
Permian Continental and Marine Biota of South-Central Mexico: A Synthesis

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ABSTRACT

The Permian marine and continental sedimentary sequences in south central México and the biota contained in them are analyzed in this paper. The fossil flora and fauna are contained in Permian strata that correspond to the Guacamaya Formation in the states of Hidalgo and Veracruz; to the Patlanoaya, Los Hornos, Cuxtepeque, and Matzitzzi Formations in the state of Puebla; to the Olinalá Formation in the state of Guerrero; to the Ihualtepec, Ixtaltepec, and Yododeñe Formations in the state of Oaxaca; and to the Paso Hondo Formation in the state of Chiapas.

The microfaunistic association of Olinalá fusulinids can be correlated with the Guadalupe Mountains and the La Mar Formation of Texas in the U.S.A., and with the Difunta Formation of Coahuila and strata of the states of Sonora, Guerrero, and Oaxaca in Mexico. Fusulinids from the Olinalá, Ihualtepec, and Yododeñe Formations suggest that during the Late Permian (Wordian-Capitanian), these organisms were part of the same paleogeographic province that comprised Texas, Arizona, New Mexico, and California in the United States, and northern Sonora, Chihuahua, Coahuila, extending into central Mexico.

INTRODUCTION

The marine and continental outcrops from the upper Paleozoic of Mexico are scarce relative to their territorial extent because the region experienced deformation caused by complex plate interactions. In addition, the Paleozoic rocks are covered by a thick sequence of Mesozoic and Cenozoic sediments and Cenozoic volcanic rocks.

Nevertheless, the scarce outcrops of the upper Paleozoic rocks contain abundant invertebrates, including fusulinid foraminifers, bryozoa, brachiopods, mollusks, ostracods, crinoids, and algae. The continental flora fossils are scarce but identifiable. The purposes of this paper are: (1) to integrate the paleontology data available for the Permian in Mexico, (2) to establish regional stratigraphic correlations, and (3) to provide new insights into the Permian paleogeographic subprovinces.

This work is important because it contributes information about the lithology, flora, and fauna from different marine and continental sequences of central and southern Mexico.

PREVIOUS WORKS

Several investigations have been made of the upper Paleozoic of Mexico, mainly of the Permian in central and southern Mexico: Aguilera (1896) made the first geological study in the Tehuacan, Puebla, region. Thompson and Miller (1944) described fusulinids of the Paso Hondo Formation in southeastern Chiapas. Carrillo-Bravo (1961, 1965) discovered Permian plants of Leonardian age in the Tlahuelompa–San Mateo region in Hidalgo and Veracruz states. Silva-Pineda (1970) described flora of the upper Paleozoic from the south of Puebla (Matiziti Formation). Buitrón-Sánchez (1977) published the discovery of the gastropod *Bellerophon* (*Bellerophon*) *crassus* Meek and Worthen in the Paso Hondo Formation of Chiapas. Patiño-Ruiz and Moreno-Cano (1981) discovered rocks from the upper Paleozoic in the Calnali, Hidalgo, region. Flores de Dios and Buitrón-Sánchez (1982) revised the stratigraphy of the La Montaña de Guerrero and described the Olinalá Formation. Corona-Esquivel (1983) studied the stratigraphy of the Olinalá-Tecocoyunca, Guerrero, region. González-Arreola and Corona-Esquivel (1984) presented new determinations of Permian ammonites from Olinalá, Guerrero. In 1986, Vázquez-Echeverría discovered Paleozoic marine rocks in the San Salvador Patlanoaya region southwest of Puebla,

which he described informally as the Patlanoaya Formation. Villaseñor et al. (1987) cited fossils from the same region. Enciso de la Vega (1988) reported a new Permian locality dated by fusulinids in Cuxtepeque–Peña Colorada, Puebla.

New investigations in the 1990s were made by Vachard et al. (1993), who presented a preliminary study of the Olinalá escarpment. Gonzalez-Arreola et al. (1994) studied Permian fauna of the Los Arcos Formation (Olinalá Formation) in Guerrero. Cantú-Chapa (1997) pointed out that Permian sedimentary sequences in Mexico are generally divided into lower and upper parts, depending on the presence of goniatites. The lower section is characterized by the presence of *Perrinites* in the states of Chihuahua, Coahuila, Puebla, and Chiapas, and the upper part is characterized by the presence of the goniatites *Waa-genoceras* and some ceratites (xenodiscids) in Sonora, Coahuila, and Guerrero (Olinalá). Vachard et al. (1997a) reported a new locality with abundant Lower Permian age invertebrates in Pemuxco, Hidalgo. Vachard et al. (1997b) discussed upper Paleozoic sedimentary sequences in relation to the Mixteco and Oaxaca Terranes. Vachard et al. (1997c), and Vachard and Pantoja (1997) published papers on the evolution of Mexico during the late Paleozoic. Weber (1997a, b) reviewed new fossil material of the Matiziti Formation and suggested a Leonardian age for this unit. López-López (1997) described late Paleozoic brachiopods from the Olinalá, Guerrero, region. Vachard et al. (1998) studied the facies and environments of the upper Paleozoic (Patlanoaya Formation). Arellano et al. (1998) studied a turbiditic sequence with abundant Permian fossils from Pemuxco, Hidalgo. Sánchez-Zavala et al. (1999) did a stratigraphic review of the Paleozoic of Mexico and its relation to Gondwana and Laurasia.

Recently, Esquivel-Macías (2000) and Esquivel-Macías et al. (2000) reported on the late Paleozoic brachiopods and crinoids of Olinalá, Guerrero, and Patlanoaya and Cuxtepeque, Puebla. Vachard et al. (2000a) described fusulinid fauna of the Patlanoaya, Puebla, region. Silva-Pineda et al. (2000) revised the Permian conifers of the Guacamaya, Patlanoaya, and Olinalá Formations. Flores de Dios et al. (2000a, b) presented a study of the Upper Permian Olinalá, Ihualtepec, and Yododeñe Formations of the Zapoteco and Mixteco Terranes in southern Mexico. Silva-Romo and Mendoza-Rosales (2000) discovered upper Paleozoic plants in Piedra Hueca, Puebla. Ramírez et al. (2000) discovered Permian rocks that he named the “Los Hornos Formation” in the Hornos de Zaragoza,

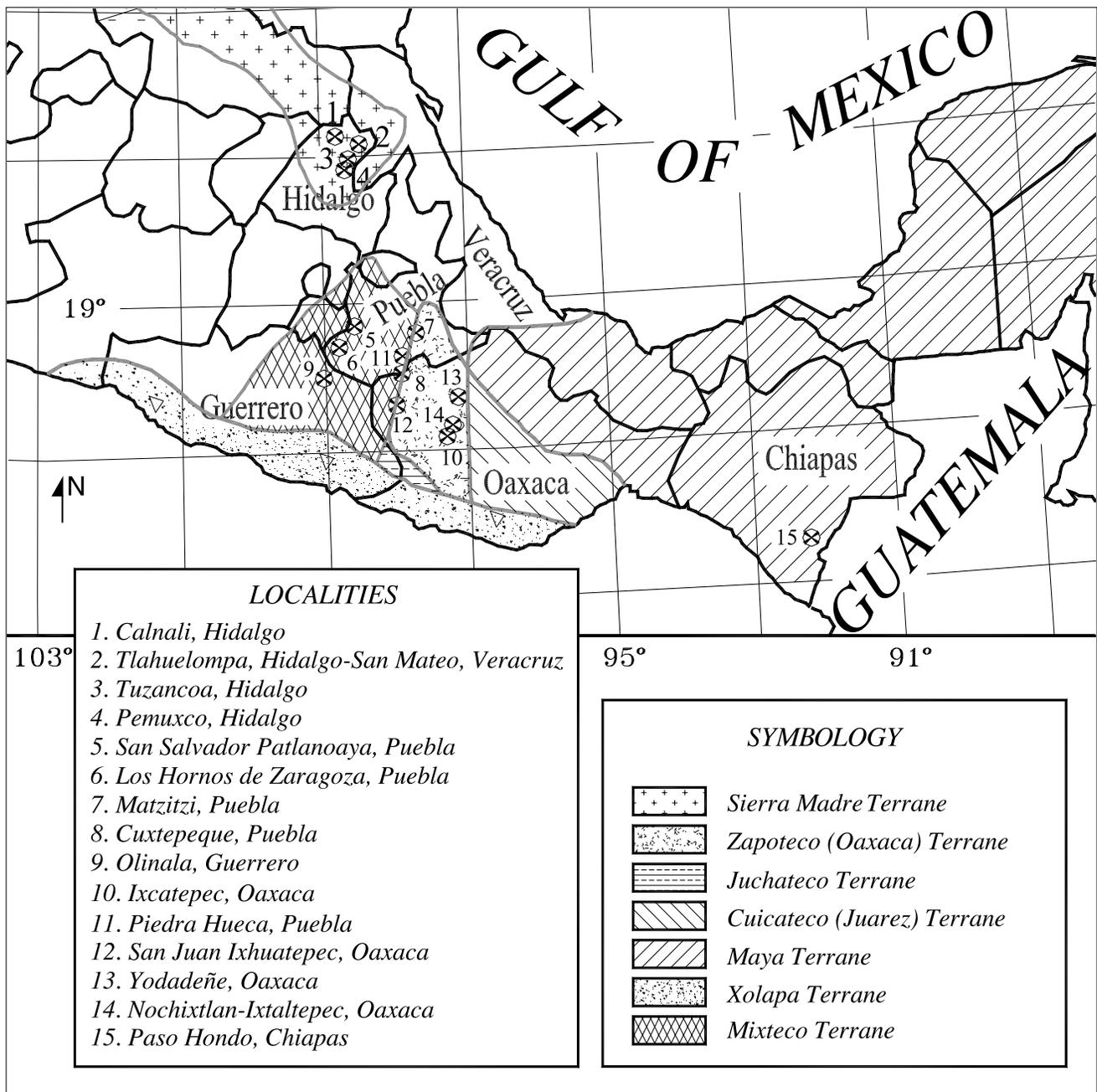


Figure 1. Tectonostratigraphic terranes and Permian localities with outcrops of marine and continental sequences of South-Central Mexico.

Puebla. Hernández-Láscares (2000) and Galván-Mendoza (2000) studied the stratigraphy and paleoecology of the Matzitzi Formation in Puebla.

GEOTECTONIC SETTING

The unmetamorphosed Paleozoic marine and continental sequences that crop out in southern Mexico show great lithological complexity and varying facies, including continental, reef, and marine

facies. The relations between these sequences are obscured by widely separated and limited outcrops. The localities where they have been reported are: Tiñu, Santiago, Ixtaltepec, Yododeñe, Matzitzi, Patlanoaya, Olinalá, Piedra Hueca, and Cuxtepeque (Figure 1).

The basement for these formations is the Acatlan Complex in the Mixteco Terrane and the Oaxaqueño Complex in the Zapoteco Terrane (Campa-Ureña and Coney, 1983). The first unit deposited over both

the Missourian and lower Virgilian (Pennsylvanian), a *Pseudofusulina* and *Rugosochunella* from the Wolfcampian (Permian), and a *Paraskinnerella* and *Skinerella* from the middle Leonardian. Vachard et al. (2000b) published a biostratigraphic and paleogeographic distribution of Permian fusulinids (Wolfcampian-Leonardian) from Mexico and its application in reconstructing the paleogeography of Mexico's upper Paleozoic suspect terranes.

LOS HORNOS FORMATION (WORDIAN)

The Los Hornos Formation was proposed by Ramírez et al. (2000). It is a sequence of approximately 60 m of conglomerate and sandstone, fossiliferous

limestone (gastropods, echinoderms, bivalves, fusulinids, and crinoids), and sandstone and shale (Figure 4), which is exposed north of the Hornos Zaragoza community. These strata yielded the fusulinids *Parafusulina splendens* and *P. cf. Deliciasensis* species of Wordian age. The upper contact is structural with the La Noria–Hornos de Zaragoza granite (late Devonian) and the lower contact with the Tecamate Formation.

CUXTEPEQUE FORMATION (LEONARDIAN)

This formation was described by Enciso de la Vega (1988) in the Mixteca region of Puebla, near the northwestern border of Oaxaca State and east of the town of Progreso. The section consists of limestone and chert of unknown thickness that contain the fusulinids *Swagerina cf. gruperaensis* and *Parafusulina cf. durhami* of Leonardian age.

MATZITZI FORMATION (PENNSYLVANIAN-PERMIAN)

The Matzitzi Formation crops out 40 km southwest of the city of Tehuacan, Puebla. The unit consists of sandstone with intercalations of shale and conglomerate and occasional coal horizons. This succession contains well-preserved Late Pennsylvanian flora, which was described by Silva-Pineda (1970) as ferns (*Pecopteris*), lepidodendrales (*Lepidodendron*, *Sigillaria*), Pteridospermales (*Neuropteris*) and Sphenopsida (*Calamites*). New plant findings in the Matzitzi were described by Weber et al. (1989) as *Fasciapteris*, *Taeniopteris*, *Pterophyllum Rhipidopsis* or *Gynkgoites*, *Sphenophyllum*, *Holcospermum*, *Annullaria*, *Lonesomia*, and a similar sample of *Glossopteris*, all of which suggest a younger

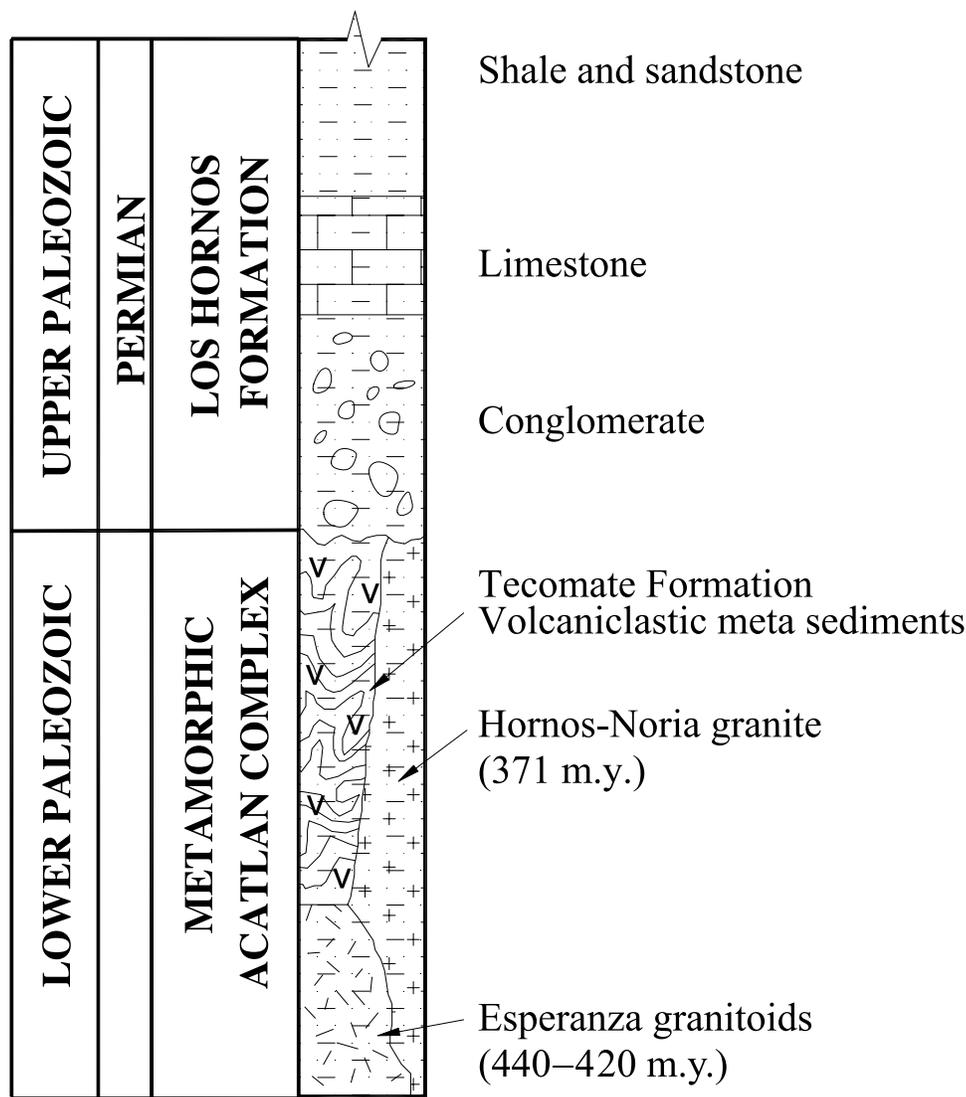


Figure 4. Stratigraphic column of the Los Hornos Formation, Los Hornos de Zaragoza, Puebla.

age for these rocks. On the other hand, Weber and Cevallos (1994) assigned this sequence a Leonardian age.

The Matzitzi overlies in angular unconformity crystalline rocks of the Oaxaqueño and Acatlan complexes, and unconformably underlies Mesozoic and Cenozoic rocks (Hernández-Láscars, 2000).

OLINALÁ FORMATION (WORDIAN-CAPITANIAN)

Flores de Dios and Buitrón-Sánchez (1982) proposed the formal name of Olinalá Formation for a Permian marine clastic that crops out near Olinalá. This formation consists, from older to younger, of 70 m of conglomerate whose clasts contain brachiopods and plants (Corona-Esquivel, 1983), carbonates, and clastic rocks. Vachard et al. (1993) first assigned these strata a Late Permian (Wordian-Capitanian) age. The lower and middle parts of the formation contain ammonites-goniatitids (*Waagenoceras*) from the Wordian, the brachiopods *Paranorella imperialis* Cloud, and plants *Neuropteris* sp., *Taeniopteris* sp., *T. fallax* Goepfert and cf. *Cordaites* sp. The presence of a small leaf of cf. *Cordaites* sp., compared with the great characteristic forms of this genus, is rare; nevertheless, several authors have reported leaves of small dimensions. In addition, *Taeniopteris*, a genus generally found in the Permian-Triassic of several regions of the world is contained in these rocks. This unit represents the youngest Permian rocks reported for Mexico.

This unit rests unconformably on the Lower Paleozoic Acatlan Complex, and it is unconformably overlain by the Middle Jurassic Cualac Conglomerate.

IHUALTEPEC FORMATION (MISSISSIPPIAN-PERMIAN)

Southeast of San Juan Ihualtepec village, in eastern Oaxaca State, a partial section of black argillites was first reported by Martínez-Keemp (1986), who assigned them a tentative Late Paleozoic age based on field relations. Flores de Dios et al. (1992) reported the crinoid *Florucyclus granulosis* and *Cyclocaudez costatus* species (Moore and Jeffords, 1968) and the fenestelid *Bryozoan* sp. *bryozoa*, confirming the Mississippian-Permian age of these rocks. Vachard et al. (1997c) identified the fusulinids *Parafusulina deliciasensis* sp. (Dumbar and Skinner) of Wordian age. The presence of this microfossil permits the

Wordian paleogeographic reconstruction from California and Texas to Sonora, Coahuila, Guerrero, and Oaxaca in Mexico.

The upper contact is an unconformity with the Lower Jurassic Cualac Conglomerate, and the lower contact is an unconformity with the Acatlan Complex.

IXTALTEPEC FORMATION (PENNSYLVANIAN-PERMIAN)

In the Santiago Ixtaltepec area, the Ixtaltepec Formation consists of platform calcareous sandstone, shale, and siltstone that contain Pennsylvanian bivalves, brachiopods, bryozoans, crinoids, gastropods, and trilobites, and also Permian crinoids *Cyclocaudex* and *Pentacrinus* (Morales and Ciomas, 1984). Limestone-bearing conglomerates in this region yielded the Permian fusulinids *Shwagerina elkoensis* and *Boultina heezen*.

The Ixtaltepec Formation is overlain by the Tiñu Formation, and the basal contact is a shear zone between the Santiago and Ixtaltepec Formations.

YODODEÑE FORMATION (PERMIAN)

In Nochixtlan-Ixtaltepec, Oaxaca, marine strata rocks were formally reported by Pantoja-Alor (1970, 1993), who defined the Yododeñe Formation as a limestone-bearing red conglomerate with intercalations of sandstone and siltstone. He established a tentative Late and Early Permian age for these rocks, based solely on field relations. Our sample collection yielded the Leonardian fusulinids *Skinmerella biconica* Skinner and *Parafusulina brooksensis* Ross. The presence of *Skinmerella biconica* in clasts of the Yododeñe Formation indicates that they must have been sourced from a still unidentified or totally eroded limestone succession that would have been contemporaneous with the upper Permian Olinalá Formation. One piece of indirect evidence for a Permian–Early Cretaceous age for the Yododeñe Formation is that it does not show the structural deformation that affected the Pennsylvanian Ixtaltepec Formation (Centeno-García et al., 1997).

Conglomerates in the sequence of red beds contain limestone clasts with fusulinids that have been identified as *Skinerella biconica* Skinner and *Parafusulina brooksensis* Ros, which indicates an early–middle Leonardian age, as well as *Parafusulina brooksensis* discovered in the Leonardian stratotype at the top of the Hessian (middle Leonardian). These fusulinids

also are characteristic of the microfaunas of the Bone Spring Formation (Leonardian stratotype) of Texas in the U.S.A.

The Yododeñe Formation limestone clasts represent a carbonate deposition event, which must have occurred during the late Permian (at least middle Leonardian in the Oaxaca Terrane). No other Triassic to Cretaceous rocks have yet been found that would determine the age of the sedimentary evolution of the Oaxaca Terrane.

Upper Paleozoic carbonate deposits were reported in Olinalá, Guerrero (Flores de Dios and Buitrón-Sánchez, 1982), and Ihualtepec, Oaxaca (Vachard et al., 1993, 1997). These Paleozoic units represent part of the sedimentary cover of the Mixteco Terrane. Both Oaxaquia and Mixteco terranes were stable during the upper Paleozoic, providing appropriate conditions for carbonate sedimentation.

The Yododeñe Formation overlies in slight unconformity the Ixtaltepec Formation and is, in turn, unconformably overlain by a Mesozoic conglomerate.

PASO HONDO, GRUPERA, AND VAINILLA FORMATIONS (PERMIAN)

Thompson and Miller (1944) divided the upper Paleozoic section in the Paso Hondo area, Chiapas, into three lithostratigraphic units: the Paso Hondo Formation, the Grupera Formation, and the La Vainilla Formation. Müllerried (1963) identified the ammonites *Waagenoceras* from the Paso Hondo species. This ammonite was reported as *Perrinites hilli* (Smith) by Miller and Furnish in 1941, who discovered these ammonites as characteristic species of Leonardian from Coahuila, Texas, New Mexico, and Oklahoma. The Grupera Formation is Wolfcampian, based on *Schwagerina chiapasensis* and *S. Gruperaensis*. The La Vainilla Formation contains crinoids, brachiopods, and fusulinids *Schwagerina figueroai* and, therefore, is younger than Wolfcampian and older than Leonardian.

In the Chicomuselo region, in the southern part of Chiapas, Buitrón-Sánchez (1977) described the gastropod *Belerophon* (*Bellerophon*) *crassus* Meek and Worthen of middle Permian age, which is associated with the fusulinids *Schwagerina*, *Eoverbeekina*, *Stafella*, *Nankinella*, and marine algae (*Tubiphytes*). The age assigned to the Paso Hondo Formation is Permian (Leonardian) based on fusulinids, already mentioned, that are indicator foraminifers of a tropical or subtropical sea (Hernández-García, 1973).

DISCUSSION

In South-Central Mexico, outcrops of the Guacamaya, Patlanoaya, Los Hornos, Cuxtepeque, Matzitzzi, Olinalá, Ihualtepec, Ixtaltepec, Yododeñe, and Paso Hondo Formations contain Permian continental and marine biota that allow for a precise stratigraphic correlation (Figure 5).

The Guacamaya Formation of Wolfcampian-Leonardian age crops out in the states of Tamaulipas, Hidalgo, and Veracruz and contains Leonardian fossil flora represented by the *Pecopteris*, *Sphenopteris*, *Neuropteris*, cf. *Odontopteris*, cf. *Callipteris*, cf. *Gigantopteris*, *Cordaites*, and *Walchia* genus. Fossil fauna include abundant fusulinids, among them *Skinnerella* genus, characteristic of the lower Leonardian, and fragments of crinoids (*Cylindrocauliscus*, *Cyclocaudex*), bryozoans, and algae (*Tubiphytes*). The Patlanoaya Formation (Wolfcampian-Leonardian) is exposed in the Izucar de Matamoros, Puebla region, and contains flora (cf. *Sigillaria* sp., *Neuropteris* sp., *Supaia merriani* White, *Walchia* sp.), fusulinids (*Pseudofusulina*, *Rugosochusenella*), and crinoids (*Cyclocaudex*). The Los Hornos Formation crops out to the north of Los Hornos de Zaragoza, Puebla, and contains Leonardian fauna (*Paraskinnerella*, *Skinnerella*). The Olinalá Formation crops out near Olinalá, and contains Wordian *Waagenoceras*, fusulinids (*Parafusulina*, *Rausserella*, *Codonofusiella*) and the brachiopod *Paranorrella*. Scarce flora include *Neuropteris* sp., *Taeniopteris* sp. cf. *T. Fallax* Goepfert, and cf. *Cordaites* sp. The contact with the upper carbonate portion represents, in terms of sedimentology, a contact by subaerial erosion. The sequence is a carbonate ramp where the inner ramp is characterized by shallow-water boundstone, crinoid packstone-grainstone, and grainstone, in which bivalves, gastropods, and microfossils are found. Also found are *Parachaetes*, in carbonate sand benches containing mainly crinoids in floatstone.

The middle part of the ramp is built by crinoids, bryozoans, bivalves, brachiopods, small foraminifers (*Abadella* ex gr. *Conformis*) and fusulinids (*Codonofusiella extensa* Skinner and Wilde, *Parafusulina bosei* Dumbar and Skinner, *Schbertella* gr. *S. Australis* Thompson and Miller) in sandstone and limestone of Wordian-Capitanian age.

The deep part of the ramp is a muddy carbonate mound (Lime Mound) of cyanobacteria (*Tubiphytes aelisacus*), calcareous sponges (*Porichtofenis*), and bryozoans, which trap a fine calcareous mud that gives origin to a typical stromatolitic structure. The fusulinid association of the Olinalá can be correlated

ERA	DIVISION	MIXTECO TERRANE				OAXACA TERRANE							
		MEXCALA-OLINALÁ	Ihualtepec-Patlanoaya	Zapotitlán-Tlaxiaco									
CENOZOIC	QUATERNARY	RECENT											
		PLEISTOCENE				Chilapa Fm. San Marcos Andesite Yucudac Andesite	Andesites						
	TERTIARY	PLIOCENE	Oapan Fm.			Suchixtlahuaca Fm. Cerro Verde Fm.	Sosola Fm.						
		MIOCENE	Buena Vista Andesite		Yanhuitlan Fm.	Llano de Lobos Fm. Yanhuitlan Fm.	Yanhuitlan Fm.						
		OLIGOCENE	Tilzapotla Rhyolitic	Tamazulapan Fm.	Huajuapán Fm.	Tamazulapan Fm. Huajuapán Fm.	Tecomatlan Fm.						
		EOCENE	Balsas Group										
		PALEOCENE	Tetelcingo Fm.										
		MESOZOIC	MAASTRICHTIAN	Mexcala Fm.			Marga Yucunama	Marga Tilantongo				Mendez Fm.	
				SANTONIAN								San Felipe Fm.	
			TURONIAN	Cuautla Fm. (?)								Agua Nueva Fm.	
CENOMANIAN	Morelos Fm.		Teposcolula Fm.	Teposcolula Fm.	Cíplapa Fm.	Teposcolula Fm.				Tamaulipas Superior Fm.			
ALBIAN	Huizaco Fm. Zicapa Fm.		Puebla Group	San Juan Raya Fm.		Puebla group				Tamabra Fm.			
APTIAN				Zapotitlán Fm.						Abra Fm.			
NEOCOMIAN										Pimenta Taman Santiago			
JURASSIC	UPPER			Caliza con Cidaris	Mapache Fm. Cz Cidaris	Chimeco Fm.					Tepexic		
	MIDDLE		Tecocoynca Group	Tecocoynca Group Tacamazuchitl	Tecocoynca Group	Tecocoynca Fm.	Etlatongo Fm.				Cahuasas Huayacocotla		
TRIASSIC	LOWER		Conglomerado Cualac	Conglomerado Cualac		Consuelo Group					Huizachal		
	UPPER					Yododeñe Fm.							
	MIDDLE												
	LOWER	Las Lluvias Ignimbrite	Las Lluvias Ignimbrite	Las Lluvias Ignimbrite									
PALEOZOIC	PERMIAN	Olinalá Fm.	Ihualtepec Patlanoaya Fm.	Cuxtepec	Olinalá Fm.					Guacamaya Tuzancoa			
	PENNSYLVANIAN				Matzitzi Fm.	Ixtaltepec Fm.				Otlamacatla			
	MISSISSIPPIAN						Santiago Fm.						
	DEVONIAN	ACATLAN COMPLEX											
	SILURIAN												
	ORDIVICIAN												
CAMBRIAN													
PRECAMBRIAN							OAXAQUEÑO COMPLEX		Huiznopala gneiss				

Figure 5. Stratigraphic correlation between the Mixteco and Oaxaca Terranes.

to the Guadalupe Mountains of Texas, the La Mar Formation of California, the Difunta Formation of Coahuila, and with Sonora, Guerrero, and Oaxaca in México.

The Ihualtepec Formation is limestone and siliciclastics with fusulinids (*Parafusulina*) of early–middle Wordian age (zones PG2 or PG3). The paleogeographic association of *Parafusulina* is with northern California and Texas in the U.S.A. and with the states of Sonora, Coahuila, Guerrero, and Oaxaca in México, and also with the middle Permian Paso Hondo Formation in Chicomuselo in southern Chiapas. The

Ihualtepec contains the gastropod *Bellerophon* (*Bellerophon*) *crassus* Meek and Worthen of middle Permian age, the fusulinids *Schwagerina*, *Eoverbekina*, *Stafella*, and *Nankinell*, and Leonardian marine algae and continental plants. The Permian is considered an arid period during which several groups of plants became extinct and only a few elements continued into the Mesozoic.

Depositional environments involved platforms and mixed ramps (carbonate and siliciclastics). Sedimentary sequences have a marked andesitic volcanic influence. A complex paleogeography depicts North

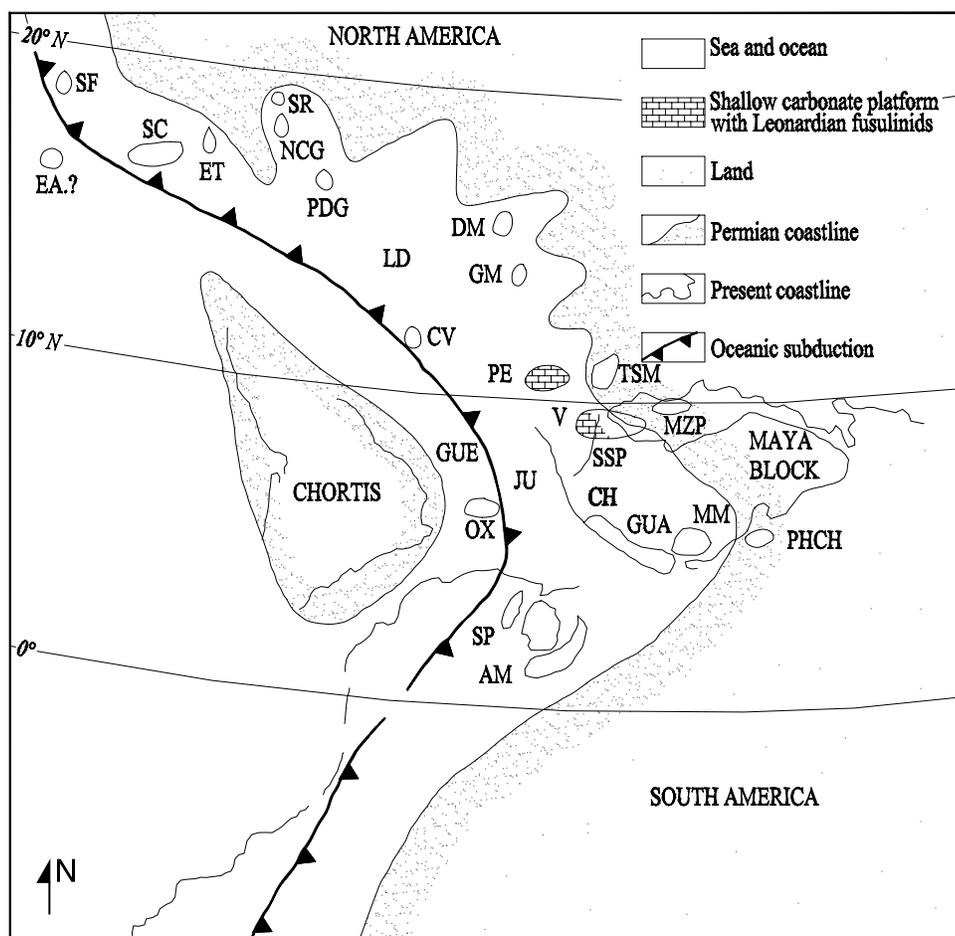


Figure 6. Permian paleogeographic map. Abbreviations: AM = Mérida Andes (Venezuela); CH = Chiapas State; CV = Ciudad Victoria (Tamaulipas); DM = Diablo Mountains (Texas); EA = El Antimonio (Sonora); ET = El Tigre (Sonora); GM = Glass Mountains (Texas); GUA = Guatemala; GUE = Guerrero State; H = Hidalgo; JU = Juchatengo (Oaxaca); LD = Las Delicias (Coahuila); MM = Maya Mountains (Belize); MZP = Matzitzi (Puebla); NCG = Nuevo Casas Grandes (Chihuahua); OX = Oaxaca State; PDG = Placer de Guadalupe (Chihuahua); PE = Pemuxco (Hidalgo); PHCH = Paso Hondo (Chiapas); SC = Central Sonora; SF = San Felipe (Baja California Norte); SP = Sierra de Perija (Colombia); SR = Sierra de Santa Rita (Chihuahua); SSP = San Salvador Patlanoaya (Puebla); TSM = Tlahuelompa–San Mateo (Hidalgo-Veracruz).

and South America separated by the Maya Block, a subduction zone along the western margin of the continent, with marine sedimentation in the west and continental sedimentation in the east (Figure 6). The Yododeñe Formation crops out in the Nochixtlan Ixtaltepec area and consists of limestone-bearing conglomerates deposited in alluvial fan systems. Some clasts contain the fusulinids *Schwagerina elkoensis* and *Boultonia heezen*, which have also been reported in Nevada in the U.S.A. On the other hand, middle Wolfcampian fusulinids such as *Skinnerella biconica* Skinner and *Parafusulina brookensis* Leonardian are recognized in the Bone Spring Formation.

Likewise, the fusulinids of the Olinalá Ihualtepec and Yododeñe Formation suggest that during the late Permian (Wordian-Capitanian), these organisms were part of the same paleogeographic province that comprised Texas, Arizona, New Mexico, and California in the U.S.A., and northern (Sonora, Chihuahua, Coahuila) and central Mexico.

CONCLUSIONS

The marine and continental fossil biota are found in Permian-age rocks that correspond to the Guacamaya Formation in the state of Hidalgo and Veracruz; the Patlanoaya, Los Hornos, Cuxtepeque, and Matzitzi Formations in the state of Puebla; Olinalá Formation in the State of Guerrero; Ihualtepec, Ixtaltepec, and Yododeñe Formations in the state of Oaxaca; and the Paso Hondo Formation in the state of Chiapas.

Outcrops in the states of Veracruz and Hidalgo, show a thin strata of continental siliciclastic turbiditic sequence in the base, prograding upward to a marine-strata sequence that belongs to the Guacamaya Formation (Otlamalacatla-Tuzancoa). The continental rocks contain plants that consist of Sphenopsida (*Equisetum*, *Calamites*, *Annularia*), Pteridosperms, (*Neuropteris*, cf. *Odontopteris*, cf. *Callipteris*, cf. *Gigantopteris*), ferns (*Pecopteris arborescens* Brongniart, *P. onita* Brongniart, *Sphenopteris*, *Neuropteris*), and conifers (*Cordaites*, *Walchia*). The marine strata contains crinoids of the genus *Skinnerella* and *Staffella* from the Wolfcampian-Leonardian, crinoids (*Cyclocaudex plenus*, *Preptopremum rugosum*, *cyclocrista chenev*), fenestellid Bryozoans, algae, and spiriferid-brachiopods remains.

The Permian biota of Patlanoaya Formation, located to the southeast of Izucar de Matamoros, Puebla, comprises a limited flora represented by lepidodendral (cf. *Sigillaria*.), Pteridosperms (*Neuropteris* sp., *Supaia marriani* White), and conifers (*Walchia*). Invertebrates are abundant. Between them are found fusulinids (*Pseudofusulina*, *Rugosochusenela*) and ammonites *Properrinites* of Wolfcampian age. The Patlanoaya Formation also contains brachiopods (*Wellerella* sp.), bivalves (*Schizodus*, *Palaeomutela*), ammonites (*Perrinites hilli* Smith), gastropods (*Omphalonema*), fusulinids (*Paraskinnerella*, *Skinnerella*), and algae (*Tubiphytes obscurus* Maslov) of Leonardian age.

The Los Hornos Formation that crops out in the Hornos de Zaragoza, Puebla region, contains a marine fauna constituted of gastropods (*Straparollus*), bivalves, fusulinids (*Paraskinnerella*, *Skinnerella*), crinoids (*Cyclocaudex plenus* Moore and Jeffords), and icnofossils; the faunistic associations define a lower Permian age (Leonardian).

The Cuxtepeque Formation crops out in the occidental hillside of the Cuxtepeque hill, near the Peña Colorada settlement on the boundary between the states of Puebla and Oaxaca; the marine biota consist of crinoids and fusulinid fragments of the specie *Schwuagerina* cf. *S. gruperiensis* and *Parafusulina* cf. *P. durhami* from the Leonardian.

The Matzitzi Formation crops out in the Tehuacan, Puebla region, and is characterized by its abundant and well-preserved flora from the Pennsylvanian-Permian represented by several ferns species (*Pecopteris* and *Fasciapteris*), lepidodendrales (*Lepidodendron*, *Sigillaria*), Pteridospermales (*Neuropteris*, *Holcospermum*), esphenopsids (*Sphenophyllum*, *Calamites*, *Anularia*), and cycas (*Taeniopteris*, *Pterophyllum*).

The Olinalá Formation consists of Permian marine rocks from the Wolfcampian-Capitanian with numerous fusulinid foraminifera (*Parafusulina bosei* Dunbar and Skinner, *Rausarella erratica* Dunbar, *Codonofusiella extensa* Skinner and Wilde), ammonites (*Waagenoceras*, *Stacheoceras*, *Agathiceras*), brachiopods (*Paranorella imperialis* Cloud, *Dictyoclostus depressus* Cooper, *Composita* sp., *Wellerella* sp., *Orbiculoidea* aff. *O. missouriensis* (Shumard), *Canocrinella* sp., *Composita grandis* Cooper). Associated marine rocks of shallow-water fragments of the continental plants cycas-benettitales (*Taeniopteris* cf. *T. fallax* Goepfert), Pteridosperms (*Neuropteris* sp.), conifers (cf. *Cordaites* sp.), and equisetals were found.

In the northwest of Oaxaca, limestones of the Ihualtepec Formation crop out with *Schwuagerinids*

and *Parafusulina deliciasensis* Dunbar and Skinner (*P. maleyi*) from the lower–middle Wordian, and the crinoids *Cyclocaudex typicus* Moore and Jeffords, *Cyclocrista lineata* Moore and Jeffords, *Pentagonopteris insculptus* Moore and Jeffords, and *Pentaridica rhoti* Moore and Jeffords.

The Pennsylvanian-Permian Ixtaltepec Formation consists of shale, siltstone, sandstone, and a minor proportion of limestone that has brachiopods, gastropods, corals, trilobites, crinoids, and index fossils of Pennsylvanian age. This faunal association suggest a reef and perireef environment. The geologic contact between the Santiago and Ixtaltepec Formations is defined by a shear zone. The slip is similar to the one observed with the Tiñu Formation, representing in both structures a slip northward. In the region of Santiago Ixtaltepec, Oaxaca, red conglomerates with limestone clasts contain the species *Schwuagerina elkoensis* and *Boultonia heezeni*, Permian index fusulinids.

The existence of Permian-age fusulinids in clasts of the Yododeñe Formation, which not affected by the structural deformation detected in older units, such as the Ixtaltepec Formation, indicates a post-Permian to Lower Cretaceous age for the unit.

The Paso Hondo fossiliferous limestone that crops out in the southeast of Chiapas contains the gastropod *Bellerophon* (*Bellerophon*) *crassus* Meek and Worthen from the middle Permian, which is associated with the fusulinids *Schwagerina*, *Eoverbekina*, *Stafella*, and *Nankinella*, ostracods, corals, brachiopods, crinoids, and marine algae of the *Tubiphytes* genus. In addition, well-preserved continental plants remain as impressions in carbonaceous shale.

The Permian paleogeography can be interpreted as large continental areas to the south (North America, Maya and South America Blocks) bordered by coastal environments, and a siliciclastic platform westward with some carbonate banks. It is interpreted as a deep-sea zone eastward, in which thick siliciclastic sequences were accumulated in submarine fans.

The volcanic influence is associated with the presence of a subduction zone, also to the east, that causes volcanism with volcanic rock of andesitic composition.

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