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Hydrocerbon Deposits of the Border Region between Mexico and the United States and Potential Exploitation Problems in Transboundary Deposits: A Preliminary Report

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INTRODUCTION

This article is divided into two parts, the first of which presents a schematic evaluation of the geology of the Mexican northern border region, on land and on the marine continental margins. It discusses their structural style and stratigraphy and the existing or potential transboundary deposits according to known or predictable geologic conditions. The second part is concerned with the problems which can arise in transboundary reservoirs with an uncoordinated type of exploitation. It proposes some technical alternatives for a coordinated exploitation.

GEOLOGIC EVALUATION OF THE MEXICAN NORTHERN BORDER REGION

For practical reasons, the geology of the Mexican northern border region will be discussed from west to east in the following order: the Pacific Continental Margin; Baja California; Sonora; Chihuahua; Coahuila; Tamaulipas (including Nuevo Leon); and the Gulf of Mexico Continental Margin.

Pacific Continental Margin

This margin includes the structural province known as the Continental Borderland, which extends from Point Conception, California, to the Vizcáino Peninsula, Baja California (Figure 1). Its history is complex, involving a former Mesozoic subduction margin which was later disrupted by plate collision and evolved into a transform boundary. These combined events gave rise to complicated structures and to peculiar sedimentary styles.

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In the first margin stage a thick section of Cretaceous and lower Tertiary forearc sediments were deposited. These are found from the Great Valley in California to Baja California, where they are exposed along the coast.[1] Strata of this age have also been crossed by deep wells offshore.

In Miocene time the breakup of the margin and the associated block faulting originated the structure of the present continental shelf. Its fault controlled bathymetry was characterized by elongated troughs and wide ridges, locally emerging as islands. New depositional environments were created in the isolated troughs where sediments with a high organic content were deposited and preserved, thus producing the source rocks of the great fields of southern California.[2] Later filling of the basins with sandy turbidites gave rise to excellent reservoirs.

Both oil and gas are produced from the upper Tertiary of southern California; Paleocene and Cretaceous strata produce gas. The predominant traps are folds or fault related.[3] However, despite the apparent geologic continuity along the continental borderland, the exploration has not been successful in the border region. On the United States side several wells were dry. On the Mexican side all efforts have been concentrated farther to the south, in the Vizcáino Basin, where some gas is produced onshore. An offshore well drilled near Cedros Island was dry.

In the inner shelf basins the Miocene deposits are continental to shallow marine and are dominated by volcanic constituents.[4] The same features are observed in the Miocene strata of coastal Baja California.[5] On the outer shelf the border region includes some major basins like the San Clemente, Velero, and No Name Basins, and some smaller depressions.[6] A well drilled in the Cortés Bank penetrated a thick section of Upper Cretaceous, lower Tertiary, and deep marine Miocene.[7] The Miocene was found to have a good hydrocarbon potential.

These facts suggest that little or no production is to be expected from the inner basins of the shelf in the border region, particularly due to the

1. *See* R. LÓPEZ, GEOLOGÍA DE MÉXICO (1982).

2. *See* Graham & Williams, *Tectonic, Depositional and Diagenetic History of Monterrey Formation (Miocene), Central San Joaquin Basin, California*, 69 AM. A. PETROL. GEOL. BULL. 385 (1985).

3. *See* Crain, Mero & Patterson, *Geology of Point Arguello Discovery*, 69 AM. A. PETROL. GEOL. BULL. 537 (1985).

4. *See* T. Lamb, Geology of the Coronado Islands (Master's Thesis, California State University, 1974, available in the California State University Library).

5. *See* Lozano, *Evaluación Petrolifera de Baja California, México*, 27 BOL. ASOC. MEXICANA GEOL. PETROL. 104 (1975).

6. *See* Krause, *Tectonics, Bathymetry and Geomagnetism of the Southern Continental Borderland West of Baja California, Mexico*, 76 GEOL. SOC'Y AM. BULL. 617 (1965).

7. R. Paul, R. Arnal, J. Basinger, C. Claypool, J. Bolle, C. Lubeck, J. Patterson, R. Foote, R. Slettene, W. Sleter, J. Taylor, R. Tudor & F. Webster, Geological and Operational Summary, Southern California Deep Stratigraphic Test OCS-CAL 75-70 No. 1, Cortes Bank Area Offshore Southern California, U.S.G.S. Open-file Report 76-232, March 1976, at 65.

unfavorable characteristics of the Miocene section. Although the basins situated on the outer shelf show distinct possibilities of containing hydrocarbon deposits, they lie in a great depth of water—approximately 1,000 meters. Because of the technical difficulties of exploiting deposits at that depth, their economic significance is presently small.

Baja California

Northern Baja California is crossed from north to south by a great intrusive mass, the Peninsular Batholith.[8] West of the batholith, the proximal facies of the sedimentary units that occur in the offshore basins are exposed. They include a prebatholithic, partly metamorphosed carbonate series associated with volcanics; a postbatholithic upper Cretaceous and lower Tertiary terrigenous sequence; and thick Miocene volcaniclastic deposits.

East of the batholith, the structure of northern Baja California is controlled by the activity of the San Andreas fault system. The origin of most of the basins is related to movement along the faults. The basins are filled with thick sections of predominantly continental deposits. In the Gulf of California, where 8,000 meters of sediments were deposited in Pleistocene and recent times, a high heat flow favored the organic maturation and gave rise to gas production.[9]

In the border region, the Salton Trough extends from the Imperial Valley into Mexico. It contains 7,000 meters of Miocene to Quaternary deposits, for the most part continental, although it also includes Pliocene marine strata. The northern Baja California region as a whole is chiefly an important geothermal province.

Sonora

Northern Sonora lies on the southern margin of the North American craton and its geologic history is similar to that of Arizona. Paleozoic and older sediments were deposited on a Precambrian basement and suffered little deformation. Scattered outcrops of upper Precambrian, Paleozoic, and Mesozoic rocks point to the existence of a thick sedimentary section that was intruded by great batholiths during late Cretaceous and early Tertiary time.[10]

Erosion and sedimentation prevailed in the early Tertiary. Block faulting

8. *See* R. Gastil, R. Phillips & E. Allison, Reconnaissance Geology of the State of Baja California (Geological Society of America, Memoir 140).

9. Pérez, *Algunos Resultados de la Investigación geológico-geofísica en la Porción Noroccidental del Golfo de California*, 34 BOL. ASOC. MEXICANA GEOL. PETROL. 71 (1982).

10. *See* R. LÓPEZ, *supra* note 1.

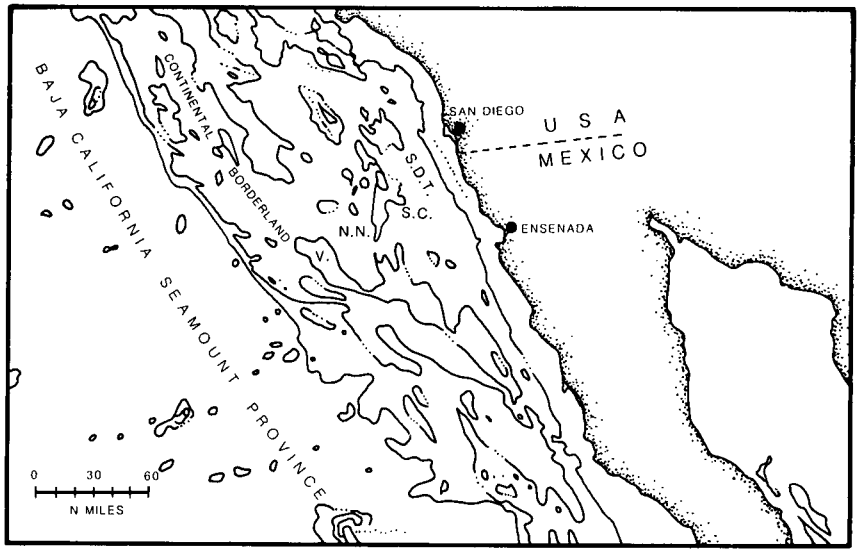

FIGURE 1. Continental Borderland (modified from Moore, 1969). SDT: San Diego Trough; SC: San Clemente basin; NN: No Name basin; V: Velero basin.

occurred during Miocene time and was followed by volcanism. The troughs were filled by continental volcaniclastic deposits. At the same time a marine transgression began to be noticed in the southwestern part of the state and reached the western edge of northern Sonora during Pliocene time.[11] Later deposits were continental and deltaic. The prospects for exploration in the border region are believed to be poor, with the possible exception of the eastern area bordering Chihuahua.

Chihuahua

Northern Chihuahua also lies on the margin of the North American craton. This region includes two large structural provinces and a thick stratigraphic sequence consisting of marine deposits of Cambrian to Cretaceous age. In Paleozoic time the Pedregosa Basin was surrounded by great platforms covered by about 2,000 meters of limestones; these features extended into Arizona and New Mexico.[12] The Paleozoic section is an important exploration object. Its source rocks are Devonian to Permian basinal shales; its reservoirs are lower and late Paleozoic shelf carbonates and sandstones. The traps are located in shelf margin dolostones and sandstones.

11. *See* Guzmàn, *Geología Cenozoica del Noreste de Sonora Incluyendo su Mar Patrimonial*, 33 BOL. ASOC. MEXICANA GEOL. PETROL. 3 (1982).

12. *See* Tovar, Vàsquez & Lozano, *Interpretación Geológico-Geofísica, Porción Norte de Chihuahua*, in 3 SIMPOSIO DE GEOLOGIA DEL SUBSUELO REYNOSA 93 (1976).

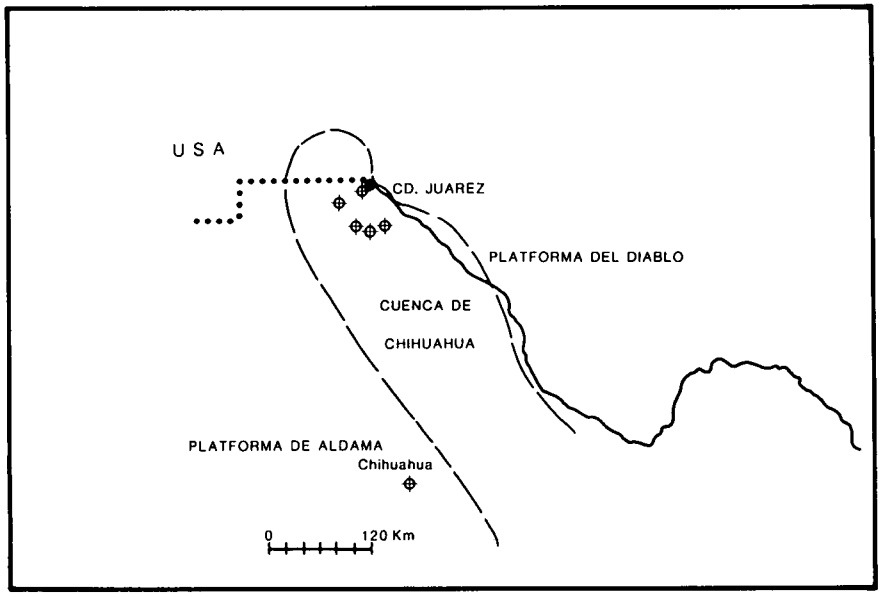

FIGURE 2. The Chihuahua Trough (from De Ford, 1969).

During Mesozoic time a new basin, the Chihuahua Trough,[13] was formed on reactivated Paleozoic tectonic elements (Figure 2). Paleozoic formations are overlain by Jurassic evaporites and Jurassic and Cretaceous marine deposits. The Upper Jurassic is believed to be a good source rock. On the surrounding Cretaceous platforms, biostromes, dolostones, and marginal sands are potential reservoirs. Good structures were formed by the early Tertiary Laramide deformation and by the subsequent block faulting caused by the Basin and Range event.

In northern Chihuahua oil shows are common.[14] Though no commercial production has been found to date in the border region, it is conceivable that hydrocarbon deposits will be found in the future in this area.

Coahuila

Northern Coahuila is located on a Paleozoic positive element. A folded and metamorphosed basement is overlain by lower Cretaceous basal sands and middle to upper Cretaceous platform carbonates.[15] The Cretaceous

13. *See* DeFord, *Some Keys to the Geology of Northern Chihuahua*, in NEW MEXICO GEOLOGICAL SOCIETY FIELD TRIP GUIDEBOOK 61 (1969).

14. *See* Thomson, Tovar & Conley, *Oil and Gas Exploration Wells in the Pedregosa Basin*, in NEW MEXICO GEOLOGICAL SOCIETY 29TH FIELD CONFERENCE GUIDEBOOK 331 (1978).

15. *See* W. Bloxsom, A Lower Cretaceous (Comanchean) Prograding Shelf and Associated Environments of Deposition, Northern Coahuila, Mexico (Master's Thesis, University of Texas at Austin, Oct. 17, 1972, available in the University of Texas at Austin Library), and Pedrazzini, Basañez, Màrquez & Suàrez, *Facies de la Serie Comanche en el Subsuelo de la Plataforma del Burro, Coahuila*, 6 REV. INST. MEXICANO PETRÓLEO 16 (1979).

Plataforma del Burro[16] is equivalent in time and facies to the Edwards Plateau. In Albian time the Maverick Basin was formed on the shelf, thus complicating the facies distribution and rendering the exploration more difficult.

Oil and gas shows are common in the whole stratigraphic column. In the adjacent part of Texas the production is obtained from the Glen Rose and also from fractured Austin and Buda formations. In Coahuila, hydrocarbons are produced from fractured reservoirs of the Lower Cretaceous Cupido and La Peña formations. In the Piedras Negras Basin a good production has been obtained from Campanian-Maestrichtian carboniferous deltaic deposits. Several fields are located on both sides of the Rio Bravo and transboundary deposits may possibly exist (Figure 3).

Tamaulipas (including Nuevo León)

Northern Tamaulipas is part of the Mesozoic Rio Grande Embayment and includes the Tertiary Burgos Basin. From the point of view of exploration, its interest is varied because it extends from the Jurassic to the Miocene. However, most of the gas production of this province has been obtained from the Tertiary reservoirs.

Jurassic

A Jurassic major trend forms a narrow strip that pinches out to the west against the Plataforma del Burro (Figure 4).[17] Terrigenous sedimentary rocks interfingered with evaporites are overlain by oolitic limestones and dolomitic calcarenites of the Olvido and Novillo Formations. Highly porous dolostones form a parallel band bordering the Rio Bravo south of Nuevo Laredo.

Jurassic rocks produce from the Novillo Formation in the Anahuac field southwest of Nuevo Laredo. The source rock is believed to be the Upper Jurassic, downdip to the east. The strata suffered little deformation and the traps are mostly stratigraphic.[18] The Jurassic facies can be followed into the United States, to the Smackover Trend, and production exists in the border region.

Cretaceous

The Lower Cretaceous consists of shelf carbonates which, during Barremian-Aptian time, formed a wide platform that covered northeast Mex-

16. *See* Gonzàlez, *Bosquejo Geológico de la Zona Noreste*, in 3 SIMPOSIO DE GEOLOGÍA DEL SUBSUELO, REYNOSA 5 (1976).

17. *See* Madrid, *Consideraciones Geológico-Económicas del Juràsico Superior, Noreste de México*, in 3 SIMPOSIO DE GEOLOGÍA DEL SUBSUELO, REYNOSA 193 (1976).

18. *Id.*

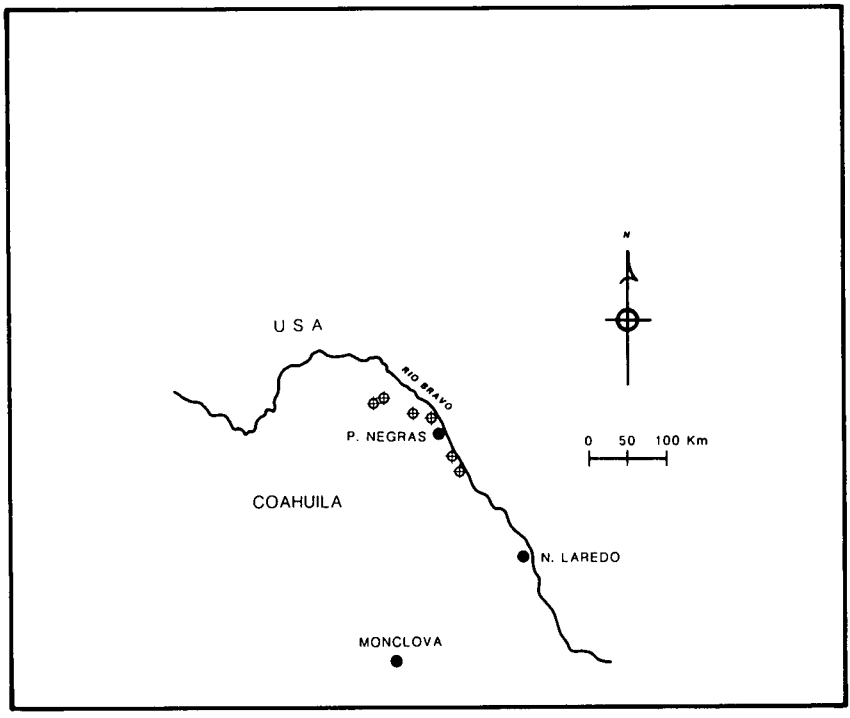

FIGURE 3. The Piedras Negras Province, Northeast Mexico.

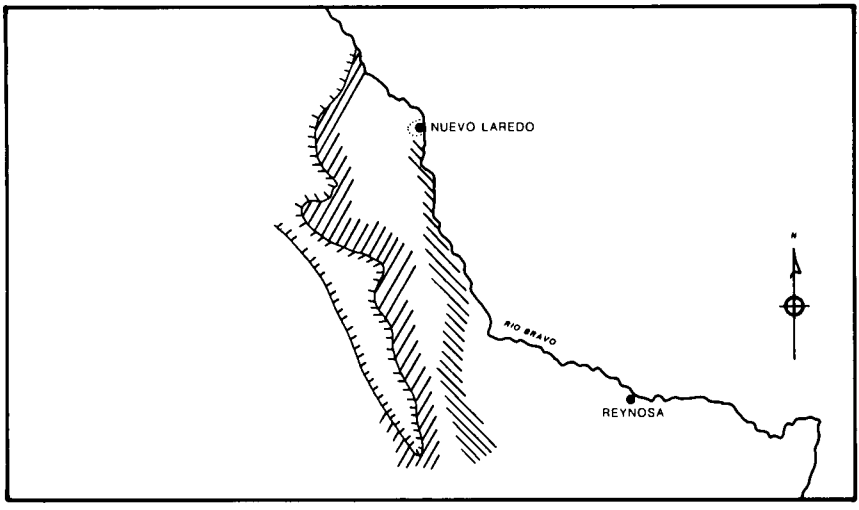

FIGURE 4. Jurassic Producing Trends in Tamaulipas–Nuevo León (modified from Madrid, 1976).

ico.[19] This platform was bounded to the southeast by an arcuate reef complex that can be followed from Nuevo Laredo to Monterrey (Cupido Trend) (Figure 5), and also extends to Texas, where it is called the Sligo Trend. This zone includes reef and fore reef facies. A parallel dolomitic band, the Padilla Formation, shows high porosities. Gas shows were found in the Cupido in the Anahuac and Totonaca Fields, where it lies very deep. The border region can be considered potentially productive from the Cretaceous.

The Tertiary sequence is a very thick accumulation of terrigenous sediments, deposited in shallow neritic to bathyal environments. This sedimentation reflects the sea level fluctuations occurring during the major regressive event that have lasted to the present time.

The principal deformation was produced by the Laramide orogeny; Paleocene and Eocene structures are parallel to the Sierra Madre Oriental. The whole region was later affected by normal faulting that gave rise to echelon blocks sinking to the east. The Tertiary producing trends form parallel bands diminishing in age from west to east (Figure 6).

Paleocene-Eocene

This thick sequence consists of shales and sandstones that were deposited on a low shelf during a regressive event interrupted by small transgressions.[20] The retreat of the sea left behind a system of sand bars parallel to the coast and large sand blankets. Growth faults gave rise to thick sand bodies. Post-depositional normal faults produced a system of blocks. The region was deformed in late Cretaceous, middle Paleozoic and late Eocene times. In this complex situation traps are both stratigraphic and structural. The effect of faulting is often combined with erosional unconformities. Due to the faulted blocks, many independent closures exist in each field.

More than fifty sand reservoirs have been identified; gas and condensates are produced. Many fields in Texas and Mexico produce from these reservoirs. The most important Mexican fields are located in the Nuevo Laredo area where gas is produced from the Paleocene Midway Formation; the structures are faulted anticlines. The greatest structure is Arcos, south of Nuevo Laredo.[21] Near Presa Falcon, fields located in

19. *See* Màrquez, Zàrate & Salinas, *Evaluación Económico-Petrolera de la Serie Coahuila en el Golfo de Sabinas y al E y Se del Elemento de "El Burro,"* in 3 SIMPOSIO DE GEOLOGÍA DEL SUBSUELO, REYNOSA 160 (1976).

20. *See* Echànove, *Geología del Paleoceno-Eoceno, Cuenca de Burgos*, in 3 SIMPOSIO DE GEOLOGÍA DEL SUBSUELO, REYNOSA 245 (1976).

21. *See* E. De la Fuente, Estudio Geologico de los Campos Petroleros Matamoros y Santa Fe, Localizados en el Estado de Tamaulipas (Universidad Nacional Autónoma México, Facultad de Ingeniería, Tesis Profesional, 1967).

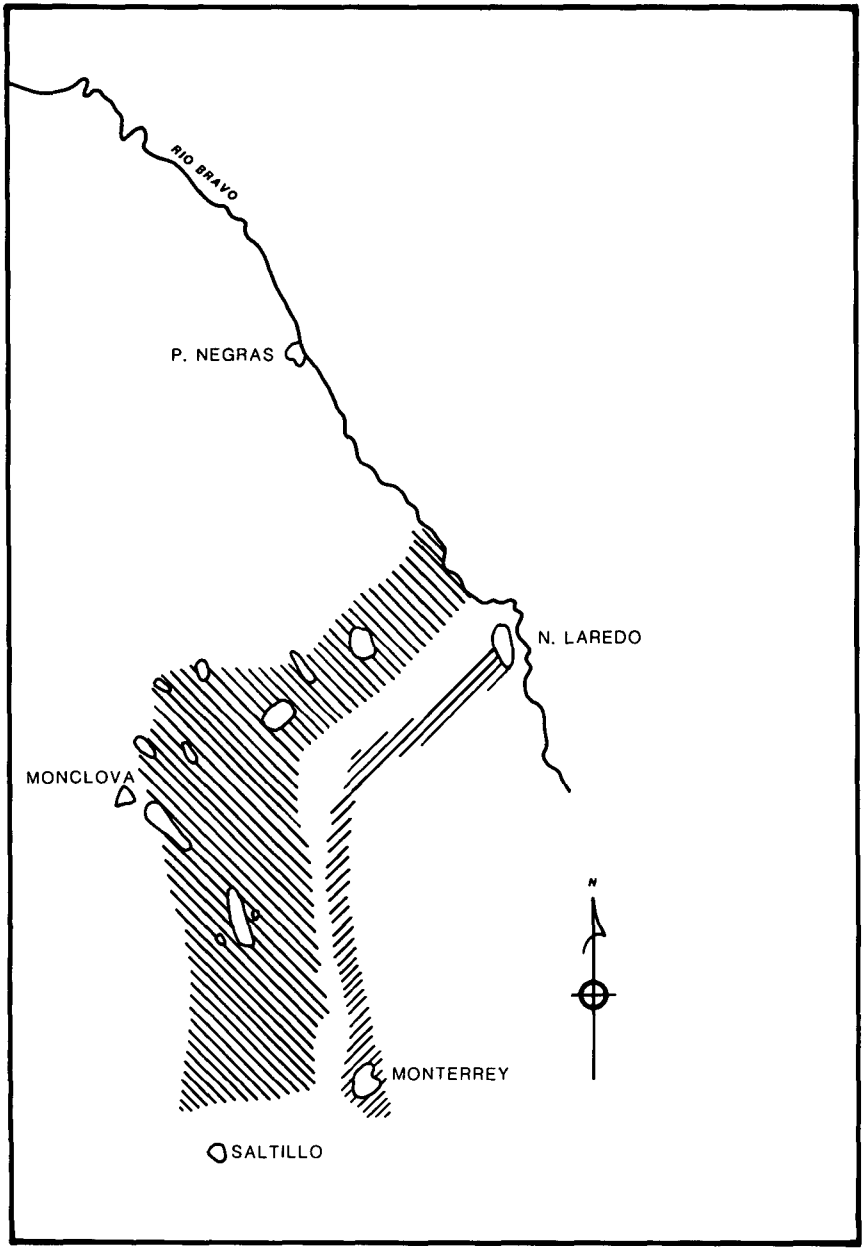

FIGURE 5. Lower Cretaceous Producing Trends in Northeast Mexico (modified from Márquez *et al.*, 1976).

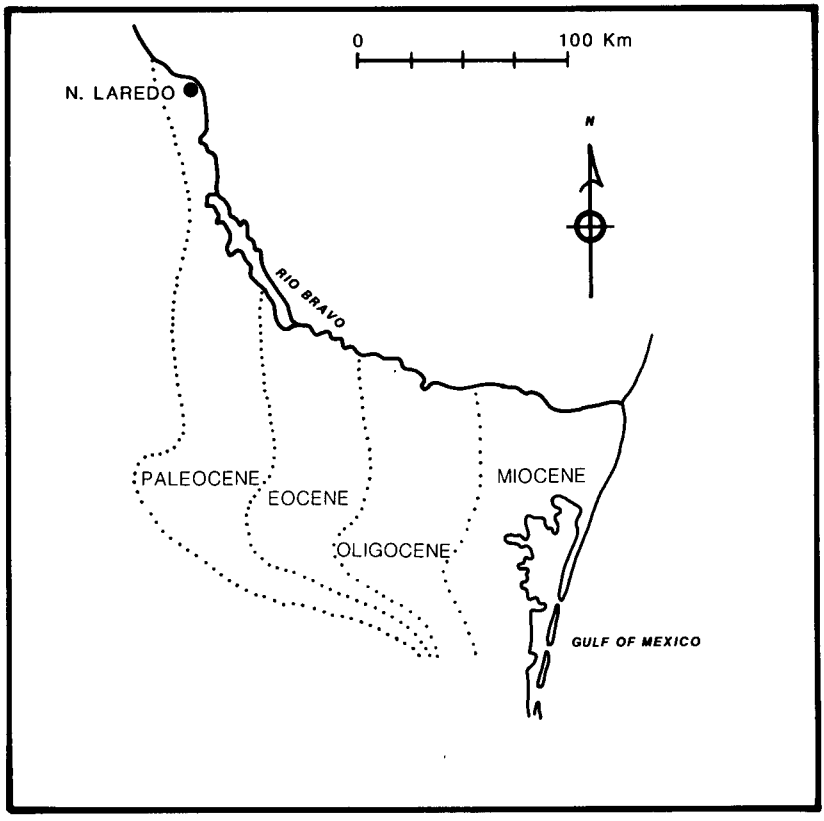

FIGURE 6. Tertiary Trends in the Burgos Basin.

Zapata County and in Mexico exploit the same reservoirs, though not the same structures. A case of transboundary deposit is represented by the Consolidated Field in the United States and the Jaujal Field in Mexico, where both countries exploit the same structure.

Oligocene

The Oligocene overlies the Eocene unconformably. The sedimentary sequence is non-marine to the west and marine to the east, shallow neritic to bathyal.[22] In early Frio time, in a complex of offshore bars growth faults caused the accumulation of sand in the fallen blocks, many of which show reverse dip. Post-depositional faults were active in late Oligocene time. The Oligocene strata form a faulted homocline with original

22. *See* Rodríguez & Bush, *Estratigrafia del Oligoceno de la Cuenca de Burgos: Estudio Regional*, 6 REV. INST. MEXICANO PETRÓLEO 16 (1974).

dip to the east. The sand bodies are the reservoirs, often bounded by faults.

The Oligocene is an important oil and gas producer. The principal field is the Reynosa Field, which produces from sandstone bodies; the structure is a fold bounded by a growth fault. The sandstones are separated by thin shale beds, thus giving rise to multiple reservoirs. The most important structure is located in Mexico; the corresponding fields in McAllen, Texas exploit the same deposits but different structures.

Miocene

Miocene outcrops cover a wide area of the Gulf Coast in Tamaulipas. The sedimentation is regressive, though in middle and upper Miocene some sea level fluctuations occurred. The Miocene sequence was deposited in quiet tectonic conditions and the structures are not significant. Growth faults predominate and post-depositional normal faults also exist. Wells drilled near the coast to a depth of 4,000 meters reached only the middle Miocene.

A small production was found in the Matamoros, Santa Fe, and La Luz fields (Figure 7). The fact that a thick sand section and hydrocarbons both exist gives hope for future exploration.[23] The Santa Fe structure is located near the Rio Bravo, northeast of Matamoros; the structure is an asymmetric anticline dislocated by faults.[24] The Vista del Mar field of Texas is located northeast of Santa Fe; its producing horizon can be traced into Mexico but shows little economic potential.

Gulf of Mexico Continental Margin

On the shelf and slope of the Gulf of Mexico Continental Margin a thick section of Tertiary terrigenous sediments overlies Mesozoic carbonates and evaporites. The Continental Shelf has a width of about ninety kilometers. Growth and normal faults are the predominant structures; some broad anticlines are produced by the movement of deep-seated clay masses. In the upper slope the Tertiary strata are uplifted by small salt diapirs. The lower slope is underlain by large salt masses separated by deep and narrow troughs filled with thick clastic deposits. The slope ends in the Perdido massif where large folds involve Cretaceous and Tertiary strata. The folds are believed to have a salt or shale core.[25] On the shelf, the information obtained from offshore Neptuno 1 well and from deep wells drilled on the Texan shelf reveal that the Miocene section is com-

23. *See* Gonzàlez, *supra* note 16.

24. *See* E. De la Fuente, *supra* note 21.

25. *See* Foote, Martin & Powers, *Oil and Gas Potential of the Maritime Boundary Region in the Central Gulf of Mexico*, 67 AM. A. PETROL. GEOL. BULL. 1047 (1983).

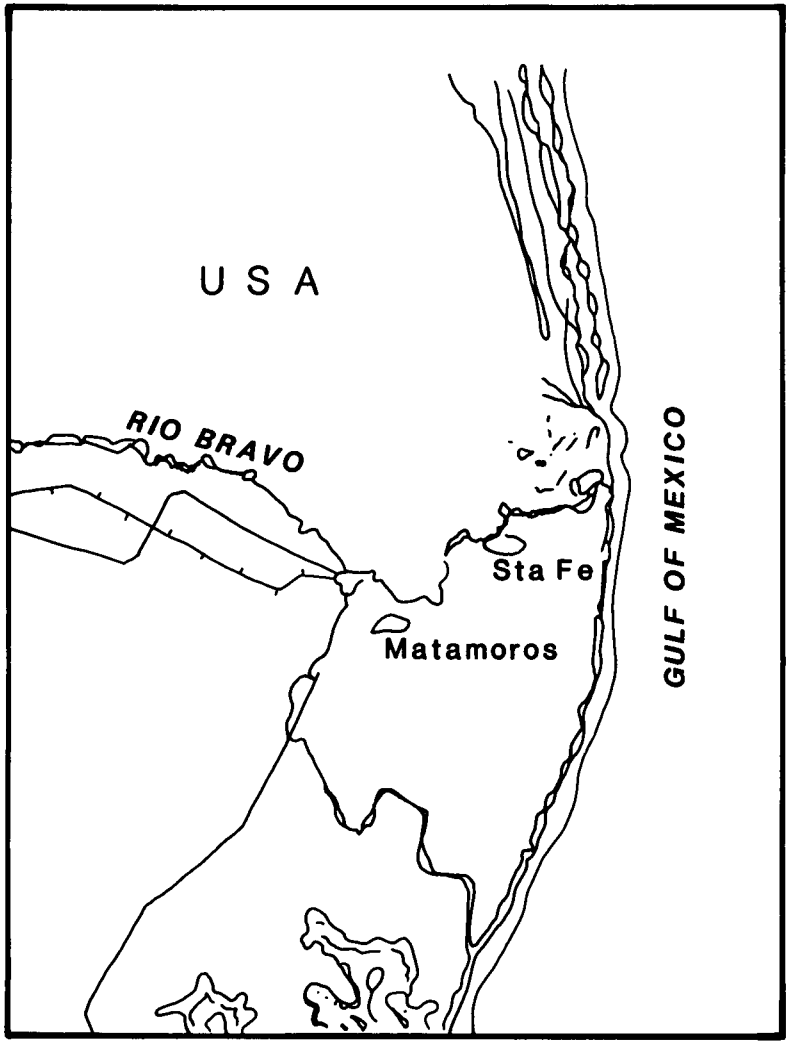

FIGURE 7. Miocene Fields in Tamaulipas (from de la Fuente, 1967).

posed mainly of shales, with irregularly interbedded sands.[26] Near the coast of Texas some wells have reached the Oligocene.

No hydrocarbons have been found on either side of the border. In offshore Texas the nearest production is found east of Corpus Christi, along the Corsair fault trend. Gas is produced from the Miocene and from the Oligocene Frio Formation.[27] This province is believed to contain large

26. *See* Gonzàlez, *supra* note 16.

27. *See* Raring, *Oil and Gas Development in South Texas in 1984*, 69 AM. A. PETROL. GEOL. BULL. 1595 (1982).

resources of gas which should have migrated from deeper regions through regional growth and normal faults. The shelf region should provide suitable traps, both stratigraphic and structural. However, the lack of large sand bodies may explain why the exploration in the border region has been unsuccessful to date.

If the continental slope is considered, the Tertiary filling of the troughs may contain both source rocks and reservoirs. It is known that the upper Tertiary has a good potential for gas, both biogenic and thermogenic. The traps should be amply provided by the diapiric intrusions and by the associated faults.

Although it is possible that hydrocarbon deposits may still be found on the shelf of the border region, they will more likely be discovered in the Tertiary basins of the slope. However, because of the great depth of water involved, whatever deposits are present are not considered to be significant.

Observations Regarding the Geology of the Northern Border Region

This rapid survey of the geology of the northern border region enables one to identify the localities where the existence of transboundary deposits is known and where they will be discovered with great probability in the future. It can be stated that: (1) transboundary deposits are known in the fields producing from early Tertiary rocks in the Nuevo Laredo area; (2) a number of fields on both sides of the Rio Bravo (Rio Grande) exploit the same reservoirs, though not the same structures; (3) the probability of discovering transboundary deposits is well founded in northeast Mexico, where the hydrocarbon production from Mesozoic and Tertiary rocks follows trends that extend on both sides of the border; and (4) in the other provinces of the northern border region, including both continental margins, the production of hydrocarbons is poorly developed, due either to difficulties in exploration or to unfavorable characteristics of the rocks. However, in some regions, especially on the continental shelves, a good potential for future exploration is believed to exist.

PROBLEMS IN EXPLOITING TRANSBOUNDARY DEPOSITS

Antecedents

There are no antecedents to coordinated exploitation of hydrocarbon deposits in Mexico, due to the fact that they belong to the nation, and that their exploitation is attuned to the interests of a single party, Petroleos Mexicanos (PEMEX). In the border region with the United States, the exploration and exploitation of hydrocarbons have been going on for more than a quarter of a century, but the authors are not aware of any case of unified or coordinated exploitation between the two countries.

The oldest exploited area is found in the Frontiera Noreste District of Petroleos Mexicanos, where the deposits consist mostly of dry gas and, in a minor quantity, of humid gas and condensate; the same conditions are found in areas of recent development of the District, namely in the Sabinas Basin. Although it is well known that the reservoir formations show a stratigraphic continuity across the borderline, the porous zones are lenticular and thin, and show little continuity from well to well. Consequently, few possibilities exist for any important hydraulic continuity across the dividing line. According to this historic background of the hydrocarbon discoveries in the border region, the discussion concerning their potential exploitation problems will be based on some properties of dry gas deposits.

Potential Exploitation Problems of Gas Deposits

The problems of a gas deposit exploited by different and uncoordinated or non-unified parties are fairly clear and derive from two principal aspects: (1) the original distribution of fluids in the reservoir; and (2) the migration of fluids in the reservoir during exploitation.

Original Distribution of Fluids

In general terms, a reservoir is constituted by a porous and permeable rock underlying an impervious formation. This couple is associated with a geologic accident, structural and/or stratigraphic, which hinders the escape of the hydrocarbons, brought to the site by the drag effect of the deep aquifers. Such a system has, from its origin, a high degree of heterogeneity, in all directions, of the parameters and characteristics which control two concepts of great importance: the storage capacity of the rock, and the flow capacity of the rock-fluid system. Consequently, two premises are drawn, with particular influence on the problems being discussed: (1) in a hydrocarbon deposit, there is no relationship between a given fraction of the total area of a reservoir and the fraction of the total volume of hydrocarbons contained under it; and (2) the flow rate of the hydrocarbons can be completely different from one point of the reservoir to the other.

Migration of Fluids

At the beginning of the exploitation of a deposit by the drilling of wells, the mass balance of the hydrocarbons is broken, due to the fact that part of it is extracted from limited zones which can be considered as points of very low pressure. The previously discussed distribution of the extraction points and the combined characteristics of the storage and flow capacity cause a larger or smaller quantity of fluids to move, more

or less easily, toward the extraction points in every zone. Macroscopically, this is represented by the migration of the fluids in the reservoir, taken as a continuous hydraulic system, and without taking into consideration the administrative limits on the surface. Some important premises resulting from these considerations are: (1) the volume of hydrocarbons which can be recovered from a given zone of a volumetric gas deposit has generally no relationship with the recoverable volume originally existing in that zone; (2) in general terms, the zones with the greatest density of wells will recover the greatest proportion of the volume originally contained in a gas deposit; and (3) the parts of a gas reservoir having wells with a high extraction rate may recover greater hydrocarbon volumes than the ones originally contained in them.

Alternatives of Coordinated Exploitation

The unified exploitation of a deposit is an operation technique which is adopted when such deposit is exploited by different parties. The most profitable exploitation, under the most equitable conditions, is desired.

The most profitable exploitation implies that, taking the deposit as a unit, the greatest recovery is obtained under the best economic conditions. Taking into account also the greatest equity, the former concept is transferred to each of the parties involved in the exploitation. Speaking of a unified exploitation involves the existence of a body which technically and economically manages the exploitation of a deposit, taken as an indivisible physical unit, and which represents a single interest, compounding the different interests of the parties.

Accordingly, the planning of the alternatives for the unified exploitation of a hydrocarbon deposit includes three basic aspects: technical, economic, and legal. The technical and economic aspects are strongly related, due to the fact that the technically recommended exploitation process in a given case may involve great investments in equipment, chemical substances, workovers, well conditioning and well completion, etc. At the same time, the different zones of the field may contain parts of the deposit which, following one or another exploitation process, increase or decrease in importance and value.

In general terms, other countries have carried on the coordinated exploitation of hydrocarbon deposits in the following ways: (1) taking as a premise the fact that a deposit is an indivisible, physical unit; (2) undertaking detailed reservoir engineering studies to determine the best technical exploitation scheme economically applicable to the reservoir as a unit; (3) unifying the different interests involved in the deposit by negotiation regarding the characteristics in each zone, regarding the importance of these characteristics in the development of the process to be

applied, and regarding the content of hydrocarbons and the quality of the reservoir rock; and (4) creating an entity for the technical and economical management of the exploitation of the deposit, through unified interests and through the process which the parties adopt.[28]

Conclusion and Recommendation

As identified in the first part of this article, the border region contains some important hydrocarbon deposits. Future economic production is foreseen in some areas, particularly northeast Mexico, and is not excluded in the deep offshore margins of the Pacific and the Gulf of Mexico.

The known cases of transboundary deposits occurring at the Mexico-United States border are not significant at the present, and apparently are being exploited locally by both countries' operators. However, due to the increasing potential of deep offshore technology it is in the interest of both parties to anticipate future problems that can arise as exploration and exploitation move into deeper marine areas, and to promote their solutions by developing a unified exploitation system which should favor the most profitable recovery from any transboundary deposit.

This exploitation system should be based on flexible legislation due to the multivariate character of oil and gas deposits. It should take into account joint economic planning and technical management of the deposit in view of providing equal profit to each partner of the agreement, preserving valuable resources and reducing environmental damage.

28. *See generally* Székely, *The International Law of Submarine Transboundary Hydrocarbon Resources: Legal Limits to Behavior and Experience for the Gulf of Mexico*, and Utton & McHugh, *An Institutional Arrangement for Developing Oil and Gas in the Gulf of Mexico*, in this volume.