

AAPG Memoir 90

Petroleum Systems in the Southern Gulf of Mexico



Edited by C. Bartolini and J. R. Román Ramos

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ON THE COVER: Church of the Virgin of Guadalupe in Real de Catorce, San Luis Potosi State in Central Mexico. The church was built in 1775 and is part of the old cemetery. The lower part of the hill exposes continental redbeds (red colors) of Early and Middle Jurassic age, whereas the white, upper part, of the hill consists of Upper Jurassic marine carbonates. Photograph by Claudio Bartolini.

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Calgary, Alberta T2P 1G7
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About the Editors



Claudio Bartolini is a Senior Exploration Geologist with the Repsol Regional Studies Group in Madrid, Spain. He first was involved in the exploration of deep and ultra-deep waters Gulf of Mexico Basin, and subsequently transferred to the Alaska Exploration Team. Claudio worked three years as an exploration geologist after he received his B.S. degree in geology from the College of Engineering, University of Sonora, Mexico. He earned a M.S. degree in geology from the Geosciences Department at the University of Arizona, and after graduation he worked for four years as an exploration geologist for Gold Fields Mining Corporation in Arizona, California and Mexico. In 1992, he enrolled at the University of Texas at El Paso, and earned a Ph.D. degree in geology in 1997, with a major in tectonics and sedimentary basins. Claudio was the recipient of a NASA Scholarship during the five years at the doctoral program. While pursuing his doctoral studies, Claudio worked as a consultant geologist in Mexico and Central America for Canadian exploration companies. After finishing his doctoral program, he joined ARCO International Oil and Gas Company, Latin America exploration group. Later, he was a basin researcher for IHS Energy in Houston, Texas. Claudio is the senior editor of the 1999 Geological Society of America Special Paper 340, *Mesozoic Sedimentary and Tectonic History of North-Central Mexico*. He also edited (2001) AAPG Memoir 74, *The Western Gulf of Mexico Basin: Tectonics, Sedimentary Basins and Petroleum Systems*, and more recently, AAPG Memoir 79, *The Circum-Gulf of Mexico and the Caribbean: Hydrocarbon Habitats, Basin Formation, and Plate Tectonics*. Claudio Bartolini maintains a strong interest on the Paleozoic and Mesozoic geology and tectonics of Mexico, with emphasis on sedimentary basins and petroleum systems.

Juan Rogelio Román Ramos is a leader of the geological petroleum system modeling at the Mexican Petroleum Company (PEMEX). He earned his B.S., M.S., and Ph.D. degrees as a Petroleum Geologist in Moscow, Russia between 1976 and 1987. He began his professional career in 1988 with the Mexican Petroleum Institute as a research scientist of the Enhanced Oil Recovery from tight and naturally fractured carbonated reservoirs. Simultaneously, he was teaching the Sedimentary Petrology class at the National University (UNAM), and was a member of the National Research System. In 1992 he joined PEMEX Exploracion & Produccion where he developed and supervised geochemical studies and geological modeling for the northern Mexican hydrocarbon basins, and participated in technologic transfer projects dealing with basin modeling and exploratory risk evaluation. From 1999 to 2004, Juan Rogelio was a Project Leader for the western Deepwater Gulf of Mexico where he supervised sampling programs leading to the geochemical characterization of hydrocarbons seeping from Gulf floor, data acquisition programs and geological interpretation. This latter project led to the delimitation of plays and the definition of the first drill locations in the Mexican Ridges and Perdido Fold Belt Deepwater Provinces. Since 2005, he has coordinated basin and petroleum systems studies for the Northern Regional Exploration Asset, creating the foundation for a better understanding of inter-regional 3D geological relationships, by modeling the generation and migration of hydrocarbons in the Tampico-Misantla, Burgos and Sabinas Basins, and relating them to the deepwater Gulf of Mexico. These studies have defined new areas with economically interesting petroleum potential. In 2006, he was elected as the Leader of the Integrated Network for Geological Modeling for Petroleum Exploration. Juan R. Román Ramos is an active member of the Mexican Petroleum Geological, Geophysical and Engineers Associations, where he has served as a Delegate President; Director of the Membership, and Technical Studies Commissions. He was recognized in 2006 as Distinguished National Expert. He has promoted affiliation with the American Association of Petroleum Geologists, has coordinated the visits of AAPG Distinguished Lecturers to Mexico, and has also collaborated in the organization of Joint AMGP-AAPG Conferences.

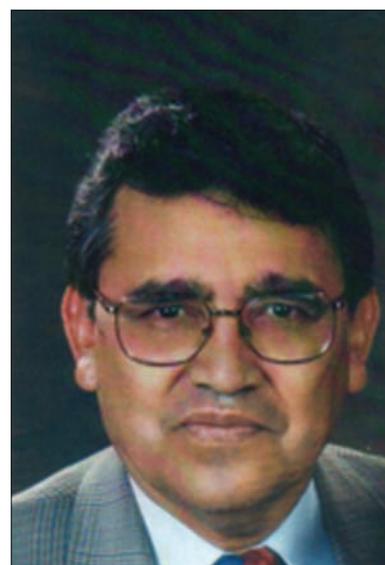


Dedication



Teodoro Díaz González (deceased) was born in Cerralvo, Nuevo Leon, Mexico on November 9, 1917. He earned his bachelor's degree from the University of Texas at Austin in 1940. Teodoro was among the pioneering geologists at Petroleos Mexicanos (Pemex) where he began as a geologist in 1940. He was geological party chief from 1942 to 1950, and was promoted to Chief Geologist for Pemex's north-east region from 1950 to 1966. He was promoted again to Manager of Subsurface Geology for the central exploration division from 1966 to 1967, and Senior Exploration Advisor from 1967 to 1973, the year he retired from Pemex. Teodoro implemented the systematic application of petrophysics to evaluate the petroleum potential of Jurassic and Cretaceous sequences in all the Mexican basins. Upon retirement, he became a valued consultant for Pemex and the Mexican Commission of Electricity. Teodoro was a member of the Mexican Association of Petroleum Geologists (AMGP), the American Association of Petroleum Geologists (AAPG), the Geological Society of America (GSA), the Mexican Geological Society (SGM), and the College of Geological Engineers of Mexico (CIGM). During his career his technical capabilities were recognized by participation in prestigious industry efforts, including committee member of the Cretaceous Symposium in the Western Hemisphere in 1956; leader for field trips during the XX International Geological Congress (1956); committee member for the Basement Map of North America produced by the AAPG and the U.S. Geological Survey in 1967; honorary committee member of the American Commission on Stratigraphic Nomenclature from 1966 to 1969; and the Martillo de Plata (the Golden Hammer) Medal awarded by the Mexican College of Geological Engineers and the Mexican Geological Society in 1997. Teodoro Díaz González published important national and international papers related to the petroleum geology of Mexico, including "The Geology of Northeastern Mexico," the University of Texas at Austin, in 1959; "Exploration and Production Results from the Offshore Extension of the Mexican Cretaceous Golden Lane," AAPG Annual Meeting, 1969; "Litología y correlación estratigráfica del Paleozoico Superior en la región de Palomas, Chihuahua, México," National Convention of Petroleum Exploration and Exploitation Engineers, AAPG, El Paso, Texas, November, 1961; and "Posibilidades petrolíferas de la región de San José de las Rusias a Sabino Gordo, Tamaulipas," First Mexican Petroleum Technology Convention, Mexico City, February, 1950.

Rafael Sánchez Montes de Oca (deceased) was born in Tuxpan, Veracruz, Mexico on May 10, 1938 and passed away in the city of Veracruz, Mexico on February 22, 2007. Rafael was a mentor and friend to many Mexican and visiting international geologists. He was a person with great human qualities including a fine sense of humor, a passion for geology, a love of fieldwork, and one who took joy in sharing his knowledge. He is survived by his wife, Lucina del Pilar Ferreiro Pérez, and children Leonardo Rafael, Lucina del Pilar, and Daniel Arturo Sánchez Ferreiro. Rafael completed his geological studies at the National Polytechnic Institute in 1960. In 1961 he was an intern in the Council of Non-Renewable Natural Resources where he completed his thesis entitled "The Surface Geology of the Mining District of Huautla, Morelos" which he defended that year, earning the title of Geological Engineer with Honors. Rafael joined the Southern District of Pemex in 1962 as an assistant field geologist, subsurface geologist and geological interpreter. From 1967 to 1974 he was the chief of a surface geology survey team and pioneered the use of satellite imagery for regional interpretation as part of a petroleum evaluation of the geologically complex and logistically challenging Sierra de Chiapas. From 1975 to 1981 Rafael was superintendent of geological operations for the Southern District of Pemex where he actively participated in the discovery of the Reforma and Campeche Sound oil fields. Between 1982 and 1989 he served as the general superintendent of exploration in Pemex's Northern and Southeastern Districts. In 1989 Rafael moved to Pemex headquarters in Mexico City where he was a leader in geological evaluation and planning until retiring in

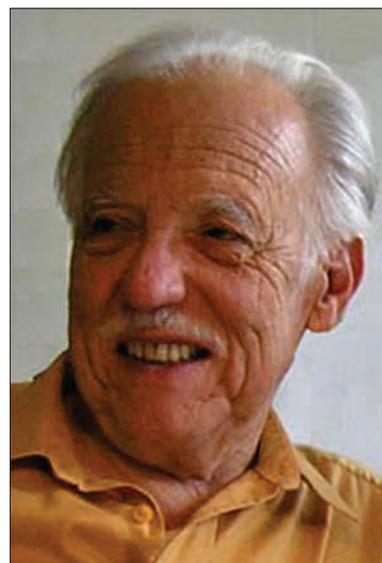


1996. After retiring he consulted for private companies, including holding the position of exploration manager for ICA in Colombia during 1998 and 1999. Between 2002 and 2004, in an assignment from which Rafael derived tremendous satisfaction, he was responsible for the Field Geology Training Program at the National Polytechnic Institute together with the Technical Exploration Group of Pemex. During this work, he authored five geological synopses of the Sierra de Chiapas, which encapsulated his unique understanding of this area. He continued as an advisor and mentor in the Technical Exploration Group of Pemex until late 2006. Rafael Sánchez Montes de Oca was a member of the Association of Petroleum Engineers of Mexico (AIPM), the Mexican Association of Petroleum Geologists (AMGP) where he served as National President from 1992 to 1994, and the American Association of Petroleum Geologists (AAPG). AAPG presented Rafael with its Special Commendation Award in recognition of his work benefiting the international community of petroleum geologists. In 2006, the Mexican Association of Petroleum Geologists recognized Rafael for his invaluable contribution and leadership in the formation of new geoscientists for the national petroleum industry, and who presently are the technical foundation of Pemex.



José Carrillo Bravo was born in Zapotitlan Salinas, Puebla, Mexico. After finishing high school he moved to Mexico City and enrolled in the National Polytechnic Institute where he earned a bachelor's degree in geology with honors in 1951, becoming one of the first geologists to graduate from that institution. José Carrillo worked for Petroleos Mexicanos (Pemex) from 1952 until his retirement in 1989 as exploration manager for integration and interpretation in Pemex's Subdivision for Primary Production. As a Pemex geologist, José first described the Paleozoic section of northeastern Mexico, particularly the Silurian, which was unknown until that time. He was the first to document and date Triassic and Jurassic continental redbeds in the Gulf of Mexico coastal region. He also proposed, and later proved, the existence of the Mesozoic Valles-San Luis Potosi platform, thereby confirming the existence of central Mexico's Mesozoic Basin. He was also the first to identify several Tertiary paleocanyons in eastern Mexico, and proposed and documented the existence of the regional Tertiary unconformity responsible for the migration and accumulation of oil along the western margin of the Gulf of Mexico. For many years, José Carrillo Bravo was responsible for reviewing, analyzing and documenting Pemex's exploratory wells. Additionally, for 26 years he was a part-time faculty member at the National Autonomous University of Mexico (UNAM) and the National Polytechnic Institute (POLI) where he is revered for his outstanding academic standards and distinguished lectures. José Carrillo Bravo has received a number of honors and awards, including Distinguished Member and former president of the Mexican Academy of Engineering (1987), the Geological and Petroleum Engineering National Award (1982), Honorary Member of the National Commission of Science and Technology (Conacyt) (1976), and the American Association of Petroleum Geologists (AAPG) Distinguished Service Award. He has been a member of AAPG since 1960. Selected publications of José Carrillo Bravo include "Exploración Petrolera de la Cuenca Mesozoica del Centro de México," 1982, *Bol. Asoc. Mex. de Geól. Petroleros*, v. XXXIV, n. 1, p. 21-46; "Paleocañones Terciarios de la Planicie Costera del Golfo de México," 1980, *Bol. Asoc. Mex. de Geól. Petroleros*, v. XXXII, n. 1, p. 17-55; "La Plataforma de Valles – San Luis Potosí," 1971, *Bol. Asoc. Mex. de Geól. Petroleros*, Vol. XXIII, n. 1-6, p. 1-102; "Estudio Geológico de una parte del Anticlinorio de Huayacocotla," 1965, *Bol. Asoc. Mex. de Geól. Petroleros*, v. XVII, n. 5-6, p. 73-96; "Geología del Anticlinorio de Huizachal Peregrina, al NW de Cd. Victoria, Tamaulipas," 1961, *Bol. Asoc. Mex. de Geól. Petroleros*, v. XIII, n. 1 y 2, p. 1-98; "Notas sobre el Paleozoico de la Región de Cd. Victoria, Tamps.," 1959, *Bol. Asoc. Mex. de Geól. Petroleros*, v. XI, n. 11 y 12, p. 671-680.

Abelardo Cantú-Chapa has had a distinguished career as a paleontologist with experience in the Mesozoic paleontology and biostratigraphy of Mexico. He has made important contributions to an understanding of the origin and evolution of the Gulf of Mexico, and to offshore Mesozoic stratigraphy. Abelardo earned his bachelor's degree in Mexico in 1956 at the University of Nuevo León and the National Polytechnic Institute. After two years as a micropaleontologist for Petróleos Mexicanos (Pémex), he studied sedimentology and sedimentary petrography at the University of Marseille, the French Petroleum Institute in Paris, and the University of Paris. In 1962, he earned his doctorate *Docteur ès-Sciences Naturelles* from the Université de France at the Sorbonne with a dissertation on the biostratigraphy of Upper Jurassic and Cretaceous ammonites of Mexico. His dissertation was published in the *Société Géologique de France, Memoire No. 99* (1963). He has published more than 100 papers and abstracts, with numerous presentations in national and international congresses. From 1962 to 1966, Abelardo was in charge of Pemex's macropaleontology laboratory, holding the same position at the Mexican Petroleum Institute from 1966 to 1989. He was chairman of the Geology Graduate Program at the National Polytechnic Institute from 1992 to 1995, and from 1995 to 2001 he served as its chairman of Graduate Studies and Research. Abelardo is the coeditor of the *American Association of Petroleum Geologists Memoir 75*, which was published in 2001. During his tenure at the National Polytechnic Institute, Abelardo directed 23 master's theses and 10 bachelor's theses on petroleum geology, mining geology, and geological risk, and he continues to serve on thesis committees. Over the years, Abelardo Cantú-Chapa received major research grants from the National Commission of Science and Technology (Conacyt) and the National Polytechnic Institute Division of Graduate Studies and Research to support petroleum and mining related research programs under his leadership. Abelardo has been recognized for his active participation in the Mexican System of National Research. His research has also been recognized by Mexican and international geological institutions. His specific awards include an honors diploma and the medal from the National Polytechnic Institute in recognition of 30 years of academic contributions; the Juan de Dios Batiz Award for 30 years of service to the National Polytechnic Institute; a diploma and prize from the College of Mexican Geological Engineers for his contributions to geology during the Twentieth Century; and an honorary membership in the College of Mining, Metallurgical and Materials Engineers. Recently, Abelardo's initiative to create the National Center for Geosciences and Hydrocarbons Administration was approved by both chambers of the Mexican Legislature. Cantú's most recent contributions to the petroleum geology of Mexico are included in this AAPG memoir.



Jaime Rueda Gaxiola graduated in 1961 as a geological engineer from the National Polytechnic Institute and then worked for the Natural Resources Commission until 1963. He earned his Ph.D. in geology at Lille University, France in 1967, graduating with honors for his dissertation on the palynology and petrography of coal in the Sabinas Basin. Jaime has pioneered the application of palynology and organic geochemistry to hydrocarbons exploration in the Mexican sedimentary basins and has received many honors for his life-long dedication to the geosciences, including member of the Scientific Committee of CONACYT in 1997; president of the Geosciences, Sea, and Atmospheric Sciences Committee of CONACYT in 1993; member of the Earth Sciences Committee of CONACYT in 1991; Lazaro Cardenas Medal and Award in 1989; National Research Scientist of SNI-SEP in 1988; and selection as one of 20 final candidates to be the first Mexican astronaut. Jaime is presently a professor at the College of Superior Education at the National Polytechnic Institute in Mexico City, where he has been teaching since 1972. Jaime was director of the College of Engineering and Architecture from 1986 to 1987, subdirector of the Geosciences Department from 1980 to 1983, academic coordinator for the Geological Engineering Division from 1975 to 1976, and chairman of laboratories in the Geosciences Department from 1973 to 1974. He has been the academic advisor for 32 bachelor's

theses and has also taught at the graduate level. He has trained petroleum professionals for Pemex, the Mexican Petroleum Institute, and the Venezuelan and Chinese petroleum institutes. Jaime has written three books on applied palynology, another on natural hazards, and 38 professional papers published in Mexican and international forums. He conducted 19 research projects for the Mexican Petroleum Institute between 1968 and 1999, and in 1978, he founded the Institute's Department of Palynostratigraphy and Organic Geochemistry. In 1979, he was a member of the scientific team aboard the Glomar Challenger studying the Gulf of California. Jaime Rueda Gaxiola has been a member of 13 professional societies, and, over the years, has served as vice president of the Association of Geological Engineers of the National Polytechnic Institute, vice president of the Mexican Association of Petroleum Geologists, vice president of the Mexican Geological Society, and vice president of the College of Geologists of the Mexican Republic. He continues to be a highly regarded geologist with expertise in Mesozoic palynology, palynostratigraphy, and organic geochemistry.



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Introduction

Claudio Bartolini

The petroleum geology of Mexico remains relatively unknown to the international geoscience community because of the limited number of articles published in international forums by geoscientists from Petroleos Mexicanos (PEMEX) and the Mexican Petroleum Institute. Sensitive Pemex data have traditionally been treated with strict confidentiality. Thus, in the realm of Mexican petroleum exploration over the last 70 years, the publication of Memoir 90 is a watershed event as the first international publication that is devoted exclusively to Mexican authors from the petroleum sector. In consideration of the confidentiality issues, cultural differences, and the language barrier, this pioneering volume is a tremendous achievement. We strongly believe that it sets an important and encouraging precedent for future international publications by Mexican geoscientists.

The 20 articles that comprise this book cover the onshore and offshore Mexican basins of the Circum-Gulf of Mexico Basin. Most of them have a multidisciplinary approach, with special emphasis on hydrocarbon exploration and petroleum geology. General subjects include petroleum systems, salt tectonics, structural geology, petroleum geochemistry, sequence stratigraphy, sedimentology, sediment provenance, play fairways, regional geology, biostratigraphy, and more.

In order to expand the geographic coverage of the original manuscripts submitted, we included four extended abstracts and one paper on the petroleum geology of Mexico, which were recently published by AAPG. These publications are a great complement to the diverse petroleum exploration topics covered in this volume. The extended abstracts and paper are placed at the end of the book/CD as complimentary chapters. We decided to provide the readers with both a book and a CD. The book will be entirely in color, as well as the CD, which also contains complete color versions of the articles for the convenience of our readership.

A large number of individuals contributed to the great quality of AAPG Memoir 90 in the form of their very constructive and accurate manuscript reviews. Our special thanks go to Joshua Rosenfeld, Angel F. Callejon, Gary Prost, Horacio Parent, Carlos Rivero, Francois Roue, Jon Blickwede, Mark Rowan, Abhijit Basu, Louis Liro, Scott Krueger, Thomas Buerkert, Carl Steffensen, Joe Cuariale, Mark Gordon, Emilio Garciacaro, Marc Edwards, William Ambrose, Jaap Klein, Carl Fiduk, Fred Diegel, Thomas Ewing, Arthur Berman, Terry Poulton, Mark Jiang, Christopher Denison, Norman Rosen, Pari Rosen, Ricardo Veiga, John Bacheller III, Peter Cobbold, Charles Winker, and Andrew Horbury.

Memoir 90 reflects a high degree of cooperation and a strong relationship between PEMEX and Repsol. Both companies have made a great effort to produce a book that will not only yield new insights into the petroleum geology of Mexico, but will also mark the beginning of a new era for PEMEX geoscientists.

We thank PEMEX for allowing the publication of articles related to the petroleum geology of Mexico, which will greatly benefit our geoscience community. Our appreciation goes to Antonio Escalera Alcocer, PEMEX subdirector of exploration in the southern region, for his encouragement and the support provided to Mexican geoscientists during the publication stages of the memoir.

We, the editors and authors, are grateful to Repsol E&P U.S.A. for being the sole financial sponsor of our volume and making possible the production of an affordable book for the Panamerican geoscientific community. We are particularly indebted to Jose C. Vicente Bravo, Repsol's North America exploration manager, who greatly encouraged the senior editor and supported this project from its inception.

We thank AAPG for their continued support of the geosciences. This book is another example of AAPG's relevant contributions to the geoscientists of the world.

The volume's editors are grateful to the authors for their dedication, hard work, and the extra effort required during the seemingly endless time-consuming tasks associated with manuscript preparation.

This book is dedicated with great respect to Abelardo Cantú Chapa, Jaime Rueda Gaxiola, and José Carrillo Bravo for their lifelong commitment to the geosciences

and for their important contributions to the petroleum geology, geological research, and academic advancement of Mexico. Our dedication also goes to Teodoro Díaz Gonzáles (deceased) and Rafael Sanchez Montes de Oca (deceased) for their contributions to the petroleum geology of Mexico and their pioneering exploration work at PEMEX.