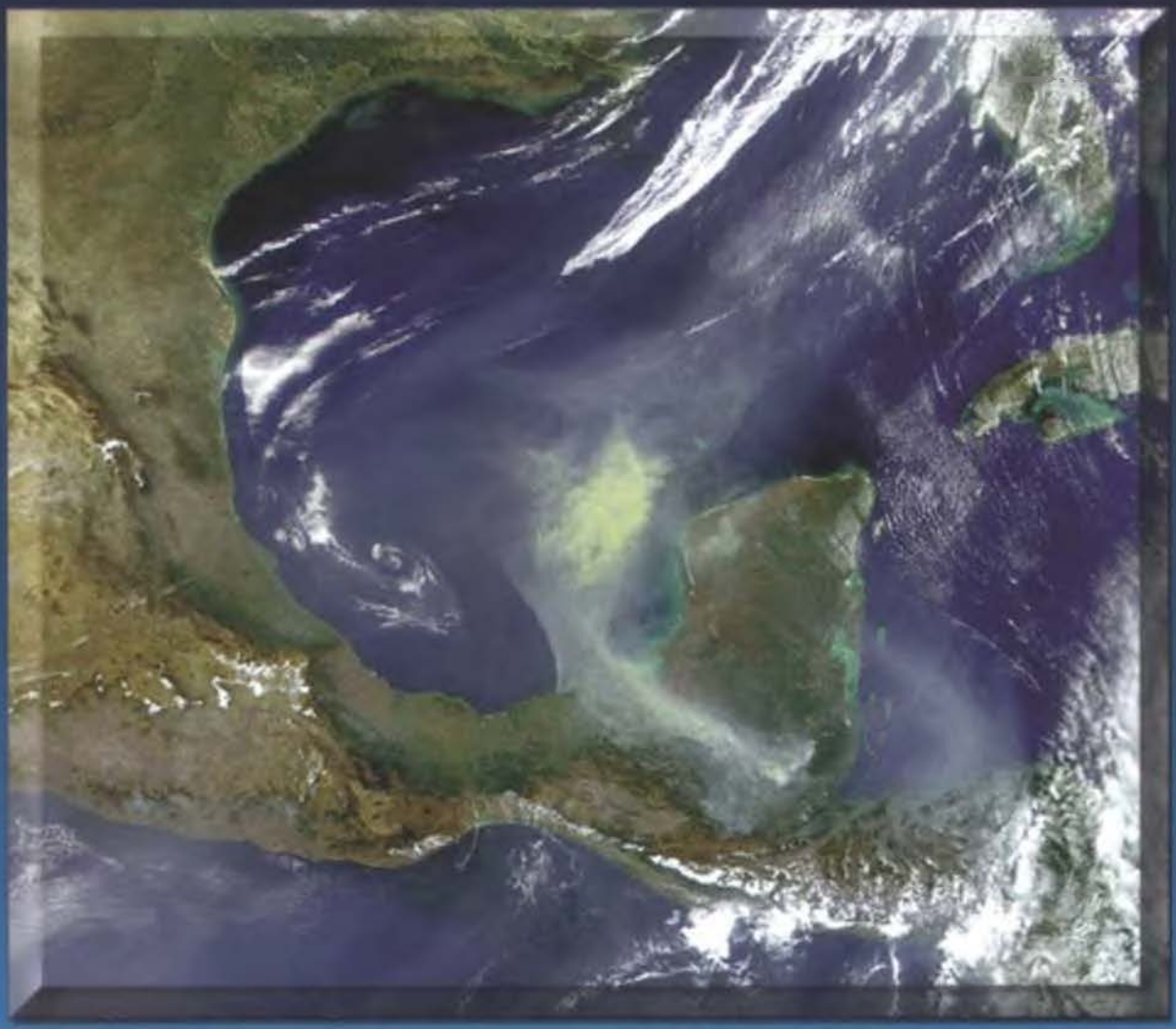
AAPG Memoir 75

The Western Gulf of Mexico Basin

Tectonics, Sedimentary Basins, and Petroleum Systems



Edited by
Claudio Bartolini, Richard T. Buffler, and Abelardo Cantú-Chapa

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Dedication

We dedicate this volume to the paleontologists of Mexico, the United States, and Europe for more than 50 years of important paleontologic and biostratigraphic contributions to the geology of the Mexican Republic. This particular group of professionals has provided valuable research to both academia and industry, particularly to Petróleos Mexicanos (PEMEX), the Instituto Mexicano del Petróleo, the Instituto de Geología, and to several departments of geology at different universities in Mexico.

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The Western Gulf of Mexico Basin

Tectonics, Sedimentary Basins, and Petroleum Systems

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About the Editors

Claudio Bartolini received his B.S. degree in geology from the University of Sonora, Mexico. He earned an M.S. degree in geology from the University of Arizona, and after graduation worked for four years as an exploration geologist for Gold Fields Mining Corporation in Arizona, California, Nicaragua, and Mexico. Subsequently, he enrolled at the University of Texas at El Paso, and earned a Ph.D. in geology (tectonics and sedimentary basins) in 1998. After finishing his doctoral program, he joined ARCO International Company, Latin America exploration group. Bartolini is the senior editor of the 1999 Geological Society of America Special Paper 340, *Mesozoic Sedimentary and Tectonic History of North-Central Mexico*. He has organized several symposia on the geology of Mexico, and is one of the founders of the new Latin American Association of Earth Sciences (www.alacit. org). He has focused his research on the Paleozoic and Mesozoic regional geology, plate tectonics, and sedimentation of Mexico. Bartolini is presently employed with the IHS Energy Group in Houston, Texas, where he is involved in research on oil and gas fields in Mexico, Central America, and the Caribbean.

Richard T. Buffler received his B.S. in geology from the University of Texas at Austin in 1959 and his Ph.D. in geology from the University of California, Berkeley, in 1967. After short stints with Shell Oil Company, Shell Development Co., and the University of Alaska, he joined the University of Texas Institute for Geophysics (then located in Galveston) in 1975 as a research scientist. Shortly thereafter, he joined the faculty of the Department of Geological Sciences in Austin. While in Galveston, Buffler began his career as a marine geologist/geophysicist, as well as his long-term work on the geologic history of the Gulf of Mexico Basin, which he continues today, based in Austin. His most recent Gulf projects involve an industry-sponsored basinwide synthesis of the Cenozoic history of the basin and a geophysical study of the Chicxulub K/T impact crater on Yucatán. He also recently has returned to his land roots with geologic field projects in Eritrea, Eastern Java, and northern Mexico and along the New Mexico/Arizona border.

Abelardo Cantú-Chapa is a Mexican paleontologist with experience in the paleontology and biostratigraphy of Mexico. He earned his bachelor's degree from the University of Nuevo León and the Instituto Politécnico Nacional in 1956. After two years as a micropaleontologist, working in the Burgos Basin for Petróleos Mexicanos (PEMEX), he studied sedimentology and sedimentary petrography at the Maritime Station d'Endoume of the University of Marseille and the French Petroleum Institute in Reuil Malmaison, Paris. In 1962, he earned his doctorate from the Université de France at the Sorbonne in Paris with his dissertation on the biostratigraphy of Upper Jurassic and Cretaceous ammonites of Mexico. On returning to Mexico, Cantú-Chapa was appointed director of the Macropaleontology Laboratory at the Instituto Mexicano del Petróleo. There, he was responsible for the study of Mesozoic ammonites of Mexico. From 1966 to 1987, he was a research scientist at the same institute, where he continued his studies of ammonites and of core and cuttings samples from PEMEX wells. Cantú-Chapa is currently chairman of the Graduate School of Geology and professor of paleontology and stratigraphy at the Instituto Politécnico Nacional in Mexico City. A specialist in Mesozoic ammonites, he has published numerous stratigraphic studies, utilizing logs and core and outcrop data for most regions of Mexico. He has also published a systematic study of Mexican Paleozoic cephalopods.

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Introduction

The Gulf of Mexico Basin is one of the best-known and most highly explored petroleum basins in the world. The literature on the basin is enormous and continues to grow each year. The deep-water part of the basin is now one of the most prolific new provinces in the world, and it is the continued focus for oil and gas exploration. Here the industry leads the world in the application of modern drilling and production techniques. Despite all this focus on the Gulf of Mexico Basin and its successes, there is still a noticeable gap in our knowledge about a major part of the basin that lies primarily in Mexico. The literature about the geology and petroleum aspects of this part of the Gulf Basin has been sparse and slow in coming, despite some excellent work over the years by academic and petroleum workers in Mexico. This is a result partly of the proprietary nature of much of the work in company files. This attitude is now changing in Mexico, and we believe that this volume represents a milestone toward sharing some of this excellent new work with the world community. We are proud that AAPG can be part of this endeavor.

We have assembled in this memoir for the first time a set of papers that focuses entirely on the Mexican part of the Gulf of Mexico Basin. These papers provide an enormous amount of new data on all aspects of this part of the basin, ranging from structure to stratigraphy to petroleum geology, and they represent a major new contribution to the overall geology of the Gulf of Mexico Basin. Perhaps the most important contribution of this volume is that 13 of the papers are direct contributions from Mexican authors, including papers by members of PEMEX (the Mexican national oil company), the Instituto Mexicano del Petróleo (IMP), the Instituto de Geología from Universidad Nacional Autónoma de México, and the Instituto Politécnico Nacional. Also of major significance as a volume from the AAPG is the common thread that runs through most of the papers, which is the understanding of petroleum systems in Mexico and the implications for exploration and production.

The 21 chapters of this volume are grouped into five general topics: regional studies, structural geology, sedimentary basins, stratigraphy, and oil and gas fields. The papers in each topic are arranged stratigraphically, from oldest to youngest. Although only certain topics may be of specific interest to some readers, there is overlap between topics.

First are five papers of regional importance, including a new look (Cantú-Chapa, Chapter 1) at the early Mesozoic history of the Gulf as a major province of the Pacific realm, prior to its formation and opening in the latest Jurassic. Next is a geophysical look (Bartolini and Mickus, Chapter 2) at the northeastern part of the basin, which allows the delineation of crustal blocks that can be interpreted in terms of both the late Paleozoic to early Mesozoic history of the region as well as the later Laramide deformation. The next paper in this section is a massive synthesis of both the southern and western margins of the basin by Goldhammer and Johnson (Chapter 3). This paper compiles a huge amount of data from both Mexican outcrops and the literature to present working models for the Mesozoic reconstruction of these large areas, documented by sets of paleogeographic maps. This paper is destined to be the definitive synthesis of these areas for a long time to come. The fourth regional paper (Magoon et al., Chapter 4) is a summary of the southern Gulf of Mexico petroleum system. It discusses source rocks; the generation, expulsion, and migration of hydrocarbons; and the traps and reservoirs of this huge and complex system. It concludes with estimates of the enormous undiscovered reserves (23.3 billion barrels of oil and 49.3 trillion cubic feet of natural gas) and future potential global impact of this huge area. The fifth paper (Guzmán et al., Chapter 5) is an overview of the petroleum geochemistry of oils from different basins and subbasins in the Gulf of Mexico Basin. The authors present the geochemical characterization of a wide selection of the produced oils in the petroleum provinces of the Mexican Gulf Coast region. Biomarker and isotope data establish the distinction of five major genetic groups, which were derived from a wide range of ages and types of source rocks.

The second set of three papers focuses mainly on regional structural provinces and periods of deformation The first two (Carrillo et al., Chapter 6; Gray et al., Chapter 7) are concerned with the evolution of the Sierra Madre Oriental Laramide fold belts in the northwestern basins, including their burial history. Of particular significance is the documentation of their subsequent uplift and exhumation, a little-known part of the history of northeastern Mexico. The third paper (Meneses-Rocha, Chapter 8) deals with the complex tectonic history of the southern margin from the Mesozoic through the Cenozoic, which combines at different times all three types of plate motions—extensional, strike-slip, and contractional deformation. This complex deformational history, which continues today, greatly influenced the hydrocarbon systems in this part of the world.

Next we have three papers that discuss new data about the structure and stratigraphy of three major basins of eastern Mexico, all with different histories. The La Popa Basin (Lawton et al., Chapter 9) is the most fascinating, because salt domes are exposed in outcrop, and here the complex history of these structures and their influence on sedimentation can be documented. Following is a paper by Equiluz (Chapter 10) on the Sabinas Basin just to the north, an area with significant gas potential, and on which almost no new data have been published in many years. Prost and Aranda (Chapter 11) discuss

the Veracruz Basin, a major hydrocarbon basin to the south. Included are some new ideas about the evolution of the basin, as well as a presentation of its petroleum systems.

Eight papers (several authors, Chapters 12–19) deal with different aspects of the Triassic through Cenozoic stratigraphy of the region. Included are work based on outcrops and, most importantly, new subsurface and well information not previously available. The papers apply modern sequence-stratigraphic principles, although there are different approaches to how the Mesozoic is subdivided, i.e., by unconformities or by regional transgressions. Several papers provide new surface and subsurface biostratigraphy and paleontology (both micro as well as macro) for the region. Of particular significance in many of these papers are not only the regional but also the global implications of some of the new data presented. The final two papers (Martínez-Castillo, Chapter 20; Williams-Rojas and Hurley, Chapter 21) are about specific oil and gas fields, with particular reference to understanding the reservoirs of these fields in southern Mexico.

Unfortunately, these 21 papers represent only part of the new works we had hoped to include. There are many more studies and papers in progress, which we hope will be published soon as complements to this volume.

Perhaps one of the most interesting revelations of this volume and one of its most important overall conclusions is that the Gulf of Mexico Basin is not strictly a passive margin, as most models have traditionally implied. It becomes extremely clear that the structural and stratigraphic history, particularly of the western margin, as outlined in this volume, has been enormously influenced by the Pacific active-plate margin realm. This influence began with the Triassic and Jurassic arc systems to the west, and it continues today with the effects of the active Polochic-Motagua plate boundary to the south and the Late Cenozoic uplift along eastern Mexico. These Pacific tectonic influences, combined with the passive-margin salt and shale tectonics and gravity systems such as the Peridido and Mexican Ridges fold belts, make the western Gulf of Mexico Basin one of the most complex and fascinating basins in the world.

This volume complements the recently published Geological Society of America Special Paper 340 on the Mesozoic geologic evolution of north-central Mexico. Most of the papers in this volume focus on the evolution of eastern Mexico and the Gulf of Mexico coastal and offshore regions, whereas the Special Paper included a variety of papers on the onshore geology of the north and central parts of the country. The one exception in this book is the paper by Goldhammer and Johnson, which overlaps with their paper in the GSA Special Paper. Their GSA paper emphasized the facies and cyclicity of the Mesozoic carbonates. It included details on facies (sedimentary structures, grain types, etc.) and also dealt with high-frequency cycles and third-order sequences. Their paper in this volume, on the other hand, is concerned strictly with second-order sequences and regional paleogeography. Although there is some overlap, we believe it is important to include this major synthesis in this volume to make it available to the AAPG readership.

Finally, it is a great pleasure to have contributed to the petroleum geology of Mexico and the Gulf of Mexico Basin. We hope this memoir will serve as a source of inspiration for future geologic research and petroleum exploration in this complex but enchanting region of North America.

Claudio Bartolini
Richard T. Buffler
Abelardo Cantú-Chapa