Geology of the Huizachal Redbeds, Sierra Madre Oriental, Mexico.

Robert Burnley Mixon

Louisiana State University and Agricultural & Mechanical College

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SIERRA MADRE ORIENTAL, MEXICO.

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SIERRA MADRE ORIENTAL, MEXICO

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geology

by

Robert B. Mixon
B.S., University of Alabama, 1953
M.S., Louisiana State University, 1958
January, 1963
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Macrofossil identifications were made by G. Arthur Cooper, Head Curator, Department of Geology, United States National Museum, and R. W. Brown, R. W. Imlay, S. H. Mamay,

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ABSTRACT

The Huizachal Group consists of two redbed sequences separated by a pronounced angular unconformity. Exposures occur only in the cores of anticlines in the Sierra Madre Oriental fold belt but well data suggest a wide distribution in the subsurface of the Gulf Coastal Province.

The lower redbed sequence, designated La Boca Formation, is composed of Late Triassic and Early Jurassic post-orogenic sediments eroded from uplifted portions of Late Paleozoic fold belts. In Tamaulipas and Nuevo León the La Boca includes more than 6,000 feet of gray, green, and red mudstones, siltstones, shales, sandstones, and conglomerates derived chiefly from granitic and low- to medium-grade metamorphic terranes. Most beds are of fluvial origin but minor volumes of lacustrine and paludal sediments are included. West and south of Nuevo León and Tamaulipas the La Boca overlaps and/or interfingers with marine beds. At all known localities the La Boca was folded, faulted, and intruded by diverse types of igneous materials prior to deposition of younger Jurassic strata.
The upper redbed sequence, designated La Joya Formation, is of Middle to early Late Jurassic age. In some areas it may include beds as old as Late Liassic. The La Joya consists of up to 600 feet, or more, of continental, marginal, and marine mudstones, sandstones, and conglomerates deposited during and after the post-Early Liassic, pre-Late Jurassic deformation and uplift which affected La Boca and older rocks.
CHAPTER I

INTRODUCTION

Redbeds, which have been assigned ages ranging from Permian to Jurassic, are widely present beneath definite Late Jurassic strata in the subsurface of the Gulf Coastal Province of the United States and Mexico. They are also exposed beneath Late Jurassic strata at many localities in the Sierra Madre Oriental of northern and eastern Mexico where they have been designated Huizachal formation (Imlay et al., 1948) or Huizachal Group (Mixon et al., 1959).

Throughout much of northeastern Mexico the Huizachal red beds and associated evaporites constitute the basal beds of a thick Mesozoic sequence which unconformably overlies more highly deformed Late Paleozoic and older rocks. The pre-Cretaceous portion of the Mesozoic, including marine limestones and shales in addition to the red beds and evaporites, has long been of interest to geologists because of its striking similarity to equivalent rocks found only in the subsurface in the Gulf Coastal Province of the United States (see Fig. 1).
Figure 1. Comparison of Lower Mesozoic Sections, Sierra Madre Oriental and Ark-La-Tex Region
Neither of these Lower Mesozoic sequences is fully understood. In the Gulf Coastal Province the character and relationships of the strata are obscured by a thick cover of younger rocks. In the Sierra Madre Oriental, exposures are excellent but have been little studied. Consequently, studies of the Lower Mesozoic strata of the Sierra Madre, in particular the redbeds and evaporites, should contribute greatly to a better understanding of (1) depositional environments and regional relationships of their counterparts in the Gulf Coastal Province, and (2) Early Mesozoic paleogeography and paleotectonics of the southern margin of the North American continent.

The purpose of this study has been (1) the accumulation of basic stratigraphic, structural, and petrographic information relating to the Huizachal redbeds and (2) the application of these data to problems concerning the Early Mesozoic stratigraphy, paleogeography, and paleotectonics of northeastern Mexico. The study is a portion of a more extensive program of research, concerned primarily with the Mesozoic stratigraphy of northeastern Mexico, which is being conducted by graduate students working under the direction of Boyd Professor Grover E. Murray at Louisiana State University.
KEY TO LOCALITIES SHOWN IN FIGURE 2

1. Villa Juárez uplift
2. Sierra del Borrego (Sierra de San Julian)
3. Sierra de Candelaria (Sierra del Toro)
4. Sierra de la Ventura (Sierra de Rocamonte)
5. San Pablo area
6. Rancho Alamar area
7. Mezquital area
8. Aramberri area
9. Huizachal anticlinorium
   a) Los Angeles, Guayabas, and Rosario Canyons
   b) El Olmo, La Boca, and Santa Lugarda Canyons
   c) Arroyo Seco, Caballeros, and Peregrina Canyons
   d) Novillo and La Reja Canyons and Huizachal Valley
10. Miquihuana area
11. Sierra de Catorce
12. Zacualtípán area of Huayacocotla anticlinorium
Figure 2. Areas of Outcrop of Huizachal Group
Area of Outcrop

Although the Huizachal redbeds are widely present in the subsurface in this region, the total area of outcrop is not large. Exposures, which occur in the cores of anticlines in the Sierra Madre Oriental fold belt, are small inliers within broad expanses of younger Mesozoic strata.

Most redbed outcrops are concentrated in five widely separated localities: the Huizachal anticlinorium, southwestern Tamaulipas; the Sierra de Catorce, northern San Luis Potosí; the Sierra de Candelaria and Sierra del Borrego, northern Zacatecas; the Villa Juárez uplift, eastern Durango; and the Huayacocotla anticlinorium, Hidalgo and Veracruz (see Fig. 2). Outcrops of lesser extent occur in the San Pablo-Alamar-Mezquital-Aramberri area of southern Nuevo León, the Sierra de la Ventura of southern Coahuila, and the Miquihuana area of southwestern Tamaulipas.

Physiography

Exposures of the Huizachal redbeds occur only in the cores of anticlines in the Sierra Madre Oriental fold belt, a structural unit which is coincident with the physiographic province bearing the same name. The main portion of this
Figure 3. Sierra Madre Oriental Physiographic Province
physiographic province comprises the arcuate belt of folded Jurassic and Cretaceous sediments, mostly limestones, extending from the state of Puebla north and west to eastern Durango (see Fig. 3). From the apex of this arc, in Nuevo León, lesser folds extend northwestward to the Big Bend region of Texas.

The eastern ranges of the Sierra Madre Oriental from Monterrey southward (High Sierra of Raisz, 1959) are formed of long, narrow, closely spaced anticlinal. Valleys are located along both synclinal and anticlinal axes. The topography is rugged. Peaks and escarpments are formed mostly of thick Cretaceous limestones which in this climate are very resistant to erosion. Elevations range from about 1,000 feet at the western edge of the Gulf Coastal Plain to a maximum of about 13,000 feet at Cerro Peña Nevada in southwestern Tamaulipas.

The western ranges of the Sierra Madre Oriental are divided by Raisz into two subprovinces, the Lower Ranges and the Cross Ranges. The Lower Ranges consist of north-south trending folds which parallel those of the High Sierra to the east. They differ from the High Sierra in their lower relief and in the separation of the individual ranges, one from another, by wide, alluvium-filled valleys. The Cross Ranges
Figure 4. Southeasterly view of Rancho Alamar area, southern Nuevo León. (1) Village of Pablillo; (2) Puerto de Cieneguillas; (3) Cerro Infiernillo; (4) La Muralla; (5) Cañon de la Alamar; (6) Cañon de San Vicente; (7) Río Pablillo; (8) Coastal Plain; (9) Cerro El Pilón.
comprise the east-west trending ranges in Durango, Coahuila, and Zacatecas. They are similar to the High Sierra but are not so high or so closely spaced. Both the Cross Ranges and the Lower Ranges differ from the High Sierra in that Jurassic rather than Cretaceous limestones are the main mountain-forming rocks of many of the individual ranges.

Chronologic Review of Previous Work

1925 P. A. Robertson, geologist for the Mexican Gulf Oil Company, proposed the name Huizachal for redbeds exposed at the Rancho Huizachal and other nearby areas in the Sierra Madre Oriental west of Ciudad Victoria, Tamaulipas.

1940 Arnold Heim, at one time geologist for the Shell group of oil companies, tentatively assigned a Permian age to redbeds (Huizachal) which he had examined in 1925 while engaged in field studies in the front ranges of the Sierra Madre Oriental between Ciudad Victoria and Tamazunchale.

1943 Ralph W. Imlay summarized the distribution, gross lithic character, and stratigraphic relations of the Huizachal redbeds as known at that time. He pointed out the possibility that the redbeds might have been
deposited throughout the period from latest Triassic to early Late Jurassic but considered them to be most probably of early Late Jurassic age because "lithologically similar red beds associated with salt occur at the base of the Upper Jurassic near Chinameca, Veracruz, in southern Mexico." The redbeds were correlated with the Eagle Mills Formation of the southern United States on the basis of stratigraphic position and similar lithic characteristics.

**1948** Edmundo Cepeda noted that the redbeds (Huizachal Group) exposed in the Cañon de Catorce, northern San Luis Potosí, consist of two rock units separated by a pronounced angular unconformity. He referred to these two units as the upper and lower members of the Lechos Rojos formation, an informal designation for the redbeds used by many geologists at that time.

**1948** Imlay, Cepeda, Alvarez, and Díaz formally defined the Huizachal formation, designated a type section in Huizachal valley southwest of Ciudad Victoria, Tamaulipas, and reviewed its stratigraphic and lithic characteristics. They suggested an early Late Jurassic (upper Oxfordian) age for the Huizachal.

**1956** H. K. Erben considered redbed sedimentation in
east-central Mexico to have encompassed most of Middle Jurassic time. Because of their position beneath the Tepexic Calcarenite (see p. 17), redbeds in this region were believed to be no younger than Callovian.

1956 W. E. Humphrey supposed the Huizachal to be late Early Jurassic-Middle Jurassic sediments deposited concurrently with post-Liassic, pre-Late Jurassic orogeny. The incipient regional metamorphism and spotty distribution of Liassic sediments in eastern and southern Mexico led him to infer widespread deformation and erosion in that region prior to the Late Jurassic. He concluded that post-Liassic orogeny might also have taken place in northeastern Mexico.

1956 Zoltan de Cserna considered redbed sedimentation in northeastern Mexico to have taken place throughout the greater part of the Jurassic and to have been initiated, possibly, in the Late Triassic. He believed the Huizachal to be the product of the erosion of structures produced during Permo-Triassic deformation.

1958 Field work by Mixon demonstrated that the Huizachal in southwestern Tamaulipas consists of two
mappable rock sequences separated by an angular unconformity. Redbeds above the unconformity and below Upper Jurassic limestones were designated La Joya Formation. Beds below the unconformity and above Permian strata were designated La Boca Formation. Late Triassic plants were collected from the La Boca.

1959 Mixon, Murray, and Díaz formally defined the La Joya and La Boca Formations. They suggested that the Huizachal be elevated to group rank and used as a rock unit to include the two lithically similar redbed sequences in the Sierra Madre Oriental, southwestern Tamaulipas.

1959 José Carrillo proposed the name Cahuasas Formation (see p. 17) for redbeds in Hidalgo, Veracruz, and Puebla which overlie the Huayacocotla Formation (see p. 16) and underlie the Tepexic Calcarenite. Formerly, these redbeds had been included in the Huizachal.

In 1960, Carrillo discovered a thick redbed sequence near Zacualtipán, Hidalgo, below the Huayacocotla Formation and above Permo-Carboniferous strata, which is correlative with the La Boca Formation.
CHAPTER II

SUMMARY OF REGIONAL STRATIGRAPHY

Precambrian and/or Lower Paleozoic Metamorphic Rocks

The metamorphic complex exposed in the cores of folds near Ciudad Victoria, Tamaulipas, and Aramberri, Nuevo León, comprises the oldest known rocks in northeastern and east-central Mexico. The metamorphics are predominantly schists but gneisses form a considerable portion of the sequence in the Ciudad Victoria area. Although these rocks can be definitely dated only as pre-Mesozoic, the occurrence at Ciudad Victoria of fault blocks of relatively unmetamorphosed Silurian and younger Paleozoic sediments within the metamorphics suggests that they are pre-Silurian.

Schists at Miquihuana, Tamaulipas (Imlay, 1943b, p. 1477), and gneissic rocks near Zacualtipán, Hidalgo, are possibly equivalent to the metamorphic complex of the Victoria-Aramberri region.
Middle and Upper Paleozoic Sedimentary Rocks

Middle Paleozoic sedimentary rocks are known only in the Ciudad Victoria area where approximately 200 meters of Silurian, and possibly Devonian, limestones and shales occur in fault blocks within the crystalline complex.

Thick sequences of Permo-Carboniferous geosynclinal-type arenaceous-argillaceous sediments are exposed in the Ciudad Victoria area, the Las Delicias-Acatita area of Coahuila, and the Zacualtipán area of Hidalgo.

Upper Paleozoic (?) Metamorphic Rocks

Rodgers et al. (1956 and 1957) and de Cserna (1956) report metamorphic rocks, tentatively assigned to the Upper Paleozoic, in the Caopas area of northern Zacatecas. The sequence consists largely of green phyllitic rocks, altered basic volcanics, and mica schists.

Pre-Mesozoic Granitic Rocks

Flawn and Díaz (1959, p. 228) have presented evidence for the existence of an extensive pre-Mesozoic granitic terrane in the subsurface in north-central Mexico. They suggest that the granitic rock was emplaced in one of the interior zones of the Ouachita structural belt.
Outcrops of pre-Mesozoic granite occur in the Las Delicias area, Coahuila, and in Cabelleros Canyon, Tamaulipas. Hornblende granites of uncertain age, probably pre-Mesozoic, crop out in the Potrero de la Mula area, Coahuila.

Mesozoic Sedimentary Rocks

Over much of northeastern Mexico the Huizachal redbeds and associated evaporites (Minas Viejas gypsum) constitute the basal strata of a thick Mesozoic sequence which unconformably overlies moderately to highly deformed Late Paleozoic and older rocks (see Fig. 5). The redbeds and evaporites are overlain in turn by an extensive sheet of limestone, the Zuloaga Formation, or by the Zuloaga's nearshore equivalent, the La Gloria Formation. The La Gloria is characterized by sandstone and conglomerate but some sections consist mainly of limestone. The age of the Zuloaga and La Gloria has been definitely established as Late Jurassic (Oxfordian) on the basis of their faunal assemblages.

In east-central Mexico the Huayacocotla Formation, a sequence of dark claystones and siltstones, separates the lower Huizachal (La Boca redbeds) from the upper redbed

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1 José Carrillo, personal communication.
### MESOZOIC FORMATIONS, SIERRA MADRE ORIENTAL

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<tr>
<th>Region</th>
<th>Eastern Durango</th>
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<th>Northeastern Hidalgo</th>
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<td>Southwestern Tamaulipas</td>
<td>Northwestern Veracruz</td>
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<td>Northwestern Veracruz</td>
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<tr>
<td>Northeastern Hidalgo</td>
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</tbody>
</table>

### TERTIARY

- **DIFUNTA GROUP**
  - PARRAS FM
  - CARACOL FM
  - INDIDURA FM
  - MENDEZ FM
  - SAN FELIPE LS
  - AGUA NUEVA FM

### CRETACEOUS

- **CUESTA DEL CURA LS**
  - AURORA LS
  - UPPER TAMAULIPAS LS
  - OTATES BEDS
- **CUPIDO LS**
  - LOWER TAMAULIPAS LS
  - TARAISES FM

### JURASSIC

- **LA CASITA FM**
  - LA CAJA FM
  - LA GLORIA FM
  - ZULOAGA LS
  - OLVIDO GYPSUM
  - TAMAN FM
  - TEPEXIC FM
  - CAHUASAS REDBEDS
- **LA JOYA REDBEDS**
  - MINAS VIEJAS GYPSUM
  - HUAYACOCOTLA FM
  - ?

### TRIASSIC

- **LA BOCA REDBEDS**

---

**Figure 5**
sequence--called Cahuasas Formation in this region. As in northeastern Mexico the redbeds are overlain by Upper Jurassic limestones, including the Tepexic Calcarenite and equivalent beds called "limestones with Nerinea."

In both northeastern and east-central Mexico the aforementioned sequences are overlain by several thousand feet of Upper Jurassic-Cretaceous marine limestones, shales, and claystones. Subordinate sandy materials interfinger with the finer sediments in areas bordering old highs.
CHAPTER III

STRATIGRAPHY

HUIZACHAL GROUP

The Huizachal formation was formally defined by Imlay et al. (1948, p. 1743) as:

... the 1,400 feet, or less, of red beds directly underlying the normal marine Upper Jurassic in eastern and northern Mexico, overlying marine Lower Jurassic in the Huasteca area of Veracruz, Puebla, and Hidalgo, and overlying Paleozoic or probable pre-Cambrian rocks at other places. Its contact with the Lower Jurassic appears to be an erosional unconformity. Its contact with the overlying limestones of Oxfordian or Kimmeridgian age is an angular unconformity at several places and is clearly erosional at most places. The type section is designated as the southwest side of the Huizachal Valley near the head of Arroyo Juan Capitan, approximately 20 kilometers south-southwest of Victoria, Tamaulipas. This section is selected because the exposures are excellent and can be reached by car from Victoria on an all-weather road in approximately 1½ hours. From the viewpoint of bracketing the red beds within the Jurassic, the thick section near Huehuetla, Hidalgo, would be preferable as the type, but it can now be reached only with pack animals. The name Huizachal formation was originally proposed by P. A. Robertson in 1925 in a report prepared for the Mexican Gulf Oil Company on the Sierra Madre west of Victoria, Tamaulipas.
Figure 6. Type section of Huizachal redbeds, southwest of Rancho Huizachal, Tamaulipas. Redbeds extend about half way up right-hand spur. Uppermost 109 feet of the section constitute the La Joya Formation. Rocks in foreground are intrusions into La Boca Formation.

Figure 7. Angular contact between La Joya and La Boca Formations south of Rancho La Joya, Huizachal valley, Tamaulipas. Basal La Joya conglomerate forms small scarp in right center of photo and extends to left and right. Conglomerate and La Joya strata above are essentially parallel to scarp-forming Zuloaga Limestone which caps ridge. La Boca strata (lower half of photo) dip steeply to right.
In 1957, field studies in the Huizachal anticlinorium, Sierra Madre Oriental, near Ciudad Victoria, Tamaulipas, demonstrated that the Huizachal in this area is divisible into two mappable lithic sequences separated by a pronounced angular unconformity (see Figs. 7 and 9, Plates IV and V). Both sequences are present in the type section of the Huizachal formation in Huizachal Valley near Ciudad Victoria (see Fig. 6). The type section, reproduced from Imlay et al. (1948, p. 1765) may be interpreted as follows:

Huizachal formation (=Huizachal Group)*
(upper sequence)*

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
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</thead>
<tbody>
<tr>
<td>Conglomerate, red, poorly sorted, pebbles are angular, range from one-half inch to five inches in diameter, and consist of red sandstone and shale and various igneous and metamorphic rocks</td>
</tr>
<tr>
<td>Sandstone, medium- to coarse-grained, well bedded, red</td>
</tr>
<tr>
<td>Shale, sandy, thin-beded, red</td>
</tr>
<tr>
<td>Conglomerate as above but coarser, some bolders as much as eight inches in diameter</td>
</tr>
</tbody>
</table>

(angular unconformity)*

(lower sequence)*

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, coarse-grained, red</td>
</tr>
<tr>
<td>Shale, sandy, red</td>
</tr>
<tr>
<td>Sandstone, coarse-grained, thin-beded, red</td>
</tr>
</tbody>
</table>

*Material in parentheses inserted by writer.
Figure 8. Principal Canyons in Ciudad Victoria Area
Sandstone, thin-bedded, red, alternating
   with red shale .......................... 20
Sandstone, very coarse-grained, red ................ 15
Conglomerate, red .................................. 8
Shale and sandy shale, a few beds of red,
   fine-grained sandstone, rests on
   metamorphic rocks ............................. 170

Total thickness ..................................... 377

As a result of the studies in the Victoria area, Mixon (1958) and Mixon, Murray, and Díaz (1959) suggested that the Huizachal be raised to group rank and used as a rock unit to include the two lithically similar redbed sequences in the Sierra Madre Oriental in southwestern Tamaulipas. The lower sequence of redbeds, below the unconformity and above Permo-Carboniferous strata, was designated La Boca Formation. The upper sequence, above the unconformity and below Upper Jurassic limestones, was designated La Joya Formation.

Subsequent field studies have shown that the two redbed sequences of the Victoria area are regional in extent.

La Boca Formation

Definition

The La Boca Formation (see also Mixon et al., 1959) consists of more than 2,000 meters of green, gray, and red mudstones, shales, siltstones, sandstones, and conglomerates
Figure 9. Geologic Map of Huizachal Valley, Southwestern Tamaulipas
in northeastern and east-central Mexico which angularly overlie Paleozoic strata and Early Paleozoic or Precambrian metamorphic rocks. In northern San Luis Potosí, strata considered to be of older Mesozoic age conformably underlie the La Boca (see Plate III). In different areas the La Boca is overlain angularly by the Huayacocotla, La Joya, Zuloaga, and Olvido Formations (see Plates III-V).

Exposures along the Rio San Pedro in La Boca Canyon, Tamaulipas, approximately 27 kilometers northwest of Ciudad Victoria, constitute the type section (see Figs. 8 and 10).

Areal Extent

Known outcrops of the La Boca redbeds are confined to three widely separated areas: the Sierra Madre Oriental of southwestern Tamaulipas and southern Nuevo León, the Sierra de Catorce of northern San Luis Potosí, and the Huayacocotla anticlinorium of northern Hidalgo and northern Veracruz. The appreciable separation of these exposures, together with occurrences in numerous deep wells in the Gulf Coastal Province, suggest that the La Boca is widely present in the subsurface in northeastern and east-central Mexico.
Figure 10. Geologic Map of La Boca Canyon Area, Southwestern Tamaulipas
Stratigraphic and Lithologic Characteristics

Nuevo León and Tamaulipas

In southern Nuevo León and southwestern Tamaulipas the La Boca Formation consists of two basic rock types: red strata and gray-green strata. The alternation of these two rock types permits the La Boca to be divided vertically into four mappable rock-stratigraphic units, each unit consisting essentially of a single gross rock type (see Figs. 11 and 21). At some localities certain of the rock units inter-finger to a limited extent, usually within a short vertical distance above and below their contacts, but as a whole they are remarkably homogeneous. The four rock units may possibly be intertonguing lithofacies which completely or partially replace each other laterally but this can not be demonstrated on the basis of available outcrops. On the contrary, the rock units appear to be rather persistent, at least in a north-south direction (parallel to depositional strike ?), and major intertonguing, if present, probably occurs in an east-west direction.

For convenience of discussion the four rock units are here designated, from oldest to youngest, as Members A, B, C, and D. Members A and C are composed largely of red to
Figure 11. Stratigraphic Relations and Lithic Subdivisions of La Boca Formation at Type Locality

- Varicolored shale and light-gray limestone.
- Gray limestone.
- Red mudstone and sandstone.
- Gray and green shale, siltstone, sandstone, and conglomerate. 400 meters.
- Mainly red mudstone and sandstone with some conglomerate beds. 900-1000 meters.
- Gray and green shale, siltstone, sandstone and conglomerate. 300 meters.
- Red and pink mudstone, sandstone and conglomerate. 150-200 meters.
pink mudstone, sandstone, and conglomerate. Members B and D consist of green and gray shale, siltstone, sandstone, and conglomerate. In a few areas (see Figs. 11 and 21) the uppermost part of the exposed La Boca section includes red strata which conformably overlie Member D. These strata may constitute the basal beds of a third red rock unit of considerable thickness and extent but available outcrops are insufficient to demonstrate this supposition conclusively.

**Member A:** The basal member of the La Boca Formation is composed of those red beds which unconformably overlie Paleozoic sediments and Early Paleozoic or Precambrian metamorphics and which underlie, conformably, the gray-green strata of Member B. Depending on the locality, the contact between Members A and B may be abrupt or there may be an interfingering relationship. The red beds are most typically exposed in Santa Lugarda, La Boca, and Olmo Canyons in Tamaulipas, and in Alamar and San Vicente Canyons in southern Nuevo León (see Figs. 8 and 16).

Member A is predominantly white, pink and red sandstone with lesser amounts of conglomerate and red mudstone.

The conglomerates consist largely of well-rounded pebbles and cobbles of granitic rocks but include some fragments of red beds and metamorphics (see Figs. 12 and 13).
Figure 12. Conglomerates in Member A, at type locality of La Boca Formation, La Boca Canyon, Tamaulipas.

Figure 13. Near view of lower right portion of Figure 12. Cobbles consist largely of granitic rock types.
Boulder-size material is incorporated in the conglomerates in a few areas.

Sandstones may be grouped into two principal types: (1) white to pink, coarse-grained sandstone and (2) red to maroon, fine- to medium-grained sandstone. Sandstone beds of the first type are characterized by an irregular base, the presence of conglomeratic materials in their basal portion, marked thickness changes in short lateral distances, and well-developed cross-bedding. The red and maroon sandstones are more persistent laterally and cross-bedding is not nearly so well-developed.

In the central portion of the Huizachal anticlinorium, Member A is 150 to 200 meters thick but decreases in thickness northward to less than 30 meters in Guayabas Canyon. North of Guayabas the member thickens again to more than 220 meters in the Rancho Alamar area. At the Rancho Alamar its base is not exposed.

**Member B:** This member includes gray and green beds between and interfingering with the red strata of Member A below and Member C above. It is typically exposed in the central and northern portions of the Huizachal anticlinorium. Lithically similar beds exposed in several canyons in the Rancho Alamar area are tentatively correlated with Member B.
Figure 14. Fragment of silicified log, genus *Araucarioxylon*, from Member B of La Boca Formation, Tamaulipas.

Figure 15. Angular contact between Members B and C of La Boca redbeds (left and lower right) and La Joya-Zuloaga sequence (upper right), Guayabas Canyon, Tamaulipas. La Boca beds show apparent dip of about 35 degrees toward lower left. La Joya-Zuloaga sequence dips at about 20 degrees toward lower right.
Member B consists mostly of gray sandstone and conglomerate but includes some gray to green shale and siltstone. The sandstones and conglomerates weather deeply to green, brown, and orange-brown.

Cross-bedding, cut- and fill-structures, and poor sorting characterize the coarser sediments. In these beds silicified tree trunks, up to three meters in length, are common (see Fig. 14).

Conglomerates are composed largely of pebbles of vein quartz but also contain fragments of shale, siltstone, chert, and various types of low-rank metamorphic rocks. The absence of granitic rock types, such as compose the conglomerates of Member A, is striking.

In the Ciudad Victoria area Member B is about 300 meters thick. Gray-green beds in the Rancho Alamar area tentatively correlated with Member B are 300 to 350 meters thick.

**Member C:** Member C is the thick red sequence between and interfingering with the gray-green strata of Member B below and Member D above. It is well exposed in the Huizachal anticlinorium from Peregrina Canyon northward to Guayabas Canyon. The upper red unit in the Rancho Alamar area (see Fig. 21) may be equivalent to Member C.
Figure 16. Location of Outcrops of La Boca Redbeds, Rancho Alamar Area, N.L.
Figure 17. Outcrops of La Boca Redbeds, San Pablo Area, N.L.
This member consists mostly of red mudstone and sandstone but contains some beds of conglomerate. The latter are composed of pebbles of vein quartz and smaller amounts of metamorphic and igneous rock fragments. Sandstones are similar to the red and maroon sandstones of Member A.

Member C is 900 to 1,000 meters thick in the Ciudad Victoria area. The incomplete thickness of equivalent (?) strata in the Rancho Alamar area is approximately 120 meters.

**Member D:** This member consists of gray-green beds which overlie and interfinger with Member C. In different areas it is overlain conformably by red La Boca sediments (see p. 28) or unconformably by either the La Joya Formation or the Zuloaga Limestone. Good sections are exposed in the Huizachal anticlinorium from Santa Lugarda Canyon northward to Guayabas Canyon. In addition, the sequence of gray-green strata exposed in the upper ends of Novillo and Peregrina Canyons (see Figs. 18 and 19), which is in fault contact with the crystalline core of the anticlinorium, is tentatively correlated with Member D rather than Member B on the basis of its similar thickness and the apparent lack of fossilized tree trunks like those which are so abundant in Member B.

Lithically, Member D is very similar to Member B,
Figure 18. Divide between Novillo and La Reja Canyons, Tamaulipas. Scarp-forming quartz pebble conglomerates on ridge in middle distance are within thick section of gray-green strata tentatively correlated with Member D of La Boca Formation.

Figure 19. Lower slopes of Cerro La Cuchilla del Burro, Novillo Canyon, Tamaulipas. Grass-covered slopes extending from lower right toward center of photo are developed on serpentine dike which intrudes La Boca conglomerates.
consisting predominantly of gray sandstone and conglomerate with lesser amounts of green and gray siltstone and shale. As far as is known, these strata do not contain silicified logs such as those occurring in Member B.

The thickness of this member in the La Boca Canyon area is 400 to 500 meters.

San Luis Potosí

Redbeds correlated with the La Boca Formation are exposed in the Cañon de Catorce on the western side of the Sierra de Catorce, an anticlinal uplift in northern San Luis Potosí. Here, as in the Huizachal anticlinorium, thick redbeds are overlain with pronounced angularity by the La Joya Formation. They overlie or interfinger with an unnamed sequence of gray to black, greenish-weathering claystone containing minor amounts of siltstone and sandstone. Correlation of these redbeds with the La Boca Formation is based on lithic similarity, stratigraphic position, and a similar deformational history. Like the La Boca beds in Tamaulipas, these strata were folded and intruded by igneous materials before deposition of the overlying La Joya redbeds (see Plate III and Fig. 32).

The La Boca sequence in the Catorce area comprises gray, green, and red mudstone, sandstone, and conglomerate.
Figure 20. Westerly view into upper portion of Cañon de Catorce, northern San Luis Potosí. Foreground is portion of old silver mining town of Real de Catorce. Highest peaks in middle and far distance are held up by the resistant Zuloaga Limestone. Slopes between peaks and gorge are developed on La Joya Formation. Gorge itself is eroded into metamorphosed La Boca beds and pre-La Joya igneous intrusives.
Conglomerate types include (1) gray, green-weathering beds composed largely of rounded pebbles of vein quartz and low-rank metamorphic rocks, and (2) red strata consisting of extremely angular pebbles and cobbles of fine-grained volcanic rocks.

Fine-grained La Boca sediments possess a well-developed slaty cleavage and locally have been altered to phyllites and spotted slates. In the upper part of the Cañon de Catorce, between Purisima and Real de Catorce, a considerable portion of the La Boca sequence has been altered to low-grade schist (see Figs. 20 and 32). The derivation of the schist from La Boca sediments is proved by (1) gradational contacts and (2) relic bedding and remnants of relatively unmetamorphosed redbeds preserved within the schist.

The greater degree of alteration of the La Boca strata, in comparison with younger formations, and the increase in grade of metamorphism of the La Boca sediments toward some of the pre-La Joya igneous bodies indicate that the metamorphism is mainly the result of pre-La Joya igneous activity and deformation.

**Hidalgo and Veracruz**

Recent field studies by Petroleos Mexicanos in the central portion of the Huayacocotla anticlinorium, Sierra
### DIAGRAMMATIC STRATIGRAPHIC SECTIONS
Sierra Madre Oriental, Southern Nuevo Leon and Tamaulipas

#### CIUDAD VICTORIA AREA

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<tr>
<th>System</th>
<th>Huizachal Valley</th>
<th>La Reja Canyon (eastern end)</th>
<th>Novillo Canyon (eastern end)</th>
<th>Peregrina Canyon (eastern end)</th>
<th>Arroyo Seco Canyon</th>
<th>Santa Lugarda Canyon</th>
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**Figure 21**
Madre Oriental, have disclosed the presence of thick redbeds above unnamed Permo-Carboniferous strata and below the Huayacocotla Formation. Both contacts are angular unconformities. Stratigraphic position, lithology, and paleontologic evidence (see Table I) indicate that this sequence is correlative with the La Boca beds of northeastern Mexico.

Typical strata are exposed a few kilometers northeast of Zacualtipán, Hidalgo, in canyons of the Tlahualompa, Tianguistengo, and Chinameca rivers. Lithically, they are very similar to strata of the Ciudad Victoria area but the average grain size appears to be somewhat finer.

**La Joya Formation**

**Definition**

The La Joya Formation (see also Mixon et al., 1959) comprises redbeds in Tamaulipas, Nuevo León, and San Luis Potosí which overlie the La Boca Formation with pronounced angularity and which conformably, disconformably, or angularly underlie the Upper Jurassic Zuloaga Limestone. In some areas in Tamaulipas and Nuevo León the La Joya laps over the La Boca onto Paleozoic strata and Early Paleozoic or Precambrian igneous and metamorphic rocks (see Fig. 23). At a few places the La Joya is absent and the Zuloaga rests
Limestone; gray, thin-to thick-bedded.

unconformity

9. Conglomerate and conglomeratic sandstone. 10.10m

8 Sandstone with a few thin conglomeratic beds, pink and red, fine to coarse grained. 19.7m

7. Sandstone; pink to red, coarse to very coarse grained, cross-bedded. 5.2m

6. Claystone, siltstone, and fine grained sandstone; red, sandstone finely cross-bedded. 13.0m

5. Claystone and siltstone; bright red. 2.0m

4 Sandstone; light gray, fine grained. 0.3m

3. Claystone and siltstone; bright red. 2.0m

2 Limestone; gray, thin-bedded. 1.0m

1. Conglomerate of pebbles and cobbles of La Boca redbeds. 6.0m

angular unconformity

Mudstone and siltstone, red.

*Total thickness not shown

Figure 22. Type Section of La Joya Formation at Rancho La Joya, Huizachal Valley, Tamaulipas
on the La Boca or on older rocks (see Plates I-VI).

Exposures along the north side of Huizachal valley, Tamaulipas, from the village of La Joya westward to the head of the valley, constitute the type section (see Figs. 8, 9, and 22).

Areal Extent

Strata of the La Joya Formation are exposed in (1) most of the large canyons cut into the Huizachal anticlinorium, southwestern Tamaulipas, (2) the cores of folds near Aramberri and Mezquital, southern Nuevo León, and (3) several canyons on the western side of the Sierra de Catorce, an anticlinal uplift in northern San Luis Potosí. In addition, the Jurassic redbeds of Coahuila, Zacatecas, and Durango appear to be correlative with the La Joya.

Stratigraphic and Lithologic Characteristics

Tamaulipas and Nuevo León

The La Joya sequence exposed in Tamaulipas and Nuevo León consists generally, from bottom to top, of (1) a basal conglomerate of highly variable composition and thickness, (2) a thin limestone and limestone conglomerate, (3) red mudstones and fine sandstones grading upward into (4) red to pink, fine to very coarse, cross-bedded sandstones and
Figure 23. La Joya Formation, north wall of Peregrina Canyon, north of abandoned Rancho Peregrina, Tamaulipas. La Joya overlies complexly folded Lower Permian strata which form irregular slopes in foreground. Lower of two small scarps, which slope from left to right through middle of photo, is formed by basal conglomerate of La Joya. Upper scarp and bench above are held up by Zuloaga Limestone. Peak in upper right is Lower Cretaceous limestone.
conglomerates. In certain areas in the southern portion of the Huizachal anticlinorium, conglomeratic sandstones in the uppermost part of the formation are green or gray.

**Basal Conglomerate:** The basal conglomerate varies considerably in composition, grain size, and thickness within short distances. In most areas it consists of pebble- and cobble-sized material with interstitial and interbedded sand. At a few places, for example, Caballeros Canyon, the conglomerate is composed largely of boulders (see Figs. 24 and 25). Where the conglomerate overlies the La Boca, most of the pebbles and cobbles are derived from that formation. Analogously, where it overlaps the La Boca onto the crystalline complex forming the core of the Huizachal and Aramberri uplifts, it consists mostly of igneous and metamorphic rock fragments.

**Limestone Member:** The limestone member is composed of well-bedded to lenticular, red and gray, crystalline limestone. Some beds consist of alternating laminae of gray limestone and red argillaceous material (see Fig. 26). At places the forementioned strata are overlain by red mudstones containing considerable fragmental and/or nodular limestone. The member is especially well-developed in the
Figure 24. Basal conglomerate of La Joya Formation in banks of main arroyo, Caballeros Canyon, near the abandoned Rancho El Consuelo, Tamaulipas. Here the conglomerate consists of cobbles and boulders of the La Boca redbeds and Paleozoic and Precambrian sedimentary and metamorphic rocks.

Figure 25. Boulders of La Boca sandstone partially weathered out of La Joya basal conglomerate at above locality.
Figure 26. Alternating laminae of gray limestone and red mudstone, limestone member of La Joya Formation, near Rancho Huizachal, Tamaulipas. Laminated beds commonly show highly contorted bedding, apparently due to slumping after deposition.
Peregrina Canyon area, where it is about 15 meters thick, and in Huizachal Valley north of the Rancho Huizachal. South and east of the Rancho Huizachal the limestone thins to a feather edge. It appears to be absent in the Rosario-Guayabas Canyon area.

**Redbeds:** The limestone member is overlain by bright-red mudstones and siltstones with some interbedded fine-grained, finely cross-bedded sandstones (Units 3, 5, and 6; Fig. 22). Mudcracks are present but rare in this portion of the section. These beds grade upward into red to pink, fine-to very coarse-grained, cross-bedded sandstones and conglomerates (Units 7, 8, and 9).

**San Luis Potosí**

In the Sierra de Catorce area, northern San Luis Potosí, the La Joya redbeds overlie the La Boca Formation and older strata with great angularity (see Plate III). Their contact with the Zuloaga Limestone, above, is abrupt but conformable.

The La Joya is much thicker in this area than in the Ciudad Victoria-Aramberri area of Tamaulipas and Nuevo León. Here it consists generally, from top to bottom, of the following sequence (Baker, 1922, p. 44):
Figure 27. Westerly view toward Cerro de la Bufa (left center), near mouth of Catorce Canyon, San Luis Potosí. Highest peaks are capped by Zuloaga Limestone. Escarpment in foreground is formed by the La Joya basal conglomerate.

Figure 28. Easterly view toward Iglesia de Guadalupe, near Real de Catorce, San Luis Potosí. Brownish-red strata above and to right of church are upthrown block of La Joya Formation. White and gray beds to left and right of La Joya are downthrown blocks of Zuloaga Limestone.
3. Shales, marly, below and calcareous marls with thin interbeds of limestone above. . . .
   Its thickness is perhaps 100 ft. (30.5 m.).
2. Sandstone, argillaceous, below and shales, arenaceous, above. . . .
   Its thickness is about 400 ft. (122 m.).
1. Conglomerate . . . coarser below and finer above.
   Its thickness is at least 100 ft. (30.5 m.).

Coahuila, Zacatecas, and Durango

Only reconnaissance-type studies have been made of the pre-Cretaceous redbeds of southern Coahuila, northern Zacatecas, and eastern Durango (Kellum, 1936; Imlay, 1938; and Rodgers et al., 1957). However, the lithic character of the redbeds and their position beneath the Zuloaga Limestone or La Gloria Formation and above Upper Paleozoic metamorphic rocks indicate that they are correlative with the Huizachal (Imlay, 1952; Rodgers, 1956; de Cserna, 1956; Erben, 1956).

Concordant relationships between the Huizachal of this region and the overlying Jurassic-Cretaceous sequence indicate that the redbeds were not deformed by the post-Liassic, pre-Late Jurassic orogeny which affected La Boca and older strata in nearby areas. Thus, these redbeds appear to be younger than the La Boca sequence and equivalent, at least in part, to the La Joya.

Coahuila: According to Imlay (1938, p. 1659), small outcrops of redbeds occur along an anticlinal axis in the
Sierra de Rocamonte (Sierra de la Ventura), six miles southwest of La Ventura, Coahuila. The exposed section consists of approximately 20 feet of red shale, red sandstone, and conglomerate. The conglomerate is composed of angular fragments, up to a foot or more in diameter, of red shale, red sandstone, and yellowish quartzite. The red beds are overlain by the Zuloaga Limestone; their base is not exposed.

Zacatecas: In northern Zacatecas the Huizachal crops out beneath the Zuloaga Limestone in the cores of two large anticlines forming the Sierra de San Julian (Sierra del Borrego) and the Sierra del Toro (Sierra de Candelaria). The sequence of red siltstones, sandstones, and conglomerates varies appreciably in thickness from place to place and is absent over a considerable area west and north of the village of Caopas (Rodgers et al., 1957, p. 14). Here the Zuloaga Limestone directly overlies phyllitic and schistose rocks which de Cserna (1956, p. 14) tentatively assigned to the Permo-Carboniferous.

Durango: The red bed sequence in the Villa Juárez uplift, eastern Durango, comprises 500 to 1,000 feet of interbedded red shale, fine-grained sandstone, and lava (Kellum, 1936). According to Kellum, the lavas are dominantly
andesitic but include some rock types resembling latite and dacite.

In this area the Huizachal is overlain disconformably by sandstones and conglomerates of the La Gloria Formation, considered by Imlay to be the nearshore equivalent of the Zuloaga Limestone. The base of the redbeds is not exposed.

**Summary:** The redbeds of this region consist of red shales, siltstones, and conglomerates. Their maximum exposed thickness is in the Villa Juárez uplift where they are estimated by Kellum to be 500-1,000 feet thick. Although their contact with the overlying La Gloria and Zuloaga Formations is disconformable, the redbeds appear to be folded concordantly with the overlying Upper Mesozoic sequence at all known localities. Their base is exposed only in northern Zacatecas where they overlie metamorphic rocks of possible Late Paleozoic age.
CHAPTER IV

FLORA AND FAUNA

La Boca Formation

Flora

Plant remains, in the form of leaf and stem impressions, are common in Members B and D in Tamaulipas and Nuevo León and in lithically similar beds in Hidalgo and Veracruz. However, most remains are fragmentary and few localities have yielded identifiable specimens. Fossils of stratigraphic value have been obtained from only two localities, one in Tamaulipas and one in Hidalgo.

The Tamaulipas locality is on the eastern slopes of Cerro La Cuchilla del Burro in Novillo Canyon, about 15 kilometers west of Ciudad Victoria (see Fig. 29). The plant fossils,¹ principally cycadeoids, occur in siltstones and fine sandstones within a thick gray-green sequence tentatively correlated with Member D. Roland W. Brown, formerly with the

¹See Table I, p. 57, for identifications.
Figure 29. View of Cerro La Cuchilla del Burro north-westward across Novillo Canyon, Tamaulipas. Hilly terrain in foreground and middle distance is underlain by gneisses and schists. Open grassy slopes just over tops of palms near center and left of center are developed on large serpentine dike intruding metamorphic rocks and La Boca redbeds. Slopes between dike and light-colored peaks above are underlain by conglomerates within a thick sequence of gray-green strata tentatively correlated with Member D of the La Boca Formation. Plant remains, suggesting Late Triassic age for the La Boca, were collected from ridge extending down and to right from highest peak in photo.
United States National Museum, has suggested a Late Triassic age for the plants. According to Dr. Brown none of the species represented has yet been reported from Jurassic localities.

The locality in northern Hidalgo, discovered by Carrillo in 1961, is in the Huayacocotla anticlinorium, east of Zacualtipán. Fossil plants\(^2\) have been collected from two sites, one on the trail connecting Tlahualompa, Hidalgo, with the village of San Mateo, Veracruz, about three kilometers northeast of Tlahualompa, and one in the Arroyo de Coyumetla, approximately six kilometers north of Tianguistengo. Both sites contain abundant plant material, most of which is referable to the Mesozoic cycadeoid complex. The same species have been reported previously from Early Jurassic rocks (Huayacocotla Formation) at nearby localities.

Silicified tree trunks are very common in both the Ciudad Victoria and Rancho Alamar areas but appear to be restricted to Member B. An exception is a single log, of the same type as those in Member B, found in the pre-La Joya volcanic sequence exposed in the core of the Mezquital anticline.

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\(^2\)See Table I for identifications.
Table I. List of plant fossils from La Boca Formation and Mezquital volcanic sequence

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>PLANT TYPE</th>
<th>LOCALITY</th>
<th>STRATIGRAPHIC HORIZON</th>
<th>AGE</th>
<th>PERSON MAKING IDENTIFICATION</th>
<th>REPORT NUMBER</th>
<th>COLLECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pterophyllum fragile</em> Newbury</td>
<td>cycadeoid</td>
<td>NOVILLO CANYON, Tamaulipas</td>
<td>MEMBER D(?), La Boca Fm.</td>
<td>Late Triassic</td>
<td>R. W. Brown</td>
<td>0-57-34 &amp; 0-58-11</td>
<td>Mixon, Murray, Díaz, Carrillo</td>
</tr>
<tr>
<td><em>Pterophyllum inaequale</em> Fontaine</td>
<td>conifer</td>
<td></td>
<td></td>
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<tr>
<td><em>Cephalotaxopsis carolinensis</em> Fontaine</td>
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<td></td>
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<tr>
<td><em>? Podozamites sp.</em></td>
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</tr>
<tr>
<td><em>Williamsonia netzahualcoyotl</em> Wieland</td>
<td>cycadeoid</td>
<td>NOVILLO CANYON, Tamaulipas</td>
<td>MEMBER D(?), La Boca Fm.</td>
<td>Early Jurassic</td>
<td>S. H. Mamay</td>
<td>0-59-34</td>
<td>Mixon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAN PABLO, Nuevo León</td>
<td>MEMBER D(?), La Boca Fm. (undifferentiated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Araucaroxylon</em></td>
<td>conifer</td>
<td>LA BOCA CANYON, Tamaulipas</td>
<td>MEMBER B, La Boca Fm.</td>
<td>Permian to Cretaceous</td>
<td>R. A. Scott</td>
<td>0-59-19</td>
<td>Carrillo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MEZQUITAL, Nuevo León</td>
<td>MEZQUITAL VOLCANIC SEQUENCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Material with striations of calamarian origin: suggestive of Equisetites</em></td>
<td>scouring rush</td>
<td>GUAYABAS CANYON, Tamaulipas</td>
<td>LA BOCA Fm. (undifferentiated)</td>
<td>Mesozoic</td>
<td>S. H. Mamay</td>
<td>0-59-56</td>
<td>Carrillo</td>
</tr>
<tr>
<td><em>Otozamites hespera</em> Wieland</td>
<td>cycadeoid</td>
<td>ZACUALTIPÁN AREA, Hidalgo</td>
<td>LA BOCA Fm. (undifferentiated)</td>
<td>Early Jurassic</td>
<td>S. H. Mamay</td>
<td>0-62-22</td>
<td>Mixon, Murray</td>
</tr>
<tr>
<td><em>Otozamites regelii</em> Brongniart</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>Phloophyllum acutifolium</em> Morris</td>
<td></td>
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</table>
Samples of the tree trunks have been studied by Richard A. Scott who has assigned them to the genus *Araucarioxylon*. *Araucarioxylon* is a form genus for woods having the structure typical of the Araucariaceae, a modern family of conifers limited to the Southern Hemisphere. Wood of this type is found in North America in beds ranging from Permian through Cretaceous in age.

Fauna

No conclusive evidence of animal life has yet been found in the La Boca beds of Nuevo León and Tamaulipas. This may be due, in part, to unfavorable conditions of preservation and to the limited exposures of bedding plane surfaces in this region.

Erben (1956, p. 36) has reported ammonities from pre-Zuloaga beds in the Sierra de Catorce, San Luis Potosí, which he identifies as Lower Sinemurian species. Although the person submitting the sample was unable to give the exact stratigraphic horizon from which it came, its composition and color indicate that it is from either the La Joya or the La Boca. The Early Jurassic age designation suggests that the sample is from the La Boca Formation rather than the La Joya.

Beds in the upper part of the La Boca sequence near
Tlahualompa, Hidalgo, above the plant-bearing horizon, contain abundant pelecypods.

La Joya Formation

Fauna

Only one locality has yielded identifiable fossils. In Rosario Canyon, Tamaulipas, red siltstones and sandstones in the uppermost part of the La Joya basal conglomerate contain numerous internal molds and external impressions of gastropods and pelecypods. According to Norman F. Sohl, the gastropods all belong to a single naticiform species resembling *Natica georgeana* d'Orbigny from the Kimmeridgian of France. The pelecypod is a small species similar to *Eonavicula*. No definite age assignment can be made on the basis of the species present. The small number of forms obtained suggest a restricted—perhaps a brackish water—environment.

Thin limestone lenses at the base of the La Joya Formation in the Mezquital area, southern Nuevo León, contain fragments of pelecypods but preservation is too poor to permit identification.

Flora

No plant remains have been identified in the La Joya Formation.
CHAPTER V

ENVIRONMENT OF DEPOSITION

La Boca Formation

Tamaulipas and Nuevo León

In southwestern Tamaulipas and southeastern Nuevo León the La Boca consists of more than 6,000 feet of mudstones, siltstones, shales, sandstones, and conglomerates. The initial deposits (Member A) are red strata whose color, poor sorting, abundant channel sands, and non-fossiliferous character suggest that they are fluvial sediments deposited on well-drained piedmont slopes and floodplains or, possibly, the subaerial surfaces of deltas. The white to pink sandstones of Member A (see p. 31) represent channel deposits whereas the red and maroon sandstones and mudstones accumulated mainly on interfluves.

The overlying gray and green, pyritiferous, plant-bearing beds of Member B also consist largely of fluvial sediments but differ from those of Member A in that they were deposited in streams and on floodplains of a poorly drained
region. Minor volumes of dark gray to black shales and rhythmically bedded gray and green claystone-siltstone-fine sandstone sequences probably represent the deposits of swampy lowlands and shallow lakes. The marked difference in composition between Members B and A (see pp. 29 and 33) indicates different source areas for these two units. The equally marked differences in depositional environment suggest that the change in the sediment source was coincidental with a major and rather abrupt disruption of the regional drainage system.

Deposition of the red strata composing Member C followed re-establishment of good drainage. Differences between this member and Members B and D appear to be due largely to differences in depositional environment rather than differences in source areas.

The gray and green beds of Member D accumulated under environmental conditions similar to those existing during deposition of Member B.

Hidalgo

The La Boca sequence of northern Hidalgo is similar to that of Nuevo León and Tamaulipas and, as in that region, appears to consist largely of continental-to-marginal strata.
However, some beds in the upper part of the sequence contain marine or brackish-water pelecypods—indicating at least temporary incursions of marine waters.

**La Joya Formation**

The nature of La Joya deposition differs considerably from place to place. In certain areas, after an initial marine transgression, supply of sediment was sufficiently rapid to cause a buildout of non-marine over marine lithotopes. This is the case in the Ciudad Victoria area where the La Joya was deposited as a thin, discontinuous sheet—filling inequalities in the pre-La Joya erosion surface. The sequence begins with a basal transgressive marine conglomerate containing marine or brackish-water fossils in its uppermost part (see p. 59). Inclusion in the overlying limestone member of beds composed of alternating laminae of limestone and red mud indicates deposition in a body of relatively quiet water such as a lagoon or protected bay. Above the limestone member are red claystones and mudstones (Units 3, 5, and 6; Fig. 22), containing rare mudcracks, which were probably deposited in shallow waters and on bordering low mudflats. A thin, well sorted, light-gray sandstone (Unit 4) seems to represent wave-winnowed beach-type material. Coarse,
cross-bedded, poorly sorted, red conglomeratic sandstones in
the upper part of the La Joya (Units 7-9) appear to be a
buildout of stream deposits over the lower La Joya beds.
Green to gray sandstones occurring in the uppermost part of
the La Joya in certain areas in the southern portion of the
Huizachal anticlinorium may be the result of reduction which
took place after further advance of the Late Jurassic sea.
In this region the La Joya possesses disconformable to slightly
angular relations with the overlying Upper Jurassic Zuloaga
Limestone.

In basinal areas, such as the Sierra de Catorce region
of northern San Luis Potosí, the La Joya is considerably
thicker and probably represents an extensive and continuous
sedimentary unit. In the Catorce area, conglomerates and
conglomeratic sandstones grade upward into sandstones and
mudstones and these, in turn, grade into mudstones and silt-
stones interbedded, in their uppermost part, with thin lime-
stones. The contact with the overlying Zuloaga Limestone is
abrupt but conformable. The almost perfect gradation upward
from coarse to fine sediment suggests a steady encroachment
of the sea in this region with a corresponding landward
shift of lithotopes.
CHAPTER VI

LOWER MESOZOIC INTRUSIVE AND VOLCANIC ROCKS

Upper Triassic and Jurassic volcanic and intrusive rocks are almost everywhere associated with the Huizachal redbeds. To the south and east, in San Luis Potosí, Tamaulipas, and Nuevo León, igneous activity seems to have been largely restricted to La Boca time and most igneous rocks of this age are intrusive in nature. To the north and west, in eastern Durango and western Coahuila, igneous rocks associated with La Joya equivalents are dominantly flows.

Tamaulipas and Nuevo León

On the basis of composition and form of emplacement, post-Paleozoic, pre-La Joya igneous rocks in this region may be grouped into two main types comprising (1) a greenstone dike-sill complex and (2) varicolored felsites occurring mainly as small, irregular to domal intrusions but including some flows and dikes.
Greenstone Dike-Sill Complex

Greenstone dikes and sills, averaging one to six feet in thickness, are exposed from the Rancho Alamar-San Pablo area southward to Olmo Canyon in the Ciudad Victoria area (see Fig. 30). Dike rocks are aphanitic to slightly porphyritic whereas sills, which are well-developed only in the San Pablo area, are mostly porphyries.

The greenstones consist essentially of laths of albite or albite-oligoclase, chlorite, and calcite. Some contain subordinate potash feldspar. Euhedral amphibole and/or pyroxene phenocrysts have been completely replaced by chlorite and calcite. Chlorite also composes a considerable portion of the groundmass. Dike rocks in the Rancho Alamar area contain minor amounts of corroded quartz phenocrysts.

The composition of the dikes and sills suggest an assignment to the spilite-keratophyre clan.

Felsite Complex

The felsites, which are exposed only in the Rancho Huizachal area, include a variety of rock types and intrusive

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1For detailed study of igneous rocks in Huizachal area see D. D. Johnson, Master's thesis, Louisiana State University, in preparation.
Figure 30. Waterfall over greenstone sills (dark) in La Boca Formation, Arroyo de San Pablo, Nuevo León.
forms. One of the predominant types is a light-gray to bluish-gray aphanite which occurs in small domal bodies in the central and western portions of Huizachal valley (see Fig. 9). This rock is characterized, from place to place, by either flow layering or a platy parting which gives it a bedded appearance. Both the layering and the parting are of the type commonly associated with viscous melts.

The light color but low quartz content of the gray aphanites and other rock types suggest an intermediate composition. However, the original composition is difficult to determine as most of the felsites are considerably altered. They now consist largely of the secondary minerals sericite, calcite, chlorite, and hematite.

Feldspars of a few of the rock types are still identifiable—permitting a rough classification of these few. A specimen of dike rock studied by P. T. Flawn consists of completely sericitized relicts of potassium feldspar as pheno­crysts in a microgranular groundmass of partly sericitized albite-oligoclase. Dr. Flawn stated (letter to T. Díaz, April 8, 1958) that the rock might be classified as a rhyodacite porphyry or, since quartz is rare, a trachyandesite.

Red dikelets, ranging from a few inches to one or two feet in thickness, intrude both the redbeds and the earlier
Figure 31. North wall of Huizachal valley near the Rancho Huizachal, Tamaulipas. Light-colored rocks in foreground and center are igneous intrusions emplaced in La Boca red beds. Central intrusion was a topographic high on pre-La Joya erosion surface and is directly overlain by limestone member (see Fig. 22) of La Joya.
igneous rocks. Most of the dikelets are aphanitic but the central portions of some contain abundant quartz phenocrysts. These dikelets appear to be the latest and most acidic phase of the intrusive series.

Although most contacts between igneous rocks and La Boca redbeds are clearly intrusive in nature, a few are erosional. These sedimentary contacts between redbeds and igneous bodies, which are either flows or shallow intrusions into the redbeds, indicate that at least part of the igneous activity in this region was concurrent with La Boca sedimentation.

The character of the La Boca sediments in this area is additional evidence of the contemporaneity of igneous activity and redbed deposition. Numerous channel fills in the redbeds consist mainly of very angular pebbles and cobbles of igneous rocks of types identical or very similar to those of the igneous bodies cropping out in the vicinity of the Rancho Huizachal. Other beds, consisting of massively bedded, extremely poorly sorted sediments containing angular igneous materials, are suggestive of mudflows. The combination of extreme angularity and large size of the igneous rock fragments in both channel fills and "mudflows" indicates that the source of this material must have been close at hand.
Altered igneous rocks, intrusive into La Boca strata and overlain unconformably by the La Joya, crop out at several localities in Catorce Canyon, northern San Luis Potosí (see Fig. 32 and Plate III).

Purple porphyries exposed at the western edge of the town of Real de Catorce consist largely of sericite, muscovite, feldspar, and hematite. Emplacement of this porphyry appears to have caused considerable metamorphism of the host rock, originally fine-grained La Boca sediment—now altered to a low-grade schist. Away from its contact with the porphyry, the schist grades into relatively unaltered strata.

The green porphyry in the vicinity of the Socavón de Guadalupito consists mainly of feldspar and the secondary minerals chlorite, hematite, leucoxene, calcite, and dolomite. Some of the rock contains round corroded quartz phenocrysts, suggesting that the suite is on the acidic end.
Figure 32. Geologic Map of Guadalupito-Purisima Area, Cañon de Catorce
CHAPTER VII

AGE AND CORRELATION

As diagnostic fossils were not obtained from the Huizachal until recently, ages proposed by early workers were based solely on stratigraphic position and correlation with lithically similar redbeds of neighboring regions. At various times Permian, Triassic, and different Jurassic ages were proposed (see Erben, 1956; Heim, 1940; Humphrey and Díaz, 1953, 1955; Imlay, 1952; Imlay et al., 1948). However, after redbeds correlated with the Huizachal (Cahuasas Formation) were found to overlie the Lower Jurassic Huayacocotla Formation in Hidalgo, Puebla, and Veracruz, most geologists considered the Huizachal to be of Middle and early Late Jurassic age. De Cserna (1956, p. 15) suggested that the Huizachal redbeds of northeastern Mexico might have been deposited throughout most of the Jurassic and, possibly, part of the Triassic. Much of this difference in opinion regarding the age of the Huizachal resulted from failure to recognize that it includes at least two sequences of considerably different ages.
In Tamaulipas, Hidalgo, and Veracruz, the La Boca angularly overlies folded and faulted Early Permian and older strata. Hence, its basal part is post-Early Permian. The La Boca is overlain angularly, from place to place, by Early to Late Jurassic strata (Liassic to Late Oxfordian or Early Kimmeridgian).

Fossil plants\(^1\) from the upper part of the sequence in the Ciudad Victoria area suggest a Late Triassic (Rhaetic) age for at least part of the La Boca in this area. Fragmentary remains of a single plant species\(^2\) from still higher in the same section have been tentatively designated as Early Jurassic. On the basis of this evidence it seems reasonable to infer that the La Boca in this region is Late Triassic and, probably, Early Jurassic. Since there appear to be several thousand feet of La Boca strata below the horizon from which the fossil plants were collected, it is conceivable that the lower part of the La Boca could be as old as Early Triassic or even Middle to Late Permian but regional relations and geologic history hardly support such a thesis. Strata of these ages appear more likely to be missing in the Ciudad

\(^1\)See Table I, p. 57. \(^2\)Ibid.
Figure 34. Unconformable contact (on hill, sloping downward from right to left) between La Boca Formation (below) and Upper Jurassic gypsum sequence near San Pablo de Tranquitas, Galeana area, Nuevo León. Gypsum sequence may include equivalents of both Minas Viejas and Olvido Formations.
Victoria area and their absence to date at least one pulsa-
tion of the orogeny which deformed Early Permian and older
strata in this region.

To the west and south, in San Luis Potosí and Hidalgo, fossil evidence\(^3\) indicates that the La Boca beds, at least in part, are Early Jurassic. As yet, no Triassic fossils have been obtained from these areas.

The La Boca Formation is at least partly equivalent in age, and somewhat similar lithically, to the Late Triassic-
Early Jurassic Barranca Group\(^4\) (Aguilera, 1896; Dumble, 1900; King, 1939; de Cserna et al., 1961) of northwestern Mexico. The Todos Santos sequence (Sapper, 1896 and 1937) of southern Mexico and Guatemala and redbeds of the Tezuitlán uplift in Puebla and Veracruz may include equivalents of the La Boca. The Eagle Mills Formation, a thick red sequence present in the subsurface in the southern United States, appears to be correlative, at least in part, with the La Boca (Scott et al., 1961).

The La Boca may also be partly equivalent to the

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\(^3\)See p. 58 and Table I, p. 57.

\(^4\)A south-central Sonoran sequence of continental to marginal sandstone with carbonaceous shale and some coal which interfingers to the west and northwest with marine shale and limestone.
Werner-Louann redbed and evaporite sequence (see Fig. 1) which directly overlies the Eagle Mills in parts of southern Arkansas and northern Louisiana. This conclusion is supported by recent palynologic studies (Jux, 1961) suggesting an Upper Triassic-Lower Jurassic age for the Louann.

La Joya Formation

The La Joya Formation overlies the Late Triassic-Early Jurassic La Boca redbeds and older strata with pronounced angularity. From place to place, the La Joya conformably, disconformably, or angularly underlies the Late Jurassic (Oxfordian) Zuloaga Limestone or its equivalent, the La Gloria Formation. Thus, the La Joya may include strata ranging in age from late Early Jurassic to early Late Jurassic.

The La Joya redbeds of northeastern Mexico are roughly equivalent to the Cahuasas Formation (Carrillo, 1959), a redbed sequence in Hidalgo and Veracruz above the Huayacocotla Formation and below the Tepexic Calcarenite. The Serie Salina (Salt series) and Todos Santos sequences of southern Mexico and Guatemala may include equivalents of both the La Joya and the La Boca.

The La Joya redbeds and the Minas Viejas evaporites, which appear to replace the La Joya northward from the
Aramberri-Ciudad Victoria area, may be at least partly equi-
valent to the Norphlet Formation, Louann Salt, and Werner
Formation of the northern Gulf Coastal Province.
CHAPTER VIII

PALEOGEOGRAPHIC RELATIONS OF LA BOCA FORMATION

As known exposures of Triassic and Lower Jurassic strata in central and northern Mexico are widely scattered and limited in size and number (see Fig. 35), conclusions concerning the Lower Mesozoic paleogeography of this region are highly speculative. However, certain generalizations may be made on the basis of available data.

Upper Triassic-Lower Jurassic marine beds in western Sonora (King, 1939), Chihuahua (Maldonado-Koerdell, 1957), Zacatecas (Maldonado-Koerdell, 1948), and, possibly, Guanajuato (Burckhardt, 1930) suggest an extensive marine basin in western Mexico in the Early Mesozoic. East and northeast of this basin, equivalent rocks (Barranca Group in central Sonora and La Boca Formation in southern Nuevo León, southwestern Tamaulipas, and northern Hidalgo) consist of continental to marginal strata which angularly overlie folded and/or partly metamorphosed Paleozoic terranes.

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1See p. 76.
KEY TO LOCALITIES SHOWN IN FIGURE 35

1. El Antimonio area
2. Sierra de Santa Rosa
3. Las Animas area
4. Sierra de Caracahui
5. Sierra del Aguaje
6. Sierra de Moradillas
7. Sierra de Tecoripa
8. Sierra de San Javier
9. Sierras east and northeast of Tónichi
10. Cerro Suaqui area
11. Río Chico-Movas area
12. San Pable area
13. Rancho Alamar area
14. Huizachal anticlinorium
   (a) Los Angeles, Guayabas, and Rosario Canyons
   (b) El Olmo, La Boca, and Santa Lugarda Canyons
   (c) Arroyo Seco, Caballeros, and Peregrina Canyons
   (d) Novillo and La Reja Canyons and Huizachal Valley
15. Sierra de Catorce
16. Zacatecas City area
17. Area approximately 30 miles north of Guanajuato City
18. Guanajuato City area
19. Area approximately 15 miles east of San Miguel de Allende
20. Zacualtipán area of Huayacocotla anticlinorium
In intermediate areas in Sonora and in northern San Luis Potosí the Barranca and La Boca overlap conformably or inter-tongue with marine beds.

**Summary:** The Barranca and La Boca appear to be similar sedimentary units. Both sequences are composed of continental to marginal clastic materials which interfinger westward with marine strata. It seems likely that both the La Boca and the Barranca were derived from uplifted portions of Late Paleozoic fold belts to the east, or within the eastern portion, of their present area of outcrop.
CHAPTER IX

MIDDLE AND LATE JURASSIC PALEOGEOGRAPHY OF
SOUTHERN NUEVO LEÓN AND TAMAULIPAS

The existence of an emergent, pre-Cretaceous landmass in northeastern Mexico was originally proposed by Böse (1923). The land area, termed the Coahuila Peninsula, was a southern extension of the North American continent in the general area of Coahuila, eastern Chihuahua, and eastern Durango.

Imlay (1943a) and others have also proposed a long, narrow, peninsular landmass or chain of islands, designated the Tamaulipas Peninsula, extending from Texas southward through Nuevo León and Tamaulipas along what is now the eastern margin of the Sierra Madre Oriental (see Fig. 36). Burckhardt (1930, p. 89) had previously cited evidence for an insular land area to the west in the vicinity of Miquihuana, Tamaulipas (see Fig. 37). It is assumed that these land areas provided a nearby source for the Upper Jurassic arenaceous-carbonaceous-gypsiferous sediments exposed in the Sierra Madre (Imlay, 1943a, p. 525).
Figure 36. Upper Jurassic Paleogeography of Northeastern Mexico
Certain stratigraphic evidence in the Ciudad Victoria, Aramberri, and Galeana areas of southwestern Tamaulipas and southern Nuevo León points to the existence of Jurassic-Early Cretaceous source areas (and emergent landmasses?) to the west and southwest rather than to the east. The proximity of these western source areas in the Middle and early Late Jurassic is indicated by (1) the abrupt westward thinning of the La Joya and Zuloaga Formations over the pre-Upper Jurassic basement in the Aramberri area and the southern part of the Ciudad Victoria area and (2) the absence, largely through non-deposition, of the La Joya and Zuloaga in the western part of the Aramberri and Novillo-Peregrina Canyon areas (see Fig. 38 and Plates I, II, and IV). The La Joya redbeds of the Rancho Mezquital-Aramberri area grade abruptly to the southwest into a conglomerate facies.

The onlapping relationships exhibited by the La Joya-Zuloaga-Olvido sequence in the above-mentioned areas indicate a gradual westward shift of the strand line in the Late Jurassic. However, sediment continued to be supplied from the west in the latest Jurassic and Early Cretaceous as shown by (1) red conglomeratic sandstones in the basal part of the Olvido Formation, southwest of the Rancho Huizachal, which thin to the east (Mixon, 1958, p. 37) and (2) the eastward
CROSS SECTION OF MIQUIHUANA ANTICLINE, Tamaulipas
Modified from A. Heim, 1940

Portlandian strata
Redbeds (La Joya Fm?)
Tamabra Limestone
Valanginian strata

Figure 37. Cross Section of Miquihuana Anticline, Southwestern Tamaulipas
thinning Galeana tongue, a sandstone unit within the Lower Cretaceous calcareous-argillaceous sequence of the Galeana-Iturbide area, Nuevo León (Humphrey and Díaz, 1955). It seems likely that red beds in the basal Olvido near the Rancho Mezquital were also derived from the west since the Olvido is known to overlie directly the crystalline basement a short distance west of Aramberri (see Plates I and II).

Approximately 40 miles west-southwest of Ciudad Victoria, on the east flank of the Miquihuana anticline, Late Jurassic (Portlandian) limestones directly overlie red beds tentatively correlated with the La Joya Formation. On the west flank of the anticline, Early Cretaceous (Valanginian) marls are in contact with the red beds (Heim, 1940, p. 352). The onlap of the Upper Jurassic-Lower Cretaceous strata onto the red beds is the basis for the Late Jurassic-Early Cretaceous Miquihuana Island of Burckhardt.

In summary, there is little direct evidence suggesting an eastern source for the Middle and Upper Jurassic sediments exposed in the Ciudad Victoria, Aramberri, and Galeana areas. There is considerable stratigraphic evidence indicating a source area, or areas, to the west in southwestern Tamaulipas and southern Nuevo León. In the Victoria, Aramberri, and Miquihuana areas, available evidence suggests an onlapping
STRATIGRAPHIC SECTIONS, ARAMBERRI AREA, SOUTHERN NUEVO LEON

Location of Stratigraphic Sections
(See also geologic map of Arimbarri area)

- Conformable
- Unconformable
- Sub-formational boundary
- Top not measured or missing by erosion

Figure 38
relationship, from east to west, of the La Joya, Zuloaga, Olvido, and younger beds.
Figure 39. Thick Zuloaga Limestone overlying Early Paleozoic or Precambrian schist, north wall of Arroyo Contadero east of La Virgen, Aramberri area, Nuevo León.

Figure 40. Basal conglomerate and thin Zuloaga overlying schist, 1.6 miles southwest of La Virgen.
Figure 41. Olvido gypsum (upper right) overlying Early Paleozoic or Precambrian schist (left and lower right), 1.4 miles west-southwest of La Virgen.

Figure 42. Near view of unconformity between Olvido basal conglomerate and schist (see Fig. 39). Contact at geologic pick.
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VITA

Robert Burnley Mixon was born in Hamilton, Alabama, on January 4, 1931. He attended the Hamilton Elementary School and graduated from Hamilton High School in June, 1949. He entered the University of Alabama in September, 1949, and received the Bachelor of Science degree in geology in August, 1953. Upon graduation from Alabama he was commissioned in the United States Army Corps of Engineers and served until November, 1955.

He entered Louisiana State University Graduate School in February, 1956, and received a Master of Science degree in Geology in June, 1958. From February until December, 1958, he worked for the Carter Oil Company. He re-entered Louisiana State University in February, 1959, and completed requirements for the Ph.D. degree in October, 1962.
Candidate: Robert B. Mixon

Major Field: Geology

Title of Thesis: Geology of the Huizachal Redbeds, Sierra Madre Oriental, Mexico

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

October 13, 1962
GEOLOGIC MAP OF ARAMBERRI AREA
SOUTHERN NUEVO LEON
ROBERT B. MIXON
1962

Plate I
Sedimentary Rocks

RECENT

UPPER JURASSIC

UPPER and/or MIDDLE JURASSIC

- Alluvium
- Olvido Formation
- Zuloaga Limestone
- La Joya Formation
Arroyo Contadero

Rancho Mezquital

Igneous and Metamorphic Rocks

JURASSIC and/or TRIASSIC

PRECAMBRIAN and/or LOWER PALEOZOIC

Mezquital volcanics

Schist

Vertical Exaggeration
**IGNEOUS ROCKS**

**TERTIARY**

- Basalt
  - (intrusive mass)

**SEDIMENTARY ROCKS**

**UPPER JURASSIC**
- Zuloaga Limestone
  - (gray limestone)

**UPPER or MIDDLE JURASSIC**
- La Joya Formation
  - (red sandstone, siltstone, and mudstone)

**ANGULAR UNCONFORMITY**

**LOWER JURASSIC and TRIASSIC?**
- Catorce claystone
  - (dark claystone)

1. Includes pre-La Joya igneous materials and metamorphic rocks derived from La Boca sediments.
2. Informal designation used in this report for gray to black claystones underlying the La Boca Formation.

- Mining development
- Abandoned mine
- Mine shaft
- Tunnel entrance

GEOLOGIC MAP

NORTH

R. B. MIXON,
IC MAP OF CAÑON DE CATORCE AREA
NORTHERN SAN LUIS POTOSI

MIXON, D. D. JOHNSON, and T. G. MAGEE
1961
SEDIMENTARY ROCKS

CRETACEOUS
- Undifferentiated Cretaceous beds
- La Casita Fm
- Olvido Fm
- Zuloaga Fm

UPPER JURASSIC
- La Joya Fm

UPPER and/or MIDDLE JURASSIC
- La Boca Fm

LOWER JURASSIC and/or TRIASSIC

CERRO LA CUCHILLA DEL BURRO - R

GENERALIZED CROSS SECTION OF HUI:
La Joya and Zuloaga Formations absent from western flank of anticline.

Topography based on Cd. Victoria Que.

No Vertical Exaggeration.

Kilometers

Plate IV
A DEL BURRO - RANCHO LA PRESA
SECTION OF HUIZACHAL ANTICLINORIUM

Formations absent by non-deposition on
northern flank of anticlinorium

and on Cd. Victoria Quadrangle, 14Q-b2

No Vertical Exaggeration

Kilometers
PLANE TABLE TRAVERSE
ORIENTATION OF PEGEGRINA CANYON
SOUTHWESTERN TAMAULIPAS

S. Baker, C. E. Chandler, R. B. Mixon
1956

Modified by Mixon, 1962

LOCATION MAP

Rancho Los Troncones
La Libertad A'
**Sedimentary Rocks**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendez Fm</td>
<td>Gray claystone</td>
</tr>
<tr>
<td>San Felipe Ls</td>
<td>Thin-bedded gray limestone and green shale</td>
</tr>
<tr>
<td>Agua Nueva Fm</td>
<td>Thin-bedded black limestone and shale</td>
</tr>
<tr>
<td>Cuesta del Cura Ls</td>
<td>Thin-bedded black limestone with chert</td>
</tr>
<tr>
<td>Upper Tamaulipas Ls</td>
<td>Thick-to thin-bedded gray limestone</td>
</tr>
<tr>
<td>Otates beds</td>
<td>Thin-bedded gray limestone and shale</td>
</tr>
<tr>
<td>Lower Tamaulipas Ls</td>
<td>Thick-bedded, stylolitic, gray limestone</td>
</tr>
<tr>
<td>La Casita Fm</td>
<td>Thin-bedded block limestone and shale</td>
</tr>
<tr>
<td>Olvido Fm</td>
<td>Pale gray limestone and varicolored shale</td>
</tr>
<tr>
<td>Zuloaga Ls</td>
<td>Thick-to thin-bedded dolomitic limestone</td>
</tr>
<tr>
<td></td>
<td><em>unconformity</em></td>
</tr>
<tr>
<td>La Joya Fm</td>
<td>Red claystone, siltstone and sandstone</td>
</tr>
<tr>
<td></td>
<td><em>unconformity</em></td>
</tr>
</tbody>
</table>

**Metamorphic Rocks**

- Metamorphic complex Garnet gneiss and schist

**Legend**

- Km: Kirkham Formation
- Ksf: Kassel Formation
- Kan: Kanawha Formation
- Kcc: Kanosh Formation
- Khu: Kugel Formation
- Ko: Kokopelli Formation
- Ktl: Kettle Formation
- Jlc: Jallaca Formation
- Jo: Joel Formation
- Jz: J misd Formation
- Jj: Jjes Formation

**Symbols**

- Formational contact
- Anticlinal axis
- Synclinal axis
- Ranch
- Road
- Stream

**Plate VI**
PLANE TABLE TRAVERSE
PORTION OF NOVILLO CANYON
SOUTHWESTERN TAMAULIPAS

H. J. Watson R. B. Mixon
1957

Modified by Mixon, 1962