

THE PALEOZOIC SEDIMENTARY ROCKS OF MEXICO

(Compilation of the described formations in Mexico)

CAMBRIAN ROCKS

Cananea-Cabullona area, NE of Sonora

Formation: Bolsa

Geological Province: Sonora

Location: Defined by Ransome (1904) in the Mula mountains, Cochise county, west of the city of Bisbee, SE of Arizona. In Mexico, Taliaferro (1933) described the mountains that border the Cabullona Basin in the municipality of Agua Prieta, 25 km to the SE of the city of Agua Prieta, Sonora. This formation also appears in the SW portion of the Huachuca mountains, the Ajos, Cabullona, the Mestefias and in the mining district of Cananea.

Lithology: The base of the Bolsa Formation is made up of a basal conglomerate with chips of quartz, of approximately 3 cm diameter, subrounded, and occasionally subangular. It also contains clasts, in lesser proportion, of feldspar, mica and other argillaceous minerals. The mixture is sandy, and also contains silicon cement. The thickness of the conglomerate is from 15 to 30 cm.

The middle portion of the Bolsa Formation is a sandy, large grained quartzite, and the top part is fine textured quartzite, with abundant argillaceous minerals and with silicon cement and intercalations of lutite. In both parts the presence of glauconite, magnetite, and some fragments of sedimentary and metamorphic rocks, is observable.

The sedimentary structures present in this unit are cross stratified principally in the base and polygons of dessication in the lutite intercalations of the top part.

Thickness: In the NW and SE of the Cabullona mountain range 20 m are reported (Viveros 1965). In the mining district of Cananea 188 m (Aponte 1974). In the Huachuca mountain range and in the Ajos 115 and 180 m are reported, respectively, (Aponte 1974), although Bridges (1964a) reports a thickness of 131 m for the Ajos mountain range. In the SW and S flanks of the Cabullona range the thickness is of 131 m (Cendejas y Bárcenas 1976).

Stratigraphic Relations: The bottom portion is discordant in the Ajos Sierra with the Pinal Schist of the Precambrian. In the Cabullona range and in the mining district of Cananea springs forth also in discordance the Granite Las Mestefias of the Mid-Precambrian. The upper portion is concordant and transitional with the Abrigo Formation. In the NW and SE of the Cabullona range, the top portion is discordant with the Martin limestone of the Devonian (Viveros 1965)

Fossils: There are no fossils reported in the Mexican sites. Only in the top part of the unit, in the Arizona area tracks of the *Scolithanus* sp worms, and occasionally the shells of unidentifiable brachiopods have been found.

Age: The age of the Bolsa Formation, because of its stratigraphic position, is considered to be Middle Cambrian (Aponte, 1974, Ramírez y Acevedo, 1957). Maldonado (1954) considers it to be Early to Middle Cambrian. Hayes (1975), because of the fossils, principally trilobites, of the Abrigo Formation, which locate it in the later Middle Cambrian, and the rocks of the Early Cambrian of the Caborca area, suggest that the Bolsa Formation is of the Middle Cambrian with the east part being younger than the western. Malpica and de la Torre (1980) considered the Bolsa Formation to have begun its deposit in the Lesser to Middle Cambrian.

Paleoenvironment: Because of the presence of the basal conglomerate and the cross stratified lower layers, in the Bisbee, Arizona area, Ransome (1904) considers that the Bolsa Formation was deposited in a marine climate close to the littoral. On the other hand, Lochman (1956) mentions that this

formation is a transgressive marine sandy type that apparently covered irregular topography, that in some places could have been at the beginning of the Cambric, while in other it was during the later Lesser Cambric or Middle Cambrian. Epis and Gilbert (1957) mention that the strata of both the Bolsa and Abrigo Formations demonstrate a sedimentation cycle, in which the Quartzite Bolsa shows a transgression from W to SW and the sandstone of the upper layer of the Abrigo shows the regressive phase.

Formation: Capote

Geological Province: Sonora

Location: Emmons (1910) describes this unit in the mountains of Cananea, N-center portion of Sonora. Appears in the mining district of Cananea.

Lithology: White quartzite, partially mineralized. The sericite and the pyrites are abundant in the mineralized parts. In its base it is composed by arcose angular grained conglomerate lenses with well rounded chunks that change to quartzite. The conglomerated chunks measure less than three centimeters in diameter and the quartzite ones change gradually from thick grain in the middle portions to fine grain in the upper portion where there are abundant argillaceous minerals and pyrite.

Thickness: Some authors mention a thickness of 120 m (Mulchay and Velasco, 1954) and others 244 m (Valentine 1936).

Stratigraphic Relations: The bottom portion is unknown. It was formerly believed that it rested upon the Cananean granite but findings inside of the Capote mine reveal the intrusive relation between these units (Mulchay and Velasco 1954). Malpica and de la Torre (1980) took into account that there existed an age U-Pb of 1440 +/- 5 Ma for the Cananean granite. Anderson and Silver (1971) think it probable that the granite described by Mulchay and Velasco (1954) correspond to a zone of alteration in the granite-quartzite contact that gives the appearance of being intrusive. The upper contact is concordant with the Esperanza formation (Mulchay and Velasco, 1954). Emmons (1910) thought that this contact was transitional with the Esperanza Formation

Fossils: No fossils are reported

Age: because of the stratigraphic position of this formation it is considered to be of the Early to Middle Cambrian (Mulchay and Velasco 1954; Alvarez 1949; Zendejas 1974).

Paleoenvironment: Mulchay and Velasco (1954) and Aponte (1974) suggest that the quartzite of the Capote formation originated from the Precambrian granite equivalent to Mestefias granite of the Cabullona range. The Capote and Esperanza Formations constitute a continuous stratigraphic sequence. Malpica and de la Torre (1980) thought that the Capote formation is part of the same sedimentary cycle that originated the Bolsa Formation. According to these previous authors the Bolsa and Capote Formations represent the deposit of a transgressive sea over a terrain of granitic composition that sunk and proportioned clastic material that was left exposed for a large period of time in weathering and erosion which destroyed principally feldspars and ferromagnesiums and rounded the quartz particles producing a rock with a high degree of textural maturity which constitute the Capote and Bolsa Formations. The environment was marine, close to the littoral. Malpica and de la Torre (1980) thought that the deposit conditions prevailed in all the region of Cananea-Cabullona-Bisbee-Arizona.

Formation: Abrigo

Geological Province: Sonora

Location: Defined for the first time by Ransome (1904) to define calcareous rocks of the Cambrian exposed in the mountains of the Mula, Cochise County, to the east of the city of Bisbee, SE of Arizona. In Mexico the Abrigo Formation was first mentioned by Taliaferro (1933) to describe the Paleozoic rocks of the mountain ranges that border the Cabullona Basin, district of Agua Prieta, NE of Sonora. Later studies that mention this unit refer to the description of the locality as typical of SW Arizona.

Lithology: In the base it is composed of argillaceous limestone with very thin stratification and some thin bands of flint or silex; moving upwards it changes to dolomitized limestone with sporadic sandy lenses and flint. The middle portion is of fine textured limestone (slimy mudstone), with some bits of dolomite, with some layers of sandy limestone and small lenses of lutite. The upper portion of the formation is a more sandy limestone lightly dolomitized. Also present are abundant sandy layers with small chips of quartz with dolimitic cement and small glauconite crystals, lightly oxidized (hematite).

Thickness: In the mining district of Cananea (Aponte 1974) reports a thickness of 90 m and for the Ajos range he reports a thickness of 104 m, whereas Bridges (1970) reports 173m.

Stratigraphic Relations: The bottom contact is concordant and transitional with the Bolsa Formation. For the region of Arizona and New Mexico the contact is concordant but abrupt (Hayes 1975). The superior contact is discordant with the Martin Formation of the Devonian.

Fossils: Trilobites and some species of algae.

Age: Middle Cambrian and the lower part of the Late Cambrian.

Paleoenvironment: The Abrigo Formation in the Cabullona region is composed, by and large, of lime rocks for the which Hayes (1975) suggests a deposit on top of a slight relief close to the margin of a shallow undersea limaceous platform that moved to the NE. The same author interprets the cross stratified top part of the unit as beach deposits

Epis (1958) considers the Bolsa and Abrigo formations in Arizona and New Mexico representative of an uninterrupted sequence that demonstrates a deposit of a transgressive sea from the west to the east by a Pre-Cambrian foundation and that the sandy top part of the Abrigo Formation shows the regressive phase. After the deposit of the Abrigo Formation there is no evidence of marine sediments from the Ordovician to the Early Devonian because of this it is considered that the area had already emerged (Termier 1969).

According to Bridges (1970) the regions of Bisbee, Cananea, Cabullona and the Ajos mountain range have a common geological history from the Middle Cambrian to the beginnings of the Late-Cambrian and possibly the region was a part of craton more than of the miogeocline. This suggests that the thinning at the south of the Abrigo Formation, from Bisbee to Cabullona, was higher than the northern portion and possibly this raising was greater in the direction towards where is found the city of Hermosillo. This interpretation considers that there is no appearances in the south of Sonora. After the deposit of the Abrigo Formation there is no evidence of marine sediments for the Ordovician, Silurian, and Lesser Devonian, because of which it seems logical that the area was submerged at this time (Termier 1969).

Formation: Esperanza

Geological Province: Sonora

Location: Mulchay and Velasco (1954) define this formation in the Cananea area. The Esperanza Formation caps some hills of the Cananea mountains in the mining district of the same name to the N-center of Sonora.

Lithology: The Esperanza Formation consists of limestone with stratification of the 25 cm. to 3 m., highly altered and mineralized. Some layers are completely replaced by chlorite, epidote, small

garnets, pyrite, magnetite, hematite, copper and zinc sulfates and locally gypsum (Mulchay and Velasco, 1954).

Thickness: The Esperanza Formation has a thickness of 90 m.

Stratigraphic Relations: The lower contact is concordant with the Capote Formation. The upper contact is discordant with the packet of Crystalline Limestone of the Devonian (Mulchay and Velasco 1954).

Fossils: None have been found.

Age: Because of its stratigraphic position it is given an age from the Middle Cambrian (Mulchay and Velasco 1954; Malpica and de la Torre 1980). Fries (1962) considers it to be of the Middle and Late Cambrian. Maldonado (1954) places it in the Early Devonian.

Paleoenvironment: Although the interpretation of the ecology is difficult, because of its high degree of mineralization it is considered to be an ambiance deposit similar to the Abrigo Formation, which is to say along and close to the margin of a shallow marine platform. The Esperanza Formation and the protrusions that surround it are products of the copper of the mining district of Cananea.

Caborca Area, NE of Sonora

Formation: La Ciénega

Geological Province: Sonora

Location: Defined by Stewart and his collaborators (1984) in the area of Mt. Rajón, 25 km to the south of the village of La Ciénega. It also appears in the tops of the mountains of Calvares, Pitiquito, and Clemente.

Lithology: It is divided in four units: Unit 1 is composed of dolomite and sandy dolomite of medium grain, cross stratified and laminated quartzite at its base, in lesser proportions it contains mudstone, argillaceous dolomite and sand. Unit 2: consists of dolomite and sandy dolomite cross stratified. Unit 3: laminated mudstone, fine grained quartzite cross stratified and laminated it contains intercalations of dolomite and sandy dolomite. Towards the middle part it contains grain rock with a thickness of 1.5 m. Unit 4: laminated dolomite in layers with sporadic conglomerated intraclasts

Thickness: 178 cm; units 1-4 have 76 m, 37.5 m, 37.5 m, and 27 m of thickness. (Stewart et al., 1984).

Stratigraphic Relations: The inferior contact is normal with the Tecolote quartzite. The upper contact is still not clearly defined with the Puerto Blanco Formation.

Fossils: It only contains a few fragments and traces of fossils.

Age: Because of its stratigraphic position it is considered to be of the Early Cambrian.

Formation: Puerto Blanco

Geological Province: Sonora

Location: Defined by Cooper and Arellano (1946). This type of locality is found in the extreme west of the Proveedora Mountain on the road that joins Caborca and Bisani in the area known as the pass of Puerto Blanco, 10 km to the west of Caborca, Sonora. The Cañedo Mountains, 3 km to the SE of Caborca and the Calavera Mountain along with the S sector of the Rajon range 7 km to the N58°E of the Bamore range and the extreme south of the Viejo mountain range are points of reference. It also

appears in the Berruga Range (Calavera and Berruga mountains and in the NE of the Pozo Serna mountain and to the W of the Clemente Mountain) (Anderson et al., 1978).

Lithology: This formation has a great variety of facies. In general it is composed of green lutite, sandy limestone with fossils from the Early Cambrian. The base contains limolitic lutite grey interstratified sub-arcose. Higher up it changes to green calcareous slate, with some strata of limestone and intercalations of sand. The middle part is composed of grey limestone with thin stratification with intercalations of red lutite and sandy lime with evidences of bioturbation which constitute the thickness of the unit. The upper portion is composed of intercalations of limestone, limolitic lutite, and quartzite. The sandy portions that permeate the unit show destratification (Rivera-Carranco 1987). Stewart and his collaborators (1984) observed in the middle portion of the unit a packet of calcareous limestone made up of fish egg-like grains.

Thickness: The Proveedora Mountain has a thickness of 290 m and the Cañedo 250 m (Cooper and Arellano 1946). In both sections the base is covered. In the Calaveras mountain the thickness is 456 m (Anderson et al., 1978)

Stratigraphic Relations: The upper contact is apparently concordant with the Proveedora Formation, the lower contact has not yet been defined.

Fossils: Trilobites of the Obolellaa family, characteristic of the earlier Cambrian also algae archeocyathides and brachiopods (Cooper and Arellano 1946).

Age: Early Cambrian (Anderson et al., 1978).

Paleoenvironment: In general the Paleoenvironment of the Cambrian for the W of Sonora indicates that during almost all of this period the sea that was invading all of this region was shallow warm and with formation of algae reefs and proliferation of soft-bodied primitive invertebrates and also brachiopods and trilobites. (Lochman 1954). This unit is probably older than this region because of which it has been considered that perhaps the ocean invaded this region from the NW covering a Proterozoic sedimentary foundation of these transgressive seas of the early Cambrian. No evidence is found in other areas which corroborates the theory that the seas were advancing to other areas as the lesser Cambrian was passing as happened in the Cananea-Cabullona region the basal sediments of which are younger than those of the Puerto Blanco Formation.

The presence of cockles, oolitic layers and cross laminations in the Proveedora mountain indicate mechanical accumulations begun by wave action, that could indicate marginal banks. The lutite and the thick strata of bioturbated sandstone indicate a very shallow deposit, with development of abundant benthonic fauna. On the other hand, the strata with archeocyathides indicate reef patches in fresh water. All of this could be related with a well-oxygenated lagunal ecology (Rivera-Carranco, 1987)

Formation: Proveedora

Geological Province: Sonora

Location: Defined by Cooper and Arellano (1946) in the Northern part of the Proveedora mountain 12 km W of Caborca. Other reference points are the Buelna, Prieto, Arroyos mountains. Anderson and his collaborators (1978) recognized it in the Berruga range in the W of the Clemente mountain in the NE of the Pozo Serna mountain and in the W of the Calaveras mountain. They also reported it 4 km N of the Cienega range, and in the extreme SW of the range.

Lithology: The Proveedora Formation is characterized by white fine-grained quartzite with some intercalations of gray lutite. The base is a sandy lutite with rhythmic variations of fine grained that gradually change as you go upwards to thick-grained laminas with a large quantity of micas ichnofossils. The laminated strata change laterally to calcarenites of very bioturbated that change to sandstone of fine grain. In the middle part the only thing present is sandy quartzite very mature with

medium to massive stratification and silicon cement. Also present are ichnofossils and tracks of organisms. In the upper portion the quartzite has argillaceous impurities which give it a purple color. The predominant sedimentary structure is cross stratified especially in the basal and middle portions. In the top there is parallel lamination that shows great destratification with little inclination. Malpica and de la Torre (1980) report a conglomerate in the base of the formation.

Thickness: Cooper and Arellano (1946) measured 200 m in the Buelna mountain, 270 m in the Proveedora mountain, and 30 m in the Prieto and Ajos mountains. On the other hand, in the Berruga range Anderson (1978) measured 225 m.

Stratigraphic Relations: The Proveedora Formation is concordant with the Puerto Blanco Formation. The upper contact is concordant with the Buelna Formation.

Fossils: This formation contains some fragments of olenelidos trilobites and linguloides brachiopods unidentified. It also contains in the Berruga range small tracks and possibly tubes of Scolithus sp.

Age: Early Cambrian.

Paleoenvironment: Because of the lithologic and stratigraphic characteristics and comparisons with the quartzites of the NE of Sonora (Bolsa and Capote Formations) Malpica and de la Torre (1980) consider it to be a marine deposit close to the littoral where the basal part of the formation shows a marine regression at the beginning of the deposit and, according to these authors, the basal conglomerate and the cross stratification at the base of the unit also shows this. The upper portion shows shallow marine deposits with fossil remains. The strata formed mixing of thick and fine sediments and the layers of bioturbated calcarenite and quartzite with Ichnofossils agrees with the Wunderlich (1970) and Clifton (1969) in recent deposits correspond with undersea environments. The depositing of very mature sandy quartzite with parallel laminations, which together with lightly inclined destratification, appear to show Aeolian influence.

Formation: Buelna

Geological Province: Sonora

Location: Described by Cooper and Arellano (1946) in the Caborca area. the Buelna mountain is a point of reference 15 km to the W-NW of Caborca on the train tracks to Baja California and 6 km to the N-NW of the mountains of the Proveedora range as a typical location. Other points of reference are found in the Proveedora mountain, Prieto mountain, Arroyos mountain, and Berruga range to the east of the Calaveras mountain.

Lithology: The Buelna Formation consist of lutite, limestone, and parallel fractures quartzite and dolomite highly fossilized. The base is composed of gray limestone that changes to calcareous sandstone with thin stratification and some fossil fragments. Also present is the cockle Salterella and trilobites, apparently garnered by mechanical action. The middle portion is composed of gray limestone in thick strata with intercalations of lutite and small strata of dolomite, sandy quartzite, oolitic limestone and a conglomerate with clasts of limestone with abundant trilobites. The upper portion is composed of brown sandstone of fine grain in thin fissile layers.

Thickness: In the Buelna mountain 101 m was measured, 85 m in the Prieto mountain, 100 m in the Proveedora mountain, and 50 m in the Arroyos mountain. (Cooper and Arellano 1946). Lochman (1956) measure 120 m in the Proveedora mountain. Anderson his collaborator (1978) measured 68 m in the Berruga range and in the Calaveras mountain the thickness of the unit varies from 68 to 121 m.

Stratigraphic Relations: The lower contact of the Buelna Formation is concordant with the Proveedora Formation. The upper contact is concordant with the Cerro Prieto Formation.

Fossils: This formation has an abundance of fossils. In the lower part it is composed almost exclusively by shells of *Saltarella* cephalopods sp. The rest of the formation is characterized by abundant *Olenelloides* trilobites.

Age: Early Cambrian.

Paleoenvironment: The sedimentary registers indicate that the oceans in the Cambrian were shallow with clear and warm water of moderate to high energy. The salinity of the water was normal and constant, mobile benthonic organisms proliferated there, especially trilobites which achieved a large geographic distribution. Given the correlation of the Proveedora Formation with the upper part of both the Bolsa and Capote formations it is inferred that the conditions of deposit changed to originate the Buelna Formation which according to its grain size shows 2 types of deposit: one tranquil, completely lagunar, which reflects facies of an open platform where in some occasions the base was affected by the wave action, as is shown by the accumulations of fossils and the strata with oncolites and oolites that possibly formed mobile submarine banks; the other was turbulent with characteristics similar to the facies of agitated sand on the edge of the plateau (Rivera-Carranco 1987).

Formation: Cerro Prieto

Geological Province: Sonora

Location: Defined by Cooper and Arellano (1946) in the Prieto mountain, 2 km SW of Caborca. Other reference points are: Difuntos mountain, Buelna mountain, Proveedora mountain, Los Arroyos mountain and the Berruga range.

Lithology: The Cerro Prieto Formation consists of massive dark gray limestone with abundant veinlets of calcite. It is characterized by a high content of dark, spherical bodies, concentric in structure, which, according to Johnson in Cooper and Arellano (1946) suggest the presence of *Girvanella* algae. It also shows indications of bioturbation.

Thickness: The thickness measured in the Prieto mountain is 110 m, Difuntos mountain 250 m, 65 m in the Buelna mountain and the Proveedora mountain measures 100 m (Cooper and Arellano 1946). In the Berruga range, Anderson et al. (1978) measured 88 m.

Stratigraphic Relations: The Cerro Prieto Formation is concordant with the Buelna Formation. The upper contact is apparently normal with the Arroyos Formation, although Anderson and collaborators (1978) mention the presence of a limestone conglomerate in the Berruga range which could indicate a discordance.

Fossils: The spherical structures of the *Girvanella* algae are the only fossils present.

Age: The age is not certain, but because of its position and stratigraphic relations it is considered to be somewhere from the later Early Cambrian to early Middle Cambrian.

Paleoenvironment: The algae content indicated to Cooper and Arellano (1946) extensive reef conditions towards the end of the early Cambrian. Lochman (1954) suggest that the reef deposits were formed in shallow, regressive seas. The waters were of low energy and very shallow, where the ontolitic horizons could have come about as a result of the oscillatory wave action, as occurred in the deposits of this type in the Alberta, Canada region. The tranquillity of the water suggest that the area was protected (Rivera-Carranco 1987). Malpica and de la Torre (1980) consider that this formation along with the Buelna and Proveedora formations, are related to the Capote and Bolsa formations, supported by the idea of transgressive seas that, from the Early Cambrian, began moving eastward.

Formation: Arroyos

Geological Province: Sonora

Location: First described by Stoyanov in Cooper and Arellano (1946) and afterwards studies in detail by these two, in the Arrojos mountain, 18 km W-SW of Caborca. Reference points are found in the Difuntos and Proveedora mountains. It also appears in the south part of the Ciénega mountains and to the west of the Calaveras mountain in the Berruga range. (Anderson et al., 1978)

Lithology: This formation is made up of a packet of finely stratified limestone, lutite, and argillaceous sandstone interstratified with lime. The lower part is composed of multicolored lutite with intervals of laminated micrite and thin fissile sandstone. The upper part consists of laminated micrite of thin stratification.

Thickness: In the Difuntos mountain 50 m; Proveedora 310 m and in this type of location the thickness varies from 151 to 189 m. In the Berruga range, in the south part of the Ciénega mountain, Anderson and collaborators (1978) measured an incomplete thickness of 201 m. Cooper and Arellano (1946) interpreted the changes in thickness as related to deformation.

Stratigraphic Relations: The lower contact is concordant with the Cerro Prieto formation and the upper contact is normal with the El Tren Formation. In the Arrojos mountain, the lower contact is a failure of lateral displacement, and the upper contact with the El Tren Formation, it is probably an inverse failure (Malpica and de la Torre 1980). Anderson et al. (1978) mention that in the Berruga range the basal contact of the Cerro Prieto Formation is abrupt and the presence of a limestone conglomerate could indicate a discordance.

Fossils: Mainly trilobites, although there are some *Girvanella* algae, coprolites, sponges and an abundance of brachiopods characteristic of the Middle Cambrian.

Age: Middle Cambrian.

Paleoenvironment: Because of its lithology and its similarities with the Abrigo Formation, it is believed that this unit was deposited on a surface close to the limaceous shallow marine platform, then moved NE after a regressive phase which is shown by the Cerro Prieto Formation. The Arrojos Formation shows means similar to those of the Puerto Blanco and Buelna formations, although with a greater content of terrigenous material (Rivera-Carranco 1987).

Formation: El Tren

Geological Province: Sonora

Location: This type of location is found in the Arrojos range, 18 km W-SW of Caborca. Other points of reference are found in the Difuntos, Proveedora, and Lista Blanca mountains. Anderson and collaborators (1978) report this formation in the Berruga range and (EGEOCISA, 1974 in Malpica and de la Torre 1980) report as a new location the E sector of the Pozos de Serna mountain.

Lithology: The base of the formation is constituted by gray limestone with stromatoloidal (EGEOCISA, 1974 in Malpica and de la Torre 1980). The rest of the unit is composed of a sequence of dolomitized limestone intercalated with dolostone. The stratification varies from 20 to 60 cm. It is also possible to find in some parts of the formation thin layers of anhydrite with an entriolitic structure.

Thickness: In the Arrojos mountain the thickness is 635 m, in the Proveedora mountain 300 m and in the Lista Blanca mountain 350 m (Cooper and Arellano 1946). Lochman (1956) in the Proveedora mountain 485 m. Anderson and collaborators (1978) in an incomplete section measured a little bit less than a 100 m in the Berruga range. EGEOCISA (1974 in Malpica and de la Torre 1980) in the E section of the Pozos de Serna mountain estimate the thickness to be between 150 and 200 m.

Stratigraphic Relations: The lower contact of the El Tren is concordant (Rivera-Carranco 1987) although an inverse failure (Malpica and de la Torre 1980) puts it in contact with the Arrojos Formation. The upper contact is unknown because the top is an eroded surface.

Fossils: A few trilobites tentatively considered to be of the *Parahmania* genus characteristic of the Mid Cambrian. The spotted aspect of the EGEOCISA (1974 in Malpica and de la Torre 1980) limestone relates it with the structure of algae.

Age: Because of its fauna content the El Tren Formation is considered to be of the Middle Cambrian.

Paleoenvironment: The lithology of the El Tren Formation indicates shallow seas with clear and warm waters of moderate to low energy, with constant and normal salinity. The irregular distribution of the dolomite suggest that the dolomitization was caused by re-emplacment processes after the deposit because of the effect of the backflow of waters supersaturated with magnesium.

In general the cambrian units of Caborca show abundant bioturbation, a phenomenon that shows the quantity of intrabenthonic fauna that populated the zone in that time. The composition of this terrigenous material, undulated quartz, in lesser proportion free of straight extinction, microcline, plagioclase, orthoclase, and mica, and in some strata there are large concentrations of biotite, allowing us to suppose that the terrain from which they were derived was rapidly eroded and was composed of metamorphic rock, acidic igneous rock, and pre Cambrian limestone.

The lithologic characteristics of the El Tren, Abrigo, and Esperanza Formations give the impression that the seas of the middle Cambrian were shallow in the area of Caborca and Cananea-Cabullona and transgressive towards the E. The absence of sediments from the Later Cambrian on a regional level, could indicate a general rising which obliged the seas to retreat towards the NW. To Malpica and de la Torre (1980) it was clear that on being invaded by the sea the plains were transformed into platforms and the rock deposits of the Cambrian in the Proveedora range are platforms but unstable platforms at least during the depositing of the Puerto Blanco, Proveedora, and Buelna Formations. If we take into account the clasts that alternate with limestone on top of its content of fauna the platform was stabilized during the deposit of the Cerro Prieto, Arrojos, and El Tren Formations which are mostly calcareous with benthonic fauna.

On the other hand, Stewart and collaborators (1984) after comparing the destratified strata of Cambrian units in the Caborca area with the sedimentary rocks of the pre Cambrian concluded that a considerable variation exists in the direction of the paleocurrents in the Caborca region where no dominant direction is evident; notwithstanding, in individual locations dominant paleocurrents do exist and paleocurrents pointed in the opposite direction which were produced by the back flow of the sea.

Area: NE of the State of Chihuahua (subfloor)

Pozo Los Chinos No. 1

Formation: Bliss

Geological Province: Chihuahua

Location: Although this unit has been described in the W of Texas, New Mexico, and Arizona, in Mexico it has only been reported in wells (Reynolds 1972). The Chino well No. 1 is located 110 km W-SW of Ciudad Juarez. This type of location is in the Franklin mountains N of El Paso, Texas (Richardson in Hayes, 1975).

Lithology: In its base this unit is composed of sandstone, limestone, lutite, mudstone, and dolomite interstratified by a pyritized zone and hematite nodules. The top of the unit consists of sandstone of medium to thick grained with argillaceous matrix and silicon cement.

Thickness: The thickness of the Los Chinos No.1 unit is of 32 m.

Stratigraphic Relations: The lower contact is discordant with metamorphic rocks of probably the pre Cambrian. The upper contact in its typical location is discordant with the El Paso Formation. (Reynolds, 1972)

Fossils: Brachiopods, trilobites, and cephalopods. In the Los Chinos No.1 well no fossils are found.

Age: Because of its content of fauna it is given an age from the Late Cambrian to early Ordovician. Because of its regional lithological relationships and content of fauna it is believed that the W (Cambrian-late Ordovician) part of the formation is older than the E (Ordovician) (Hayes, 1975).

Paleoenvironment: The sands of the formation were probably deposited in a shallow marine environment close to the coast during the initial phase of a great transgression. The age variation suggests that the transgression was from W to E (Lucia 1971), as occurred in the Caborca and Cananea-Cabullona areas in Sonora.

ROCKS OF THE ORDOVICIAN

Bisani-Caborca Area, NE of Sonora

Formation: Bisani (informal unit)

Geological Province: Sonora

Location: The name of Bisani was used by PEMEX from 1942 on to refer to the Mississippian rocks of the region. This name was also used by Alvarez (1949). Weller (1948) describes these same rocks as the Represo Formation, a name which was used afterwards by Fries (1962) and Brunner (1975). Malpica and de la Torre (1980) recommended the use of the name of Bisani Formation only for the Ordovician rocks of this region. This type of location is found 1.4 km to the S60°W of the Bisani Ranch.

Lithology: Dolomitized and silicated limestone with a presence of nodules and lenses of flint, that form a series of bodies of differentiable rock which from bottom to top are:

Body A: Fine to middle grained dolostone, partly silicated, lightly argillaceous, with strata of 20 to 50 cm and occasionally of 1 m with fossil fragments especially in the base.

Body B: Argillaceous dolostone containing fossils with stylolitic lines and isolated clasts of fine quartz, with fractures filled with pyrite, ferro-oxides, and silica. It contains unidentifiable fossil fragments.

Body C: Silicated dolostone of medium grain in strata of 20 to 40 cm heavily fractured. The fractures are filled with silica, ferro-oxides, and clay. Occasionally the silification completely subjugates the dolomite and in others the dolomite is subordinate to sparse fine limestone. Recrystallized fossils are observed (spicules of echinoderms, ostracods, and gasteropods) in all the middle portion of the body.

Body D: Partially silicated dolostone with fractures filled with silica and clay, in strata of 2 to 5 cm, alternating with layers of flint with silicated conodonts in layers of 2 to 10 cm. In the middle portion of the body the flint replaces almost completely the dolomite (novaculite?) which is present in the form nodules. Fragments of macro and micro fossils have been observed but not identified.

Body F: Fine grained dolostone in strata of 2 to 10 cm with remains of ostracods and crinoids. Also present are intercalations of flint and strata of 1 to 5 cm. Some unidentified micro fossils are present also. From the middle to the top part of this body the strata are heavily folded.

Body G: Dolostone with fractures filled with silica in strata of 20 to 40 cm with nodules and lenses of flint.

Thickness: Cooper and Arellano (1946) consider an incomplete thickness of 426 m. Malpica and de la Torre (1980) measured an actual thickness of 138 m. The thickness of the bodies, from base to cap, is of 5, 6.5, 50, 12, 28, 20, 16.5 m.

Stratigraphic Relations: The contacts are unknown. Although because of the closeness of the Caborca region, it is inferred that it should rest on Cambrian rocks, in discordance with the El Tren Formation, of the mid Cambrian. It is probable that the upper contact is discordant with the Murciélago Formation of the Devonian to late Silurian.

Fossils: Conodonts, microfossils and fragments of highly recrystallized macrofossils.

Age: Originally, it was given an age from the Silurian (Cooper and Arellano, 1946). Afterwards, Fries (1962) considered it to be of the Silurian-Ordovician, although he mentions that it is not confirmed. Malpica and de la Torre (1980) because of the conodonts in the lower part given an age from the Ordovician-Silurian and the Later Devonian.

Paleoenvironment: because of its lithological characteristics Malpica and de la Torre (1980) infer that the deposit environment was a platform with tranquil waters which were warm and shallow. On the other hand, Fries (1962) believes that this region was constantly sinking.

Cobachi-San Javier Area, Central Part of Sonora

Formation: Cobachi

Geological Province: Sonora

Location: These rocks were described by Dumble (1900) in the S part of the Cobachi mountain 12 km to the S60°E of the town of Cobachi and 3 km from the Venta-Colorada range following the logging trail that goes to the entrance of the Cobachi mountain. A reference point is found in the W part of the San Javier range 10 km from the abandoned Casita range and 35 km E of the Cobachi range.

Lithology: It changes from massive limestone to sandstone. Malpica and de la Torre (1980) found 7 bodies that from bottom to top are:

Body 1: Massive limestone with remains of corals partially and incipiently dolomitized, with no nodules of flint.

Body 2: Arkosic sandstone of fine grain and well-cemented, finely laminated with fragments of corals.

Body 3: Calcareous sandstone of fine-grained, well-defined in very thin laminar layers with coral remains.

Body 4: Very fine crystalline limestone in thin strata with crystallized zones of 1 to 2 cm (bird's eye).

Body 5: Arkosic sandstone of well-cemented, fine-grained in strata of 30 to 40 cm.

Body 6: Arkosic sandstone of fine grain with massive stratification well consolidated in fragments of fine conglomerate of granules and sand in a mixture of calcareous clay.

Body 7: A conglomerate composed of subangular and subrounded fragments alternated with sandstone and fine conglomerate in a sandstone-clay mixture.

Thickness: The measured thickness is not complete because the base and the top are unknown King (1939) in the Cobachi mountain. Malpica and de la Torre (1980) report a thickness of 56 m. These authors consider the thickness of the different bodies to be, from the bottom to top: 12, 7.5, 7.5, 3.5, 17.5, and 4 m.

Stratigraphic Relations: Although the lower contact is not observable, Dumble (1900) suggests that this unit rest in angular discordance on Cambrian rocks (quartzite and marble). Fries (1962) thinks that the discordance is with rocks of the late Precambrian.

The upper contact is in angular discordance with rocks of the Permian (King 1939), although the contact was also observed by fault in the E side of the Cobachi range.

Fossils: Abundant corals of the *Paleophyllum* genus and a few *Calapoecia*, *Streptelasma*, and *Heliolites*.

Age: Late Ordovician (Richmondian)

Paleoenvironment: Because of the lithology and the content of fauna it is inferred that the deposit environment was a platform close to the continental shelf which contributed sandy sediments. The fineness of these sediments and the wide range of selection could indicate that the contribution of clasts occurred periodically by means of fluvial currents that were redistributed and classified by marine currents during great extensions. To some authors this indicates that the sedimentation cycle was interrupted several times during the Paleozoic by bridging and deforming movements accompanied by periods of erosion. This is probably shown by the presence of a red conglomerate in the upper portion of this formation. Perhaps the conglomerate belongs to a younger unit (Silurian?). This period of time is not present in all the region perhaps because during this time the region rose, was deformed and eroded. However, the information necessary to corroborate this idea does not exist (Fries et al 1962).

Placer de Guadalupe Area, Chihuahua

Formation: Sóstenes

Geological Province: Chihuahua

Location: Formerly proposed by Bridges (1964). the best location is W of Placer de Guadalupe mountain. It also appears in the Solis and Enmedio mountains.

Lithology: It is composed of limestone, lutite in medium to thick strata, with flint and small stains of dolomite. It also contains two bodies of orthoquartzite in medium to thick strata towards the top of the unit which distinguishes and separates the unit from the Solis Formation. Close to its base the Sostenes Formation contains small lenses of dolomite.

Thickness: The thicknesses in the Sostenes Formation in the Placer de Guadalupe, Solis, and Enmedio mountains are 264, 265, and 280 m, respectively.

Stratigraphic Relations: The lower contact of the Sóstenes Formation is unknown (Bridges, 1964). The upper contact is transitional with the Solis Formation.

Fossils: *Palliceria* gastropods sp. and *Maclurites* sp. as well as numerous species of brachiopods, bryozoans, conodonts, very few corals and some trilobite fragments (Bridges 1964). The fossils have only been found in the calcareous portions of the formation.

Age: Early to late Ordovician. Because of the presence of fauna from the Upper Ordovician in the Solis Formation, a formation to which it is subadjacent, Bridges (1965) places the Sóstenes Formation in the Cincinnati series.

Paleoenvironment: According to Malpica and de la Torre (1980) the deposit occurred in shallow waters below the level of the wave action. Bridges (1964) suggests that the place of origin of the sandstone was probably in the N. This same author thinks it likely that the Sóstenes Formation

represents the beginning of the deepening of the geosinclina Ouachita close to Marathon, because of which this area is considered frankly transgressive towards the E and towards the N.

Formation: Solis

Geological Province: Chihuahua

Location: Defined by Bridges (1964) in the Solis mountain located in the canyon of the same name in the Monilla range between the Placer de Guadalupe and Plomosas mines. The best exposure of the formation is the Enmedio mountain 5 km S of the Plomosas mine. It also appears in the Placer de Guadalupe and Enmedio mountains.

Lithology: The lower part of the formation is characterized by lutitic limestone, limestone with flint in medium to thick strata and calcareous lutite in thin stratification. In the Placer de Guadalupe mountain the top of the Ordovic is a body of dolomitic limestone and dolomite.

Thickness: The thickness is of the Solis Formation correspondent to the Ordovician in the Placer de Guadalupe, Solis, and Enmedio mountains are 15, 36, 35 m respectively. The total thickness including strata from the Silurian-Devonian is of 230, 255, and 190 m respectively.

Stratigraphic Relations: The lower contact is transitional with the Sostenes Formation and is marked by two prominent bodies of orthoquartzites pertaining to this last formation. The upper contact is marked by a discordance with the Monillas Formation, to which it is subadjacent.

Fossils: *Sowerbyella* sp. and *Zyboospira* sp. brachiopods as well as some other species of brachiopods, some conodonts and some favositoids corals (Bridges 1964).

Age: Late Ordovician (Ashgiliano) -Silurian-Devonian.

Paleoenvironment: The conditions are identical to those of the Sostenes Formation. It shows a continuous deposit of sediments during the Ordovic, however, the lithological variations show a transitional deposit from sandstone to limestone (Malpica and de la Torre 1980).

Nochixtlán-Ixtaltepec Area, Oaxaca

Formation: Tiñu

Geological Province: Mixteca

Location: Defined by Pantoja and Robison (1967) this type of location is 8 km SW of Nochixtlán, Oaxaca on the old road to Santa Maria Tiñu. Other points of reference are found in the vicinity of San Pedro Cantaros (Totoyac section), in the surroundings of Santiago Ixtaltepec (Ixtaltepec section), 15 km NE of Nochixtlán. Malpica and de la Torre (1980) describe other locations: Itucana arroyo, 3 km NE of the town of Santiago Ixtaltepec, Totoyaca arroyo, 5 km NE of San Pedro Cantaros and in the surroundings of Santa Maria Tiñu, located on the E side of the mountain on the old road which leads to the town of Santa Maria Tiñu close to the typical location.

Lithology: The Tiñu Formation consists of a sequence of limestone, lutite, mudstone, and sandstone. Because of its lithology, it is divided into two bodies: the upper lutitic and the lower calcareous (Pantoja 1969).

The basal part of the unit is distinguished by a basal conglomerate with fragments of limestone and gneisses in a sandy calcareous mix (Malpica and de la Torre, 1980). The lower body is composed of a limestone with abundant trilobites that alternates with very fine mudstone and sandstone lightly calcareous. Towards the middle and upper portion the formation is characterized by an abundance of nodular concretions of limestone included in layers of lutite and mudstone.

Thickness: In the Tiñu section the thickness measured by Pantoja (1969) is 220 m; in the Ixtaltepec section 36 m. The thickness as measured by Malpica (1978) of the lower body only, in the Itucana arroyo 14 m, Totoyaca arroyo 22 m, and 83 m in the Santa Maria Tiñu arroyo.

Stratigraphic Relations: The lower contact is an angular discordance on gneisses of the Oaxaqueño Complex and they overcome in angular discordance a body of conglomerated limestones, which marks the beginning of the Mississippian sedimentation of the Santiago Formation.

Fossils: The most significant fossils of the Tiñu Formation are the trilobites, mollusks, cephalopods, spicules of sponge and conodonts (Robinson and Pantoja 1967; Yochelson 1968; Flower 1968).

Age: Early Ordovician. Pantoja (1969) mentions that the age goes from the late Cambrian to early Ordovician (Tremadocian).

Paleoenvironment: A shallow platform of moderate to low energy with warm water and normal salinity. The sedimentation was uniform in short periods of time, with only a small influx of terrigenous. Rowett (personal communication in Malpica and de la Torre 1980) relates the fauna of this region with the fauna observed in the Paleozoic of Peru.

NW Area of the State of Chihuahua (subfloor).

Los Chinos Well No. 1

Formation: El Paso

Geological Province:

Location: In Mexico it was only found in the subfloor of the Los Chinos Well No. 1, located in the eastern portion of the Chinos range, 110 km W-SW of Ciudad Juárez, Chihuahua. It was defined by Richardson (in Hayes 1975) in the Franklin mountains N of El Paso, Texas.

Lithology: It varies lithologically from one region to another. In the Chinos Well No.1 it consists of argillaceous limestone in thin layers and laminars with dolomitized portions. Also present are intercalations of very thin lutite with abundant organic material and nodules of flint. Towards the middle and upper portions it is composed of laminar argillaceous limestone occasionally sandy, alternating with layers of wackestone with intraclasts and bioclasts with very thin layers of irregular distribution of laminar black lutite. The layers of this formation are wavy and discordant, owing to, according to Reynolds (1972), deformation processes.

Thickness: The thickness of this formation in the well is 199 m, with an average dip of 45° which gives it an actual thickness of 140 m (Reynolds 1972).

Stratigraphic Relations: Reynolds (1972a) considered the lower contact of the Los Chinos Well to be discordant with the Bliss Formation. The upper contact is transitional with the Cable Canyon Formation.

Fossils: No fossils are found in the well.

Age: Late Cambrian-Early Ordovician.

Paleoenvironment: the lithological characteristics of this formation in the Chinos Well No.1 suggest a deposit of deep waters (Reynolds 1972). The lithological differences of this formation suggest, at least to Malpica and de la Torre (1980), a deposit in a transgressive basin towards the N and E of the well. Hayes (1975) puts the Chinos well inside of the Ouachita basin.

Formation: Cable Canyon

Geological Province:

Location: Originally studied by Richardson (1904 in Hayes 1975) in appearances in the Franklin mountains, N of El Paso, Texas. It is part of the Montoya Group (Pratt 1967 in Hayes 1975). In Mexico it has only been reported in the Los Chinos Well No.1 NW of Chihuahua.

Lithology: In the Chinos Well No.1 it is composed of a sequence of sandy dolomite. The clasts of sand are of fine to medium grain, subrounded, and poorly classified. This sequence is interstratified with sandy mudstone in thin strata and black phyllite with organic material and thin intercalation of dolomite and dolomitic limestone with bioclasts and oolites that increase in frequency towards the top of the formation.

Thickness: In the Chinos Well No. 1, 330 m were measured with a dip of 60°, which gives an actual thickness 165 m. This thickness along with the crossing in the Delaware, Texas, basin of 600 m are the best known. Both are of the subfloor.

Stratigraphic Relations: The lower contact is discordant with the El Paso Formation of the lower Ordovician (Hayes 1975). To Reynolds (1972) this contact is transitional with the Montoya Formation.

Fossils: In the base of the formation, while the well was being dug, bryozoans *Nematopora* sp. and *Ptoldicya* sp. were found. In other locations brachiopods, mollusks, pelmatozoa, a few trilobites, bryozoans and corals were reported.

Age: The bryozoans collected in the Chinos Well No. 1 indicate an age from the late Ordovician. Because of the fossils collected in other locations the formation could be from mid to Late Ordovician.

Paleoenvironment: Because of its detritic nature, stratification, thicknesses and restricted thicknesses it is believed that this formation was deposited in littorals of transgressive seas. The presence of calcareous sediments indicate that the deposit was on the edge of a shallow platform especially when the thickness of this place is considered and the increment thereof towards the Delaware basin.

Formation: Montoya

Geological Province:

Location: it has only been identified in the Chinos Well No.1 Located in the E flank of the Chinos range W-SW of Ciudad Juarez. This formation appears the same as the others in the S of the United States (Texas, New Mexico, and Arizona).

Lithology: Defined by Richardson (1908 in Hayes 1975) in the Franklin mountains, Texas. The Lithology of this formation is different in each of the locations where it appears. In the Los Chinos Well No. 1 the Montoya Formation consists of bioclastic limestone partially dolomitized that changes to dolomite in thin strata with stylolitic lines. It shows fossiliferous horizons with mollusks, brachiopods, and unidentified fossils. Inside of the dolostones, in the middle portion of the unit, there is a thin layer of brecciated limestone and towards the base, a small body of sandy dolostone.

Thickness: The average thickness of the formation is 138 m. In the Los Chinos Well No. 1, 395 m were measured with dips of 45° to 65°. Given an average dip of 50° the thickness is 254 m.

Stratigraphic Relations: In the Chinos Well No. 1 the lower contact of this unit is transitional with the Cable Canyon Formation. The upper contact is discordant with the Canutillo Formation of the Early Devonian.

Fossils: In the Chinos Well No. 1 only conodonts were found.

Age: Because of its fauna it is given an age from the Upper Ordovician.

Paleoenvironment: The lithological characteristics of this formation indicate that it was deposited in transgressive seas, after a period of erosion, or it was not deposited at the end of the lesser and mid Ordovician. The cross stratification of the basal portion of the unit in the sandy sediments imply litoral conditions. The occasional and thin-breached horizons could be a product of rapid rising accompanied by sinking. This implies that the deposit was begun in unstable transgressive seas with short regressive periods (Hayes, 1975).

SILURIAN ROCKS

Placer de Guadalupe Area, Chihuahua

Formation: Solis

Geological Province: Chihuahua

Location: Defined by Bridges (1964) in the Solis mountain located in the canyon of the same name located in the Monilla range, between Placer de Guadalupe and Plomosa mines. It also appears in the Placer de Guadalupe mountain.

Lithology: The middle part (Silurian) of the Solis Formation towards the base is represented by a dolostone. The rest of the Siluric part is thin to medium Strata of intraclastic limestone.

Thickness: The thicknesses of the formation belonging to the Siluric are of 88 m, 50 m, and 36 m, for the Placer de Guadalupe, Solis, and Enmedio mountains, respectively. The total thickness including Ordovic and Devonian rocks is of 230, 255, and 190 m, respectively for each of the appearances before mentioned.

Stratigraphic Relations: The lower contact is transitional with the Sóstenes Formation of the Ordovician. This contact is marked by the presence of two powerful bodies of sandstone that characterize the top of this last formation. The upper contact of the Solis Formation is discordant with the Monillas Formation of the Late Devonian-early Mississippian (?).

Fossils: The Fossils that were found in this formation are Halysites sp. and Entelophylum corals of which the later are rare (Bridges 1964). Brachiopods, corals, conodonts , and ostracods have been found.

Age: The base of the Solis Formation is from the Late Ordovician, the Middle portion of the Silurian, and the upper layers of the Devonian.

Paleoenvironment: The change of facies from dolomitic limestone, and the Placer de Guadalupe mountain, to conglomerated limestone of the Siluric and the silicated limestone with layers of flint of the early Devonian, in the Enmedio mountain and Solis canyon respectively show a complex environment of deposit (Bridges 1964). The dolomitic limestone and the conglomerate were probably deposited in shallow waters and the silicated limestone and layers of flint could have been deposited in slightly deeper waters. The presence of corals in these rocks indicates relatively shallow waters of high to moderate energy.

In the Enmedio mountain a period of erosion occurred in the middle portion from the Middle Devonian to the Early and Late Devonian. Afterwards a second interval of erosion extends from the Upper late Devonian to the late Mississippian. In the Placer de Guadalupe mountain where the erosion was more extensive these two erosional intervals continued. It is because of this that the Devonian part of the Monillas Formation is not exposed in the Placer de Guadalupe mountain nor in the Solis mountain.

Ciudad Victoria Area, Tamaulipas

Formation: Cañon de Caballeros

Geological Province: Mexican belt of miogeoclinal fold and faults of the gulf of Mexico.

Location: Defined by Carrillo-Bravo (1961) in the Caballeros canyon 600 m W of the Naranjal range 10 m S of the road that goes to the Naranjal al Aserradero range. It also appears in the Yerba range 1.5 km NW of the Vicente Guerrero range inside of the Peregrina canyon.

Lithology: The basal part, in the Peregrina canyon, is of medium stratified limestone that alternates with laminar lutite and thin strata of quartzite sandstone. The upper part contains lutite and sandy lutite. In the Caballeros Canyon the base of the formation contains 2 m of limestone and sandy fossiliferous limestone which correspond to the upper part of the lower calcareous body of the appearances in the Yerba range. On this limestone 5 m of lutite and sandy lutite rests.

Thickness: In the Peregrina canyon the thickness is 65 m, and in the Caballeros canyon it is 52 m.

Stratigraphic Relations: In the Peregrina canyon this formation rests in apparent concordance with the Victoria limestone of the Ordovician (?). The upper contact is concordant with the silicon sediments of the upper Siluric- lower and mid Devonian of the Yerba Formation (Carrillo-Bravo 1961). This same author mentions that in the Caballeros Canyon directly of gneisses and is under silicon sediments of the Yerba Formation. The lower contact in the Caballeros Canyon is by fault.

Fossils: Brachiopods, corals, trilobites, and ostracods. Microscopically bryozoans, trilobites, crinoids, ostracods, tentaculites, and other biogenic remains are distinguishable (Terrez-Giron 1970).

Age: Because of its content of fauna it is given an age from the Early Silurian (Llandoveryan)-Late Silurian (Ludlovian).

Paleoenvironment: The deposit of the limestone with trilobites, corals, and brachiopods probably occurred on a shallow platform with warm water of moderate to low energy. It is probable that the sedimentation was uniform for short periods of time with small influx of terrigenous sediments, shown by the alternation of lutite and quartzite sandstone. Afterwards sinking occurred leaving a few restricted zones with little circulation of water and an influx of terrigenous as is shown in the upper part of the formation where lutite and sandy lutite are dominant with carbonic remains, pyrite, and a few ostracods and trilobites.

DEVONIAN ROCKS

Bisani-Caborca Area, Sonora

Formation: Murcielagos

Geological Province: Sonora

Location: Defined by Cooper and Arellano (1946) in the NW of Sonora. The typical location is 3 km NW of the Bisani range where 3 small elevations appear, known as the Murcielago mountains

Lithology: A sequence of limestone, dolostone, and brecciated limestone. The basal part is composed of highly-altered dolostone. The first 25 m of the base show no stratification. The rest of the dolomitic body is 85 m and strata of 20 to 50 cm that alternates with sandy dolostone that changes to medium-grained sandstone and small strata of 2 to 3 cm. The middle part of the column is composed of limestone and strata of 10 to 60 cm occasionally brecciated with intercalations of sandy limestone of medium grain. The upper part is composed exclusively of brecciated limestone and strata of 10 to 50 cm.

Thickness: The total of thickness of the formation is 333 m. the basal part measures 100 m, the middle part 98 m, and the upper 135 m.

Stratigraphic relations: The upper and lower contacts are unknown, however the presence of Ordovician rocks in the area (Bisani Formation) suggest that the lower contact is discordant and the upper contact probably concordant with the Represo Formation of the lower Mississippian.

Fossils: Stromatoloidal, oncolites, brachiopods, bryozoans, echinodermic corals, trilobites, and gasteropods. The most abundant micro fossils are the microforaminifera, calcareous concretion, ostracods, and conodonts (Brunner 1975).

Age: Because of the fauna present in the formation it is assigned an age from the mid to Upper Devonian.

Paleoenvironment: Because of the lithology and fauna of the unit Brunner (1975) infers a deposit in the protected part of a bank or in a post reefal zone in a warm environment shallow and tranquil. Malpica and de la Torre (1980) suppose, although the lower contact of the formation is unknown, a period of erosion during the Silurian-Lower Devonian so that, afterwards, during the mid and upper Devonian a deposit of carbonates in the Murcielagos, Represo, and Venada Formations could occur. These latter 2 are from the lower Mississippian.

Cananea-Cabullona Area, Sonora

Formation: Martin

Geological Province: Sonora

Location: Defined by Ransome (1904) in Mount Martin of the Mula mountains, Cochise county W of Bisbee, SE of Arizona. In Mexico Taliaferro (1933) first described it in the mountains that border the Cabullona basin, in the NE of Sonora. The major appearances in Sonora of the Martin Formation are in the mining district of Cananea in the Huachuca and Ajos ranges (Aponte 1974), and Cabullona range (Viveros, 1965; Cendejas and Barcenas 1976).

Lithology: Compact limestone and dolomitized limestone with occasional strata of calcareous lutite. In the Huachuca and Ajos ranges and in the Cananea mining district, from bottom to top, it is composed of sandy limestone, of powerful thicknesses that change vertically to a fine limestone and dolomitic limestone with some intercalations of sandstone and strata. Viveros (1965) mentions that in the Cabullona range this formation is divided into two bodies: The lower is composed of limestone with strata of 60 cm to 1 m, with stalks of crinoids; the upper body is composed of limestone with thin stratification and an abundance of flint lenses.

Thickness: Aponte (1965) reports a thickness of 46 m in the Cananea mining district, 62 m in the Huachuca range, and 150 m in the Ajos range. The total thickness of the Cabullona range, according to Viveros (1965) is approximately 260 m.

Stratigraphic Relations: The lower contact is discordant with the Abrigo Formation of the lower Cambrian. Viveros (1965) considers that the sediments of the Abrigo Formation are not present in the Cabullona range and that a well defined discordance exists between the quartzite of the Bolsa Formation of the mid Cambrian and the Martin Formation. The upper contact of the Martin Formation is discordant with the scabrous limestone of the Mississippian.

Fossils: Principally brachiopods of the *Atrypa* and *Spirifer* genus, on top of abundant corals some of them silicated belonging to the *Pachyphyllum* and *Coenites* genus.

Age: Because of its fauna it is given an age from mid to Upper Devonian (Aponte, 1965).

Paleoenvironment: The lithology of the formation suggests a deposit in a sea with a shallow platform of warm water, where reefs developed and invertebrates, like the brachiopod, proliferated. The greatest thickness of the formation is towards the NW, which could show a deposit in a transgressive sea which probably began in the mid Devonian, moving from E to W, on top of a discordance perhaps produced by the immersion of the area towards the end of the Cambrian. Or perhaps, there was no deposit in the Ordovician-Silurian, or that these were eroded during the Ordovician-Silurian. This is believed because in areas close by, such as the S of Arizona and New Mexico and in Placer de Guadalupe, Chihuahua there are Ordovician sediments. In the Huachuca and Ajos ranges the sediments of the Martin Formation could be slightly younger than those of the Caballona range.

Formation: Caliza Cristalina Inferior

Geological Province: Sonora

Location: Defined by Mulchay and Velasco (1954) in some of the Cananea mountains in the mining district of Cananea, in the N-central part of Sonora where it appears irregularly.

Lithology: It is characterized by limestone in strata of 50 cm to 1 m, lightly mineralized, with magnesium oxide, copper and zinc sulfates and chlorite and epidote.

Thickness: The thickness of the unit is 106 m of which the lower 76 are of the Devonian and the remaining 30 of the Mississippian.

Stratigraphic Relations: The lower contact is discordant with the Esperanza Formation of the Middle Cambrian. The upper contact is concordant with the Caliza Cristalina Superior of the Early Mississippian.

Fossils: There is a scarcity of fauna in this unit, nonetheless, in the lower part *Spirifer* brachiopods, crinoids and corals.

Age: The presence of these fossils suggests an age from the mid to Upper Devonian (Mulchay and Velasco 1954).

Paleoenvironment: The deposit conditions are similar to those of the Martin Formation, which is to say it was deposited on a shallow platform. The similarity of this unit with the Martin Formation suggests that they are the same unit.

Placer de Guadalupe Area, Chihuahua

Formation: Solis

Geological Province: Chihuahua

Location: Defined by Bridges (1964) in the Solis mountain located in the canyon of the same name in the Monilla range, between the Plomosas and the Placer de Guadalupe mines. The best exposure is located on the Enmedio mountain 5 km S of the Plomosas mine. It also appears in the Placer de Guadalupe mountain.

Lithology: The part belonging to the Devonian of this formation includes a body of silicated limestone with flint in medium strata. The layers and nodules of flint increase towards the top of the unit. In the Placer de Guadalupe mountain the unit has no flint and the strata are thicker.

Thickness: The thicknesses of the Devonian of this unit are: 127 m, 169 m, 119 m, for the Placer de Guadalupe mountain, Solis canyon, and Enmedio mountain, respectively. The total thickness of the unit in these same locations is 230 m, 225 m, and 190 m, respectively.

Stratigraphic Relations: The lower contact is transitional with the Sóstenes Formation of the Ordovician. The upper contact is discordant with the Monillas Formation of the Late Devonian-early Mississippian (?).

Fossils: Mainly brachiopods (*Levenea*, *Leptocoelia*, *Acrospirifer*, *Atrypa*, and *Strophonella*). Also some corals (*Alveolites* and *Favosites*) and conodonts (*Distacodus* and *Icriodus latericrescens*).

Age: The majority of fossils are from the Lower to Middle Devonian. The *Icriodus latericrescens* indicates the Lower to Middle Devonian. The lower and middle part of the Solis Formation correspond to the Late Ordovician and Silurian, respectively.

Paleoenvironment: The conditions are identical to those of the Sostenes Formation. It shows a continuous deposit of sediments during the Ordovician, however, the lithological variations show a transitional deposit from sandstone to limestone (Malpica and de la Torre, 1980).

Formation: Monillas

Geological Province: Chihuahua

Location: Defined by Bridges (1964) in the mountain and canyon of the same name, located between Plomosas and Placer de Guadalupe mines. The best exposure is found in the Enmedio mountain and in the Monillas canyon.

Lithology: It is composed of argillaceous limestone and lutite, situated between 2 powerful sequences of limestone (Solis Formation and Pastor Formation). Bridges (1964) divides into two bodies separated by a discordance. the lower body is of the Middle to Late Devonian and the upper body is of the late Mississippian to early Pennsylvanian and is composed of sandy, argillaceous limestone.

Thickness: The lower body has a thickness in the Enmedio mountain of 33 m and in the Monillas canyon 7 m. the total thickness of the formation is 50 and 47 m respectively. Hawkins (1975) reports a thickness of 90 m in the Monillas canyon and Hernández-Rios (1975) measured 70 m in the Placer de Guadalupe mountain. This last thickness belong exclusively to the Carboniferous portion.

Stratigraphic Relations: The lower contact is discordant. The upper contact is gradational with the Pastor Formation. There is a discordance that separated the sediments deposited during the mid and late Devonian from those deposited during the late Mississippian-early Pennsylvanian.

Fossils: The fossils which mark the lower body of the Monillas Formation are the tentaculite *Styliolina* and the brachiopod *Orbiculoidea*. Other fragments that are present are the brachiopods *Acrospirifer*, *Leptocoelia*, and *Meristella* and the conodonts *Hindeodella*, *Icriodus latericrescens*, and *Polygnathus linguiformis*.

Age: The age of the lower body is not precise because one part could belong to the Middle to Late Devonian and the other part to the early Mississippian, although it could belong to the early part of the Late Devonian.

Paleoenvironment: The deposit characteristics for the lower body could have been a shallow platform very close to the continental shelf with an influx of sand and lime. The fineness of the clasts and the carbonites could indicate that the influx of these was done periodically by means of currents that distributed the sediment along large extensions of the sea bed.

Ciudad Victoria Area, Tamaulipas

Formation: La Yerba

Geological Province: Mexican belt of miogeoclinal folds and faults of the Gulf of Mexico.

Location: Defined by Carrillo-Bravo (1961) in the Yerba range 1.8 km from the Vicente Guerrero range inside of the Peregrina range. It also appears 400 m E of the Aserradero ranch, and between and the Naranjal ranch inside of the Caballeros canyon.

Lithology: It is composed of silicated rocks with lutite, sandstone, and a little bit of limestone partially dolomitized. The base of the formation of the Yerba range is composed of 20 m of silicated sediments, reported by Carrillo-Bravo (1961) as novaculite with white and yellow flint. The upper part of the formation in this location is 40 m of lutite that alternates with strata of fine grain sandstone.

In the Caballeros Canyon the lower part is shown by more than 40 m of silicated sediments in strata of 2 to 40 cm. On these novaculites (?) rest 20 m of lutite that alternate with argillaceous sandstone. The top has a thickness of 210 m and contains partially dolomitized limestone with very fine intercalations of lutite.

Thickness: The thickness of the formation in the Yerba ridge is 60 m and 70 m in the Caballeros canyon.

Stratigraphic Relations: The lower concordant over Siluric sediments of the Cañon de Caballeros Formation. The upper contact is discordant with the Vicente Guerrero Formation of the Mississippian.

Fossils: The fauna is constituted by some Chonetes sp. brachiopods. In the intercalated lutite with the dolomitized limestone of the upper part remains of some Devonian plants were found.

Age: Because of fossils found in the unit it is given an age from the Middle Devonian.

Paleoenvironment: The origin is uncertain given that no radiolarians and diatoms or spicules of sponge in the novaculites have been found. On the other hand, the clastic sediments that appear over and under the novaculite are apparently derived from a close continental zone deposited in shallow seas as the reported fossils indicate. Rapid change in the level of the sea in a small space could have occurred, so that the novaculites could have been deposited in deep seas close to the coast line. The dolomitized limestone could have been deposited in shallow seas.

Area NW of Chihuahua (subfloor)

Chinos Well No. 1

Formation: Canutillos

Geological Province:

Location: Defined by Nelson (1940) in the Franklin mountains of El Paso Texas. It also appears in Arizona, New Mexico, and the W of Texas. In Mexico it has only been reported in the Chinos Well No. 1 (Reynolds 1972), located in the E margin of the Chinos range, 1010 km W-SW of Ciudad Juarez, Chihuahua.

Lithology: In the Well it is represented by a sequence of dolostone that in some parts has abundant flint. The dolostone varies from fine grain to thick with a saccharoidal texture and porosity from regular to good.

Thickness: In the Chinos Well No. 1, 311 were measured. Reynolds (1972) mentions that the places where it appears the thickness is 50 m because of which he thinks that there are probably undetected faults in the Well, or that dolostone from the Fusselman Formation of the lesser to middle Silurian, reported in neighboring areas, but not in the Well, is being included.

Stratigraphic Relations: The lower contact is discordant with the Montoya Formation. The upper contact is discordant with the Percha Formation.

Fossils: During the digging some crinoids recrystallized bioclasts and conodonts were identified.

Age: The age of the formation based on fossils reported in other locations is of the early to mid Devonian (Rosado 1971).

Paleoenvironment: The sediments of this unit were possibly deposited in a shallow platform environment. Reynolds (1972) postulates the edge of a platform. Kottowski (1965) suggests a deposit in a shallow, muddy, epicontinental sea over an eroded surface originated in the Silurian and part of the Early Devonian. Rosado (1975) comments that the depth of the seas increase towards the mid and late Devonian a time in which the precipitation of the carbonates diminished and the black lutites of the Percha Formation were deposited.

Formation: Percha

Geological Province:

Location: Defined by Gordon (1907 in Reynolds 1972) SE of Hillsboro, New Mexico. It also appears in Texas and part in Arizona. In Mexico it has only been reported in the Chinos Well No. 1 (Reynolds, 1972).

Lithology: It consists of a sequence of lutite and mudstone that changes progressively towards the upper part to very argillaceous mudstone in the top of the unit with abundant intercalations of laminar black lutite carbonaceous with fractures filled with calcite quartz and pyrite.

Thickness: The thickness of the unit in the Chinos Well No. 1 was 182 m with an dip of 65° which gives a real thickness of 77 m. The maximum thickness measured is 87 m in the Big Hatchet range.

Stratigraphic Relations: The lower contact is discordant and abrupt with the Canutillo Formation. The upper contact is transitional with the Keating Formation of the lower Mississippian. Concerning this latter contact Reynolds (1972) comments that there might be a discordance between these formations but it was impossible to detect this during the digging because of the homogeneity of the lithologies placing the contact where the lutite and the argillaceous mudstone of the Percha Formation changed to less argillaceous mudstone in the Keating Formation.

Fossils: No fossils were found in the Well.

Age: Because of stratigraphic position and some fossils identified at other locations, in the neighborhood of New Mexico, it was given a Late Devonian age.

Paleoenvironment: Because of its lithological characteristics it is inferred that it was deposited in deeper waters than those of the shallow platform that those of the Canutillo Formation were deposited. Rosado (1975) comments that the lutite of the Percha Formation was deposited in a basin known as the Percha Basin by a canal aligned W-E limited to the S by the platform of the Canutillo Formation and towards the N by the Oñate Formation. The Percha Formation was deposited after a regression of the seas that left the Canutillo dolostone exposed to erosion and originated a discordance in a small lapse of time between the late Middle Devonian and the Middle Upper Devonian because of which in some places of the sediments of the basin they discordantly cover the priorly mentioned platforms, which is how the subfloor of the NW of Chihuahua was interpreted.

Mississippian rocks

Bisaní-Caborca Area, Sonora

Formation: Represo

Geological Province: Sonora

Location: Defined by Cooper and Arellano (1946). Afterwards, Weller (1948) described it in an informal fashion. It only appears in the Caborca, Sonora area, 1 km N80°W of the Bisani Ranch. This location consists of a small, isolated elevation, circular in its base, and a little bit more than 80 m high.

Lithology: It consist of 8 bodies without apparent effects of erosion or deformation. From base to top they are:

Body A: Partially fractured and silicated dolostone in strata of 15 to 30 cm. It has abundant microfossils, macrofauna, chiefly crinoids, brachiopods and trilobites, partially dolomitized, with frequent intercalations of black flint.

Body B: Dolomitic limestone, composed of fragments of crinoids (encrinite), without stratification.

Body C: Microcrystalline fossiliferous (biomicrite) limestone, in strata of 20 to 50 cm, with remains of crinoids, bryozoans, and a few trilobites, separated by layers or lenses of black flint. It shows argillaceous zones and some dolomitized stains.

Body D: Microcrystalline limestone with abundant microfossils in strata of 10 to 40 cm. There are some remains of crinoids bryozoan spicules of sponge and probably ostracods. There are also some isolated nodules of flint.

Body E: Microcrystalline petlitic (biomicrite) limestone, in strata of 10 to 20 cm partially silicated with isolated remains of crinoids, bryozoans, mollusks, and solitary corals. There are also intercalations of lenses of black flint of 2 to 5 cm thickness.

Body F: Microcrystalline limestone partially dolomitized with remains of crinoids, brachiopods, ostracods, etc. The strata are of 10 to 20 cm with no lenses of flint.

Body G: Microcrystalline limestone in strata of 5 to 20 cm. It has abundant remains of echinoderms, brachiopods, ostracods, and bryozoans. There is also black flint of 2 to 5 cm.

Body H: Microcrystalline limestone in strata of 10 to 30 cm, with isolated microfossils and coral remains. Occasionally lenses of black flint are observable.

Thickness: 80 m have been measured in this formation but the real thickness is not yet known because the lower contact is unknown and the top of the formation is eroded.

Stratigraphic Relations: The lower contact does not appear and the top of the unit is eroded. However, Fries (1962), infers that the upper and lower contacts are concordant with the Murcielagos and Venada Formations respectively.

Fossils: Throughout the entire unit in the different bodies there are fossils the most common being crinoids, bryozoans, brachiopods, ostracods, corals, and mollusks. Inside of the micro fauna the foraminifera are the most abundant. In the micritic part there are zones of calcareous concretions. The conodonts are easily identifiable in all of the column and allowed the age of the unit to be fixed.

The conodonts that were found are: *Polygnathus communis communis* early Kinderhookiano-Osageano, *Siphonodella quadruplicata*, *Siphonodella isosticha* and *Siphonodella obsoleta* of the upper kinderhookiano, *Gnathodus typicus* and *Gnathodus cuneiformis* of the early Osageano.

Age: The age of the formation is from the lower Mississippian (Kinderhookiano-Osageano).

Paleoenvironment: Because of its paleontologic and lithologic characteristics the deposit of the formation could have occurred in a calcareous platform or bank. Because of the foraminifera present Brunner (1975) suggests a deposit in a lagunar environment of a calcareous bank or post-reefal. For

Fries (1962) the NW region of Sonora because of the lithology of the calcareous fossiliferous muds, and with smaller portions of sands and limes it could have been a cratonic platform towards the E while the W portion passed to a region of myogeosinclinal that went slowly sinking that was slowly, gradually, and uninterruptedly sinking.

Formation: Venada

Geological Province: Sonora

Location: Described by Cooper and Arellano (1946) and defined by Weller (1948) the typical location is found 1.3 km W of the Bisani ranch in the Caborca, Sonora area.

Lithology: The typical location, and only appearance of this formation, consists of a small, elongated appearance pointed NW to SE of some 200 m length and 90 m height. The lithology consists of three bodies of rock which from base to top are:

Body A: Biogenic (biomicrite) limestone with abundant remains of crinoids and scarce remains of bryozoans, ostracods, brachiopods, and occasionally trilobites in strata of 20 to 60 cm. The middle part of the body is recrystallized with partially silicated and dolomitized zones. The last 3 m of the body is microfossilic limestone (sponges) with isolated fragments of solitary corals.

Body B: Micrococles of crinoids (calcirudite) in thin strata with remains of bryozoans, brachiopods, and ostracods. There are zones recrystallized by dolomitization and towards the top the fragments are finer and change to calcarenite.

Body C: Brecciated limestone in strata of 10, 20 and 60 cm with nodules of black flint. There are abundant microfossils and remains of crinoids, bryozoans, brachiopods, ostracods, and trilobites.

Thickness: The measured thickness for this formation is 87 m, but it is not real because the lower contact does not appear and the top is eroded.

Stratigraphic Relations: The lower contact does not appear and the upper limit is eroded.

Fossils: Microscopically crinoids, forming cockles, fragments of bryozoans, brachiopods, ostracods, and scarce corals predominate. Microscopically the conodonts are the most abundant there are also some foraminifera.- The most abundant conodonts: *Savusgnathus* sp *Taphognathus* cf. *T. varians* (Brunner, 1975).

Age: Because of the conodonts it is given an age from the late Meramecian (Brunner, 1975). Before this Cooper and Arellano (1946) gave it the same age because of the brachiopod *Perditocardinia dubia* (Hall) in the coral *Caninophyllum sonorensis* (Easton).

Paleoenvironment: The environmental conditions under which this unit was deposited where those which dominated during the Mississippian in the northern region of Mexico. It was characterized by a shallow, warm, generally tranquil sea, possibly in a carbonated platform or bank with abundant crinoids and fenestral bryozoans. Both fossil groups are the most important during the Mississippian in the construction of reefs.

Cananea-Cabullona Area, Sonora

Formation: Caliza Cristalina Superior

Geological Province: Sonora

Location: Defined by Mulchay and Velasco (1954) to describe a body of recrystallized limestone in contact with the Esperanza Formation dividing it into 2 units: Caliza Cristalina Superior and Inferior.

It appears in some of the Cananea mountains that surround the mining district of the same name located in the N-central part of the state of Sonora.

Lithology: Characterized by dolomitized argillaceous limestone, heavily fractured, with igneous intrusions and abundant copper veins, generally parallel to the stratification. In the upper part of the unit almost at the contact it has a horizon with copper, lead, and zinc sulfates with alternating zones of chlorite and epidote.

Thickness: The total thickness of the Caliza Cristalina is 106 m, of which 76 belong to the Caliza Cristalina Inferior of the Devonian. Mulchay and Velasco (1954) believe that 15 to 30 m belong to the Caliza Cristalina Superior.

Stratigraphic Relations: The lower contact is transitional with the Caliza Cristalina Superior. The upper contact is concordant with the Chivatera Formation.

Fossils: The fossil content is low. Mitchell (1928) describes some corals and brachiopods.

Age: The fossils content, although scarce, suggests an age of the Mississippian.

Paleoenvironment: Shallow platform.

Formation: Caliza Chivatera

Geological Province: Sonora

Location: Defined by Mulchay and Velasco (1954). It appears in the mining district of Cananea.

Lithology: Limestone with mineralized horizons. These horizons contain copper sulfides, lead, and zinc parallel to the stratification. Generally the limestones are altered to chlorite and epidote with calcopyrite sphalerite, pyrite, calcosite, bornite, and small quantities of calcite and quartz.

Thickness: Mulchay and Velasco (1954) calculated a thickness between 15 and 30 m.

Stratigraphic Relations: The lower contact is concordant with the Caliza Cristalina Superior. The upper contact is concordant with the Puertecillos Formation.

Fossils: The content is scarce and little is recognizable.

Age: Because of the few recognizable fossils and its stratigraphic position it is considered to be of the lower Carboniferous (Mississippian).

Paleoenvironment: Shallow platform.

Formation: Escabrosa

Geological Province: Sonora

Location: Defined by Ransome (1904) in the Escabrosa range in the S of Arizona. In Mexico the most detailed works of this formation are those of Viveros (1965). It appears in the Cananea-Cabullona area, in the Cabullona range. It has a wide distribution in the N center portion of Sonora.

Lithology: It consists of fine, compact limestone in strata of 2 to 3 m with recrystallized, dolomitized, and silicated zones with intercalations of 1 to 1.5 m of argillaceous, fine, sandy limestone with grains of quartz and garnet. There are also nodules of flint, irregularly distributed. The upper part contains the greatest recrystallization and dolomitization of the unit. In the Cabullona range it consists of recrystallized limestone in thick strata with development of calcarenites that change to sandy

limestone. It contains abundant remains of crinoids and corals. There are also flint lenses with irregular distribution.

Thickness: Aponte (1974) thinks 50 m for the Cananea mining district, 98 m for the S flank of the Huachuca range and 180 m in the Ajos range. In the SW flank of the Cabullona range 192 m appear.

Stratigraphic Relations: The lower contact is concordant in all the area with the Martin Formation of the Devonian. The upper contact is only observed in the Huachuca range and in the Cananea mining district and is concordant with Horquilla Formation. In the Cabullona range Viveros (1965) mentioned that the Escabrosa Formation is discordantly subadjacent with the Bisbee group of the lower Cretaceous and in the Ajos range the top is eroded and is covered by volcanic rocks of the Tertiary (Henrieta Formation).

Fossils: All the formation is fossiliferous with fragments of crinoids predominating especially in the upper portion where they form reefs of encrinite. It contains principally crinoids, brachiopods, solitary corals, bryozoans fenestral, and other unrecognizable organisms. Of the recognizable corals worthy of notice is the *Neozaphrentis* genus Grove; of the bryozoans there is the genus *Cladochonus* Goldfuss. In the Ajos range the *Avonia*, *reticulariopsis*, *Cyrtospirifer* and *Torinifer* brachiopods were identified (Viveros, 1965).

Age: The fossils of this unit have a variable reach some are Mississippian-Permian, others Devonian-Permian, and some upper Devonian-upper Mississippian, which together give a Mississippian age (Malpica and de la Torre, 1980).

Paleoenvironment: Shallow, tropical seas of circulation tranquil waters while oxygenated and transparent with light, but continuous subsidence. Which is to say transgradient towards the E which permitted the development of abundant colonial marine fauna.

To Bahlburg (1977) the Escabrosa and Paradise Formations represent the same carbonated sequence (Tamaroa sequence) which extends from Arizona and central New Mexico, towards the SE to the NE of Sonora and NW of Chihuahua. In all the Mississippian there were no vertical movements which could have interrupted the sequence in all of Cananea-Cabullona. Afterwards the unit suffered hydrothermal processes with enrichments of veins of chalcocite and concretions of wollastonite (Aponte, 1974).

Formation: Caliza Puertecitos

Geological Province: Sonora

Location: Defined by Blake (1904), later Emmons (1910) gave it the name of Caliza Puertecitos. This unit appears in the Cananea mining district and in the Huachuca range where Aponte (1974) named it Horquilla Formation.

Lithology: It consists of a sequence of recrystallized limestone in medium strata. In the Huachuca range it contains a series of fine, partially recrystallized limestone in strata of 0.5 to 1 m. with abundant nodules and lenses of flint. It shows frequent intercalations of slated limestone of 30 cm thickness and lenses of sandy limestone.

The sequence is, in all of its thickness, is uniformly fractured. As in all of the area of appearance it is intruded upon by alteration zones in the limestone.

Thickness: Aponte (1974) reports 80 m in the SW of the Huachuca range and 120 in the Cananea mining district. However, Mulchay and Velasco (1954) think that the later location has a thickness of 610 m.

Stratigraphic Relations: The lower contact is concordant with the Caliza Chivatera. Aponte (1974) and Zendelas (1973) believe that this contact is, in the areas where they studied the formation

concordant with the Escabrosa Formation. The upper contact is eroded and covered in discordance by volcanic rocks of the Tertiary in all of the area.

Fossils: In the Cananea mining district the fauna is very poorly preserved. However, in the Huachuca range there exists fossil fragments which, because of their quantity and grade of preservation, the crinoids, brachiopods, fusulinids, and some foraminifera, are especially noticeable.

Age: Because of its fossil content it is given an age from the mid Mississippian to the late Pennsylvanian.

Paleoenvironment: This unit was deposited in conditions similar to the Caliza Escabrosa. This means in tropical seas on a subsident platform, with accumulation of fossil remains. The presence of fusulinids makes one think that the sediments are from the edge of the platform.

Sierra de Teras Area, Bavispe, Sonora

Formation: Unidad I

Geological Province: Sonora

Location: Defined by Tovar (1968b) the area of appearance is located in the Teras range, Sonora.

Lithology: Thick limestone of medium to thick stratification with a brecciated aspect in the base. It also contains nodules and lenses of black flint.

Thickness: In the Santa Rosa canyon Tovar (1968b) measured 298 m.

Stratigraphic Relations: The lower contact is unobservable and the upper is normal with the thin limestone intercalated with lutites of Unit II.

Fossils: It possesses abundant Crinoids which form true cockles, a few bryozoans, brachiopods, and corals. Telles and Malpica (1975) detected 7 micro facies with characteristic fossils, among which they point out: *Earlandia* cf. *E. clavatula*, *Earlandia*, sp. and *E. cf. vulgaris*. Also present are the calcareous alga *Koninckopora* sp. and the *Calcisphaera pachysphaerica*, *Stacheoides tenius* and *Asphaltina Cordillerensis*.

Age: Viséan in Europe and lower Meramecian-Chester in North America, which are of the upper Mississippian.

Paleoenvironment: The fossils of this unit are typically marine benthonic of shallow waters.

Formation: Unidad II

Geological Province: Sonora

Location: Defined by Tovar (1968b) in the Teras range, Sonora.

Lithology: The lower part is composed of mudstone and argillaceous packstone in medium to thick strata with some intercalations of lutite. This body of limestone is interrupted by a quartz- latitico porfidica whose thickness is 123 m. the upper part contains limestone in thin to medium strata with argillaceous and occasionally nodular parts. Intercalated with lutite and argillaceous mudstone.

Thickness: The basal portion measures 148 m. and the middle portion 263 m, which gives a total thickness of 411 m.

Stratigraphic Relations: The lower contact with Unit I is covered. However Tovar (1988b) considered it normal, marking it where thin strata of limestone intercalated with lutite appeared. The upper

contact is partly covered without erosion. Tovar (1968b) signals it where a sequence of limestone with flint appears.

Fossils: It chiefly contains crinoids and brachiopods. Tellez and Malpica (1975) distinguished 5 microfacies with the subsequent microfossils: *Earlandia* cf. *E. elegance*, *Calcisphaera pachysphaerica*, *Polyderma plavskensis*, *Stacheoides tenuis*, *Asphaltina cordillerensis* some fusilinids like *Millerella* sp. and *Archaeodiscidae* among which these were distinguishable, *Archaeodiscus stilus*, *Neoarchaeodiscus* sp. *Quasiarchaeodiscus* sp. *Asteroarchaeodiscus bachkiricus*.

Age: The age of the lower rocks according to the brachiopods is Mississippian (Cooper in Tovar 1968b). According to the microfossils described by Tellez and Malpica (1975) the age is Merimecian-Chesterian (upper Mississippian). The upper layers of the unit Wilson (in Tovar 1968b) gave them an age from the Pennsylvanian, based on the presence of *Komia* sp. and the fusilinids *Fusilina* sp., *Triticites* sp.

Paleoenvironment: The micro fauna indicate deposit in shallow waters of high energy.

Area NW of the State of Chihuahua (Palomas Range and Subfloor)

Formation: Keating

Geological Province: Chihuahua

Location: Defined by Ransome (1904) as the base of the Escabrosa Group in the area of Bisbee, Arizona. In Mexico it appears in the Palomas range (Diaz and Navarro 1964; Tovar 1968a). It was also recognized in the subfloor of the Los Chinos Well No. 1 (Reynolds 1972a).

Lithology: Fine to lithographic limestone with abundant nodules of flint. In the Los Chinos Well No.1 Reynolds (1972a) describes it as a sequence of lightly argillaceous partially dolomitized limestone with sandy zones and intercalations of lutite-mudstone.

Thickness: In the Palomas range it is 33 m in the upper part (Diaz and Navarro 1964). Tovar (1968a) in the same range measured an incomplete section of 37 m. In the Chinos Well No. 1 Reynolds (1972a) considers the real thickness to be 165 m.

Stratigraphic Relations: The lower contact is concordant and transitional with the Percha Formation of the late Devonian. The upper contact is concordant with the Hachita Formation.

Fossils. The fossils are poorly preserved, however, pelecypods, crinoids, bryozoans, brachiopods, calcareous concretion and ostracods are identifiable.

Age: The age of the unit was determined by correlation and its stratigraphic relation giving it an age of the Kinderhookian Osagean (lower Mississippian), because the fossils content does not definitely determine the age.

Paleoenvironment: The presence of crinoids and pelecypods suggests shallow seas on a platform. The dark coloration of the unit indicates the presence of carbonous material probably preserved by a rapid burial or perhaps by a reducing environment of euxinic seas with tranquil waters. This is not provable because of the presence of Benthonic colonial organisms which require water circulation.

Formation: Hachita

Geological Province: Chihuahua

Location: Defined by Armstrong (1962) in the S part of Blue mountain in the Chiricahua range of Arizona. In Mexico it appears in the Palomas range (Tovar, 1968) and in the subfloor of the Chinos Well No. 1 (Reynolds 1972 a).

Lithology: Biogenic sequence or massive encrinura with nodules of flint which takes up 2/3 of the formation. The rest is a massive biogenic limestone with fragments of crinoids, brachiopods, bryozoans, and endotrypaea in the lower part.

In the Palomas range it is shown by a sequence of dolomitic limestone and dolostone of crinoids (Cockles of crinoids or encrinura) in strata of 30 to 60 cm (Diaz and Navarro 1964). Tovar (1968) mentions limestone and dolostone with abundant crinoid stalks cross stratified. Tellez and Malpica (1971) divide the formation into 8 micro facies. In the Chinos Well No. 1 the top is a sequence of packstone and grainstone with sporadic intercalations of lutite. The middle part is totally recrystallized and the lower part is partially dolomitized (Reynolds 1972a).

Thickness: Diaz and Navarro (1964) measured 90 m in the Palomas range. Tovar (1968) in the E flank of the same range measured 73 m. Reynolds (1972a) in the Chinos Well No.1 estimated 104 m thickness.

Stratigraphic Relations: The lower contact is concordant and is well defined by the lithologic change with the Keating Formation. The upper contact in the Chinos Well No. 1 is transitional with the Paradise Formation (Reynolds 1972a). Diaz and Navarro (1964) and Tovar (1968) considers it to be erosionally discordant with the Paradise Formation.

Fossils: Crinoids, fenestral bryozoans, and, in lesser proportion brachiopods, ostracods, calcareous concretion, some foraminifera, fragments of trilobites and echinoderms, and unidentifiable fragments.

Age: According to Armstrong (1962) the age is Osageano-Merimerician (later lower Mississippian-early upper Mississippian). The Calceithaera fauna of Baxter (1960), the Cryptostomata sp. and Calcisphaera fimbria bryozoans. This last from the Devonian-Mississippian has made it more difficult to locate precisely the age of the unit (Tellez and Malpica 1971).

Paleoenvironment: A platform under conditions of calcareous bank as is shown by the reef fauna. Tovar (1968) because of the cross stratified in fers sea plains although this structure could have been formed by take away of the deposited remain is its original position when the organisms die (Tellez and Malpica 1971).

Formation: Paradise

Geological Province: Chihuahua

Location: Defined by Stoyanow (1926) in the Chiricahua range close to Paradise, Arizona. In the N of Mexico it has been identified in the Palomas, Rica, and Boca Grande ranges (Zeller 1965; Diaz and Navarro 1964; Tovar 1965). This unit was also identified in the Chinos Well No.1 (Reynolds 1972a).

Lithology: It consists of compact calcareous lutite occasionally laminar with isolated intercalations of calcareous, argillaceous sandstone and also thin strata of sandy dolomitized limestone and crinoidal limestone. This body in the Palomas range is almost all of the formation with a thickness of 17 m (Diaz and Navarro 1964).

In the Chinos Well No. 1 the lithology of the unit consists of black carbonous lutite in some parts it is calcareous which changes to mudstone of the same characteristics alternating with argillaceous, calcareous sandstone. It also shows intercalations of fine limestone (mudstone) and bioclastic limestone (packstone) and oolitic with abundant fossils throughout. It also shows stilolithic lines. All of the unit is mightily folded.

Thickness: Diaz and Navarro measured 107 m in the Palomas range. On the E flank Tovar (1965) measured 99 m. In the Chinos Well No. 1 Reynolds (1972a) reports 90 m of thickness.

Stratigraphic Relations: The lower contact of the Chinos Well is concordant and transitional (Reynolds, 1972a). In the appearances in the SW of New Mexico it is also concordant and transitional (Zeller 1965). On the contrary, in the Palomas range, it is discordant and is marked by an eroded upper surface with a lithologic change of the formations and Horquillas and Paradise (Diaz and Navarro 1964; Tovar 1965). IN the Chinos No. 1 the contact is unobservable (Reynolds 1972a).

Fossils: All of the unite is fossiliferous containing abundant brachiopods, crinoids, and partially recrystallized and pyratized gasteropods. It also contains fusilinids fenestral bryozoans, algae, a few ostracods and ichnoderms. In the lower horizons there were identified fragments of trilobites foraminiferos: *Tuberina* sp. *Calcisphaera fimbriata*, *Tetrataxis* sp. *Tetrataxis conica* and *Cilcishaera*. Which along with the fusilinids *Millerellas* sp. and *Paramillerella* sp. determine the age of the formation (Baxter).

Age: Merimecian-Chesterian (early, upper Mississippian).

Paleoenvironment: Shallow platform seas with proliferation of colonial pelagic benthonic organisms. The oolites and calcarenites imply wave action and the sandy horizons littoral zones during short periods of time. The discordant contacts accompanied by periods of erosion give the idea of risings of the sea bed before and after the deposit of this formation.

Placer de Guadalupe Area, Chihuahua

Formation: Monillas (upper member)

Geological Province: Chihuahua

Location: It appears in Placer de Guadalupe, Monillas canyon and Enmedio mountain with sensible lithological changes between one location and another.

Lithology: In general terms it consists of recrystallized argillaceous limestone and carbonaceous. In Placer de Guadalupe the limestone is of thin to mid stratification that changes to sandy limestone in the surrounding calcareous strata. There are also nodules of flint in the limestone and brachiopod remains. In the Monillas canyon the formation is largely calcareous in thick strata. Especially in the carbonaceous limestone there are nodules of flint, abundant brachiopods, and some crinoids. In the Enmedio mountaion it is divided into two bodies, the lithology of the lower is similar to that of the monillas canyon and the upper consists of slate like grey lutite in thin strata with abundant brachiopods.

Thickness: The thicknesses are of 33 m in Placer de Guadalupe, 40 m in the Monillas canyon, and 17 m in the Enmedio mountain.

Stratigraphic Relations: The lower contact is discordant with the lower body of the Monillas formation. This is shown by a hiatus between the early mid Devonian and late Mississippian (Bridges, 1965). The greater hiatus was reached in the Placer de Guadalupe (early mid Devonian-late Mississippian) and the lesser in the Enmedio mountain (mid Devonian-lower Mississippian).

The upper contact is concordant with the Pastor Formation of the Pennsylvanian although the boundary between the formations has been difficult to establish. Bridges (1965) fixes it from the change of disappearance of some fossil species.

Fossils: Brachiopods, crinoids, bryozoans, (productids) fusilinids, (schubertellido), some conodontos and some unrecognizable organs. In the Monillas canyon the brachiopods *Buxtonia* sp., *Crurithyris* sp., *Punctospirifer* sp., and *Chonetes* sp.

In the Enmedio mountain the brachiopods *Chonetes* sp., and *Leiorhynchus* sp., the bryozoan, *Overtonia* sp. Also identified was the gasteropod *Glabrocingulum* sp. (Bridges, 1965) and the conodontos *Cavusgnathus* sp. *Hindeodelli* sp. *Metalonchodina* sp. *Neoprioniodus* sp. *Prioniodus* sp.

Spathagnathodus sp. (Bridges, 1965). In Placer de Guadalupe only some *Chonetes* sp. brachiopods were collected.

Age: The upper body of this unit is late Mississippian (Meramecian) early Pennsylvanian (Derryano). Bridges (1965) considered the age of the calcareous body of the Monillas canyon to be of the Mississippian-early Pennsylvanian and those of the upper argillaceous body of the Pennsylvanian. Bridges (1965) believes that the gastropod identified in the Enmedio mountain is late Mississippian-Pennsylvanian and Bridges (1965) in the same location believed that the identified brachiopods come from the Mississippian or post Devonian. The conodonts that Bridges (1965) identified are from the upper Mississippian (Chesterian) (Malpica and de la Torre, 1980).

The stratigraphic range of the carboniferous fauna has made difficult to locate precisely the age, because of which it has been taken as a reference to establish the upper contact of the Monilla Formation of the groups of fauna from the late Mississippian-early Pennsylvanian and those of the Pennsylvanian which would put the stratigraphic range of the formation inside of the early Pennsylvanian.

Paleoenvironment: The presence of brachiopods, pelecypods and some bryozoans indicate shallow seas. However, the argillaceous-carbonaceous character of the limestone with thick stratification suggests long periods of closed seas with little circulation of proliferous life under reducing conditions or perhaps rapid burial of organic material that was preserved with the aid of contributions of clay. The abundance of terrigenous materials indicates supply fountain close by, by means of fluvial currents, and or costal lines.

Ciudad Victoria Area, Tamaulipas

Formation: Vicente Guerrero

Geological Province: Mexican belt of Miogeocline folds and faults of the Gulf of Mexico.

Location: Defined by Carrillo-Bravo (1961) in the Huisachal-Peregrina anticline. The type-locality is in the Peregrina Canyon close to the Vicente Guerrero Range, it also appears in the abandoned Peregrina range, and in the Caballeros canyon 150 m NW of the abandoned aserradero close to the Naranjal range.

The rocks of this formation generally appear by fault, restricted to small areas.

Lithology: It consists of quartziferous sandstone of medium to thick grain in strata of 20 cm to various m of thickness, argillaceous sandstone with some thin conglomerate lenses. It also shows thin intercalations of lutite. The unit contains abundant fauna towards the top.

Thickness: Close to the Vicente Guerrero range 160 m were measured which is the maximum. In other appearances the thickness is less until it reaches some few m.

Stratigraphic Relations: The lower contact is concordant with the Yerba formation of the Devonian (Carrillo-Bravo 1959). The upper contact is in angular discordance with the Del Monte Formation of the lower Pennsylvanian.

Fossils: It has abundant brachiopods among which, especially noticeable are: *Reticularia pseudolineata*, *Spiriferina* sp., *Athyris lamellosa*, *Chonetes* sp., *Syringothiris* sp., *Tetracema* sp., and *Subtrigonia* sp. (Carrillo-Bravo, 1961).

Age: Lower Mississippian

Paleoenvironment: Warm and shallow platform seas with tranquil waters as is shown by the colonial fauna; the sandy nature of the formation indicates the nearness of the coast, with argillaceous aluvial period of fluvial currents.

The absence of a deposit in the upper Mississippian and the angular discordance between the Vicente Guerrero and Del Monte Formations, implies a tectonic event towards the end of the lower Mississippian that lifted and folded the Vicente Guerrero Formation, partly eroding it. These movements equate with the Wichita disturbances of the upper Mississippian in the U.S.A.

San Jose de Gracia Area, Sinaloa

Formation: San Jose de Gracia

Geological Province: Sinaloan orogenic belt

Location: Defined by Carrillo-Martinez (1971) in the NE of Sinaloa. The best appearances are: Sinaloa River, between Tohayanas and Chicorato, Sinaloa in the San Jose de Gracia, Ondo, El Cuervo, and Mezcalitos arroyos. It also appears in the lomerios located in the surroundings of San Jose de Gracia, Santa Maria, Chicorato, and Agua Caliente de Peña.

Lithology: It varies from one location to another. In the neighborhoods of San Jose de Gracia, it consists of a sequence with fine limestone in the base (micrite) with intercalations of speckled slate and quartzite. There are nodules of flint and carbonaceous material in the limestone and slate. Also observable are recrystallized and sulfide zones.

The middle part consists of massive mudstone with lenses of argillaceous limestone and interstratification of massive quartzite. The upper part is a sequence of quartzite with interstratification of cross stratified lutite. Close to Santa Maria the previous lithology changes to massive quartzite with stratified and folded flint. In Chicorato, Sinaloa, the upper body contains calcareous banks of fine grain in thick and massive strata with lenses of flint. In some sites there is a discordant relation with the bodies of slate to which it is subadjacent, but in the Mezcalitos arroyo and in the Tepaycansa both units are concordant.

In the road between Sinaloa de Leyva and Chicorato, the lithology is totally clastic. It consists of graywacke impure calcareous sandstone and argillaceous-sandy rocks with minerals such as chlorite, sericite, talc, with low grade metamorphoses. In the Santa Cruz or Bayos cliffs, and in the Guamuchil arroyo strata of clastic sediments are observable in the form of a flint breccia cemented by silicon. This clastic sequence is continually intruded upon by acidic-intermediate igneous bodies that originate contact metamorphism with development of minerals such as the garnet and tactites.

Thickness: The real thickness of the unit is unknown. However, in the range that is close to the "pyramid" Carrillo-Martinez (1971) measured 800 m.

Stratigraphic Relations: The base of the formation is unknown although it is inferred that the lower contact could be tectonic with the Sonora complex of the pre Cambrian.

The upper contact is in angular or tectonic discordance with metamorphic Mesozoic rocks or with volcanic and volcanoclastic rocks of the lower and mid tertiary.

Fossils: The lower body of the San Jose de Gracia Formation shows three fossiliferous horizons with remains of echinoderms, crinoids, ostracods, fenestral bryozoans, and fragments of trilobites, some *Calispajeras* sp., undetermined foraminifera, *Millerella* sp., fusulinids, some endothyrida and some fragments of organisms of chitinous-phosphatic material (conodonts?).

Age: Because of the fusulinids of the lower part of the unit and age from the lower Mississippian-upper Pennsylvanian was determined.

Paleoenvironment: Because of the bituminous and clastic character of some regions, it is inferred that in this region the seas were transgressive with short, regressive periods. The bituminous character of the lower body supposes euxinic environment of closed, tranquil seas with little circulation that

avored the preservation of organic material. The brachiopods and crustaceans in the middle body of the formation imply a shallow, brackish medium and the clastic character of the formation implies the supply fountain very close by, and deposited in a littoral environment.

Nochixtlan-Ixtaltepec Area, Oaxaca

Formation: Santiago

Geological Province: Mixteca

Location: Defined by Pantoja and Robinson (1967) in the Pulgas arroyo in the surroundings of Santiago Ixtaltepec. Other sections are those of the Itucana and Totoyaca arroyos.

Lithology: It consists of a predominantly clastic marine sequence constituted by sandstone, lutite, and mudstone that alternate with calcareous horizons. In the basal part carbonates predominate. The basal part is a calcareous conglomerated sandstone followed in the middle part by a succession of limestone (wackstone-packstone) and towards the upper part making up more or less 3/4 of the unit lutite with intercalations of calcareous fine grain sandstone in thin strata.

In the Totoyaca arroyo the top of the unit is composed of limestone (wackstone-packstone) that alternates with lutite and calcareous mudstone.

Thickness: In its type-section the thickness is 192 m (Pantoja and Robinson 1967). Malpica (1978) measured 50 m in the Totoyaca arroyo and 200 m in the Itucana arroyo.

Stratigraphic Relations: The lower contact is an angular discordance with the Tifú Formation. The upper contact is transitional with Ixtaltepec Formation which, according to Pantoja (1969) is determined by the thick layer of sandy limestone of the Santiago Formation on which rests a thick sequence of mudstone.

Fossils: There are principally brachiopods, crinoids, byozoans, and scarce solitary corals located chiefly in the top of the formation.

Age: Because of the presence of Kitakamihyras sp. and Rotaia sp. Cooper in Pantoja (1969) considers a Mississippian age for this formation.

Paleoenvironment: Along with the Ixtaltepec Formation it is considered a product of the same sedimentary cycle which is described in the Ixtaltepec Formation.

Chicomosuelo Area, Chiapas

Formation: Santa Rosa Inferior

Geological Province: Chiapan belt of folds and faults

Location: Dollfus and Monserrat (1868) defined this formation in the surroundings of Santa Rosa, Alta Verapaz department, Guatemala. In Mexico Hinojosa (1964) identified it and proposed as the type-location Ahuacate river in the NW of Chicomosuelo, Chiapas. The unit extends towards the NW of Chicomosuelo into the city of Concordia over a surface of approximately 450 sq km.

Lithology: It consists of a sequence of lutite, mudstone, and mudstone with some intercalations of very fine grain sandstone. All of the unit is affected by a low grade metamorphism which gives it the appearance of slate, monotone, with occasional intercalations of quartzite.

The strata of slate and quartzite are of laminars of up to 30 cm.

Thickness: The maximum thickness measured by Hinojosa (1964) is 6420 m in the section of the Ahuacate river. The presence of two guide horizons, one lithologic that belongs to a quartz conglomerate and the other paleontologic with crinoids and pelecipodos which are not repeated corroborate this thickness.

Stratigraphic Relations: The lower contact has not been observed but is inferred to be discordant with the foundation. The upper contact is an angular discordance with the Satan Rosa Superior Formation.

Fossils: The identified crinoids are *Cyclopentagonopa granulosa* and the pelecipodos are of the *Aviculopecten* genus.

Age: Upper Mississippian.

Paleoenvironment: Because of the presence of crinoid stalks, pelecipodos, fossils plants, and abundant primary structure such as: ripples of wave action, cross stratified and graded, current grooves, which suggests a shallow deposit medium of low energy. Possibly extensive lagunar deposits occasionally stagnant (Hernandez 1973b). The area must have had a great subsidence to permit the deposit of the great thickness of the unit

Pennsylvanian rocks

Areas NW of the state of Chihuahua (Palomas range and subfloor) and NE of Sonora (Cananea-Cabullona)

Formation: Horquilla

Geological Province: Sonora-Chihuahua

Location: Defined by Ransome (1904) in the SE of Arizona. Afterwards Guilluly and Colaborators (1954) in Reynolds (1972a) formally named the Naco group subdividing it into 6 formations: Horquilla, Earp, Colina, Epitaph, Scherrer, and Concha. Zeller (1965) recognized the Horquilla Formation in the SW of New Mexico and extends it towards the S of Arizona and NW of Chihuahua. In the Palomas range, Chihuahua, it was recognized by Diaz and Navarro (1964) and Tovar (1965). It has also been reported in the Chinos Well No. 1 (Reynolds 1972a). Wilson and colaborators (1969) studied it in the Franklin, Palomas, and Big Hatchet ranges. These same authors recognized it in the Pedregosa, Chihuahua basin and Oro Grande, New Mexico basin.

Lithology: The base, in the Palomas range, is sandstone of quartz, cross stratified that changes to conglomerate with occasional lense like intercalations of mudstone and lutite. There are also intercalations of oolitic and bioclastic limestone with abundant fossil fragments. This body transitionally changes to micritic limestone with argillaceous horizons of cyclical sedimentation. On top of this body massive limestone partly calcarenitica with erosion zones of conglomeratic limestone rests. On top of this there rests a series of lutite and nodular argillaceous limestone that at the same time is under a body of limestone of thin stratification with abundant fauna. Over this body there is another of massive oolitic limestone with very shallow waters of high salinity and scarce fauna. On top of this sequence there is an argillaceous body with thin intercalations of sandstone and limestone which correspond to the top of the Pennsylvanian. In the Palomas range and in Cananea the Horquilla Formation is intruded upon by igneous rocks. Diaz and Navarro (1964) describe nodules of flint in the top of the Derrian and of the Desmoinesian.

In the Chinos Well No. 1 a sequence of mudstone, wackestone, granistone, of bioclasts, oolites and crinoids, with fragments of brachiopods and fusulinids with brecciated zones in some intervals was described. There are also irregular intercalations of lutite and stylolitic lines.

Thickness: Diaz and Navarro (1964) measured a composed section with an incomplete thickness of 1,035 m. Tovar (1965) measured 1,149 m. Wilson and colaboradores (1969) 1,150 m. Reynolds (1972a) in the Chinos Well No. 1 reports a thickness of 573 m.

Stratigraphic Relations: The lower contact is discordant with the Paradise Formation, where a basal conglomerate of the Horquilla Formation is observed. The upper contact is concordant with the Earp formation of the Permian.

Fossils: Remains of brachiopods, corals, crinoids, and foraminiferos preferentially distributed in the Pennsylvanian part of the unit. Bryozoans, trilobites, echinoderms, and crinoids, algae and gastropods are found towards the top of the unit. The fusilinids are distributed throughout the unit.

Age: The *Callicisphaera* sp. and *Polyderma* sp. foraminiferos indicate an age from the lower Pennsylvanian (Morrowano) to the lower Permian (Wolfcampian).

Paleoenvironment: The content of fauna and the lithologic characteristics, show that the deposit was begun over an eroded surface with shallow, transgressive seas close to supply fountain of terrigenous. The cross stratification and the absence of fusilinids in the base of the sequence indicate littoral conditions over transgressive surface towards the east where we have the thinnest thicknesses. The rest of the formation of greater thickness was deposited in shallow platform seas with developement of colonial organisms in tranquil and circulating waters of normal salinity with some intervals of high energy that permitted the developement of oolites and calcareous sandstones. Towards the close of the Pennsylvanian and in the top of the formation there were favorable conditions for the development of biostroms and very shallow waters (less than 1 m) of high energy in which ostracods, fusilinids, filoides algae, and Tubiphytes along with other colonial organisms.

Cananea-Cabullona Area, Sonora

Formation: Horquilla

Geological Province: Sonora

Location: Informally defined by Zendejas (1973) and Aponte (1974). It only appears in the Huachuca range and in the Cananea mining district.

Lithology: It consists of partially recrystallized limestone in strata of 0.5 to 1.0 m with abundant nodules and lenses of flint. There are also intercalations of slate like limestone of approximately 30 cm stratification. There are also lenses of sandy limestone. All of the unit is fossiliferous. In the mining district of Cananea it is intruded upon which causes the presence of hydrothermalism which causes the presence of marble and veins of chalcocite and wollastonite (Mulchay and Velasco 1954).

Thickness: Aponte (1974) measured 80 m in the SW of the Huachuca and 120 m in the Cananea mining district (Mulchay and Velasco 1954).

Stratigraphic Relations: The lower contact is concordant with the Escabrosa Formation. The upper contact is eroded and covered by volcanic rocks of the Tertiary.

Fossils: In lower part crinoid remains (encrinite) predominate, fragments of brachiopods, fusilinids and some unidentifiable organisms. In the rest of the unit there are foraminifera which, along with the fusilinids served to date the unit. Aponte (1974) identified on the genus level *Bradyna* sp., *Parafusulinella* sp., and *Millerella* sp.

Age: Mid-Upper Pennsylvanian.

Paleoenvironment: Tropical subsident platform seas with great accumulation of fossils. The fusilinids indicate the edge of the platform which is not propitious for the developement of calcareous banks.

Placer de Guadalupe Area, Chihuahua

Formation: Pastor

Geological Province: Chihuahua

Location: Defined by Bridges (1964) between the Plomosas mine and Placer de Guadalupe mountain. The best location is in the Placer de Guadalupe mountain. It also appears in the Plomosas mine, Monillas canyon, and Enmedio mountain.

Lithology: It consists of micritic limestone in thick to massive strata with bioclasts of brachiopods, crinoids, echinoderm spicules, corals, and fusilinids. In the base there are intercalations of laminar lutite and nodules of black flint. Towards the top the limestone is recrystallized. In the location of the Plomosas mine the limestone is marbilized in the base. In the Placer de Guadalupe mountain the top is a crinoid cockle (encrinite) and in the Monillas canyon there is lutite at the top.

Thickness: The thicknesses vary from one location to another, in the Placer de Guadalupe mountain it is 360 m (Newell et al 1956) In the Enmedio mountain it is 255 m (Bridges 1964).

Stratigraphic Relations: The upper contact is concordant with the upper body of the Monillas Formation the upper contact is an angular discordance with the Plomosas Formation (Bridges, 1964 in Hernandez-Rios, 1973b).

Fossils: Brachiopods, crinoids, corals, algae, and conodonts, gasteropods, and fusilinids which are the most common. Of the identified fusilinids are: *Fusilina* sp., *Fusulinella* sp., and *Wedekindellina* sp. of the Desmoinesian: *Kamsenella* sp., *Teriticites* sp., of the Missourian: *Triticites* pauper of the Virgilian and *Paraschwagerina* ? sp., *Schwagerina* sp., *Chalaroschwagerina* ? sp. of the Wolfcampian.

The identified brachiopods are all of the Pennsylvanian, none are present in the Wolfcampian layers and they are: *Anticuatonia* sp., *Cleiothyridina* sp., *Hustedia* sp., *Schuchertella* sp., *derbyia* (*Spirifer*) *texasus* (Meck) and *Neospirifer* sp.

The identified conodonts are: *Cavusgnathus* sp., *Gnathodus roundyi* (Gunnell) *Himdeodella* sp., *Idiognathodus delicatus* (Gunnell) *Phragmodus* sp., *Prioniodus* sp., *Spathognathodus* sp., and *Stroptognathodus* sp. All of these fossils are of the Desmoinesian or older. The colonial coral *Chaetetes* sp. The *Ivanovia* sp. algae abounds locally in some horizons except in the lower layers.

Age: Early Pennsylvanian (Morrowan) -early Permian (Wolfcampian).

Paleoenvironment: Platform seas with development of colonial fauna. The fusilinids, however, indicate the platform edge but this is not feasible because the pelagic forms could have been transported by marine currents to more shallow seas and the benthonic organisms are a deciding factor in Paleobathymetry.

Ciudad Victoria Area, Tamaulipas

Formation: Del Monte

Geological Province: Mexican belt of miogeoclinal folds and faults of the Gulf of Mexico

Location: Defined by Carrillo-Bravo (1959) in the base of the Monte ridge 600 m W of the Peregrinas ranch in the Peregrina canyon. It also appears in the Naranjal ranch and E-NW of the Aserradero in the Caballeros canyon and in the Boca canyon and in the N part of the Huisachal-Peregrina anticline. The appearances of this unit are discordant unfailing blocks with the subadjacent formations.

Lithology: In the type-locality it consists of a basal conglomerate of 4 m thickness formed by subangular fragments of sandstone and lutite and clay-calcareous cement. Over this conglomerate there

appears a body of clastic limestone with remains of corals and crinoids in strata of 5 to 60 cm. These layers change to sandy limestone in strata of 20 to 60 cm. that form banks of more than 2 m with a total thickness of 30 m. Resting over the limestone is found a sequence of sandstone of mid to thick grain with fragments of lutite in medium to thick strata. A body of lutite with intercalations of fine sandstone rests over the sandstone sequence. The thickness of the detritic sequence is 175 m. In the Caballeros canyon the lithology is similar only the thicknesses of the member of the unit are less. In the Boca canyon all that appears are the upper clastic members of the formation.

Thickness: The real thickness is unknown because the top is absent by fault in the Peregrina and Caballeros canyons but it is estimated that it should be more than 200 m. If it is considered that the appearances of the Boca canyon belong to the upper part of the unit, the total thickness would be 400 m.

Stratigraphic Relations: The lower contact is observable in the Peregrina and Caballeros canyons. And is an angular discordance with rocks of the lower Mississippian (Vicente Guerrero Formation) Devonian (Yerba Formation) and Silurian (Cañon de Caballeros Formation). The upper contact is unknown although in the Monte range there is observed a contact by fault with rocks of the Permian. In the Boca canyon the rocks of the Pennsylvanian are surrounded by fault between sediments of the Huisachal Formation of the upper Triassic and igneous intrusive rocks.

Fossils: The fossil content of the formation is not abundant but remains of bryozoans, corals, ammonites, fusulinids, and other foraminifera. The corals that were identified are: *Stereocosma* sp. of the Derriani. In the Caballeros canyon the ammonites *Pseudoparalegoceras amotapense* and *Eosianites* sp. of the lower Pennsylvanian were recognized. In the Boca canyon there were identified *Peritrochia* (Marathonites) cf. *Genti* (Smith) of the Pennsylvanian (Carrillo-Bravo 1959)

In the Peregrina and Caballeros canyon Thompson and collaborators in Carrillo-Bravo (1961) identified the following fusulinids: *Millerella* sp., *Fusulinella* sp. (similar to the *Fusulinella acuminata* Thompson *Profusulina* sp., *Eostaffella* sp., same as *Paramillerella* sp.) *Staffella* cf. *S. depressa* and *Profusulinella* sp. All are of the lower Pennsylvanian.

Age: Upper and lower Pennsylvanian.

Paleoenvironment: The presence of corals indicates shallow, warm, and tranquil seas. The fusulinids indicate the edge of the platform and the ammonites are characteristic of plankton and nekton which can move and are common in basin and shallow sea deposits. These bathymetric indicators and the lithologic nature indicate shallow platform seas with strong a supply of terrigenous material derived from close by mountains. The presence of basal conglomerates indicates a period of erosion before the deposit of the conglomerate which is a product of transgressive seas and which was deposited on top of the existing formations.

The presence of Pennsylvanian rocks in the Gonzalez Well, located more than 100 km S-SE of the Huisachal-Peregrina anticline suggests a wide distribution of these rocks in the subsurface.

Formation: Piloncillos

Geological Province: Chihuahua

Location: Hawkins (1975) describes this formation in an informal fashion and mentions that it appears in the NE of Mexico.

Lithology: Massive limestone (micritic).

Thickness: 120 to 180 m.

Stratigraphic Relations: The lower contact is unknown and the upper in an angular discordance with the "Delicias Formation".

Fossils: Crinoids.

Age: Pennsylvanian

Paleoenvironment: Shallow carbonate platform probably similar to the deposit of the pre Permian rocks of the Ciudad Victoria, Tamaulipas area (Del Monte Formation).

Nochixtlan-Ixtaltepec Area, Oaxaca

Formation: Ixtaltepec

Geological Province: Mixteca

Location: Defined by Pantoja and Robinson (1967). The type-locality is 700 m N of Santiago Ixtaltepec. It was also recognized in the Itucana and Totoyaca arroyos.

Lithology: Sequence of lutite, mudstone, and sandstone with lenses of limestone intercalated. The base contains mudstone over which rests a thick layer of sandy limestone on which rests a series of mudstone, calcareous fine grain sandstone and layers of lightly argillaceous limestone until a thickness of 100 m is reached. The following 80 m are of lightly sandy lutite with intercalations of fine grained sandstone which are classified as subgraywackes cuarsosas bien clasificadas and clay-calcareous mix. There follows a sequence of 170 m of mudstone and fine grain sandstone micacea. The last 175 m are of sandy lutite with thin intercalations of limestone (mudstone-wackestone) with scarce fossil content.

Thickness: Pantoja and Robinson (1967) measured in the type-section 430 m and in the Pulgas arroyo 525 m.

Stratigraphic Relations: The lower contact is concordant with the Santiago Formation and the upper contact is discordant with the Yododeñe Formation of the Permian (?). The top of the unit is eroded.

Fossils: Crinoids, brachiopods, fenestral bryozoans, the occasional trilobite, solitary corals, ostracods, and radiolarians (?). Pantoja (1969) in the lower and middle portions of the unit report productids and spiriferid such as *Anthracospirifer occideous*, *Inflatia* sp., *Reticularia* sp., *Rhynchopora* sp., and *Neochonetes* sp.

Age: Mid to early Pennsylvanian.

Paleoenvironment: The base of the unit was probably deposited in a marine environment of clear waters moderately shallow and well oxygenated of a calcareous platform with development of small bioherms. Malpica (1978) suggests that the alternation of mudstone and calcareous sandstone with limestone signal regular changes in the sedimentation conditions which could show a type of deposit over a neritic or perhaps at the edge of a basin where there was an active tectonic process with a supply of clasts and periodic incursions that are favorable to the depositing of flysch. The abundance of sediments towards the end of the Mississippian which culminates with the deposit of this unit could indicate a paused sinking of the basin with periods of greater influx of material.

After the depositing of the Ixtaltepec Formation there were subaerial deposit conditions with limited transgressions and regressions signalled by a Permian conglomerate of the Yododeñe Formation. The supply of conglomerates makes evident the retrogression of the Paleozoic seas and the rising of the region.

Chicomosuelo Area, Chiapas

Formation: Santa Rosa Superior

Geological Province: Chiapan belt of folds and faults

Location: Described by Hinojosa (1964) in the type-section located NE of Chicomosuelo, Chiapas. This unit is distributed in a surface area of 200 sq. km.

Lithology: It consists of lutite and mudstone lightly calcareous and sandy. It occasionally alternates with thin strata of cross stratified sandstone. It also shows calcareous and ferruginosos nodules.

In the upper part of the formation there are observable horizons of fossiliferous limestone (wackestone to packstone) biogenic and lightly oxidized.

Thickness: Hernandez-Rios (1973b) reports a thickness of 1,000 m NE of Chicomosuelo. In the locations of Corralito-Chicomosuelo, Monter Redondo, Guadalupe Victoria, and Comolapa river the same author measured 320, 410, and 140 m respectively.

Stratigraphic Relations: The lower contact is discordant over the Santa Rosa Inferior Formation. The upper contact is discordant or transitional with the Grupera Formation.

Fossils: The fossil content is scarce in the base and increases towards the top. Crinoids, bryozoans, brachiopods, foraminiferos, ostracods, gasteropods, and rodoficeas algae are the fossils found. It also contains micro fossils, among which especially noticeable are: *Komia* sp., stromatoporids of the mid and upper Pennsylvanian (Desmoinesian-late Virgilian); rodoficeas algae *Cuneiphyces* sp., and the foraminifero *Tetrataxis* sp. (Malpica 1977).

Age: Mid-upper Pennsylvanian

Paleoenvironment: Continental shelf with shallow and brackish waters during a maximum transgression and the beginning of a regression signaled by carbonates of the top of the unit where the sediments accumulated probably in a marginal lagoon where they were subject to the action of weak currents.

Permian Rocks

Antimonio-Caborca Area, Sonora

Formation: Los Monos

Geological Province: Sonora

Location: Defined by Keller (1928) in the Monos Mountain located 2.4 km from the town of Antimonia, Sonora.

Lithology: The lithology is variable and is unknown in the base. In general the rocks show a strong deformation with development of foliation. From the base to the top 6 bodies of rock were identified which are:

Body 1: Mudstone and slate-like lutite in strata of 10 to 20 cm.

Body 2: Fractured partially recrystallized limestone with silified zones. In the base it has abundant fauna.

Body 3: Argillaceous limestone in strata of 10 to 40 cm. with abundant fauna, the foraminiferos predominating.

Body 4: Limestone of variable stratification with abundant fauna. It sporadically shows horizons of slate-like lutite.

Body 5: Partially argillaceous limestone in strata of 20 to 40 cm. It contains nodules of black flint and abundant fauna with dominating brachiopods that form cockles and bryozoans.

Body 6: This body is the upper one although it is probably not the top of the unit. It consists of limestone in thin strata with nodules of flint and abundant fauna.

In the base of the unit it is intruded upon by a porphyritic andesitic y doleritic body.

Thickness: The real thickness of the formation is unknown and the maximum known thickness of this formation was measured by Brunner and de la Torre (1974 in Brunner 1977) and is 495 m.

Stratigraphic Relations: The base is intruded upon by a porphyritic andesitic and a dolerite because of which the lower contact is unknown. The top of the formation is apparently eroded and a discordance exists between the mid Permian and the upper Triassic.

Fossils: The unit contains abundant fauna composed of brachiopods, bryozoans, some ostracods, echinoderms, sponge spicules, mollusks, scarce trilobites, algae, and fusulinids as well as some unrecognizable fossils.

The identified brachiopods are: Dictyclostus, Composita and Spiriferellian cripotomados bryozoans and some siclostomados of the Fistulipora type, pelesipodos like Mialina sp., Nucula sp., and Aviculopecten montpelierensis (Girty) the ammonite Wagenoceras dieneri (Bose), the foraminifero Parafusulina antimonioensis (Dunbar). Also observed were the Lomphophyllidium tetricorals and the filoides algae

Age: Middle Permian.

Paleoenvironment: Shallow marine waters tranquil and warm which were propitious for the development of colonial fauna. The presence of clastic sediments shows the closeness of a coast line perhaps towards the east.

Sierra de Teras Area, Sonora

Formation: Unidad III

Geological Province: Sonora

Location: Sierra de Teras, Sonora

Lithology: Dolostone and limestone of thick stratification with abundant intercalations of flint.

Thickness: 391 m in the Santa Rosa canyon (Tovar 1968b)

Stratigraphic Relations: Lower contact is concordant with Unit II. The upper contact is concordant with Unit IV.

Fossils: Fusulinids, gasteropods, and occasionally brachiopods. Telles (1975) identified the following genera: Schwagerina eolata, Schwagerina sp., Monodiexodina sp., Staffella sp., Schubertella sp., Pseudoreischelina sp., Nankinella sp., Parastaffella sp., Oketaella sp., Boultonia (?) sp., Toriyamaia cf. T. americana.

Age: Lower Wolfcampian-upper Wolfcampian (lower Permian).

Paleoenvironment: Continental shelf with shallow waters.

Formation: Unidad IV

Geological Province: Sonora

Location: Sierra de Teras, Sonora

Lithology: Fine grain limestone in thin stratification partly argillaceous with intercalations of lutite and nodules of black flint.

Thickness: 241 m in the canyon of Santa Rosa (Tovar 1968b).

Stratigraphic Relations: The upper contact is concordant with Unit III. The upper contact is concordant with Unit V.

Fossils: Isolated remains of crinoids, brachiopods, and fusilinids.

Age: Upper Wolfcampian-lower Leonardian (?) (lower Permian).

Paleoenvironment: Continental shelf with shallow waters.

Formation: Unidad V

Geological Province: Sonora

Location: Sierra de Teras, Sonora

Lithology: Dolostone and limestone mudstone in strata of variable thickness. It contains nodules of flint.

Thickness: The thickness measured in the Santa Rosa canyon is 339 m Tovar (1968).

Stratigraphic Relations: Lower contact is concordant with Unit IV. The upper contact is discordant with clastic rocks of the upper Aptian (Tovar 1968b).

Fossils: They are principally *Parafusulina* sp. fusilinids and crinoids in the lower part of the unit and brachiopods in the upper part. Of the fusilinids the following species have been identified: *Triticites* sp., *Schwagerina* sp., *Pseudoschwagerina* sp., *Paraschwagerina* sp., *Parafusulina* sp., *P. imlayi*, *P. skinneri*, and *P. sonoraensis*.

Age: Leonardian (Permian).

Paleoenvironment: Continental shelf with shallow waters.

Areas in the NW of Chihuahua (Palomas range, Chinos, Santa Rita, La Salada, and Subfloor)

Formation: Earp

Geological Province: Chihuahua

Location: Gilluly and colaboradores (1954) defined this formation inside of the Naco group in the SE of Arizona. This unit is the base of the group. In Mexico this formation has been reported in the Palomas range (Diaz and Navarro 1964b) and in the Chinos Well (Reynolds 1972).

Lithology: Sequence of microcrystalline to lithographic limestone in thin strata alternating with dolostone in medium strata laminar lutite, sandstone and limestone. 40 m from the base there is a lens-like body of 30 m maximum thickness of gypsum and anhydrite with intercalations of lutite and dolostone. On top of the anhydrite there is a series of argillaceous limestone and dolostone with a horizon of flint. The rest of the formation is an intercalation of limestone and dolostone.

Thickness: In the Palomas range 215 m (Diaz and Navarro 1964b), Tovar (1968a) reports 244 m in the N hangin of the anticline located N of the Campana mountain. In the Chinos Well No. 1, Reynolds (1972a) measured 123 m.

Stratigraphic Relations: The lower contact is concordant with the Horquilla Formation. In the Chinos Well No. 1 this contact is transitional. The upper contact is concordant with the Colina Formation.

Fossils: In the lower part there are brachiopods, gasteropods, crinoids, ostracods, and some amodicidos. The rest of the unit contains echinoderms, bryozoans, spicules of sponge, fusilinids, (Staffella sp., Paraschwagerina sp., "Schubertella-Eoschubertella ?" sp., and Schwagerina sp.) and algae.

Age: Lower Permian (Wolfcampian?)

Paleoenvironment: Continental shelf with very shallow waters (as shown by the algae). The presence of sandstone indicates high energy evaporites lagunar zones which are not shown in all of the areas which indicates topographic changes.

Formation: Colina

Geological Province: Chihuahua

Location: Palomas range and Chinos Well No. 1 (Diaz and Navarro 1964; Reynolds 1972a)

Lithology: Micritic limestone in strata of 10 to 60 cm. In the top the limestone is argillaceous with intercalations of calcareous sandy lutite in strata 10 to 30 cm. It also contains intercalations of calcareous sandstone, lightly argillaceous, which occasionally changes to sandy lutite. In the Chinos Well No. 1 it consists of a sequence of limestone with dolomitized stones and intercalations of mudstone and fine-grained calcareous sandstone towards the top of the unit.

Thickness: Diaz and Navarro (1964) measured 185 m in the Palomas range. Tovar (1968a) at the S of the Palomas range measured 115 m. In the Chinos Well 336 m were cut (Reynolds 1972).

Stratigraphic Relations: The lower contact is gradually concordant with the Earp Formation (Diaz and Navarro 1964). The upper contact is gradational with the Epitaph formation (Diaz and Navarro 1964; Zeller 1965 in Reynolds 1972).

Fossils: Brachiopods, gasteropods, corals, bryozoans, ammonites, fusilinids (Staffella sp., "Schubertella-Eoschbertelli" Ozowainella sp., and biwaella sp.), and calcareous algae. The micro fossil content is: Globivalvulina sp., glomospira sp., Nodosaria sp., Toveritina sp., and Calcisphaera sp.).

Age: Upper Wolfcampian (lower Permian)

Paleoenvironment: Continental shelf with shallow seas with some intervals of high energy waters. The presence of calcareous algae indicates periods of very shallow seas of 1 to 5 m depth.

Formation: Epitaph

Geological Province: Chihuahua

Location: Palomas range, Chihuahua (Diaz and Navarro 1964b; Tovar 1968a), Chinos and Snata Rita ranges, Chihuahua (Patterson 1978; Tovar 1969; Telles 1975b), Chinos and Espia No. 1 Wells (Reynolds 1972; Lemus 1972).

Lithology: It contains 2 bodies: the lower is composed of lutite with interstratification of sandstone, dolomite, breccia, and conglomerate; the upper is composed of dolostone in strata of 2 to 5 m with

intercalations of limaceous lutite lightly calcareous with nodular fracture and nodules of quartz lightly calcareous, fine grain sandstone conglomerates, and breccia constituted by irregular fragments of limestone and dolomitic limestone in calcareous mix.

Thickness: The lower body measures approximately 150 m. The upper has 320 m of dolomite, 130 of sandstone, and the conglomerate along with the breccia has a thickness of 20 m. In the Palomas range the thickness is 475 m (Diaz and Navarro 1964). Tovar (1968a) measured 448 m in the same location. In the Chinos range it is 240 m (patterson 1978). In the Chinos Well it is 303 m (Reynolds 1972b) and in the Espia Well No. 1 234 m (Lemus 1972).

Stratigraphic Relations: The lower contact is concordant and gradual with the Colina Formation. The upper contact is also concordant with the Scherrer Formation.

Fossils: The lower body contains algae and brachiopods. The rest of the unit contains amodicidos, calcitorea Globivalvulina sp., sponge spicules, and echinoderms.

Age: It is not precisely defined, however, because it is considered part of the same sedimentation cycle as the Colina and Epitaph Formations it is considered to be of the upper Wolfcampian (?)-Leonardian (lower Permian) (Reynolds 1972 a; Malpica and de la Torre 1980).

Paleoenvironment: Continental shelf with shallow seas. The breached zone indicates a period of subaquatic erosion. The terrigenous horizons indicate periods of accumulation derived from nearby area deposited in littoral zones. Reports of Gypsum crystals in the Chinos Well NO. 1 give evidence of the extreme shallowness of the seas.

Formation: Scherrer

Geological Province: Chihuahua

Location: Palomas range (Diaz and Navarro 1964; Tovar 1969) and Espia Well No. 1 (Lemus 1972).

Lithology: Limestone sandstone lightly calcareous partially argillaceous with intercalations of calcareous mudstone.

Thickness: It varies from a few m to 10 and 20 m.

Stratigraphic relations: The lower contact is concordant. The upper contact is transitional with the Concha Formation.

Fossils: Undeterminable

Age: Wolfcampian (?) (Tovar 1969). Reynolds (1972b) and Lemus (1972) believe it to be Leonardian (?).

Paleoenvironment: Transgressive seas or littoral deposit close to a deposits of mass towards the E is inferred.

Formation: Concha

Geological Province: Chihuahua

Location: Palomas, Chinos, and Santa Rita ranges (Diaz and Navarro 1964; Tovar 1969; Patterson 1978). It was also recognized in the Chinos and Espia No.1 Wells (Reynolds 1972b; Lemus 1972).

Lithology: It consists of 2 bodies: the lower is composed of sandy limestone in the base with nodules of flint and bioclastic horizons which change to biogenic calcarenite. In the Chinos Well No. 1 there

are intercalations of medium-grained sandstone and mudstone. The upper body is formed of dolostone and limestone with fossiliferous horizons.

In the Santa Rita range the unit is composed of 3 bodies: the lowest of dolostone in strata of 25 cm to 1.6 m with nodules of flint; the middle body is formed of dolostone in strata of 20 cm to 1.5 m with intercalations of lutite and sandy dolostone and sandstone with flint; the upper body is formed of dolostone in strata of 20 cm to 2.0 m with flint nodules and fossiliferous horizons.

Thickness: In the N flank of the Campana mountain in the Palomas range the thickness is 241 m (Tovar 1969). Diaz and Navarro (1964) measured in an unspecified location within the Palomas range 180 m. In the Chinos range the incomplete thickness is 325 m and in the Santa Rita range the complete thickness is 70 m (Tovar 1969). In the Espia Well the thickness is 337 m with 50 m taken off for a fault (Lemus 1972). In the Chinos Well No. 1 the complete thickness is 74 m.

Stratigraphic Relations: The lower contact is transitional with the Scherrer Formation. The upper contact is discordant with rocks for the lower Cretaceous. In the Santa Rita range it is concordant with the Santa Rita Formation of the Leonardian (Patterson 1978; Tovar 1969).

Fossils: Fusulinids (*Parafusulina durhami* Schwagerina sp., *Parafusulina* sp.), crinoids, bryozoans, corals, echinoderms, gasteropods, ostracods, and some trilobites and algae. It also contains the microfossils *Tuberitina* sp., *Globochaeta alpina*, and *Globivalvulina* sp.

Age: Leonardian (lower Permian).

Paleoenvironment: Continental shelf with shallow seas and intervals of high energy.

Formation: Santa Rita

Geological Province: Chihuahua

Location: N of Chihuahua in the Santa Rita range (Patterson 1978).

Lithology: It contains 4 bodies. The first is composed of medium-grained sandstone with fragments that vary from sub-angular to subrounded inside of a calcareous cement. The second body is dolostone with flint nodules and intercalations of sandstone and sandy dolostone and lutite. The third body is a conglomerated dolostone and dolomitic conglomerate interstratified with quartzitic sandstone and lutite in layers of up to 10 m. The fourth and last body is of dolostone with flint nodules and intercalations of quartzitic sandstone partly calcareous and conglomerated. All of the formation is fossiliferous.

Thickness: 280 m in the Santa Rita range (Tovar 1969).

Stratigraphic Relations: The lower contact is concordant with the Concha Formation. The upper contact is discordant with rocks of the lower Cretaceous.

Fossils: *Tuberitina* sp. estromatolitos some amonites, brachiopods, and gasteropods.

Age: Leonardian (lower Permian).

Paleoenvironment: Shallow platform seas with time intervals of very shallow, high energy seas. The breached zone indicates rising with probably subaerial erosion. The terrigenous sediments indicate nearby fountain of littoral conditions. The oxidized zones show sea level fluctuation. Towards the end of the Leonardian the seas retreated from the area and returned to the Cretaceous.

Formation: Sin Nombre

Geological Province: Chihuahua

Location: Salada Range (Tovar 1969 in Telles 1975b).

Lithology: It has 2 bodies. The lower consists of calcareous sandstone with intercalations of argillaceous limestone and dolomitic limestone. It contains abundant fossiliferous horizons. On occasion the sandstone changes to sandy limestone. The upper body consists of dolostone and dolomitic limestone with flint nodules and abundant fossil remains.

Towards the top of the unit 2 eroded surfaces with a conglomerated horizon each one of +/- 20 m thickness are observable.

Thickness: In the Salada range 2 sections were measured one of 359 m and the other 140 m (Tovar 1969 in Telles 1975b).

Stratigraphic Relations: The lower contact is unknown and the upper is discordant with lower Cretaceous rocks

Fossils: Brachiopods, crinoids, echinoderms, trilobites, bryozoans, fenestrals, ostracods, fusulinids (Schubertella-Boultonia) and some microforaminifera (Climacammina sp.).

Age: Wolfcampian (lower Permian)

Paleoenvironment: Shallow platform seas with proliferation of fauna which originated encrinites and biostromes of colonial organisms. The abundance of sandstone in the base indicates very shallow seas or high energy littoral conditions.

Area NW of Chihuahua (Subfloor)

Moyotes Well No. 1

Formation: Abo

Geological Province: Chihuahua

Location: S part of the Manzano range close to Scholle, New Mexico (Needham and Bates 1943 in Hernandez-Rios 1972). It also appears in the Sacramento, San Andres, Robledo ranges and in the area of Silver City all of which are in New Mexico. In Mexico it has only been recognized in the subfloor of the Moyotes Well located in the S prolongations of the messillas bolson, New Mexico.

Lithology: Conglomerated sandstone composed of quartz grains and igneous rocks in a mudstone mixture and silicon cement which formed the base of the unit. The upper part consists of silicated mudstone with intercalations of conglomerated sandstone with silicon cement. All of the formation is metamorphized.

Thickness: In the Moyotes Well it is 56 m, 20 of the lower body and 36 of the upper (Hernandez-Rios 1972).

Stratigraphic Relations: The lower contact is discordant with Precambrian rocks of the metamorphized intrusive foundation. The upper contact is interdigitated which shows a change of facies from continental to Marine. In the type-locality it is transitional with the Yeso Formation.

Fossils: All that has been identified are the fossil woods Supaia, Gigantopteris, and Glenopteris (Kattlowksi in Hernandez-Rios 1972).

Age: Late Pennsylvanian and or early Wolfcampian (lower Permian).

Paleoenvironment: Continental to coastal in foothills facies of aluvial planes. The fossil woods make it continental in its type-locality. The lithology of the Moyote Well No.1 could indicate transgressive seas in a littoral zone which at the end of the Wolfcampian gained depth with the depositing of the Hueco Formation.

Formation: Hueco

Geological Province: Chihuahua

Location: W flank of the Hueco mountains, Texas (Richardson 1904 in Hernandez-Rios 1972). In Mexico it has only been identified in the Moyotes Well No.1 (Hernandez-Rios 1972).

Lithology: It contains 2 bodies of rock; the lower consists of limestone mudstone, wackestone and packstone, both fossiliferous and partially carbonaceous, with thin intercalations of black lutite in the base. The upper body consists of very fine dolostone with fossiliferous horizons partially recrystallized and silified with inclusions of gypsum irregularly distributed and occasionally flint nodules. In the middle part of the upper body thin oolitic and pelets limestones are observed.

Thickness: Lower body 212 m, upper body 802 total thickness 1,014m. In the type-locality it is 400 m.

Stratigraphic Relations: The lower contact is discordant (?) with the Abo Formation. The upper contact is concordant with the Yeso Formation.

Fossils: Fusilinids (*Schwagerina* sp., *Pseudoschwagerina* sp., *Schubertella* sp., *Climacamina* sp., *Globivalvulina* sp., *Paleotexularia*), crinoids, endothyrida foraminifera.

Age: Lower Permian (Wolfcampian).

Paleoenvironment: Shallow transgressive platform seas which were favorable to the formation of oolites and evaporites.

Formation: Yeso

Geological Province: Chihuahua

Location: Yeso mesa NE of Socorro, New Mexico (Lee 1909 in Hernandez-Rios 1972). In Mexico it has only been recognized in the Moyotes Well (Hernandez-Rios 1972).

Lithology: There are vertical and lateral lithological variations from one area to another. In the Moyotes Well, it consists of 4 members; the lowest with 110 m consists of occasionally alternating sandy grey dolostone and quartzite of mid to fine grain, well cemented with silica. There are frequent thin intercalations of white gypsum and mudstone towards the upper part. The next body of 70 m thickness consists of dolostone with sporadic layers of quartzitic sandstone and occasional occlusions of gypsum. On top of this body, with 55 m thickness rests another of dolostone and quartzitic sandstone with evaporites. The fourth and last body consists of 110 m of quartzitic sandstone occasionally conglomerated of an argillaceous mixture and silicon cement with intercalations of quartzite, oolitic dolostone limestone and evaporites; the base is of silified mudstone with small occlusions of gypsum.

Thickness: 345 m in the Moyotes Well No. 1 of which 110 m, 70 m, 50 m, 115 m, correspond to the different numbers of the unit from bottom to top.

Stratigraphic Relations: The lower contact is concordant with the Hueco Formation. The upper contact is discordant with the Casita Formation of the upper Jurassic.

Fossils: Archaeodidae foraminifera.

Age: Leonardian (lower Permian).

Paleoenvironment: Internal neritic with evaporation zones with frequent changes of the coast line. The presence of gypsum and anhydrite indicate a very shallow platform environment with intervals of high energy which generated oolites. It is probable that the scarcity of the fauna is a result of rapid fluctuations in the coast line which formed the bars originated lagunar conditions ideal for the precipitation of evaporites. The frequency of these conditions originated regressive seas towards the W which retired from Mexico at the end of the Leonardian except in the area of Antimonio-Los Monos in Caborca, Sonora where they were maintained in very shallow conditions until the Guadalupian.

Mazatán-Cobachi Area, Sonora

Formation: Mazatán

Geological Province: Sonora

Location: Mazatan range, Cobachi and San Francisco mountains, N of Subiate, Sonora, and in the San Javier range W of Hermosillo (Dumble 1900; King 1944).

Lithology: Limestone in strata of 40 to 80 cm and flint nodules with isolated intercalations of lutite.

Thickness: The real thickness of the unit is unknown. King (1944) measured 500 m, Schuchert (1935) measured 50 m in the Mazatan range and 25 m in the Colorada range W of the Casita town.

Stratigraphic Relations: The lower contact is discordant with the Cobachi Formation of the Ordovic. The upper contact is eroded.

Fossils: Crinoids, fusulinids (*Parafusulina gumbeli*), brachiopods (*Linoproductus*), and colonial corals.

Age: It is not exactly known but Malpica and de la Torre (1980) only described the rocks belonging to the Permian (Wolfcampian ?-Leonardian).

Paleoenvironment: Tropical seas with shallow, warm, and tranquil waters which permitted the development of colonial fauna. The powerful thickness indicate a gentle and continuous subsidence which aided the sea in its advance over the continent.

Placer de Guadalupe Area, Chihuahua

Formation: Plomosas

Geological Province: Chihuahua

Location: Plomosas mine and Placer de Guadalupe and Enmedio mountains (Hernandez-Rios 1975; Hawkins 1975).

Lithology: This unit shows a very varied change of facies locally. In the Placer de Guadalupe mountain there is a sequence of calcareous lutite which changes to mudstone alternating with sandstone with subrounded clasts of fine-grained quartz in an argillaceous mixture and with silicon-calcareous cement. There are occasional thin strata of fine limestone partially recrystallized with some development of bioclasts.

In the Plomosas mine Bridges (1964) describes mudstone towards the basal part that changes laterally to thin, fine limestone. On top of the mudstone there rests a thickness of calcareous lutite and on top of this there is a conglomerate generously distributed with gravel of 7 to 10 cm of limestone, rhyolite, quartzite and flint in a sandy mix and silicon-calcareous cement. On top of the conglomerate rests fine biogenic limestone which is interrupted by an incline of rhyolite which is contemporary with the

sedimentation. On top of the rhyolite there is alternating mudstone and fine sandstone with silico-calcareous cement. Over this there is another powerful thickness of conglomerate similar to the first.

Towards the E of the Plomosas mine the unit consists of calcareous mudstone in thin strata with intercalations of fine limestone and fine-grained sandstone with silicon-calcareous cement on top of which a reef bank was deposited with pre and post reef facies and marginal facies. The reef is composed of crinoids, pelesceopods, sponges, and algae in the central part. In the edges it contains fusilinids and brachiopods.

On top of the reef bank a horizon of conglomerated sandstone rests in discordance which is under a powerful thickness of mudstone.

Thickness: The thicknesses vary from one location to the other, and are apparently incomplete. In the surroundings of Placer de Guadalupe, Hernandez-Rios (1975) measured 810 m incomplete thickness. Barradas (in Hernandez-Rios 1975) measured 2800 m of lutites and sandstones in Carrizalillo, close to Placer de Guadalupe. Bridges (1964) measured 762 m incomplete thickness in the Enmedio mountain and mentions that the maximum thickness is 1,050 to 1,400 m in the surroundings of the Plomosas mine and Placer de Guadalupe.

Stratigraphic Relations: The lower contact is discordant with the Pastor Formation. The upper contact is apparently concordant with the Verde Formation.

Fossils: Fusilinids (*Triticites* sp., *Parafusulina* ? sp., *Schwagerina* ? sp., and *Pseuschwagerina* cf. *P. gerontica* [Dumbar and Skinner]), corals, crinoids, some ammonites, gastropods (*Babylonites* sp., *Discotropis* sp., *Boylea* gigante), brachiopods (*Leiorhynchoidea* cf. *L. bisulcata* [Shumard] and *Composita* sp.), conodonts (*Gondolella* sp.,), blue-green calcareous algae (*Coactilum* sp. and *Macroporella* sp.), sponges (*Heliospongia vokesi* [R. H. King] *actinocoelia* sp., *girtyocoelia dumbari* and *Guadalupia* sp.), ostracods, bryozoans, and corals.

Age: Wolfcampian-Leonardian (?) (lower Permian).

Paleoenvironment: Shallow seas oscillating between transgressions and regressions with a close by supply of terrigenous sediments. The oscillations began before the Permian and during this period became regressive. The presence of conglomerate indicates a rising of nearby areas exposed to erosion. The rocks which are above and below the reef are in angular discordance which indicates deposits of talus, with an interruption which allowed the deposit of the reef in very shallow water conditions (less than 1 m).

The presence of volcanic material in the unit could be the product of some tectonic phase which is related with that of the Delicias-Acatita, Coahuila region, where volcanic rocks were related with tectonic movements of the close of the Paleozoic, possibly related with the Appalachian orogeny.

The sedimentation during the early Permian in the Cuervo range is similar to that of the Placer de Guadalupe but without interruptions of the column nor volcanic contributions which confirms, at least to Malpica and de la Torre (1980) that the area which suffered perturbations and risings was located more towards the E.

Formation: Verde

Geological Province: Chihuahua

Location: Camino arroyo close to Placer de Guadalupe, SE of the Enmedio mountain, N and SE of the Plomosas mine.

Lithology: The base consists of conglomerate of 20 m thickness, of heterogeneous clast composition composed of rounded fragments of up to 10 cm of limestone, flint, and sandstone poorly classified in a sandy-argillaceous mix and silicon-calcareous cement. On top of the conglomerate there rests a

sequence of +/- 600 m of lutite that alternates with mudstone and immature, subrounded, fine-grained sandstone and silicon-calcareous cement.

Thickness: Hernandez-Riolds (1975) measured 620 m and Bridges (1965) considers a thickness between 650 and 700 m.

Stratigraphic Relations: The lower contact is concordant although the presence of conglomerate could make one think that it is discordant, which doesn't necessarily indicate an absence of deposit, but instead a lithologic change in the sedimentation. Bridges (1965) considers this contact with the Plomosas formation by *cavalgamiento*.

The upper contact is discordant with the Casita Formation of the upper Jurassic.

Fossils: It has none.

Age: Late Leonardian (lower Permian).

Paleoenvironment: It has a regressive character of very shallow seas and of eminently terrigenous contribution from a near-by fountain. The presence of gypsum indicates a very shallow platform with periods of gentle rising that began because of short time periods of evaporitic basin. The almost total roundness of the conglomerate fragments indicates a far-away supply fountain probably N and E which is where the continental areas were located.

Formation: Rara (Villa Aldama)

Geological Province: Chihuahua

Location: SW of Placer de Guadalupe, NW of Villa Aldama on the E flank of the Cuervo of Peña Blanca range (Ramirez and Acevedo 1956). The most complete section appears in the Juan de Dios arroyo.

Lithology: A sequence of lutite, sandstone, phyllite, and slate with occasional lenses of limestone, quartzitic loam and conglomerate. It is considered a "flysch" divided in 2 bodies: the lower interturbidity (?) and the upper turbidity (Mellor 1978).

Thickness: 3,600 m (Ramirez and Acevedo 1956), however Mellor (1978) says that the thickness is not greater than 1,200 m.

Stratigraphic Relations: The lower contact does not appear and the upper is a stratigraphic and angular discordance with the Cretaceous rocks of the Vigas Formation.

Fossils: All that is observed are some poorly-conserved remains of crinoids and brachiopods, and poorly-conserved impressions of vegetable remains (Ramirez and Acevedo 1956). Mellor (1978) reports the fusulinids *Schwagerina* sp., and *Pseudoswageria* sp.

Age: Early Permian (Wolfcampian).

Paleoenvironment: Turbidic.

Delicias-Acatita Area, Coahuila

Formation: Capas Sardinias (Informal unit)

Geological Province: Coahuila platform

Location: SW of Coahuila between the parallels 26°00' and 26°30' and the meridians 102°45' and 103°45' which includes the Delicias and Remedios ranges and the Delicias and Acatita valleys.

Lithology: It is divided in 2 parts (Wardlaw et al., 1979); the lower consists of conglomerated lutite and greywacke where the greater part of the clasts are limestone, fragments of crinoids, and sporadic bryozoans, fusilinids, and brachiopods. The upper part contains lutite with Perrinites (King 1944).

Thickness: 320 m

Stratigraphic Relations: The lower contact is unknown and the upper contact is concordant with the Tordillo layers and is given where the lutites with Perrinites and a thick section of greywacke begins.

Fossils: Fusilinids, microforaminifera, paleotextularidos, amodiscidos and algae (Telles and Nestell 1978).

Age: Early-mid Leonardian (lower Permian; Malpica and de la Torre 1980).

Paleoenvironment: Shallow continental shelf waters.

Formation: Capas Tordillo

Geological Province: Coahuila platform

Location: SW of Coahuila between the parallels 26°00' and 26°30' and the meridians 102°45' and 103°45' which includes the Delicias and Remedios ranges and the Delicias and Acatita valleys.

Lithology: Sequence composed of a powerful thickness of greywacke, thin lutite and mudstone, and bioclastic limestone also in thin strata.

Thickness: 800 m (Wardlaw et al., 1979).

Stratigraphic Relations: The lower contact is concordant with the Sardinas layers and the upper is also concordant with the Palo Quemado layers.

Fossils: Schwagerina sp. fusilinids and scarce foraminifera.

Age: Late Leonardian (Roadian).

Paleoenvironment: Shallow marine waters of low energy.

Formation: Capas Palo Quemado

Geological Province: Coahuila Platform.

Location: SW of Coahuila between the parallels 26°00' and 26°30' and the meridians 102°45' and 103°45' which includes the Delicias and Remedios ranges and the Delicias and Acatita valleys.

Lithology: It is divided in 2 parts (Wardlaw et al., 1979); the lower consists of lutite with concretions of ammonites and brachiopods. The upper part contains greywacke with conglomerated portions that contain fossiliferous limestone and chips with fusilinids and brachiopods. It also contains bioclastic limestone in medium strata with brachiopods and ammonites and in the middle part of the unit there is a thin layer of lutite with ammonites, brachiopods, and gasteropods.

Thickness: 500 m.

Stratigraphic Relations: The lower contact is concordant with the Tordillo layers. The upper contact is concordant with the Difunta layers.

Fossils: Fusilinids, microforaminifera, algae, bryozoans, brachiopods, and mollusks.

Age: Guadalupian (upper Permian)

Paleoenvironment: Shallow marine waters.

Formation: Capas la Difunta

Geological Province: Coahuila Platform

Location: SW of Coahuila between the parallels 26°00' and 26°30' and the meridians 102°45' and 103°45' which includes the Delicias and Remedios ranges and the Delicias and Acatita valleys.

Lithology: It is divided into 3 parts (Wardlaw et al., 1979); the lowest consists of massive fossiliferous limestone, the middle part consists of greywacke with sporadic strata of fossiliferous limestone, lenses of limestone, and limestone pebbles in the conglomerated parts as well as thin layers of lutite and mudstone there are also some sills. The upper body consists of fossiliferous massive limestone and lutite with Timorites in the top (King et al., 1944).

Thickness: 680 m of which 130 are of the lower body, 400 of the middle body, and 150 of the upper portion.

Stratigraphic Relations: The lower contact is concordant with the Palo Quemado layers. The upper contact is concordant with the Colorada layers.

Fossils: Fusulinids, echinoderms, ostracods, paleotextulariids, algae, ammonites, and brachiopods.

Age: Early and mid Guadalupian (upper Permian).

Paleoenvironment: Marine benthonic with shallow waters.

Formation: Capas la Colorada

Geological Province: Coahuila Platform

Location: SW of Coahuila between the parallels 26°00' and 26°30' and the meridians 102°45' and 103°45' which includes the Delicias and Remedios ranges and the Delicias and Acatita valleys.

Lithology: It is divided into 2 parts; the lower consists towards the base of tuffaceous greywacke followed by greywacke and lutite. In the top there is lutite with Kingoceras (King et al., 1944). The upper part consists of greywackes; towards the top it contains black lutite which, in the S portion, is directly under gypsum and carbonated rocks of the Cretaceous.

Thickness: 600 m.

Stratigraphic Relations: The lower contact is concordant with the Difunta layers. The upper contact is discordant with Cretaceous rocks.

Fossils: Fusulinids, foraminifera, brachiopods, cephalopods, and algae.

Age: Late Guadalupian (upper Permian)

Paleoenvironment: Shallow marine waters.

Ciudad Victoria Area, Tamaulipas and subfloor (Gonzalez Well No. 101)

Formation: Guacamaya

Geological Province: Mexican belt of miogeoclinal folds and faults of the Gulf of Mexico.

Location: Guacamaya ranch, Peregrina and Huizachal-Peregrina canyons, Tamaulipas. It also appears in the Caballeros, Arroyo Seco, Santa Lugarda, La Boca, and El Olmo canyons (Carrillo-Bravo, 1961). It has also been reported in the Gonzalez Well No. 101, 98 km NW of Tampico, Tamaulipas (Toledo, 1957).

Lithology: Lutite and sandstone with local variations, that form bodies of varied thicknesses. In the Peregrina Canyon, the sandstone changes to calcarenite, and then changes to sandy limestone and limestone with fusulinids, in strata of 30 to 40 cm. A conglomerate of 10 m thickness with subangular fragments of up to 30 cm of limestone with fusulinids, similar to what is under it, and black carboniferous lutite covers it in angular discordance.

In the Caballeros canyon the sandstone is from thick-grained to conglomerated, with a horizon of fine conglomerate, of angular and subangular fragments of black lutite. In the Santa Lugarda canyon the sequence is of lutite and sandstone.

In the Boca Canyon the lutite-sandstone sequence shows a body of 20 (?) of carboniferous lutite with thin bands of sandy lutite in layers of 5 to 60 cm. Lastly, in the Olmo canyon it consists of black lutite in strata of 5 to 30 cm which alternates with sandstone with fusulinids, and fucoidales (worm tracks) marks, identical to those of the type-locality.

Thickness: In the Peregrina canyon it is estimated to be 800 m although the contacts are unknown. It is considered that the thickness of this formation is greater than 1,000 m.

Stratigraphic Relations: The lower contact by fault with Paleozoic formations that are older (Fries, 1962). The upper contact is an angular discordance with the Huizachal Formation of the upper Triassic and with the Zuluaga and Joya Formations of the upper Jurassic.

Fossils: Fusulinids (*Schwagerina* sp., *Parafusulina Sapperi* [Staff], *Tricites* sp., *Tricites* cf. *Crekensis* *Ozowainella* sp., *Schwagerina* cf. *diversiformis* and *Schwagerina* sp.), crinoids and plants.

Age: Permian (Wolfcampian-Leonardian).

Paleoenvironment: It is a "flysch" originated in the era following the Appalachian Orogeny characterised by a great deposit of detritus in subsident wells which created shallow seas on the edge of the platform with proliferation of benthonic fauna and preservation of organic material by a rapid burial originated by the great periodic contribution of argillaceous material. The conglomerated horizons imply periodic oscillations of the ocean bed with periods of erosion. The volcanic clastic horizons are probably a phase of post-tectonic vulcanism.

Molango-Calanali-Tianguistengo Area, Hidalgo

Formation: Otlamalacatla (informal unit)

Geological Province: Mexican belt of miogeoclinal folds and faults of the Gulf of Mexico.

Location: In the Huayacocotla anticline in the surroundings of the Otlamalacatla ranch and Tuzancoa (Ochoa-Camarillo, in preparation).

Lithology: Sandstone and lutite with abundant fauna.

Thickness: It is undetermined.

Stratigraphic Relations: The lower contact is tectonic, the upper contact has not been observed (Ochoa-Camarillo, in preparation).

Fossils: Trilobites and brachiopods.

Age: Pennsylvanian (?) - lower Permian (Wolfcampian-Leonardian).

Paleoenvironment: It is described along with that of the Tuzancoa Formation.

Formation: Tuzancoa (informal unit)

Geological Province: Mexican belt of miogeoclinal folds and faults of the Gulf of Mexico.

Location: In the Huayacocotla anticline in the surroundings of the Tuzancoa town over the dirt road that joins the town of Tuzancoa with Xochicoatlan (Ochoa-Carrillo, in preparation).

Lithology: Volcanisedimentary sequence that consists of volcanic breccia with lenses of limestone intercalated with abundant fusulinids and crinoids; and intervals of tuffaceous sandstone and lutite.

Thickness: Undetermined

Stratigraphic Relations: the stratigraphic relations are undetermined.

Fossils: Fusulinids (*Tricites* sp., *Schwagerina* sp., *Paraschwagerina* sp. cf. *P. roveloi* [Thompson and Miller] *Monodiexodina* sp. among others), crinoids, gasteropods, brachiopods (*Neospiriger* sp., *Chonetina* sp. among others), bryozoans, sponge spicules, trilobites (*Phillipsia* sp.) estromatolitos, filoides algae, and foraminifera.

Age: Lower Permian (Wolfcampian-Leonardian).

Paleoenvironment: It was probably an arc of islands. There are still no concrete data to interpret the origin.

Nochixtlan-Ixtaltepec Area, Oaxaca

Formation: Yododeñe

Geological Province: Mixteca

Location: Yododeñe arroyo E of Yododeñe in the area of Nochixtlan Oaxaca (Pantoja and Robinson, 1967).

Lithology: Conglomerate with intercalations of mudstone and calcareous sandstone.

Thickness: 500 m. It is considered incomplete (Pantoja and Robinson, 1967).

Stratigraphic Relations: The lower contact is discordant with the Ixtaltepec Formation. The upper contact is also angularly discordant with Mesozoic and Tertiary basal conglomerates.

Fossils: It contains none.

Age: Pennsylvanian-late Permian (?).

Paleoenvironment: See Ixtaltepec Formation.

Chicomosuelo Area, Chiapas

Formation: Grupera

Geological Province: Chiapan belt of folds and faults.

Location: Grupera arroyo in the surroundings of Chicomosuelo. It also appears in the surroundings of the Monte Redondo town.

Lithology: A sequence of lutite with some strata of sandstone of 6 to 15 m, which alternates with fossiliferous limestone. The lowest part of the unit, according to Malpica (1977) is a limestone with crinoids, that changes towards the middle to calcareous mudstone. In the top of the unit the limestone prevails (wackestone, packstone and grainstone). Generally in the N portion of the appearance area the carbonates predominate and in the S argillaceous sediments predominate.

Thickness: In the Grupera arroyo Thompson and Miller (1944) measured 100 m. Hernandez-Rios (1973b) measured 410 m close to the town of Monte Redondo. This last author measured 230 m in the Comalapa river. In the Lagerio-Bella Vista section, 240 m and in the Chicomosuelo-Coralito section 220m.

Stratigraphic Relations: The lower contact is discordant with the Santa Rosa superior Formation in the N portion of Chicomosuelo in the surroundings of Monte Redondo this contact is transitional. The upper contact is transitional with the Paso Hondo Formation.

Fossils: Crinoids, sponge spicules, trilobites, gasteropods, algae, brachiopods, ostracods, fenestral bryozoans, foraminifera, and fusulinids (*Pseudofusulina chiapaensis* [Thompson and Miller] and *Schwagerina gruperaensis* [Thompson and Miller]).

Age: Lower Permian (Wolfcampian).

Paleoenvironment: In the S portion of the deposit a marine environment of moderate energy occurred as shown by calcareous mud (mudstone). Towards the N the conditions are shallow and with high energy, with excessive light and oxygen developing flora and fauna possibly in the edge of a platform in which the sea currents acted strongly. The horizons of lutite and sandstone can be interpreted as temporal variations of the energy level, because the fauna is similar in all the unit.

Formation: Paso Hondo

Geological Province: Chiapan belt of fold and faults.

Location: Vainilla mountain S of the town of Paso Hondo. It also appears in the Comalapa River N of Comalapa W of the original location (Thompson and Miller 1944; Hernandez-Rios 1973b).

Lithology: A sequence of limestone and dolostone, the latter predominating towards the top of the unit. The limestone is fossiliferous, occasionally intercalated by lutite and even more rarely with buttresses of carbon. The limestone, in strata of 20 to 80 cm, is classified as mudstone, wackestone, packstone, and grainstone.

Thickness: Hernandez-Rios (1973) in the Comalapa river measured 950 m and in the Lagerio-Bella Vista section 128 m, in the Potrerillo-Pacayal section 760 m and in the Chicomosuela-Corralito section 514 m.

Stratigraphic Relations: The lower contact is transitional and concordant with the Grupera Formation. The upper contact is discordant with the Rojas Todos Santos layers.

Fossils: Corals, crinoids, ammonites, brachiopods, bryozoans, fusulinids (*Schubertella mullerriedi*, *Schubertella* sp., *Eoverbeekina* sp., *Eoverbeekina americana*, *Schwagerina* sp. *Parafusulina australis* [?] Thompson and Miller, *Staffella* sp., and *Nankinella* sp.), foraminifera, principally stromaliths, filoides, and calcareous algae.

Age: Permian (Leonardian)

Paleoenvironment: Shallow platform border similar to that of the Grupera Formation although the fossils indicate different environments. The algae, fusulinids, corals, crinoids, brachiopods, and bryozoans suggest a sublittoral environment with depths between 25 and 50 m (Malpica 1977) corresponding to the centre and S portions of the area.

In the N of the area there are the maximum thicknesses of talus breccia associated with algae that along with the crinoids form small biothermal reefs associated with solitary corals and fusulinids. These facies are considered to be of agitated seas with maximum conditions of circulation and aerations, much like a tropical-subtropical climate (Hernandez-Rios 1973b).

OLINALA-TECOCOYUNCA AREA, NE OF GUERRERO.

Formation: Los Arcos

Geological Province: Mixteca

Location: 2.4 km E-SE of Olinala in the Arcos gorge it also appears in the N-E in the Llano Grande and Viejo ranges.

Lithology: It consists of a conglomerate that changes to a conglomerated sandstone, polygenetic, composed of pebbles between 5 and 8 cm of mica and green shale, quartzite and fragments of phyllite included in the sandy mix. The middle part of the unit is sandstone of mid to thick grain. The upper part is mudstone. Towards the top there is fine-grain sandstone with intercalations of limestone and mudstone.

Thickness: It is variable and the only place where it appears completely measures 635 m (Corona-Esquivel 1981).

Stratigraphic Relations: The lower contact is discordant with the Acatlan complex. The upper contact is discordant with the Ignimbrita las Lluvias del Triacico (?) and with the Cualac conglomerate of the Jurassic (?).

Fossils: Stacheoceras and Agathiceras, brachiopods (Orbiculoidea ovals [cloud] Thamnoidea depressa [Cooper]), gastropods (Babylonites carinatus Yochelson), nautiloideos and ammonites (Paraceltites elegans, Waagenoceras dieneri Girty) among others.

Age: Mid Permian (Gonzalez-Arreola et al., 1994).

Paleoenvironment: Marine and littoral.

TECOMALTLAN-ACATLAN AREA, PUEBLA

Formation: Cuxtepec

Geological Province: Mixteca

Location: Defined by Enciso de la Vega (1988) S of Puebla, S of the town of Progreso, 35 km SW of Acatlan. The appearance extension with a N-S orientation is 3 km long and 400 m wide in the W side of Cuxtepec mountain.

Lithology: In order of abundance it contains conglomerate, lutite-gypsum, lutite-sandstone, and limestone with lateral variations of thickness. The most constant horizons are quartz conglomerate and a crinoidal limestone.

Thickness: the real thickness is unknown, however, Enciso de la Vega (1988) estimates a thickness of more or less 300 m.

Stratigraphic Relations: The lower contact is by fault or discordant with the Acatlan Formation. The upper contact is completed by the Acatlan complex. Besides which the upper part is eroded; locally small vestigial erosions of tertiary conglomerate (?) are over it.

Fossils: Fusilinids (*Schwagerina* cf. *gruperensis* [Thompson and Miller] and *Parafusulina* cf. *P. durhami*).

Age: Mid-late Leonardian (lower Paleozoic)

Paleoenvironment: An environment of neritic sedimentation close to the coast. The presence of evaporites indicates occasional developments of barriers which drew the sea nearer. Enciso de la Vega (1988) mentions a possibility of a regional acufiada sedimentation, of a miogeoclinal type developed over a passive continental margin with accumulation of sediments during the open sea and open during the closed sea without involving tectonic activity during the sedimentation, although the quartz conglomerate seen in the base of the Cuxtepeque Formation suggests tectonic activity of risings in the continent. The cyclical sequence (sandstone-lutite) could be attributed to climatic changes more than a diastrophic effects. The presence of gypsum, limestone, and oolitic flints which had not previously been reported in the S of the country suggests the existence of a littoral Permian zone of high energy and evaporation.

The absence of brachiopods, mollusks, corals, and ammonites indicate shallow turbulent waters intermittently aerated and closed to the sea. It is supposed that the probably continental areas of contribution of detritic sediments were located in the S-SW of the area.

Patlanoaya Area, Puebla

Formation: Patlanoaya (informal unit)

Geological Province: Mixteca

Location: Informally defined by Vazquez (1986) a kilometer, more or less, from San Salvador Patlanoaya, Puebla.

Lithology: It is divided into four bodies of rock.

Body 1: It is composed of sandstone, conglomerated sandstone, and mudstone with some intercalations of lutite and limestone towards the upper part. Some sedimentary structures such as cross and graded stratification are observed. The thickness is 360 m and the only fossil evidence is in the last 40 m.

Body 2: Limestone and sandy limestone in thick and medium strata with a few intercalations of calcareous-sandy lutite.

Body 3: Sandstone, conglomerated sandstone, calcareous and conglomerated sandstone, well classified in the base, on top of which rests strata of limestone, limaceous-sandy limestone of thin to mid stratification and thin horizons of conglomerate which are well classified. Over the limestone there is some argillaceous-limaceous limestone that changes to sandy mudstone with intercalations of sandstone in thin strata. These layers continue upwards to limaceous-calcareous sandstone and some strata of limaceous limestone of thin stratification. In the upper part this body contains calcareous mudstone.

Body 4: In the base it consists of heterogeneous clast composition conglomerate, the clasts are of volcanic and calcareous origin in a sandy matrix. Over this there is an alternation of limaceous lutite with calcareous nodules, sandstones, and limaceous sandstone, all of these in thin strata.

Thickness: Approximately 925 m.

Stratigraphic Relations: The lower contact is discordant with the Acatlan complex. The upper contact is an angular discordance with rocks of the mid Jurassic (Tecomazuchil Formation).

Fossils: Brachiopods, pelesciopods, cephalopods, crinoids, and plants.

Age: Body 1, lower Mississippian. Body 2, Pennsylvanian. Body 3, lower Permian (Wolfcampian). Body 4, lower Permian (Leonardian).

Paleoenvironment: Marine littoral.

ROCKS OF THE CONTINENTAL PERMIAN

Matzizi Area, S of Tehuacan, Puebla

Formation: Matzizi

Geological Province: Mixteca

Location: Matzizi mountain, SE of San Francisco Xochiltepec, Puebla (Aguilera, 1896). The formation appears in the surroundings of the town of Zapotitlan, in the Tehuacan region in the surroundings of the Caltepec, San Luis Tultitlanapa, San Luis Atolotitlan, Santiago Coatepec, and in small valleys eroded by the rivers which appear in the region (Xochiltepec-Tilapa, Caltepec, Del Castillo rivers).

Lithology: Thick grained sandstone with intercalations of thin layers of carbon and slate-like lutite. There are occasionally intercalations of conglomerate with well rounded clasts of shale, gneiss, and igneous rocks of the basal complex (Calderon, 1956).

Thickness: Because of the intense deformation, erosion, and intrusions which affect the formation, the real thickness is not known. Calderon (1956) estimates approximately 600 m. Erben (1956 in Silva 1970) estimates a thickness of 300 m.

Stratigraphic Relations: The lower contact is discordant with the basal complex. The upper contact is also discordant with the Zapotitlan and Cipiapa Formations, of the lower and mid Cretaceous, respectively and with tertiary basaltic slopes.

Fossils: There are abundant plant which belong to the species Pecopetris, Neuropteris, Calamites, Lepidodendron, and Sigilaria, among others (Silva, 1970).

Age: The species mentioned are characteristic of the upper Carbonifero of Europe, and the Pennsylvanian of America. Silva (1970) establishes a Pennsylvanian age. However, Weber et al. (1992) describes an example of Sigilaria characteristic of the Permian so this age is assigned to the formation.

Paleoenvironment: Because of the fauna reported in Europe and the United States, the vegetation was exuberant in extensive boggy basins with the same species that existed in Tehuacan (Silva, 1970). In Tehuacan, the environment was apparently more restrictive with less humidity and less vegetation and, because of this, more restricted distribution.