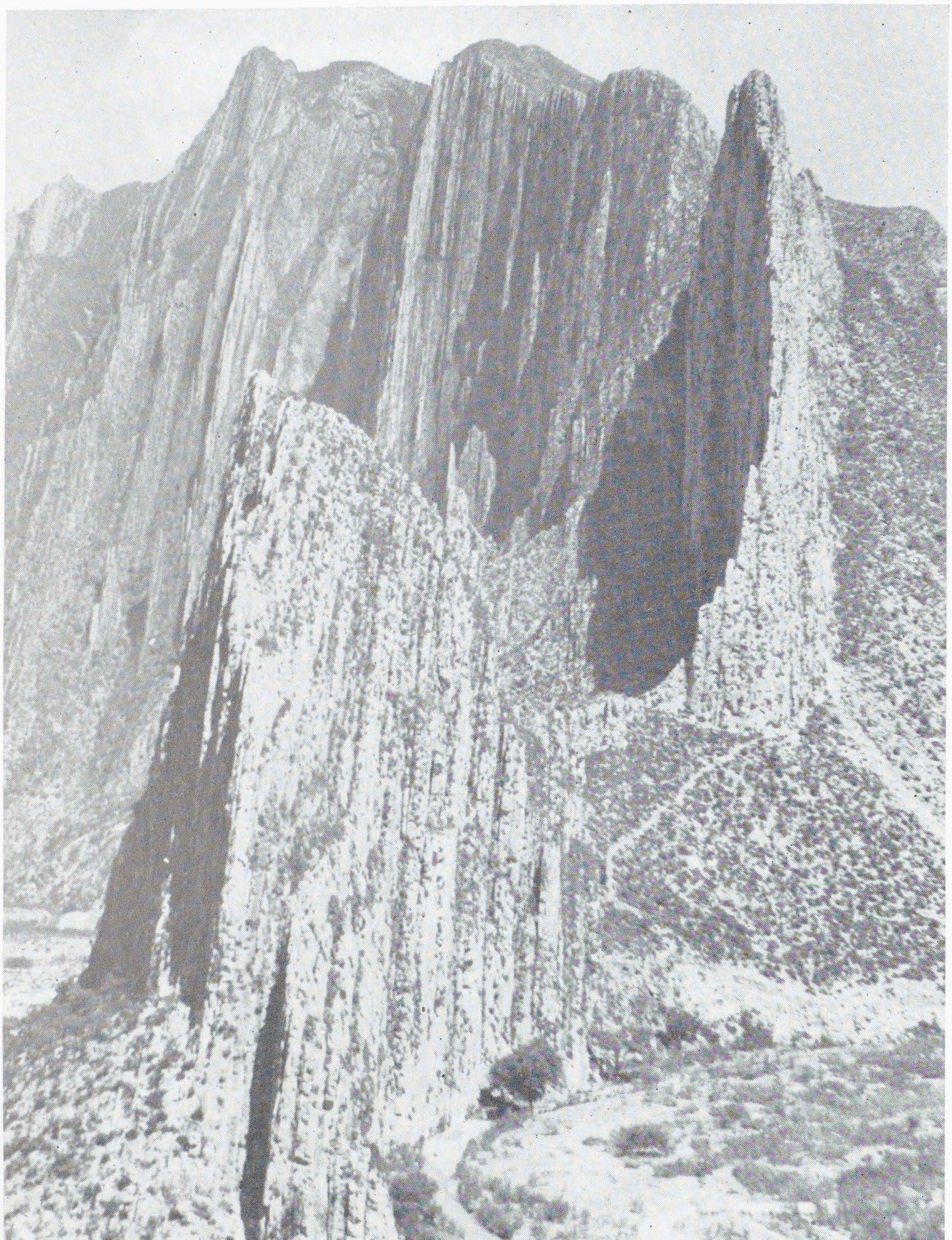

PLATE I: Vertical beds, Cañon de la Huasteca

GEOLOGY OF THE CAÑON DE LA HUASTECA AREA IN THE SIERRA MADRE ORIENTAL, NUEVO LEON, MEXICO

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I. Abstract

The observations reported in the present paper result from investigations by the students at the Tulane University Summer Field Camp in Geology during the years 1960-1962. The area involved is in the front range of the Sierra Madre Oriental of Mexico and includes the well-known Cañon de la Huasteca and the valleys immediately to the south, locally known as the Valle de San Paulo and the Valle de Muralla.

The area is a segment of the Los Muertos anticline whose core consists of the Upper Jurassic Zuloaga Limestone, which is much deformed and locally has been intruded by masses of gypsum. Overlying is a 1200 foot sequence of shales and siltstones that have Portlandian, Upper Jurassic fossils in the lower portion; these are here named the Muralla Shale. Gradationally above are almost 1200 feet of arkosic sandstones and arkose with minor conglomerates that contain an Upper Jurassic fauna, and are here named the San Paulo Sandstone. These two new formations are referred to the La Casita Group.

Lower Cretaceous formations represented include the Taraises Formation in which two members can be recognized. The basal member, consisting of approximately 200 feet of shale and highly fossiliferous limestone is here named the Los Nogales Member. This member is of late Valangian and/or early Hauterivian age, and rests on the San Paulo Sandstone with, apparently, a paraconformable contact.

The main mountain ridges bordering the valleys are composed of the rudistid-bearing Cupido Limestone, 2300 feet thick, the very fossiliferous, marly La Peña Formation, 50 to 100 feet thick, and the thick-bedded Aurora Limestone, incomplete sections of which form the outer flanks of the Los Muertos anticline.

Near the western end of the Valle de Muralla an isolated mass of Tertiary (?) clay rests upon the eroded edges of the Taraises Formation. The clays are believed to represent lacustrine deposition, but a wholly satisfactory explanation of their occurrence has yet to be advanced. Alluvium and colluvium, some of it cemented with caliche, masks the floors and lower slopes of the valleys.

There is stratigraphic evidence of an east-west trending fault along the floor of the Valle de San Paulo to the south of the present outcrop trend of the Zuloaga Limestone; it is suggested that movement along this fault may have been a contributory factor in the gypsum intrusions into the adjacent Zuloaga Limestone.

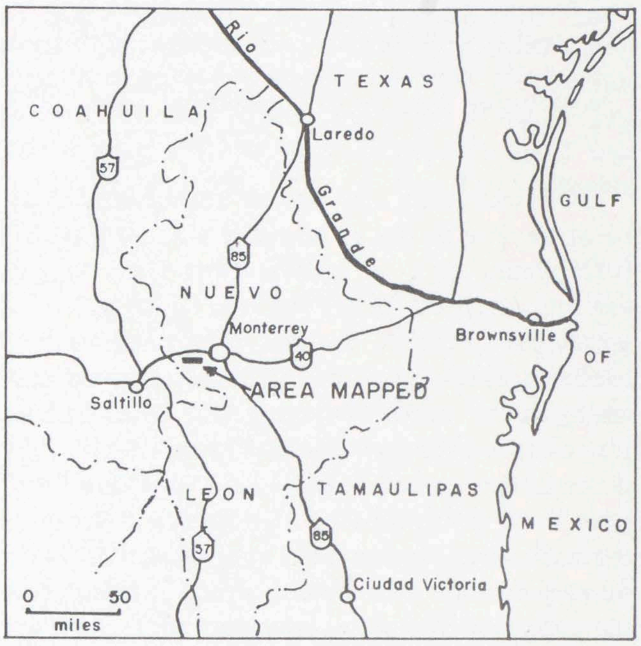

Figure 1. Geographic Location of the Huasteca Cañon Area.

II. Introduction

> "The geology and stratigraphy of the mountains in northeast Mexico are still almost absolutely unknown; even in late years the mighty ranges and deep canyons of the Sierra Madre Oriental east of Saltillo and south of Monterrey have scarcely even been crossed by a geologist and much less been studied." (Böse, 1923, p. 127)

The fact that the above statement is almost as true today as when it was first made, forty years ago, is justification for the following detailed notes on the geology of a small part of this region. The observations here recorded result from investigations carried on by students attending the Tulane University Summer Field Camp in Geology during the years 1960-1962. Included are details of a number of stratigraphic sections through the formations represented, with description of two new Upper Jurassic formations and one new member of the Lower Cretaceous Taraises Formation.

The area involved in the study is a part of the front range of the Sierra Madre Oriental of Mexico, and includes the well-known Cañon de la Huasteca and the valleys immediately behind it (see fig. 1). It lies immediately southwest of Monterrey, Nuevo Leon, and is south and southeast of the town of Santa Catarina, from which a paved road may be taken to the entrance of the Huasteca.

Structurally the region is part of the Los Muertos anticline, the most northerly of the several folds that constitute this portion of the Sierra. The valley of the Rio Santa Catarina bisects this major structure in the mapped area and the water gaps of the main channel form the Cañon de la Huasteca on the north flank of the anticline and the Cañon de Morteros on the south. The core of the anticline has been eroded to form a moderately broad east-west valley traversed by intermittent streams tributary to the Santa Catarina. The tributary valley west of the main river channel is locally known as the Valle de San Paulo and that to the east constitutes the Valle de Muralla. These names are here adopted and utilized as the geographic element in the names of the two new formations here proposed.

The writer first became interested in the Huasteca area early in 1960 when the late Commodore Penn L. Carroll (U.S.N., retired), at that time advisor to the Rector of the Instituto Tecnológico y de Estudios Superiores de Monterrey, suggested that the geological faculty of Tulane University consider the feasibility of utilizing the facilities of the Instituto as headquarters for a summer field camp. A short visit to the area during the Easter period of that year was sufficient to demonstrate that the region had much to offer geologically, and that the facilities of the Instituto would afford a superlative base for a summer camp. The only obvious drawback was the lack of topographic map coverage; but, aerial photographs were available. It was concluded that the superior exposures of the geologic section in this almost unstudied area offered many projects for student theses and dissertations which with the available aerial photographs more than offset the lack of topographic coverage. Subsequent experience, in which we have combined plane-table topographic and geologic mapping, has demonstrated that there are some advantages in that experience thus gained gives the student confidence in his ability to handle any mapping problem, with or without base maps.

A "test-run" of the camp and the field area was made in the summer of 1960 with four students; in 1961 the student number was increased to seven, all of whom were graduate students at Tulane; and in 1962, both graduate students and seniors from Tulane and other schools participated in the program. The following report and geologic map are based in large measure upon the work of these groups.

III. Acknowledgments

The writer wishes to acknowledge his sincere indebtedness to the late Commodore Carroll for calling our attention to the region as a possible site for the field camp, and also for his vigorous assistance in advancing the work of the group in the Monterrey area. Many local geologists, who were made aware of our project through Commodore Carroll's interest gave much helpful assistance and advice; all cannot be separately mentioned and thanked here, but I cannot fail to express our deep appreciation for the hospitality and courtesies extended to us and our students by Mr. Walter H. Triplett, former chief geologist for the Compania Mineria de Peñoles, S. A.

The officials at the Instituto Tecnológico have proved unflaggingly helpful and anxious to advance the work of the camp. All cannot be thanked individually, but special mention must be made of Ing. Fernando García Roel, the Rector of the Instituto and companion in the field when his official duties permit. To him, as well as to Ing. Francisco Mancillas, Dean of the Escuela Verano, to Mr. Harold Wise, Assistant to the Dean, and to Colonel Carter Hilsabeck (U.S.A., retired), successor to Commodore Carroll, go our sincerest appreciation for their efforts in behalf of the camp project.

Finally, the present writer must express his very real indebtedness to the students whose field work is here utilized, and whose project reports are freely employed; they have made the present report possible. Included in the group of 1960 were: James A. Holliday, Anthony T. L'Orsa, Arthur D. Piaggio and Emily H. Vokes, all from Tulane University. The 1961 group included: Robert F. Beyer, Jr., Victor V. Cavaroc, Jr., William E. Daughdrill, Gerald C. Glaser, Harold J. Morrow, John Sandy, Jr., and Albert P. Selph III. 1962 participants were Theodore T. Gittinger, Gary O. G. Greiner, and Louis A. Oswald, Jr., all from St. Mary's University at San Antonio, Texas; Mr. Joshua H. Rosenfeld, a former graduate student at Louisiana State University; and Leland Dennis II, a senior, and Harold J. Morrow, a graduate student from Tulane. Mr. Piaggio of the 1960 group and Mr. Morrow in 1962 were engaged in work on field projects for their Master of Science theses.

Previous Work

Although the Huasteca area has long been known as a scenic attraction, either under that name or as the Cañon de Santa Catarina, the first significant mention of the geology of the region was by Böse in 1923 (his introduction to that paper is quoted above). Böse sketches the general stratigraphic sequence and publishes (p. 200) small diagrammatic cross-sections, one of which probably would cross the area of the present geologic map. Böse and Cavins (1928, p. 17-18) note the occurrence of "sandstones and conglomerates of the Portlandian (Jurassic)" and of limestones and marls of "Infracretaceous" and "Mesocretaceous" age. They also give rough estimates of the thicknesses of some of the deposits and list characteristic fossils from certain units; but, as in the earlier paper, they do not apply local formational names to the units observed.

Finally, Humphrey (1949) makes passing mention of certain of the formations present in this region while he is discussing the stratigraphy of the Cortinas Canyon area and the western part of the Los Muertos structure.

IV. Stratigraphy

General Statement.—The geologic section exposed in the Los Muertos anticline within the area of the present study consists primarily of sediments of upper Jurassic and lower Cretaceous age. Resting upon these near the village of Los Nogales is a small deposit of clay of Tertiary or post-Tertiary age; elsewhere a mantle of Quaternary or Recent alluvium and colluvium covers the valley floors and extends for some distance up the adjacent slopes. The stratigraphic sections of the Mesozoic rocks exposed in the two flanks of the anticline are shown in figure 2. The term, "Los Nogales Member of the Taraises Formation," was proposed by Piaggio in 1962 (unpublished M.S. thesis, Tulane University). The San Paulo Sandstone and the Muralla Shale are new formation names here first proposed.

Jurassic System
Sabinas Series[1]

Zuloaga Stage
Zuloaga Limestone

The term Zuloaga Limestone was proposed by Imlay (1938, p. 1675) to designate the offshore equivalent of the La Gloria formation with the type locality in the Sierra Sombreretillo, north of Melchor Ocampo, on the Coahuila-Zacatecas border. Here there are about 1800 feet of gray limestone, mainly thick-bedded. Most of the complete sections known elsewhere appear to be thinner. The beds so named by Imlay are those that had previously been referred to as the "*Nerinea* limestone" or the "Gray limestone with *Nerinea*" by Burckhardt (1906; 1930) and by Böse (1923).

[1] For a discussion of the origin and history of the "series" and "stage" names used in this report, see Murray, 1961, pp. 287-8; 292; 297-301; 307-8.

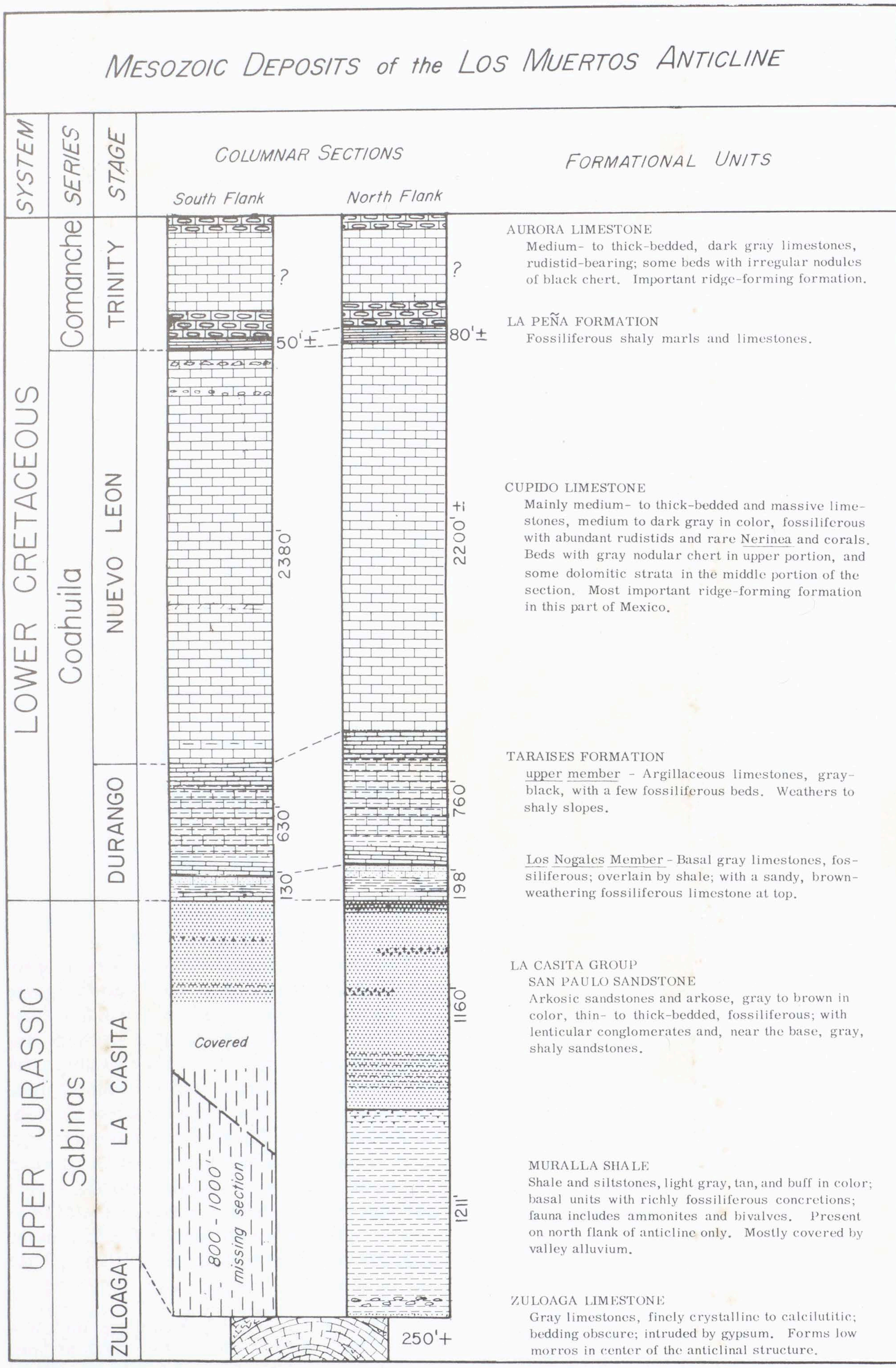

Figure 2. Stratigraphic columns comparing the Mesozoic deposits cropping out on the north and south flanks of the Los Muertos Anticline.

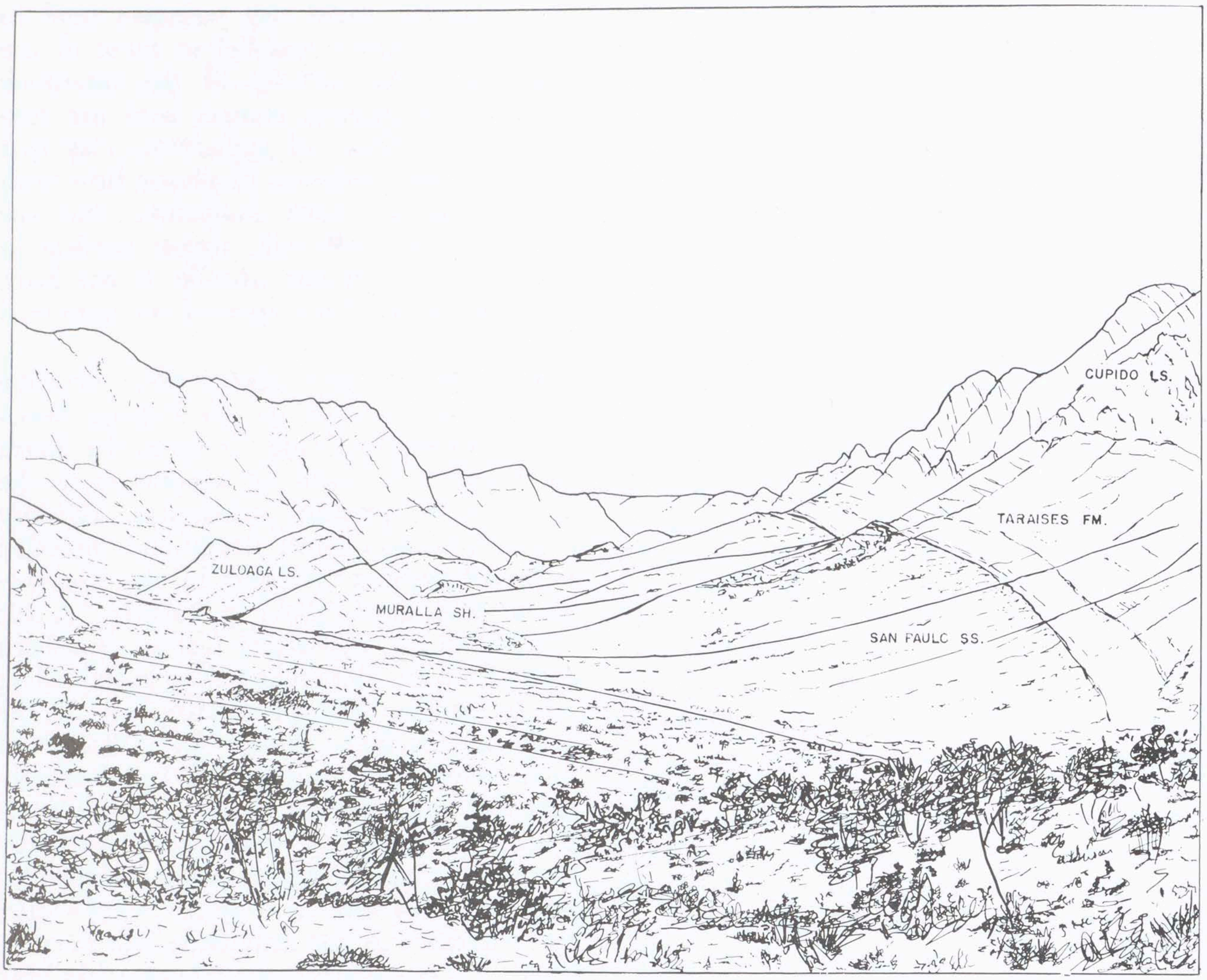

Figure 3. Valle de San Paulo; view looking westward along the north side of the valley from slopes immediately above east side of Rio de Santa Catarina.

característica del Anticlinorio de Arteaga, el autor considera que el yeso Minas Viejas subyace a dicho anticlinorio y que otros afloramientos de esta unidad, serán revelados con estudios posteriores más detallados.

"Por su posición estratigráfica, el yeso Minas Viejas se considera perteneciente al Divesiano; su desarrollo ha sido controlado por la proximidad relativa del mar y por las condiciones climatéricas prevalecientes durante su depósito."

La Casita Stage

La Casita Group

In 1936 (p. 1110) Imlay described a La Casita Formation to include "the shales, sandstones, and intercalated limestone beds lying between the La Gloria formation (below) and the Taraises formation (above)." The type locality was designated as Cañon de la Casita, located about 10 miles south of General Cepeda and about 30 miles southwest of Saltillo. The type region was described in 1937 (pp. 601-2) with measured sections, varying from 240 to 285 feet in thickness. Two lithologic members were recognized: a lower one that "consists of gray conglomeratic sandstone and ranges in thickness from about 20 to 75 feet or more. At the top, in most sections, are a few inches of friable sandstone, which contains brachiopods bivalves, and belemnites. The upper member consists principally of black shales but includes some buff or gray sandy shales, short lenses of sandstone and arenaceous limestone, and lenticular limestone nodules. Some of the nodules contain well-preserved mollusks." The formation was stated (p. 604) to be of Kimmeridgian and Portlandian age. "The basal sandstones may be of Oxfordian age."

Subsequent work has revealed much lithologic variability in the sequence of strata that occupies the position of the La Casita Formation. In 1956 Humphrey and Díaz, in a table giving the "Correlation of the Mesozoic Strata of Northeast Mexico"

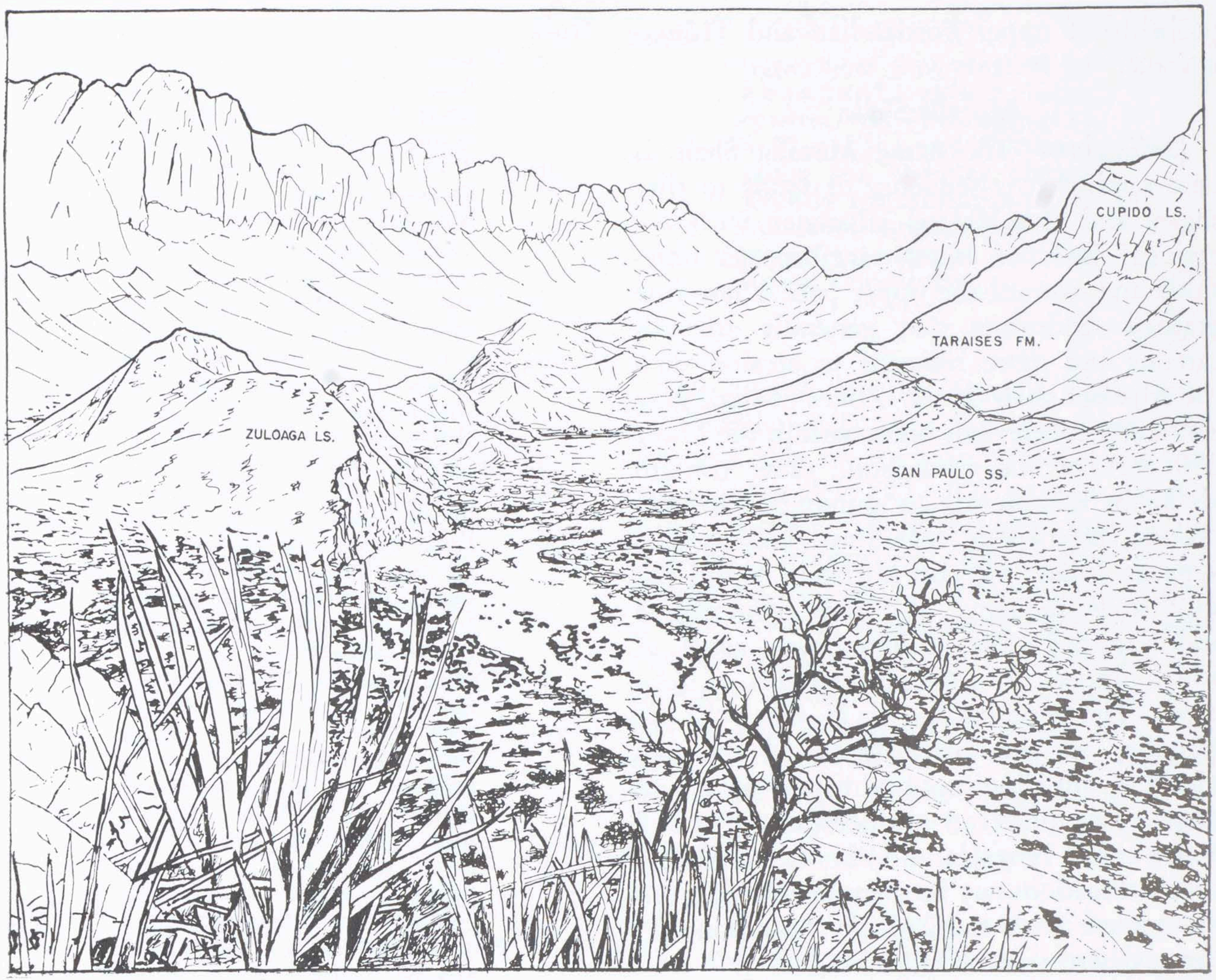

Figure 4. South flank of Los Muertos Anticline; view showing east end of Valle de San Paulo and the Valle de Muralla.

(see Humphrey, 1956, pp. 32-34) used the term "La Casita group" to specify the Jurassic strata of varying lithology that overlie the Zuloaga or La Gloria formations. Murray (1961, p. 292) pointed out that the term as thus applied was in a time-rock sense and added "Because these strata are exposed and well known in northeastern Mexico, inasmuch as they are laterally continuous with strata in the coastal province of Mexico and the United States, and because they are reasonably accessible, La Casita is used herein as a provincial stage for the youngest known late Jurassic in the coastal province to include rocks which can be equated in any reasonable way to typical La Casita and La Caja sequences." It is to be noted that this usage, since it includes strata that contain fossils of Tithonian age, is an extension of the range of the La Casita Formation at its type locality.

Within the Los Muertos anticline the deposits of the La Casita stage have a thickness varying from 2200 to 2400 feet and are readily divisible into two units which were designated as "members" of the La Casita Formation by Humphrey (1949, pp. 97-100) but which are here raised to the rank of formational units. The lower, herein denominated the Muralla Shale varies in thickness from 1164 to 1211 feet in sections measured in the region of the present study; it appears to be essentially correlative with the La Casita Formation of Imlay at its type area. The upper formation, here named the San Paulo Sandstone, consists mainly of fine- to coarse-grained, usually arkosic sandstones, with a number of lenticular conglomeratic horizons and occasional beds and lenses of very sandy limestones. Measured sections give thicknesses varying between 1130 and 1255 feet. A large fauna of pelecypod Mollusca is present together with a few sandstone casts of ammonites. The general faunal evidence seems to suggest that this unit is probably of upper Portlandian and Tithonian age.

Muralla Shale

Definition.—The name Muralla Shale is here applied to a sequence of sandy to silty shales and thin-bedded siltstones with occasional beds of highly argillaceous limestone and, toward the upper part, a few fine grained sandstones that generally are calcareous and more resistant to erosion than the adjacent shaly strata. Zones of dark gray limestone concretions occur within the lower 250 feet of the formation; these contain abundant Kimmeridgian ammonites and occasional pelecypods, including *Aulacomyella neogeae* Imlay. Certain horizons within the silty shale sequence also have compressed and flattened casts of ammonites some of which appear to represent species of *Idoceras.* The type section is in the Valle de Muralla, on the north flank of the Los Muertos anticline approximately two and one-quarter miles east-northeast of the school house at Los Nogales. An almost completely exposed section may be seen northward from the contact with the Zuloaga Limestone on the northern side of hill 3044.

Stratigraphic and lithologic features.—The non-resistant nature of the sediments comprising the Muralla Shale has resulted in a general dearth of exposures. Over much of the area studied, the formation is topographically lowest in the erosional valleys flanking the row of Zuloaga morros in the central part of the Los Muertos structure, and consequently the strata are buried under a cover of valley alluvium and colluvium. No outcrops of the Muralla have been found on the south limb of the anticline and there is reason to believe that the formation may be missing here due to strike faulting along or near the anticlinal crest; this will be discussed in a later part of this report. The most completely exposed sections are located on the north limb of the structure near the eastern and western limits of the mapped area, where the streams tributary to the Rio Santa Catarina have not eroded their courses as deeply as they have near their confluence with the main stream channel.

The section at the type locality, measured by Gary O. G. Greiner and the writer includes the following units:

Unit		Feet
5.	Finely laminated siltstones and silty fissile shales, gray to brownish-gray in color, weathering to buff. The lower 500 feet with gypsum beds in veinlets, but with occasional beds up to one foot in thickness. No fossils found	782
4.	Shale and finely laminated silts, pinkish to buff in color, weathering light gray. Occasional gypsum in bands ¼ to ½ inch thick. Unfossiliferous	52
3.	Siltstones in beds up to 12 inches thick with interbedded silty shale. Color light-gray, weathering white. Thin beds of limonite interbedded from 44 to 48 feet above the base. Unfossiliferous	76
2.	Shale, pink to pinkish buff in color, punky in texture, weathers to fine chips, light to medium gray in color. A bed of black colored silt 70 feet above base. A few indeterminate outlines of compressed ammonites observed on bedding surfaces	170
1.	Shale, and thin shaly siltstones, light gray to buff in color, weathering buff. Occasional zones of gray calcareous concretions, up to one foot in diameter; one 85 to 90 feet above the base with abundant ammonites and occasional pelecypods and petrified wood. Some of the concretions in this zone when broken reveal cores, or marginal zones of limonitic dust. Aptychi and flattened ammonites occur on shale bedding planes both above and below the zone	131
		1,211

A section approximately seven miles to the west of the type area was measured by W. E. Daughdrill, H. J. Morrow and John Sandy, Jr., of the 1961 field group. This section, which is located toward the western end of the mapped area, follows:

Unit		Feet
14.	Calcareous shales and shaly limestones, tan to gray in color, weathering to gray shale slopes. About 420 feet above the base there	

Unit		Feet
	is a 12 ft. zone with calcite veins 4 to 6 in. thick, suggestive of mineralization along folding glide planes. Unfossiliferous	640
13.	Tan to gray silty calcareous shales with occasional gray fine-grained sandstones, weathering brown, and more resistant to erosion, forming ledges. Unfossiliferous	103
12.	Sandstone, fine-grained, dense, calcareous, light brown in color, weathers to form a rusty brown ledge; no fossils	3
11.	Shale, calcareous, light gray, unfossiliferous	37
10.	Sandstone similar to unit 12	7
9.	Silty shale and siltstone, thin-bedded, light brown in color, with a very few, thin, fine-grained sandstone interbeds. Unfossiliferous	123
8.	Sandstone, light gray, weathering to rusty brown, fine- to very fine-grained with calcareous cement	11
7.	Shale, light buff to light gray in color, with local beds and lenses of hard calcareous black shale. Selenite veins and crystals common	14
6.	Sandstone, as in unit 8	2.5
5.	Shale similar to unit 7	68
4.	Sandstone, calcareous, fine- to very fine-grained, light brown in color, weathering dark brown	3
3.	Shale, light gray, buff to white in color, with some zones and lenses of black shale; resembles a diatomaceous shale; selenite abundant on bedding planes; fossils sporadically abundant on the bedding planes, especially in the light gray colored beds, including aptychi, flattened unidentifiable ammonites and pelecypods, fish scales and occasional leaf fragments	27
2.	Calcareous shale, light gray to buff in color, with occasional thin (3 to 6 in.) fine-grained sandstone or siltstone interbeds; selenite veins common; calcareous concretions, often with ammonites, occurring in zones toward the upper part of the unit; the uppermost foot marked by abundant, rather large concretions (averaging 14 x 10 x 4 in., and flattened along the bedding plane) usually containing numerous small ammonites	132
1.	Covered interval to the Zuloaga Limestone	32
		1,202.5

The contact of the Muralla Shale with the underlying Zuloaga Limestone has been observed only on the north side of the second morro (elev. 2877 ft.) west of the Rio Santa Catarina. There the basal bed of the Zuloaga is overturned, dipping 83° S. Although the contact is conformable, a stratigraphic break is suggested because the basal unit of the Muralla consists of a 6 inch bed of highly sandy limestone overlain by a 6 inch bed of coarse, poorly sorted grit. The slope of the hill down to the stream channel which interrupts the section, reveals 291.5 feet of strata, mainly buff to orange-buff claystone and silty mudstone. Ammonites and aptychi have been found in the claystones 15 and 70 feet above the base; in a 1.5 foot, black calcareous sandstone 87 feet above the base; in calcareous concretions 192 to 198 feet above the base, and in claystones 220 feet above the base.

San Paulo Sandstone

Definition.—The name San Paulo Sandstone is here applied to a sequence of fine- to coarse-grained calcareous sandstones and sandy limestones that include numerous sporadic lenticular conglomerates. The type section is exposed in the first draw west of a ridge north of the second morro west of the Rio Santa Catarina (see above). This ridge is easily recognized by a cap of a large collapsed mass of Cupido Limestone that rests upon the San Paulo Sandstone. The type section includes 1,160 feet of beds; Humphrey (1949, pp. 98-9) gives a measured section of his "upper member" of the La Casita Formation which includes 1,190 ft. of strata.

Stratigraphic and Lithologic features.—The San Paulo Sandstone is composed primarily of marine arkosic sandstone and arkose, but its most characteristic feature is the great amount of lithologic variation, both laterally and vertically; no two sections are alike in sequence, and individual units prove to be highly lenticular, changing rapidly in thickness, color and grain size along the strike. Sandstones, so highly calcareous as almost to merit designation as arenaceous limestones are replaced by pebble conglomerates within a few hundred yards along the strike. Conglomerate lenses three feet thick have an outcrop length of less than two hundred feet and pebbles as much as two inches in greatest diameter.

The type section, measured by the writer and his wife, Emily H. Vokes, follows:

Unit		Feet
40.	Marl, silty, very soft, light gray, weathers yellow	2
39.	Limestone, sandy, dark gray, weathering medium gray, lower half mottled brownish with much disseminated siderite	3
38.	Sandstone, arkosic, coarse-grained, very calcareous, dark gray, weathering a medium brownish gray; one bed	8
37.	Sandstone, arkosic, medium to coarse-grained, calcareous, much disseminated siderite (?), brownish gray, weathering brown; bedding obscure; many small vugs with calcite and quartz crystals	32
36.	Arkose, medium-grained, noncalcareous, pale yellowish brown in color, weathering a slightly lighter tone; thin-bedded and much jointed	13
35.	Arkose as in unit 36, but massive bedded and calcareous, lower 2 ft. with abundant pelecypods including *Trigonia* and *Pholadomya* (?), in matrix too hard to permit collecting	15
34.	Sandstone, slightly arkosic, noncalcareous, medium to coarse-grained, with small disseminated siderite nodules, light olive gray, weathering medium light gray; in one massive bed	10
33.	Arkose, as in unit 35, but one massive bed with a few scattered fossil fragments	16.5
32.	Sandstone, very arkosic, calcareous, medium-grained, dark gray, weathering brownish gray; casts of large pelecypods (indeterminate) near base	41
31.	Sandstone, very arkosic with abundant disseminated mica flakes, calcareous, dark gray, weathering dark brownish gray; contains abundant specimens of *Exogyra* sp.; *Gresslya* and "*Lucina*" present	8
30.	Sandstone, arkosic, noncalcareous, medium- to fine-grained, dark yellowish brown, weathering light yellowish brown, thin-bedded and much fractured with calcite veins	15
29.	Sandstone, fine-grained, well-sorted, noncalcareous, medium light gray in color, weathering rusty brown, with a very hackly fracture	6
28.	Sandstone, arkosic, coarse-grained to a grit conglomerate, dark gray, weathering dark brown; fossiliferous, fauna includes *Berriasella* (?) sp., *Exogyra* cf. *E. potosina* Castillo & Aguilera, and *Trigonia* n. sp., aff. *T. vyschetzkii* Cragin, *Nerinea* sp.	7
27.	Sandstone, arkosic, fine to medium grained, light olive gray, mostly noncalcareous, but with scattered calcareous zones which weather in a manner suggestive of concretions or boulders up to 6 in. in diameter	16
26.	Sandstone, fine- and medium-grained, medium gray, weathering medium light gray, in beds up to one foot thick, much fractured; *Exogyra* sp., *Pinna* cf. *P. quadrifrons* Cragin	11
25.	Sandstone, arkosic, similar to unit 27; *Exogyra* sp.	17
24.	Silty shale, dark gray to black, weathers to pencil-cleavage like fragments	10
23.	Sandstone, as in unit 29	1.5
22.	Sandstone, fine-grained, hard, calcareous, medium gray, weathering brownish gray; one massive bed; fossiliferous; *Pleuromya* ? cf. *P. inconstans* Castillo & Aguilera	4
21.	Sandstone, fine- to medium-grained, light to medium gray, weathering gray brown; in two hard beds, the lower of which has scattered quartz grains up to 2 mm in diameter	7.5
20.	Conglomerate, and coarse gritty sandstone with scattered pebbles of quartzitic and rhyolitic (?) composi-	

Unit		Feet
	tion; fossiliferous with unidentifiable Pelecypoda	2
19.	Sandstone, similar to unit 27, but wholly noncalcareous, massive bedded	27
18.	Sandstone, fine- to very fine-grained, noncalcareous, shaly, medium light gray, weathering light gray	21
17.	Sandstone, medium- to coarse-grained with lenses of grit conglomerate, calcareous, medium dark gray, weathering brownish gray, scattered fossil fragments, *Exogyra* sp.	31
16.	Arkose, coarse-grained, variegated dark gray and olive gray, weathers light olive gray	9
15.	Sandstone, arkosic, with much disseminated siderite (?), light olive gray, fine-grained below becoming more coarse-grained, almost a fine conglomerate at top	33
14.	Sandstone, fine-grained, noncalcareous, medium to dark gray, weathering very dark gray	23.5
13.	Sandstone, similar to unit 15; *Gresslya* sp.	12
12.	Sandstone, arkosic, fine-grained, noncalcareous, medium gray to medium dark gray, weathering medium gray	15
11.	Conglomerate, with quartz pebbles 5 to 10 mm in diameter, medium gray, weathering light gray	2.5
10.	Sandstone, similar to unit 12, with lenses of gritty conglomerate, and a conglomerate lense 8 inches thick 25 ft. below the top with fractured chert pebbles up to 2 in. in diameter	85
9.	Sandstone, very poorly sorted, fine- to very coarse-grained, locally conglomeratic, the coarse sand grains and the pebbles in the conglomeratic lenses of chert and quartz, noncalcareous, medium light gray, weathering dark yellowish brown; casts of *Gresslya* (?) 24 to 26 ft. above base	66
8.	Arkose, medium- to fine-grained, medium dark gray, weathering light brownish gray, moderately thick-bedded; interbedded with arkose, thin-bedded, fine to very fine-grained, noncalcareous, medium light gray, weathering light olive gray	89.5
7.	Sandstone, very fine-grained, noncalcareous, medium gray in color, thin-bedded and strongly jointed, weathering to coarse "pencil structure" fragments	27
6.	Arkose, similar to the medium-grained units in 8, moderately thick-bedded	51
5.	Sandstone, very fine grained, as in unit 7	32
4.	Sandstone, very fine grained and silty, slightly calcareous, thin-bedded and much fractured with calcite veins	128
3.	Siltstone, noncalcareous, medium dark gray, weathering light yellowish gray, with an 18 in. bed of silty claystone, pale red in color, at the top and three 6 in. beds of similar composition and color interbedded between 16 and 19 ft. from the top	238.5
2.	Sandstone, fine- to medium-grained, micaceous, calcareous, hard, medium gray, weathering brownish gray, in two massive beds, the upper 2.5 and the lower 4 ft. thick separated by 1.5 ft. of siltstone as in unit 3. The two resistant sandstone beds stand as dike-like ridges 18 to 20 feet high on the east wall of the tributary valley along which the section was measured	8
1.	Arkose, medium-grained, micaceous, noncalcareous, medium dark gray, weathering olive gray, thin-bedded and becoming somewhat finer grained toward the base	16
		1,160.5

Stratigraphic relations.—The contact of the San Paulo Sandstone with the underlying Muralla Shale is gradational, the line being drawn where the lithology changes from predominantly silty shale to fine-grained arkosic sandstones. In general the Muralla Shale weathers to a lighter gray tone while the shales of the San Paulo tend to be darker gray, often with a brownish color derived from the iron content of the arkose impurities.

Fossils and age.—The arkosic sandstones and conglomeratic beds of the San Paulo contain abundant, but usually poorly preserved, pelecypods, including at least three species of *Trigonia,* together with *Gresslya, Pleuromya, Pholadomya, Panopea, "Thracia," "Lucina," Astarte* s.l., *Exogyra,* and *Gryphaea* (?). The gastropods include *Nerinea, "Actaeonella,"* and naticoid forms; the cephalopods, a few ammonites and rare belemnites. The ammonites are usually in the form of sandstone casts which preserve the coarser details of ornamentation, but lack sutures. Ten feet above the base of the formation in its eastern exposures near the type area of the Muralla Shale, a specimen was collected consisting of approximately one-half whorl, marked by a whorl section approximately two-thirds as wide as high, with a rounded venter, and ornamented by moderately strong, slightly prosoradiate ribs that bifurcate approximately half way down the side of the whorl and are directly continuous across the venter. The sum of these characteristics is suggestive of the genus *Berriasella.* Somewhat higher in the section a specimen with rather compressed planulate whorls marked by numerous fine prosoradiate ribs adjacent to the venter and apparently otherwise smooth on the sides, resembles so far as can be determined from its poor preservation, illustrations of species referred to the genus *Proniceras.* A large specimen collected within the upper 30 feet of the section appears to represent a *Kossmatia*-like form. If these fossils be correctly assigned they indicate that the San Paulo Sandstone is wholly of Tithonian age.

Cretaceous System
Coahuila Series
Durango Stage
Taraises Formation

The name, Taraises Formation was proposed by Imlay (1936, p. 1111) for "a limestone formation of Valanginian age, which crops out in the western part of the Sierra de Parras." In the type region the formation ranges from 470 to 487 feet in thickness and is divisible into two members, the upper, 225 feet thick, "consists of thin-bedded limestones and nodular to splintery shaly limestones. Fresh surfaces are light gray or dark gray, and weathered surfaces are light yellowish-gray or cream. Fossils are found throughout but are especially abundant near the base. . . . The ammonite genus *Olcostephanus* (*'Asteria'*) is represented by many species and numerous individuals." The lower member, about 245 feet thick, "consists of gray limestones, and is more resistant to erosion than is the overlying member. Weathered surfaces are an inconspicuous medium gray. Ammonites are found throughout but are abundant only near the top."

In 1938 Imlay summarized the stratigraphy of the Taraises Formation in the northern Zacatecas-southern Coahuila region, and presented a systematic description of the ammonite faunas. He concluded (1938, pp. 550-552) that "in the more southern localities studied" the lower member "contains fossils which indicate both Berriasian and Valanginian ages" but to the north "the presence of *Olcostephanus* in the lowest beds suggests an age not older than the Valanginian." The upper member was regarded as being of lower Hauterivian age.

The deposits correlated with the Taraises Formation in the Valle de San Paulo-Valle de Muralla area are likewise divisible into two members which differ, however, lithologically from the Taraises as developed in its type area. The lower member, furthermore contains, near its base, abundant representatives of the ammonite genera *Acanthodiscus, Leopoldia* and *Distoloceras,* an association which Imlay (1938, p. 552) believes is indicative of a lower Hauterivian age. Hence it is believed that the deposits here referred to the Taraises Formation represent correlatives only of the upper member of the formation as present in its type locality.

The contact of the Taraises Formation with the underlying San Paulo Sandstone is apparently conformable although marked by a sharp lithologic change. However, if as indicated above, the basal member of the Taraises is of Hauterivian age, and the San Paulo is of Tithonian age a stratigraphic interval equivalent to the Berriasian and Valanginian stages is apparently absent from the section, and the contact is therefore to be described as paraconformable.

Los Nogales Member.—The lower member of the Taraises Formation as exposed in the area of the present study was named the

Los Nogales Member by Piaggio in 1962 (unpublished M.S. thesis, Tulane University) who applied the term to a "sequence of alternating shales and limestones which crop out in the . . . eastern part of the Los Muertos anticline. . . . This unit lies with apparent conformity (actually paraconformably) above the calcareous sandstones of the [San Paulo Sandstone] and below the distinctive limestones of the upper member of the Taraises Formation. An excellent exposure of these strata in a small arroyo on the north flank of the Los Muertos anticline, approximately 750 yards west-southwest of La Cuchilla, is designated as the type locality."

"The Los Nogales Member ranges in thickness from 130 to 135 feet on the south flank of the anticline, and from 185 to 198 feet on the north flank. Obscure faulting in the thick mass of shale which makes up the middle part of the unit may be the cause of the thinning on the south flank."

The member is divisible into three lithologic units, a basal sequence of resistant, ridge-forming limestones, a middle unit of soft shales that form a topographic saddle behind the limestone ridge, and an upper zone of sandy limestones, dark gray on fresh surface, that weather a rusty brown color. The type section, as measured by Piaggio includes the following strata:

Unit		Feet
10.	Limestone, dark gray to black, weathering yellowish brown, sandy with subangular to subrounded quartz grains; contains irregular patches of bright orange siderite, some altered to limonite; fossiliferous, fauna includes terebratulid brachiopods, crinoid segments, belemnites, an olcostephanid and other ammonites, and numerous smaller mollusks. A one foot zone of greenish-brown fissile shale weathering yellowish-brown that contains pyritized (altered to limonite) echinoids and olcostephanid ammonites	5.5
9.	Shale, greenish-brown, weathering pale yellowish-brown, very fissile, with small silty limestone concretions that contain distorted echinoids. Unit becomes increasingly calcareous toward top where several medium-bedded (6 to 12 inch) dark-gray, silty, fossiliferous limestones that weather yellow-brown are intercalated	22
8.	Interbedded limestones and shales: limestone, dark-gray to black, weathers yellow-brown, medium-bedded (3 to 12 inches) becoming more evenly bedded and increasingly silty toward the top of the unit; fossiliferous, with terebratulid brachiopods, belemnites and some pelecypods; alternates with shale, fissile, brownish-gray, weathering tan. Limestone-shale ratio increases upwards with shale zones approximately 10 ft. thick at bottom and 2-3 ft. thick at top	38.5
7.	Shale, dark-gray to black, weathering brownish-gray, calcareous, very brittle and poorly fissile; near the top are several 4 to 8 inch beds of silty, dark-gray limestones that weather medium gray	53
6.	Shale, brownish-gray, weathering yellowish-brown, fissile, highly contorted with distinct slaty cleavage and well-developed pencil structure; at base a 6 inch bed of very silty, unevenly-bedded dark- gray limestone that weathers gray	30.5
5.	Shale, light-gray, weathering yellowish-white, calcareous, platy, marly; at base a 2 inch bed of light brown limonitic shale that weathers a bright yellow-brown which has been traced laterally for more than one-half mile on the north side of the Valle de San Paulo	8
4.	Shale, dark-gray to black, weathering yellowish-brown, calcareous, platy, poorly fissile; at base a 2 inch bed of crystalline white calcite with minute partings of non-calcareous black shale	13.5
3.	Marl, chalky-white, weathering a dirty-yellow, soft and powdery, with occasional thin beds of black limestone that weather gray; fossiliferous with	

Unit		Feet
	limonitic concretions containing echinoids, and echinoids and ammonites replaced by limonite	10
2.	Limestone, dark-gray, weathering medium gray, very fine grained to sublithographic, dense, with numerous white calcite veins up to one inch thick transverse to the bedding; a thick (3′ 10″) bed at base, becoming increasingly thin-bedded upwards; abundantly fossiliferous with many ammonites (*Acanthodiscus, Distoloceras, Leopoldia, Neocomites, Thurmanniceras* (?), etc.), belemnites, pelecypods, occasional rhynchonellid and terebratulid brachiopods, crinoid segments, and rare corals	9
1.	Interbedded thin- to medium-bedded limestones and marls: limestones, similar to unit 2, with same fauna; marly interbeds, 2 to 7 inches thick. A 3 foot limestone bed at base	8.5
		198.5

In addition to the lesser thickness of the Los Nogales Member on the south flank of the Los Muertos anticline, measured sections reveal the following differences from those on the north flank of the structure: (1) the basal limestone sequence is slightly thicker, averaging 26 feet in thickness, and is most notably different in the almost complete absence of ammonites which are so conspicuously present on the north flank. These beds appear rather sparsely fossiliferous in outcrop with a fauna that includes belemnites, brachiopods, crinoid segments, rare corals and bryozoa. Thin sections, however, reveal that some of the beds contain abundant fragments of colonial cyclostome bryozoans and echinoid plates and spines. (2) The middle shale segment is thinner, 76 to 80 feet thick, but not greatly different, lithologically from that of the north flank. (3) The dark gray to black, brown weathering arenaceous and sideritic limestones with terebratulid bachiopods and other fossils, are in general thinner-bedded and have thicker shale units (up to 4 feet thick) intercalated between them. As a result the upper sequence is thicker, measuring up to 27 feet in some sections, although the total amount of limestone is not greatly different from that on the north flank.

Upper Member, Taraises Formation.—The upper member of the Taraises Formation consists of a rather monotonous sequence of black, fine-grained, dense limestones that weather to a light gray color and usually break down to shale-like slopes. As a result the inter-valley ridges appear to be underlain by a sequence of shales, whereas the fresh exposures in the valleys reveal the calcareous nature of the member. Some of the beds yield a strong fetid odor when struck with a hammer; a sample of such material dissolved in acid left a minor sludge of carbonaceous material and minute crystals of pyrite. The whole is suggestive of deposition under euxenic conditions. Some bedding planes, however, bear fucoidal impressions suggestive of a bottom fauna, and a few fossils, including ammonites and pelecypods occur, though not uniformly distributed throughout the section. A unit some five feet thick, located approximately 60 feet below the top of the formation has yielded numerous specimens of a gigantic species of *Harpagodes* (?). Hence it is evident that, if the depositional environment was occasionally euxenic, such conditions did not persist throughout the entire time interval encompassed within the member. The *Harpagodes* (?) zone has been recognized in all sections where the interval of its occurrence is exposed, and it constitutes a useful stratigraphic marker in this region.

A section measured on the north flank of the anticline by James A. Holliday follows; it was measured along a small draw immediately above an abandoned swimming pool that is located to the east of the saddle formed on the shales of the Los Nogales Member above the collapse block of Cupido Limestone adjacent to the type section of the San Paulo Formation:

Unit		Feet
9.	Limestone, dark grayish black, weathering medium light gray, obscurely cross-bedded, weathers to shaly slope; rocks yield strong fetid odor when struck	65
8.	Limestone, dark grayish black, weathers medium light gray, in 1 to 2 foot beds; fossiliferous with many specimens of *Harpagodes* (?) sp.	5
7.	Limestone, similar to unit 9,	

Unit		Feet
	gray black, weathering brownish gray with rough sandy surface; beds 4 to 5 feet thick; some highly fossiliferous beds in interval 20 to 55 feet below top	33
6.	Limestone, medium-bedded to massive, with thin shaly interbeds; limestone weathers to shaly slopes	565
5.	Shale, gray black, weathering brownish gray, calcareous	0.5
4.	Limestone, gray black, weathering light gray; contains a few pelecypods and ammonites that have been limonitized and are poorly preserved	1
3.	Shale, similar to unit 5	1.5
2.	Limestone, similar to unit 9, medium- to thick-bedded	51
1.	Limestone, similar to unit 2, but with much pyrite that weathers to limonitic stains	30
		752

A section measured on the south flank of the anticline, on the west side of a large tributary canyon approximately one and three-quarters miles west of Cañon de Morteros by R. F. Beyer, Jr., V. V. Cavaroc, Jr., and G. C. Glaser, well illustrates the lithologic consistency of the member:

Unit		Feet
4.	Limestone, dark gray to black, weathering light gray, dense, thick- to massive-bedded, emits a fetid odor when struck; rock weathers along joints and bedding planes to develop a resistant "blocky" surface residue	74
3.	Limestone, dark gray, weathers grayish-white, thick-bedded, fossiliferous, with numerous large *Harpagodes* (?) sp.	10
2.	Limestone, dark gray, weathering medium gray, weathers to a shaly slope; rock is medium-bedded below and becomes thicker bedded toward the top; thin shale interbeds. Some beds sparsely fossiliferous	152
1.	Limestone, light to dark gray, argillaceous, dense, weathers light gray to brownish buff in color forming fragments simulating a shale; basal beds of more pure limestone, more resistant and marked by limonitic stains	456
		692

Nuevo Leon Stage

Cupido Limestone

The Cupido Limestone, named by Imlay (1937, p. 606) for 1,415 feet of thick-bedded gray limestone exposed in the middle part of the Sierra de Parras, is the major ridge-forming formation in southeastern Nuevo Leon and adjacent areas of Coahuila. It crops out as strike ridges forming the north and south walls of both the Valle de San Paulo and the Valle de Muralla. Both the Cañon de Huasteca on the north and Cañon de Morteros on the south of the map area are cut through these strike ridges.

The formation is composed of thin- to thick-bedded and massive limestones, light brown to light gray, dark gray and black in color, and rudistid-bearing. Stylolitic suturing of the bedding planes is commonly present. Humphrey (1949, p. 102) states that in the western part of the Sierra de Los Muertos "the base is everywhere marked by a thick-bedded unit of dolomite and dolomitic limestones." In the area here under study the basal beds are all non-dolomitic limestones. There are, however, some dolomitic limestones and one or two beds of dolostone toward the middle part of the sequence.

The contact of the Cupido Limestone with the underlying Taraises Formation is conformable and is here drawn where the limestone becomes thick-bedded, resistant and cliff-forming.

Although the section in the Cañon de la Huasteca is perhaps more spectacularly exhibited, and is certainly better known to geologists and visitors, that in the Cañon de Morteros to the south is more completely exposed. A section measured mainly along the eastern wall of this canyon, with the basal beds being measured on the western wall, follows. The measurements were made by Anthony T. L'Orsa in 1961:

Unit		Feet
19.	Talus and caliche covered	6
18.	Limestone, medium to dark gray, weathering medium gray, thin- to very thick-bedded; upper foot thinly laminated; occasional rudistid pelecypods	20

Unit		Feet
17.	Limestone breccia, light to dark gray, weathering medium dark gray; appears to be intraformational breccia with slabs up to four feet long	3
16.	Limestone, medium gray to black, weathering medium to dark gray, with a few interstratified light gray beds; some rusty weathering, nodular, gray chert; rudistid bearing; stylolite columns up to one foot in length	204
15.	Limestone, dark gray, weathering medium gray, finely crystalline crowded with monopleurid (?) rudistids that have been recrystallized to white calcite. This rock has been locally "quarried" for terrazzo stone	7
14.	Limestone, medium to dark gray, weathering light to medium gray, thick-bedded, stylolitic; some fractures contain small quartz crystals embedded in calcite fracture fillings and small vugs; moderately fossiliferous with a rudistid fauna	255
13.	Limestone, medium gray to light brownish gray, weathers medium to light brownish gray, thick- to very thick-bedded, stylolitic with columns up to 8 in. long; rudistids moderately abundant	181
12.	Limestone, dolomitic, medium gray, weathering medium gray with a rough sugary textured surface. Rock is more coarsely crystalline than adjacent limestones	16
11.	Limestone, light to medium brownish gray with the lighter and darker layers alternating; weathering color corresponds approximately to color of fresh surface; medium to very thick-bedded; lighter colored beds tend to be sublithographic in texture, and more fossiliferous than the darker; fauna mainly rudistid but some *Nerinea* were noted	598.5
10.	Dolostone, medium gray, weathering brownish gray, sugary in texture	2.5
9.	Limestone, light brownish gray to dark gray with colors alternating every few feet; weathers in light to dark brownish gray bands with medium brownish gray predominating; a few isolated strata are dolomitic; thick- to very thick-bedded; sparsely fossiliferous	606
8.	Limestone, light brownish to light olive gray, weathering light gray, fine crystalline; thick- to very thick-bedded; fauna includes rudistids and large *Nerinea*	68
7.	Limestone, medium to dark gray, weathering medium gray, thick- to very thick-bedded; some beds crowded with rudistids, others sparsely fossiliferous; a single coral was observed	268
6.	Covered interval, a single limestone bed two feet thick exposed near center, medium gray, weathering lighter gray, with abundant rudistids	52
5.	Limestone, argillaceous, thinly laminated, medium gray, weathering medium gray to fissile-like fragments	3
4.	Limestone, grayish black, weathering dark gray, thick-bedded, stylolitic	14
3.	Limestone, argillaceous, with thin uneven laminations, light to dark gray and brownish gray, weathering same; interbedded with a lesser amount of thick-bedded limestone, non-argillaceous, dark gray weathering medium gray	35
2.	Talus covered interval	15
1.	Limestone, dark gray, weathering medium gray, thick-bedded, stylolitic	26
		2,380

Comanche Series
Trinity Stage
La Peña Formation

Imlay proposed the term La Peña Formation in 1936 (p. 1119) for the "lower and middle portions of the mountain-forming limestones, as exposed in the Sierra de Parras, lying stratigraphically between the Parritas formation (below) and the Aurora limestone (above)." Two members were recognized, a lower consisting of "about

1400 feet of light- to dark-gray, thick- to medium-bedded limestones, which include some shaly partings," and an upper member ranging from 50 to 80 feet in thickness which "consists of thin-bedded limestones and shales." A measured section of the lower member in Cañon Platanos south of Parras, included 2190 feet of limestones with minor shale.

In 1937 (p. 606) he proposed the name Cupido Formation for "thick-, medium-, and thin-bedded limestones above the Taraises formation and below La Peña formation" but continued to include a thick limestone sequence as the basal member of the overlying La Peña the contact being "drawn where thin-bedded and platy limestones become abundant." The distinction between the two limestone units is not apparent in the sections exposed in the Nuevo Leon area, the limestones being medium- to thick-bedded throughout the entire sequence. The writer follows Humphrey (1949, p. 103) in applying the name Cupido Limestone to the entire sequence while recognizing that the upper portion probably corresponds in stratigraphic position to the lower member of Imlay's original La Peña Formation. The latter name is thus restricted to a sequence of marls and shaly limestones with one or two more resistant limestone strata that are the stratigraphic equivalent of the upper member of Imlay's La Peña. These beds, which are abundantly fossiliferous with a rich ammonite fauna of upper Aptian age, are much less resistant than the adjacent massive limestones of the Cupido and Aurora formations and weather to a narrow strike valley whose surface is strewn with talus to the point that outcrops are rare and difficult to locate.

No section adequately exposed for measurement has been located in the present mapped area, but a partial section exposing the lower beds of the formation is well shown adjacent to a shaft sunk by the Comisión Agua Potable de Monterrey. The section penetrated in this project was slightly in excess of 15 meters thick (oral communication). The portion exposed includes the following units:

Unit	Feet
4. Limestone, dark gray weathers medium gray, in beds about 1 foot thick, dense, argillaceous; moderately fossiliferous with fauna including ammonites, belemnites, echinoids and rare pelecypods	10
3. Shale, medium light gray, weathers light gray, very marly; fauna includes echinoids, belemnites and occasional ammonites	1.5
2. Limestone, medium dark gray, weathering a grayish yellow-brown, very nodular and unevenly bedded with interbeds of gray marly shale; highly fossiliferous, with abundant ammonoids that include almost all species described by Humphrey (1949), together with nautiloids, belemnoids, rare pelecypods, gastropods, and echinoids; fossils characteristically red-colored on surface	8
1. Limestone, dark gray, weathering brownish gray, thin- to medium-bedded, very argillaceous, with thin interbeds of marly gray shale; fossiliferous, fauna including *Plicatula* sp., *Astarte* (s.l.) and other pelecypods together with rare brachiopods	5
exposed thickness	24.5

On the north side of the anticline there is a characteristic erosional notch on the east wall of the Cañon de la Huasteca near the entrance of the canyon. Unfortunately, however, the strata here are covered with talus from the adjoining Cupido and Aurora limestones and no section can be studied. On the west side of the canyon, immediately above the end of the paved road from Santa Catarina, a few fossils, collected from the saddle at the crest of the ridge are sufficient to establish the presence of La Peña at this position in the structure.

The contact with the underlying Cupido Limestone is concordant and sharp, the uppermost Cupido strata forming a distinct wall adjacent to the basal La Peña strata. Present knowledge of the faunas of the upper part of the Cupido Limestone is insufficient to permit any conclusions as to whether the sharp lithologic change between the two formations is simply a change in deposition regime or is indicative of a time lapse between them.

Trinity (?) and Fredericksburg Stages

Aurora Limestone

The Aurora Limestone, named by Burrows (1910, pp. 96-97) for 600 to 1500 feet of cherty limestones in the Sierra de La Aldea in northeastern Chihuahua, is, like the Cupido Limestone, an important mountain-forming unit. In the area of the present study it crops out at the northern entrance to the Cañon de la Huasteca, forming the front of the first ridge of the Sierra Madre Oriental, and on the southern flank of the Los Muertos structure it occurs at the southern entrance to the Cañon de Morteros to form the north wall of the broad synclinal valley south of the Valle de San Paulo-Valle de Muralla area. Only the basal beds are exposed in both outcrop belts. Fresh surfaces of the limestone are dark gray to grayish black in color and weather a medium gray in color. The beds are medium to very thick, or massive, and characteristically contain brownish-weathering black chert in irregularly shaped nodules and concretions. Stylolitic suturing of bedding surfaces is generally to be observed and rudistids are not rare in some of the strata, though absent in others.

Tertiary (?) or Quaternary System

"enigma clay"

The informal designation, "enigma clay," has been applied in the field to a small deposit located immediately southwest of the schoolhouse in the *población* of Los Nogales. The deposit consists of approximately 60 feet of thin-bedded, calcareous clay in thin beds, one to three inches thick, that are more or less alternately light grayish yellow and orange buff in color. The deposit rests upon a water-worn eroded surface of the upper member of the Taraises Formation, with, in the small area where the floor is exposed, no trace of a basal sandy, or conglomeratic, layer. The Taraises has a strike of N. 65° W. and dips 85° to the south; the clays strike N. 40° E. with dips varying between 23° and 31° S. Overlying the clays is a coarse bouldery alluvium containing large blocks of the Cupido Limestone.

In the laboratory, samples of the clay prove to contain twenty-five percent $CaCO_3$ (by weight), gave a positive test with benzidine, and after the lime had been leached out all the residue passed a 200-mesh screen. There was no trace of swelling, although the leached sample, after drying, disaggregated in water.

The origin of the clay deposit is not clearly understood. The thin, even bedding, clearly indicates subaequeous deposition, and the fineness of the material strongly implies relatively quiet waters; hence a lacustrine origin is suggested. Nevertheless, it is difficult to explain the absence of any coarser debris, especially since the deposit lies on the Taraises Formation at a point less than 400 feet from high-standing, resistant, cliff-forming strata of the Cupido Limestone. Careful examination along the entire face of the quarried area has failed to reveal even a single pebble of limestone. Furthermore, there are no traces of organic material, save for rootlets of plants that have penetrated into the deposit from above, and it is to be expected that a lake in this general region would contain some traces of leaves, or wood, and especially should have had a molluscan fauna that would have left occasional shells in the bottom sediment.

It has been suggested that the absence of coarse material might be explained if we assume that the adjacent Cupido cliffs were beneath the waters of the lake. This would require a water depth of 800 to 1000 feet and, in the general regional topographic setting now indicated, would have resulted in a lake many hundreds of square miles in area. In the light of so large a body of water it is difficult to explain the absence of any evidences of its existence other than the one small clay deposit now known.

Quaternary System

Alluvial Deposits

Extensive alluvium and colluvium covers the floors of both the Valle de San Paulo and the Valle de Muralla, and alluvium is present in both the Cañon de la Huasteca and the Cañon de Morteros. These materials include, in addition to normal valley channel and flood plain deposits, a veneer of caliche-cemented piedmont debris covering the lower slopes of the ridges that margin the valleys. For some reason not yet understood the caliche-cemented deposits appear to be more extensively developed in the Valle de Muralla, especially toward the western end where they occur at elevations as much as 600 feet above the present valley floor, reaching altitudes of almost 3,100 feet above sea level. In the Valle de San Paulo they seldom occur more than 200 feet above the valley floor.

Over most of the area the caliche-cemented deposit is sharply delimited from the valley alluvium, and the former is interpreted as the product of a depositional period characterized by a more pluvial climate than that presently existing in the region.

V. Structural Features

The Cañon de la Huasteca area lies within the broad regional structure known as the Los Muertos anticline, the prominent fold whose northern limb forms the front of the Sierra Madre Oriental in the immediate vicinity of Monterrey and westward into the eastern part of the State of Coahuila. Within the area studied the anticline is asymmetrical with the strata on the north flank dipping 80 to 90 degrees or overturned, and those on the south flank, in general, dipping less steeply. There is, however, variation in the attitude of the beds. The steepest dips recorded are in the general vicinity of the Cañon de la Huasteca on the north flank, and of the Cañon de Morteros on the south. On the north flank of the structure, within the Valle de San Paulo there is a progressive reduction in the dip angle westward from the Huasteca, until, near the western edge of the mapped area the dips are mainly in the range of 50 to 60 degrees. Outside of the Valle de San Paulo, on the northern side of the Cupido-Aurora Limestone ridge, there is a reversal of this situation, with the ridge-forming limestones becoming more and more overturned westward from the Cañon de la Huasteca until, as may be observed from the Monterrey-Saltillo Highway, the dips in the upper portions of the ridge are approximately 60 degrees to the south.

On the south flank of the anticline in the Valle de San Paulo the Cupido and Taraises formations have dips of 84 to 85 degrees to the south at stream level, but the arching of the strata into the anticlinal structure is revealed in dips as low as 70 degrees on the higher ridge elevations. Less than a mile to the west, however, dips of 36 and 38 degrees are recorded in the San Paulo Sandstone and the Los Nogales member of the Taraises Formation. From this point westward, in contrast to the situation observed in the northern part of the valley, there is a gradual increase in the angle until 60 degree dips are recorded toward the western terminus of the mapped area.

An apparent fault near the axis of the anticline also complicates the interpretation of the Los Muertos structure in the Valle de San Paulo area. This fault is nowhere visible, its trace apparently lying below the alluviated valley of the intermittent stream which flows along the south side of the Zuloaga morros that mark the anticlinal crest. The presence of the fault is inferred primarily from the insufficient room between the outcrops of the Zuloaga Limestone and the San Paulo Sandstone on the south limb of the anticline for a thickness of Muralla Shale equivalent to that measured on the north flank of the structure (see Fig. 2). Other evidence is that the few dips which could be obtained in the Zuloaga Limestone in the Valle de San Paulo section are all steeply overturned, but the San Paulo Sandstone on the south limb of the structure (and less than one thousand feet from the Zuloaga) dips from 36 to 59 degrees to the south. Finally, just beyond the western end of the mapped area on the southern margin of a Zuloaga morro the dark gray limestone is completely brecciated into fragments "floating" in a matrix of white crystalline calcite. The limestone fragments, only a few inches in greatest length, are separated by from one to four inches of calcite.

It is of interest to note, in this connection that, although Böse had earlier (1923, p. 129) commented that "one of the most astonishing features of the region is the absence of faults and overthrusts," he recognized the probable existence of the present fault which he shows in a small cross-section (p. 200) and he states (p. 324): "Along the middle of the valley probably lies a fault of small importance; toward the south the Oxfordian [Zuloaga] limestone seems to break off where the beds should begin to dip toward the south."

Some evidence as to the nature of the fault may be gained from a study of the well developed axial-plane cleavage or fan-jointing which strikes parallel to all of the observable regional structures. A compilation of the dip pattern of this cleavage was made by V. V. Cavaroc, Jr., of the 1961 field group. This revealed that the projections of the cleavage dips measured on the south flank of the anticline converged at a point northward from the convergence point of those measured on the north flank, and also somewhat deeper below the surface. Mr. Cavaroc concluded (unpublished field report): "While the number of fan dips taken [were not sufficient to permit a positive statement], the results are consistent enough to strongly indicate a major, low angle, axial thrust fault dipping about 25° northward." The amount of displacement would be in the magnitude of 800 to 1,200 feet, depending upon whether or not a portion of the Zuloaga Limestone on the south limb of the fold was also displaced as suggested by Böse.

There is general agreement that the forces which deformed the Jurassic and Cretaceous sediments into the folds now represented in the Coahuila-Nuevo Leon portion of the Sierra Madre Oriental of Mexico were derived from the south-southwest (Böse, 1923, p. 333; Humphrey, 1949, p. 113; 1956, p. 28; De Cserna, 1956, p. 69; etc.), and this is well shown in the Cañon de la Huasteca area by the steepened north dips and overturning on the northern flank of the Los Muertos anticline as compared with the gentler dips on the southern flank. But this same consideration implies that the fault movement occurred as an underthrust movement from the south to the north. It also has been generally agreed that one cause of the strong overfolding to the north is that the sediments folded were caught between the forces from the south-southwest and the margins of a now buried block of Paleozoic and early Mesozoic sediments and associated igneous rocks that was positive in late Jurassic time (and was the source of the clastics represented in the Muralla Shale and, especially, in the San Paulo Sandstone). This block represents the "Ancient Continent" of Böse (1923) and Burckhardt (1930-31) and the Coahuila and Tamaulipas peninsulas of Kellum, Imlay and Kane (1936), Imlay (1943) and of subsequent authors.

It is somewhat difficult for the present writer to visualize underthrusting in the present region which should be situated rather near the margins of the hypothecated positive block, unless some special conditions occurred. These may be found in the presence of the gypsum in the region, as evidenced by the intruded gypsum noted in the Zuloaga Limestone in the Valle de San Paulo area, and in the Sierra del Fraile to the northwest. It is here suggested that the gypsum intrusions in the Valle de San Paulo area may have been one result of the faulting in this valley, and it might even be possible that the underthrust mass, moving into a series of strata of gypsum and anhydrite would act more or less like a plunger being forced into a cylinder of liquid, to displace the evaporites and to force their movement, perhaps in part along the fault plane, and especially along the bedding-planes between the massive limestone layers of the Zuloaga. It thus may be significant that the only occurrences of intrusive gypsum in the region coincide rather precisely with the limits of the area in which the evidence for faulting noted above are to be observed.

The anomalous structural features are not continued laterally into the Valle de Muralla to the east of the valley of the Rio Santa Catarina and there is no evidence to suggest the presence of a fault at the crest of the anticline in this region. Dips are relatively steep on both flanks, although somewhat more steep on the north than the south.

Cross faults, or tear faults, noted by Humphrey (1949, pp. 114-5) on the north flank of the anticline in the region to the west of the present area have not been observed during the course of the present study. There is, on the other hand, an apparent slight southerly offset of the formations in the core region of the anticline on the east side of the valley of the Rio Santa Catarina as compared with those on the left. Furthermore the fact that the caliche-cemented alluvial deposits occur at much higher slope elevations in the Valle de Muralla than they do in the Valle de San Paulo, and the much broader outcrop width of the Zuloaga Limestone belt in the Valle de Muralla, all tend to suggest the presence of a small cross fault near the present course of the Rio Santa Catarina, and also to indicate that the east side was uplifted with respect to the west. On the other hand, the fault either did not affect the Cañon de Morteros on the southern flank, or else the movement was strictly parallel with the direction of dip, for one can easily observe the continuation of the individual strata directly opposite each other in the canyon walls. The rather sinuous course of the Cañon de la Huasteca makes it a bit more difficult to check the individual beds on the opposite walls, but they appear to be continuous across the structure, and there is no striking difference in dip on the two sides as was reported by Humphrey from the area near Las Cortinas canyon (1949, p. 115).

Collapse structures.—Incidental mention has been made of a ridge north of the second Zuloaga morro west of the Rio Santa Catarina that is capped by a large collapse mass of Cupido Limestone resting on the upturned edges of the San Paulo Sandstone. This limestone mass cannot be interpreted as an example of rock fall or talus because, although now somewhat broken up by undercutting resulting from the weathering of the softer San Paulo strata around the margins of the mass, the material obviously reached its present position without notable disruption. The mass is here interpreted as representing a form of "slip-sheet," defined by Harrison and Falcon, (1934; 1936) as "a slab of rock which has become detached from its original place on a dip-slope and has slipped down, remaining more or less intact" (1936, p. 92). In the present instance, however, the slab has slipped down on the inner side of the fold, rather than down a dip-slope, apparently because the differential erosion of the softer Taraises sediments and the highly resistant Cupido limestones left an almost vertical block of the latter without adequate buttressing. It seems that the block must have been weakened below, either by erosion or because of excessive joint or fracturing at the base, and thus have slid as a unit, rather than have toppled over from above, since the latter assuredly would have resulted in the free fall of a major portion of the mass, disrupting it to form rock-fall debris.

There is a second, well-exposed, and apparently more recently formed example of a collapse structure exhibited on the north wall of the synclinal canyon immediately to the south of the mapped area. It is located four to five miles east of the southern terminus of the Cañon de Morteros. Determination as to whether it represents a "flap" or a "slip-sheet" must await careful examination of the strata involved.

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