinas Peak, in the Salinas Peak 15-min quadrangle, Socorro County, New Mexico. At the type locality, the Salinas Peak Member consists of a basal, soft, tan shale (2.4 m or 7.9 ft) that is red in its lower part and is overlain by approximately 3 m (10 ft) of flaggy sandstone similar to that below. The unit is capped by nodular, argillaceous, blue-gray limestone with abundant, large, solitary corals of the genus *Tabulophyllum* (Fig. 2); the limestone, only 0.6-0.7 m (2-2.3 ft) thick, is an erosional wedge-edge beneath the Thurgood Sandstone Member.**

FIGURE 26—Middle unit of the Salinas Peak Member, composed of interbedded shales and well-indurated, tan siltstones and very fine sandstones. Sly Gap locality.

FIGURE 27—Middle unit of the Salinas Peak Member of the Contadero Formation, showing interbedded, tan, very fine sandstone to siltstones and tan shales. Staff is marked in tenths of meters. Rhodes Canyon locality.

The Salinas Peak Member is recognizable from the north side of Sheep Mountain (Fig. 24) southward to Cottonwood Canyon but is not separated from the rest of the Contadero Formation south of the pinchout of the Thurgood, between Cottonwood and Hembrillo Canyons (Fig. 2). In the northern part of the San Andres Mountains, it displays thicknesses of 2.7 m (9 ft) at Capitol Peak and 7.0 m (23 ft) at North Sheep Mountain and at Sly Gap (but 10 m or 33 ft at West Sly Gap, also on the south side of Sheep Mountain). The unit is 10.8 m (35 ft) thick at Salinas Peak and at Mackinson Canyon, but 12.5 m (41 ft) thick at nearby Rhodes Canyon. It thins to 7.6 m (25 ft) thick at Cottonwood Canyon, the southernmost outcrop where the member can be differentiated.

The Salinas Peak Member is divisible into three units. The lowest of these, a tan shale that is commonly reddish at the base (Fig. 25), can be traced throughout the northern area and as far south as Hembrillo Canyon and Dead Man Canyon (Fig. 2). Above this is a silty unit of brown or green shales with interbedded, thin, coarse siltstones (Fig. 26) or flaggy, very fine grained, laminated sandstones (Fig. 27). An upper calcareous unit is generally present, unless eroded away by pre-Thurgood erosion. This unit is capped by a resistant 1-2-m- (3-6 ft-) thick limestone with abundant, solitary, rugose corals of the genus *Tabulophyllum* (Fig. 28). The Salinas Peak Member rests on the uppermost limestones of the Sly Gap Formation characterized by *Phillipsastrea* (or *Pachyphyllum?), Hexagonaria*, *lowaphyllum*, and *Alveolites*, all massive colonial corals. It characteristically forms a slope-and-step weathering profile above the slopes and steps of the Sly Gap and below the slope formed on the Rhodes Canyon Member (Fig. 29).

Faunas of the Contadero Formation that are reported by Cooper and Dutro (1982, p. 20) come from the Salinas Peak Member as it is recognized in this paper in the northern San Andres Mountains. Cooper and Dutro (1982, p. 20) reported a diverse brachiopod fauna from the Salinas Peak, characterized by *Cyrtospirifer, Cyrtina, Spinatrypa, Tylothyris,* and several rhynchonellid brachiopods of late Frasnian age. They corroborated this assignment with the discovery of late Frasnian conodonts in the basal beds of the unit.

## Thurgood Sandstone Member

The Thurgood Sandstone Member of the Contadero Formation is present throughout the northern San Andres Mountains, from Cottonwood Canyon to the

FIGURE 28—Salinas Peak Member of the Contadero Formation showing uppermost limestone with solitary corals. Base of Thurgood Sandstone Member is 10 cm above head of hammer. Rhodes Canyon locality.

FIGURE 29—Devonian section at Cottonwood Canyon locality, showing slope-forming character of Sly Gap and Contadero Formations. The lower of the two main ledges in the middle of the slope is uppermost Sly Gap carbonates and the upper ledge is developed on upper Salinas Peak carbonates and the Thurgood Sandstone Member of the Contadero Formation. The upper slope is developed on the Rhodes Canyon Member of the Contadero Formation leading up to massive Mississippian carbonates above.

north side of Sheep Mountain. North of Sheep Mountain, the unit has been removed by Early Mississippian erosion or left as a thin (6-15 cm; 2.5-6 inches) residue of sand as a layer or matrix between carbonate nodules derived from underlying nodular limestones of the Salinas Peak Member. The Thurgood was deposited on an erosional surface, with evidence of downcutting into the coral-bearing, upper Salinas Peak limestone. This underlying unit is missing at Mackinson Canyon and is much reduced at Salinas Peak, where corals are present as clasts in the basal Thurgood (Fig. 2).

At the Thurgood type section at Sly Gap, Flower (1965, p. 129) reported 10-12 ft (3-3.7m) of tan-weathering, light-gray sandstone and siltstones, but noted that only A 2-11-inch (5-25-cm)-thick remnant of the unit was present at Rhodes Canyon (Fig. 30). I recorded thicknesses of 2 m (6.5 ft) at the type locality (type Sly Gap of Fig. 31); 2.2 m (7 ft) at west Sly Gap in a gully 700 ft west of the type section; and 15 cm (6 inches) of an erosional remnant on the north face of Sheep Mountain. Thicknesses to the south range from 2.1 m (6.9 ft) at Salinas Peak to less than a meter (3.3 ft) at Rhodes Canyon (Fig. 25) and 1.2 m (4 ft) or slightly more at Mackinson and Cottonwood Canyons (Figs. 2 and 29). I was not able to recognize the Thurgood south of Cottonwood Canyon, although Cooper and Dutro (1982, p. 20) report it from Dead Man Canyon.

The sandstone unit forms several resistant beds overlying the upper Salinas Peak carbonates at Sly Gap (Fig. 31). These beds are calcareous, well indurated, and weather as angular, hard sandstones with a brown surface and nodular interbeds. These are very fine sandstones to coarse siltstones (3 1/2-4f size) that are dean and well sorted, with calcareous cement (Fig. 32) and angular fragments. Burrowing is common (Fig. 33), and the beds have phosphatic pebbles at several levels, with brachiopod-shell fragments scattered throughout.

The fauna of the Thurgood Sandstone Member consists of brachiopods that 1 noted only at Salinas Peak and Rhodes Canyon. Cooper and Dutro (1982, p. 21) report brachiopods from Rhodes Canyon, with Cyr-*tospirifer* and *Evanesirostrum* among them, indicating an early Famennian age. They also report that John Huddle identified early Famennian conodont faunas

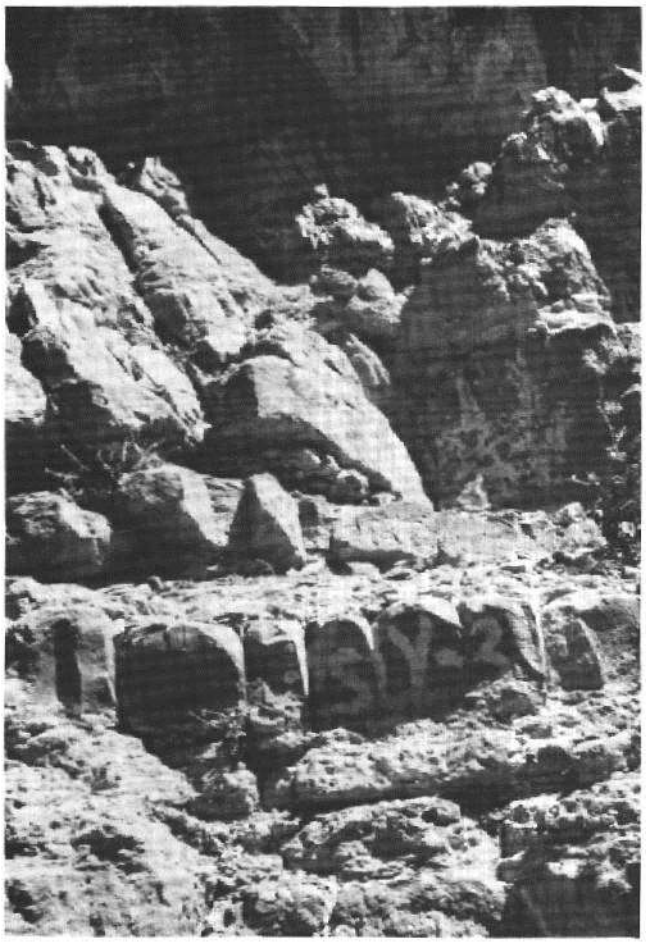


FIGURE 30—Contadero Formation. The bed marked SLY–3 is within the upper limestone of the Salinas Peak Member, while the more massive unit two beds above the bed marked is the Thurgood Sandstone Member, leading up to the Mississippian beds above. Sly Gap locality.

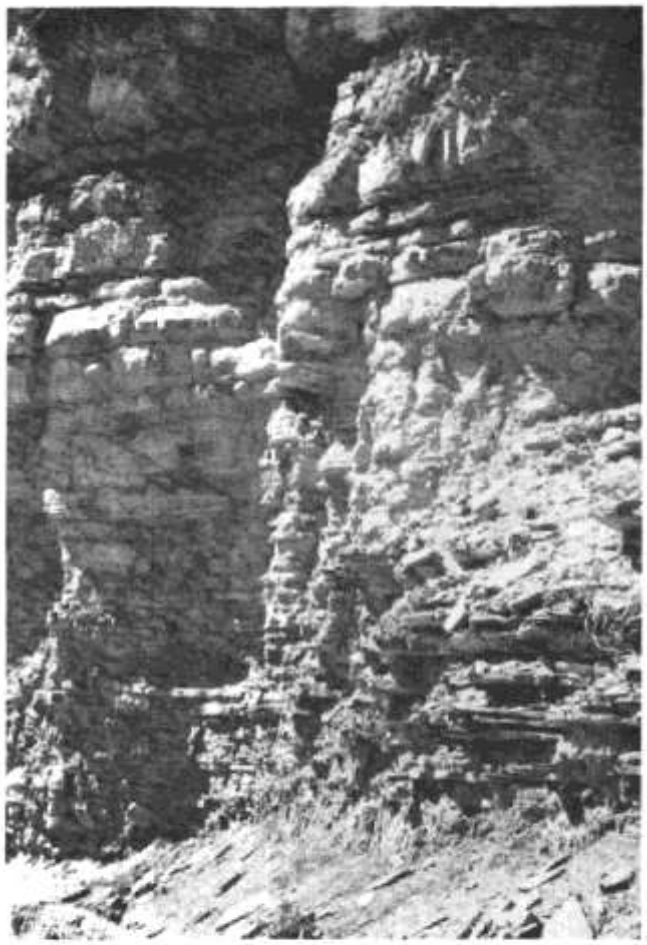

FIGURE 31—Contadero Formation. This outcrop illustrates almost the entire Contadero Formation as seen on Sheep Mountain at Sly Gap. The shales at the bottom of the photo are the basal shales of the Salinas Peak Member, which is only 8 m (26 ft) thick at this locality. The more massive beds above the prominent bedding surface at the top right are the Thurgood Sandstone Member. Locality is 300 m (330 yds) west of the Sly Gap type section on the south flank of Sheep Mountain.

from the Thurgood in Dead Man Canyon (1982, p. 21).

The unconformity beneath the Thurgood probably represents erosion near the Frasnian-Famennian boundary, and the Thurgood is the age equivalent of the lower Ready Pay Member of the Percha Formation in its type area and to the west.

## Rhodes Canyon Member

The Rhodes Canyon Member of the Contadero Formation is defined as the shale-and-siltstone sequence of Famennian age occurring at the top of the Devonian sequence in the northern San Andres Mountains. This sequence is recognized with certainty only in Cottonwood, Rhodes, and Mackinson Canyons, and on Salinas Peak; it has been eroded away further north beneath the early Mississippian unconformity. The upper Devonian shaly sequence is thus recognizable as the Rhodes Canyon Member only within the San Andres Mountains and through a north-south extent of 11-12 mi. The name "Rhodes Canyon Member" is retained to emphasize the presence of late Late Devonian (Famennian) rocks in the sequence and to insure access to the valuable information on brachiopods assigned to the Rhodes Canyon by Cooper and Dutro (1982).

Flower (1958) first named this Famennian unit as the Rhodes Canyon Formation for the 75 ft of shale overlying the Thurgood beds in the Rhodes Canyon section and published a type section (1965, p. 130) of shale and interbedded siltstones that had been ascribed to the Percha Shale by Stainbrook (1947). Stevenson (1945, p. 24) placed these beds in his Contadero Formation at its type section in Rhodes Canyon. If one removes the 7.3 ft (2.2 m) of limestone at the base of Stevenson's stratigraphic section of the type Contadero and the overlying 2.9 ft (0.9 m), since recognized as Thurgood by Flower (1958), then the remaining 56 ft (17 m) that Stevenson measured belongs to the Rhodes Canyon Member. These are brown and green shales with interbedded, thin siltstones, except in the basal-shale unit.

As recognized herein, the Rhodes Canyon Member consists of green to tan, fissile shale with thin, **burrow**ed siltstone beds directly overlain by Mississip-

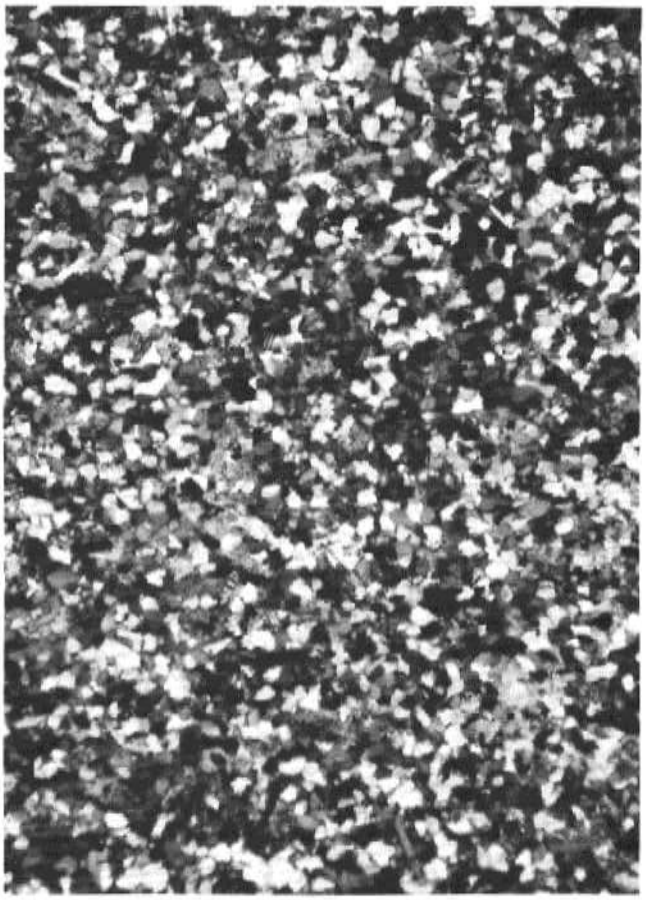

FIGURE 32—Thurgood Sandstone Member, composed of massive, fine to very fine grained, well-sorted, angular sandstone. This is the middle bed of sandstone in the type Thurgood at the Sly Gap locality. Partly crossed polarizers, ×25.

FIGURE 33—Photomicrograph of middle unit of Thurgood Sandstone Member, composed of fine-grained, burrowed, mottled, calcareous sandstone above a zone of phosphatic nodules. Burrowing has incorporated darker argillaceous matter into sandstone. Non-polarized light, ×7.5. Rhodes Canyon locality.

pian carbonates (Figs. 34 and 35); it lies conformably on the Thurgood. In the vicinity of Rhodes Canyon, the Rhodes Canyon Member forms a shale slope above the step formed by the upper Salinas Peak carbonate rocks (Fig. 29). North of Salinas Peak, the Rhodes Canyon has been removed by pre-Mississippian erosion; south of Cottonwood Canyon, it is apparently present but could not be clearly differentiated from lower Contadero beds. Thus, formal member names are not utilized in Hembrillo Canyon and southward. The thickness of the Rhodes Canyon increases from 6.8 m (22 ft) at Salinas Peak to 20.5 m (67 ft) at Mackinson Canyon, 18.9 m (62 ft) at Rhodes Canyon, and 21 m (69 ft) at Cottonwood Canyon. A medial, silty unit separates shalier units at the top and bottom of the member (Fig. 2). The uppermost beds of the Rhodes Canyon at Cottonwood Canyon are typically partly bioturbated, cross-laminated, coarse siltstones (Fig. 36), and the siltstones throughout the member are characteristically thin (3-6 cm; 1-2 inches), hard, angular grained, and burrowed.

Brachiopods are present in the Rhodes Canyon, especially in the upper shalt' part of the member. The fauna consists of *Cyrtospirifer* and several rhynchonellids and athyrids. Cooper and Dutro (1982, p. 22) note these as being of middle Famennian age and regard the Rhodes Canyon as correlative with much of the Ready Pay Member of the Percha Formation in its type area.

## Contadero Formation

South of Cottonwood Canyon, members are not recognized within the Contadero Formation. Instead, all strata between the Sly Gap and the Mississippian are lumped together in this single formation, along with a prominent tongue of black shale south of Hembrillo Canyon (Fig. 2). South of San Andres Canyon, the Contadero is not recognizable because the Sly Gap facies is not developed. Thus, the unit above the On-ate is left unnamed (Fig. 2). Thicknesses of the Contadero in this southerly area are 15.8 m (51.9 ft) at Hembrillo Canyon, 14.2 m (46.7 ft) at Lost Man canyon, and roughly 11 m (36 ft) at Dead Man and San Andres Canyons.

The Contadero lies on fossiliferous, nodular limestones of the Sly Gap Formation, although the *Phillipsastrea* (or *Pachyphyllum?) fauna* is seen only at Dead Man Canyon in the region. Above the Sly Gap is a basal, interbedded, calcareous siltstone and gray shale

FIGURE 34—Rhodes Canyon Member of the Contadero Formation, composed of tan shale with occasional thin siltstone layers in lower part of unit. Rhodes Canyon locality.

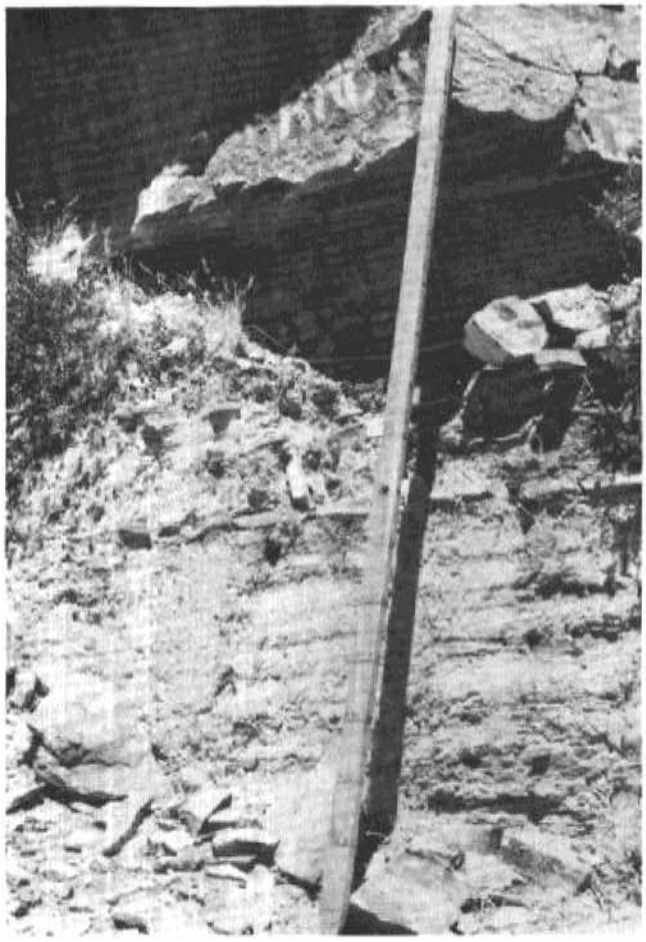

FIGURE 35—Uppermost part of Rhodes Canyon Member of the Contadero Formation, composed of tan-weathering, green, fissile shale with thin layers and lenses of fine sandstone. Overhanging strata at top of photo belong to the Lake Valley Formation (Mississippian). Staff is marked in tenths of meters. Rhodes Canyon locality.

with a reddish-weathering base at the more northerly three sections (Fig. 2). This is regarded as the same reddish, shaly, basal unit typically seen in the Salinas Peak Member to the north. The unit is 90-130 cm (34 ft) thick.

Above this basal unit lies the main body of the Contadero Formation. At Hembrillo Canyon, this unit comprises 11.3 m (37 ft) of gray, silty shale, while to the south, the silty sequence is replaced by a tongue of black, platy, fissile shale with a thickness of 6.8 m (22 ft) at Lost Man Canyon, 7.3 m (24 ft) at Dead Man Canyon, and 8.5 m (28 ft) at San Andres Canyon. At the latter locality, the black-shale sequence is broken by 1.7 m (5.6 ft) of thin-bedded sandstone (Fig. 2).

The upper unit of the Contadero is dominantly nodular or laminated sandstone at Hembrillo, Lost Man, and Dead Man Canyons, with frequent burrows and *Zoophycus*. Tan shales are interbedded with the sandstones, and the unit is commonly overlain by a thin (1 m; 3 ft) sequence of black, fissile shale. This upper unit is similar in fades to the Rhodes Canyon Member of the upper Contadero Formation at Cottonwood Canyon. Cooper and Dutro (1982, p. 20) noted a remnant of the Thurgood Sandstone Member with early Famennian conodonts in Deadman Canyon. This remnant was not observed in the course of the present study.

In the middle Contadero of Lost Man Canyon occurs a well-bedded, argillaceous, lime mudstone with brachiopod debris. This may represent the upper limestone of the Salinas Peak Member, but none of the characteristic fauna of that unit were noted in Lost Man Canyon.

As noted above, the Contadero Formation can be recognized in all stratigraphic sections studied from San Andres Canyon northward. However, the three members of the Contadero can be differentiated only from Cottonwood Canyon northward. Cooper and Dutro (1982, p. 21) note that Rhodes Canyon strata also can be identified at Ash Canyon to the south.

## Black-shale facies

Post-Oñate beds at Ash and Bear Canyons at the south end of the San Andres Mountains are a sequence of black, hard, fissile shales. This black-shale fades is equivalent in age to the Sly Gap and Contadero Formations (and possibly also to the uppermost Oñate) and is lithologically similar to the Percha Formation of southwest New Mexico. The name "Per-

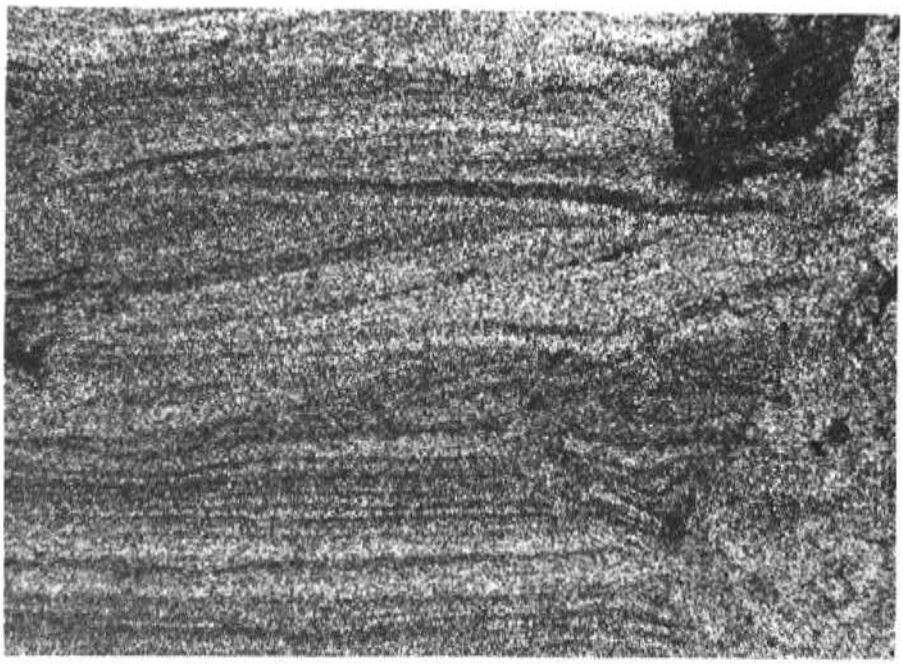

FIGURE 36—Rhodes Canyon Member of the Contadero Formation. Thin section photomicrograph of top sandstone of unit, directly underlying Mississippian rocks. This unit is a very fine grained, laminated sandstone, that has been burrowed extensively, as seen in lower right of photomicrograph. Non-polarized light, ×5. Cottonwood Canyon locality.

**cha" was employed by Seager (1981), who mapped in the southern San Andres Mountains. However, at present, age and physical relationships are unclear between the black shales of the southern San Andres and the Percha lithosome of Famennian age to the northwest and west. Clearly some black shales in this eastern area are Frasnian in age and are equivalent to Sly Gap and lower Contadero beds here and perhaps also to those in the southern Sacramento Mountains to the east. This older portion of the black-shale facies does not seem to be lithologically continuous with the Percha, and rather than being part of a single, diachronous, shale lithosome, this facies may have been deposited in a separate depositional basin, as suggested by Dutro (1983, personal communication). Thus, in this report the black shales are informally referred to as the black-shale fades equivalent of the Contadero and Sly Gap Formations. Final resolution of this problem will require further field study in the southern area and additional paleontologic information.**

**The black-shale unit is 26.9 m (88.4 ft) thick at Ash Canyon and 18.5 m (60.6 ft) thick at Bear Canyon. This facies also is represented by a tongue of black, fissile shale in the lower Contadero Formation at San Andres, Dead Man, and Lost Man Canyons (from south to north), where the tongue is from 11 to 14 m (36-46 ft) thick and occupies a lesser proportion of the Contadero northward. Dark shales of apparently identical facies also are present in the Sly Gap Formation of San Andres, Dead Man, and Hembrillo Canyons as a tongue that can be connected to the southern area of basinal deposition. In addition, this fades can be observed as thin units at various levels in the Devonian sequence throughout the San Andres Mountains. The southerly replacement of the Contadero and Sly Gap Formations by black shale has been recognized previously in the San Andres Mountains (Kottlowski, 1963, p. 26). Distribution of a dark-shale fades in the southern Sacramento Mountains (Pray, 1961, p. 56) provides additional evidence for southerly deposition. Stevenson (1945), Laudon and Bowsher (1949), and Flower (1958, 1959) consider this unit to be a dark-shale facies of the Sly Gap Formation.**

**In the southern San Andres Mountains, these dark shales clearly are lateral equivalents of Contadero and Sly Gap rocks (Fig. 2). Some of them may also be time-equivalents of the upper portion of the Oñate Formation, as the Oñate is developed at San Andres Canyon *(post-Rhyssochonetes* beds). The black shale is of both Frasnian and Famennian age in the San Andres Mountains and, possibly, in the Sacramento Mountains. This diachronism apparently is not true farther west, where Famennian conodont faunas are known from the basal or lower Percha Shale at Hermosa and its type section (Cooper and Dutro, 1982, p. 26). Bowsher (1967) also reports Famennian conodonts in the Ready Pay Member of the Percha. The Percha Shale, both the lower Ready Pay Member and the upper, calcareous Box Member, is regarded as completely Famennian in age in its type area in the Black Range, in the Cooke's Range, and in the Mimbres and Big Hatchet Mountains, all west of the San Andres Mountains.**

# Summary of depositional history

Thickness and stratigraphic relationships of the Devonian strata in the San Andres Mountains are summarized in Fig. 12. The strata span the time from late Middle Devonian to late Late Devonian and belong to the Givetian, Frasnian, and Famennian Stages of the Devonian System. This is an unconformitybounded sequence of thin stratigraphic units that contain diastems and several marked unconformities (Fig. 12).

## Givetian Stage

### Oñate Formation

The (Mate Formation is of late Givetian age and contains platform siltstones, fine sandstones, dolomites, and shaly rocks, some of which are calcareous. These carbonate-rich, fine-quartzose clastics are dolomitic in the northern San Andres Mountains, but the thickest and most limestone-rich sequence is present at the type section in San Andres Canyon. South of this locality, the Ovate thins rapidly. The suggestion is that a basin formed here in latest Givetian time and that the San Andres Canyon section was close to the margin of a southward-prograding shelf. While thinning and dolomitization took place in the carbonate-rich sediments on the shelf to the north, to the south upper (Oñate strata were replaced by basinal shales. As noted in cross section D of Fig. 12, the level of occurrence of rhynchonellid brachiopods *(Platyterorhynchus)* suggests that the uppermost Oñate beds in San Andres Canyon are, in fact, younger than the top of the formation farther north, and certainly younger than the uppermost Oñate beds to the south. This observation is also suggested by the position of the *Rhyssochonetes* fauna in the lower Oñate of San Andres Canyon and throughout the (Mate Formation of Ash and Bear Canyons to the south, where the thinned (Mate sequence apparently is the equivalent of the lower (Oñate only.

## Frasnian Stage

### Sly Gap Formation

Early Frasnian time in the San Andres Mountains was marked by platform sedimentation, with characteristic facies consisting of argillaceous carbonates and associated, carbonate-rich shales. To the south of this carbonate-rich platform, fades changes occur, and typical Sly Gap lithologies are totally absent south of San Andres Canyon (Fig. 1). In the northern part of the range, carbonate rocks that are especially well developed at the top of the Sly Gap contain stromatoporoid and colonial-coral faunas. To the south, a tongue of dark shale occurs in the lower Sly Gap, and eventually dark shales replace Sly Gap lithologies at Ash and Bear Canyons (Figs. 2 and 12). This dark-shale fades is accompanied by a decrease in thickness as the transition occurs from platform to basinal depositional environments (Fig. 12). This Devonian platform was extensive, with the argillaceous carbonates of the Sly Gap facies known from areas east (Sacramento Mountains) and west (Caballo Mountains) of the San Andres Mountains.

### Salinas Peak Member of the Contadero Formation

A terrigenous, clastic sequence developed in the northern San Andres Mountains in late Frasnian time. This sequence follows Sly Gap sedimentation, with clastics replacing the typical Sly Gap carbonates, but without an observable break in sedimentation. The Salinas Peak Member can be recognized, and apparently Salinas Peak sedimentation took place mainly north of Hembrillo Canyon. The basal, reddish to brownish shale of the Contadero Formation still extends as far south as Dead Man Canyon (Figs. 1 and 2). Fine-grained, flaggy siltstones and sandstones interbedded with Salinas Peak shales suggest a northerly source of terrigenous elastics. The upper Salinas Peak Member contains carbonate rocks with abundant coral faunas that developed as the Frasnian shelf returned to conditions more typical of the Sly Gap. This upper limestone is affected by pre-Famennian erosion throughout the northern San Andres Mountains (Fig. 12) and is absent due to erosion at Mackinson Canyon (Fig. 2). The areal extent of the upper Salinas Peak carbonates coincides with that of the basal, Famennian Thurgood Sandstone. Salinas Peak beds were totally removed by pre-Mississippian truncation northward, at Capitol Peak (Fig. 2). Frasnian beds are not easily distinguished south of Cottonwood Canyon, but reddish-weathering, brown shales are present at the base of the Contadero as far south as Dead Man Canyon (Fig. 2) and may be of late Frasnian age like the basal unit of the Salinas Peak to the north.

## Famennian Stage

Famennian deposition in the area of the San Andres Mountains resulted in the Thurgood Sandstone and Rhodes Canyon Members of the Contadero Formation in the northern part of the range and in the main bulk of the Contadero Formation farther south.

### Thurgood Sandstone Member

This middle member of the Contadero Formation, recognized throughout the northern San Andres Mountains, rests everywhere on an unconformable surface. It cannot be recognized north of Sheep Mountain (Fig. 2) but may be partially preserved as a sandy interval associated with the pre-Mississippian unconformity. These sandstones are platform deposits of burrowed fine sand and silts, with brachiopod faunas and occasional phosphatic nodules. Corals that are present as clasts in the sandstone at North Sheep Mountain and Salinas Peak (Figs. 1 and 2) were ap-

**parently reworked from the underlying Frasnian carbonates in the Salinas Peak Member. Conodont and brachiopod faunas indicate an early Famennian age for the Thurgood, making it approximately the same age as the basal Percha Shale in its type area west of the San Andres Mountains.**

## Rhodes Canyon Member

**The Rhodes Canyon Member is a shale and siltstone or sandstone sequence recognized in the northern San Andres Mountains. Bioturbated, cross-stratified, terrigenous dastics that change facies to finer grained, basinal, dark shales to the south are removed by pre-Mississippian erosion north of Salinas Peak (Fig. 12). This unit, with its argillaceous rocks rhythmically interbedded with coarser beds, reflects the influx of debris from a northerly or northeasterly source. Dark shales in this interval at Salinas Peak suggest a northerly extension of the muddy black-shale basin. South of Hembrillo Canyon (Fig. 2), the sandy and silty fades of the Rhodes Canyon Member is restricted to the upper part of the Contadero sequence, while a tongue of black shale occupies the lower Contadero position. Facies relationships suggest that subsidence, which had considerably more influence on the Devonian platform area during Famennian time than during Frasnian time, caused deposition of widespread, dark, basinal shales.**

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*Appendix follows*

# APPENDIX

Localities of Devonian statigraphic sections from north to south within the San Andres Mountains, and lastly, outside of the San Andres Mountains.

1. **Johnson Park** UP): Oñate and lower Sly Gap rocks were described along south side of road leading into Johnson Park Canyon (White Sands Missile Range secondary road 325) in NW 1/4 NE 1/4 NW 1/4 sec. 5, **T. 10 S.,** R. 5 E., Capitol Peak 15-min quadrangle, Socorro County.
2. **Capitol Peak** (CP): Oñate and Sly Gap Formations are exposed in first gulley west of down-to-the-west normal fault first encountered upon approach from southeast, up gulley in Precambrian rocks on south-southeast flank of Capitol Peak, due northwest of site D-7 (White Sands Missile Range); section is located in SE'/4 NE 1/4 NE 1/4 sec. 33, T. 10 S., R. 5 E., Capitol Peak 15-min quadrangle, **Socorro** County.
3. **North Sheep Mountain** (NSM): Oñate, Sly Gap, and Contadero Formations were described in gulley 200 m (220 yds) east of old horse trail to Sheep Mountain. Spring on north side of Sheep Mountain from hunting road through Thurgood Canyon. Section located in SW 1/4 SE 1/4 NW 1/4 sec. 18, T. 11 S., R. 5 E., Capitol Peak 15-min quadrangle, Socorro County.

3a. **Thurgood Canyon** (TC): Partial section, with upper Sly Cap and Contadero Formations described on low shoulder above hunting road up Thurgood Canyon, located 550 m (600 yds) west-northwest and 100 m lower than NSM section in SW 1/4 SW 1/4 NW 1/4 sec. 18, T. 11 S., R. 5 E., Capitol Peak 15-min quadrangle, Socorro County.

**4. Sly Gap** (South Sheep Mountain): Oñate, Sly Gap, and Contadero Formations were described one mi north of road toward Sly Gap on south face of Sheep Mountain in NW 1/4 NE 1/4 SE 1/4 sec. 25, T. **11** S., R. 5 E., Capitol Peak 15-min quadrangle, Sierra County. This is also the type section of the Sly Gap Formation of Stevenson (1945, p. 227).

5. **Salinas Peak** (SP): Oñate, Sly Gap, and Contadero Formations were described in gulley above Montoya Plateau on southwest flank of Salinas Peak, approximately $^{1}/2$ mi northeast of road up Sweetwater Creek Canyon (route 12, White Sands Missile Range) in NW 1/4 NW 1/4 SE 1/4 sec. 7, T.
   12 S., R. 4 E., Salinas Peak 7 1/2-min quadrangle, Sierra County.
6. **Mackinson Canyon** (MC): (Mate, Sly Gap, and Contadero Formations were described on north wall, just east of dry waterfall in canyon $^{2}/3$ mi from house at White Rock Well at mouth of Mackinson Canyon. Oñate description begins 15 m (50 ft) east of down-to-the-east fault that bisects the upper canyon. Location is in S 1/2 $^{S}$E 1/4 SE 1/4 sec. 33, T. 12 S., R. 4 E., Black Top Mountain 15-min quadrangle, Sierra County.
7. **Rhodes Canyon** (RC): (Mate, Sly Gap, and Contadero Formations were described above Montoya Dolomite ledge on north side of Rhodes Canyon, approximately 5/8 mi north of White Sands Missile Range route 6 (formerly NM-52), through Rhodes Canyon, in more easterly of two gullies cutting gap in Montoya Dolomite, in SW 1/4 SW 1/4 NW 1/4 sec. 9, T. 13 S., R. 4 E., Black Top Mountain 15-min quadrangle, Sierra County.
8. **Cottonwood Canyon** (CC): Oñate, Sly Gap, and Contadero Formations were described on south side of Cottonwood Canyon, up slope on Montoya Dolomite, approximately '/2 mi from road; descriptions of Oñate, Sly Gap, and lower Contadero Formations are from NE 1/4 SW 1/4 SW 1/4 sec. 4, with Rhodes Canyon Member described in center SE 1/4 SE'/4 sec. 5, T. 14 S., R. 4 E., Black Top Mountain 15-min quadrangle, Sierra County.
9. **Hembrillo Canyon** (HC): Oñate and lower Sly Gap beds were measured south of Hembrillo Canyon road (White Sands Missile Range secondary road 306), above the low Fusselman Dolomite cliff in NE 1/4 NW 1/4 sec. 11, T. 16 S., R. 4 E.; the upper Sly Gap and Contadero Formations were described on the north side of the road in a northwest-trending dry wash in the SD/4 SW 1/4 sec. 2, T. 16 S., R. 4 E., Kaylor Mountain 15-min quadrangle, Doña Ana County.
10. **Lost Man Canyon** (LMC): (Oñate, Sly Gap, and Contadero Formations were described on west side of amphitheater above Fusselman Dolomite cliff on south side of canyon, with access up dry creek flowing northeast into sec. 31; location is in SE 1/4 SE 1/4 SE 1/4 sec. 36, T. 16 S., R. 4 E., Kaylor Mountain 15-min quadrangle, Dona Ana County.
11. **Dead Man Canyon** (DMC): Oñate, Sly Gap, and Contadero Formations were described approximately 100 m (110 yds) south of road up Dead Man Canyon in NW 1/4 NW 1/4 SE 1/4 sec. 12, T. 17 S., R. 4 E., Kaylor Mountain 15-min quadrangle, Doña Ana County.
12. **San Andres Canyon** (SAC): Oñate, Sly Gap, and Contadero Formations were described on the south-facing slope of Oñate Mountain (Stevenson, 1945, p. 222) approximately 30 m (100 ft) north of the abandoned lead mine in San Andres Canyon; location is in NE 1/4 SE 1/4 SE 1/4 sec. 18, T. 18 S., R. 4 E., Bear Peak 15-min quadrangle, Doña Ana County.
13. ***Ash* Canyon** (AC): Devonian formations were described on northeast side of Ash Canyon (approximately 750 m or 820 yds southeast of concrete tank) in NE 1/4 NW 1/4 sec. 28, T. **19 S., R. 4 E.,** Bear Peak 15-min quadrangle, Doña Ana County.

14. **Bear Canyon (BC): Devonian formations were described on south flank of Goat Mountain at north end of Fusselman Dolomite ridge projecting southward into Bear Canyon in NW 1/4 NW 1/4 sec. 30, T. 20 S., R. 5 E., Lake Lucero 15-min quadrangle, Dona Ana County.**
15. **Mud Springs Mountains (MSM): Oñate and Sly Gap Formations were described at termination of the bulldozed road on south flank of hill 5505 in NW 1/4 NE 1/4 SE 1/4 sec. 24, T. 13 S., R. 5 W., Cuchillo 7 1/2-min quadrangle, Sierra County.**
16. **Hermosa (HE): Oñate, Sly Gap, and Percha Formations were described in south-facing slope above abandoned Foster—Nourse tunnel (Jahns, 1957) in Palomas mining district in unsurveyed area of Pelican mines, 1 1/2 mi east of Hermosa on north bank of Palomas Creek, Sugarloaf Peak 7 1/2-min quadrangle, Sierra County; this location is in the NE 1/4 NW 1/4 sec. 19, T. 13 S., R. 8 W. on the 1972 U.S. Forest Service map of Gila National Forest.**

*Edited by:* **Steve Blodgett**

*Drafted by:* **Olga Kurty and Linda Wells-McGowan**

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*Binding:* **Saddlestitched**

*Stork:* **Cover-80-lb. Teton Ice Blue**
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