

The Middle and Late Jurassic Intrashelf Basin of the Eastern Arabian Peninsula

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Preface

This Memoir presents an integrated interpretation of the Callovian through Tithonian history of the Arabian Intraself Basin, a single rimmed intrashelf basin extending from northeastern Saudi Arabia to Oman, from the Saudi Arabia Jurassic outcrops in the west to off-shore Saudi Arabia, Bahrain, Qatar and Abu Dhabi. Because knowledge of the intrashelf basin evolved from work which began in the 1930s in different countries and companies, stratigraphic nomenclature, age dating and other interpretations differ across the intrashelf basin region. This Memoir reviews and re-evaluates these varied interpretations, to reconcile differences and provide a comprehensive geological scenario for the evolution of the intrashelf basin.

Some of the interpretations in this Memoir are presented as strong conclusions, others as hypotheses that need further evaluation. Data in the Arabian Peninsula are closely held by the various countries and companies. The interpretations in this Memoir are confined to those which can be specifically referenced and supported by published data. Fortunately, sufficient published data are available to support a comprehensive regional interpretation. The chapters in this Memoir are subdivided into standalone geologic topics, instead of each chapter being focused geographically on a particular portion of the Arabian Intraself Basin.

Impetus for this Memoir began when I, with no prior knowledge of Middle East geology, went to work for Aramco in Dhahran in 1973, and had the good fortune to be assigned to work with a Chevron research geochemist on a major project to define source rocks in the Aramco areas for the first time. This project spanned four years and identified the late Callovian–early Oxfordian carbonate source rocks as the principal source of the Saudi Arabia Jurassic oils. The mapping of the extent of these source rocks defined the intrashelf basin within the main Aramco area. Petrographic study of core and thin sections from the source rock showed its unique character. After choosing to leave Aramco in 1981 and become an independent consultant, I carried away more questions than answers. There was a basic understanding of the intrashelf basin depositional geometry, but many questions remained regarding its regional extent, the origin of the organic matter and the unique character of the source rock, and the controlling factors of the Late Jurassic carbonate evaporite intervals, among others.

Later, a consulting project in another area on wells extending from within the intrashelf basin to the basin rim showed the basic intrashelf basin geometry. Three main sequences (Tuwaiq, Hanifa and Jubaila

Arab-D) in the most updip setting were almost entirely in shallow water facies, prograding and thinning basinward. That project helped to explain the nature and trend of the basin rim, and the transitions into the basin.

A series of multi-client projects covering Iraq and Syria studying the many thousands of thin sections in the Iraq Petroleum Company (IPC) Middle East Archive at the University of Reading showed how very different the Jurassic in the Gotnia-Mesopotamian Basin is from the Jurassic in the Arabian Intraself Basin, even though the two are only separated by the shallow water facies of the 100 km wide Rimtham Arch. (These projects were in partnership with PGA, Ltd. (www.pgal.co.uk) and the University of Reading, working with colleagues Grenville Lunn, John Scott, Mick Storey and Professor Bruce Sellwood.)

Still other projects outside the Middle East: in the Williston Basin, Gulf of Mexico rim, East Texas Basin, Sunniland, offshore West Africa, and many others showed, by comparison, how unique the Arabian Intraself Basin history was, in its origin, its source rock interval, its sequence infill, and its culmination in the Arab-Hith carbonate reservoirs and regional anhydrite seals.

My efforts to put together a comprehensive interpretation of the Arabian Intraself Basin began with preparation for seminars on the geology of the Eastern Arabian Peninsula in cooperation with former Aramco Chief Geologist Folke Johansson's Arabian Gulf Exploration Consultants. Interaction with participants, responding to questions raised and challenges made to the ideas presented, helped identify aspects that needed to be delved into more deeply. Conversations with Shaun Perkins at Conoco led to obtaining funding to prepare a summary, with assistance from their librarian in acquiring a comprehensive set of papers on the region. That summary led to further seminars and consulting for various companies, where often still more questions were raised, all of which contributed to refining this regional synthesis.

Another pastime, sailing and making offshore passages including transatlantic required learning more about oceanic weather, global wind patterns, and climatic belts. Seeing variation in oceanic weather first-hand led to questioning what were the palaeolatitudes during the evolution of the Arabian Intraself Basin and how that impacted its evolution. The conclusion is that palaeolatitudes, palaeo-wind directions and strength were all important factors, which are incorporated into these interpretations.

Acknowledgements

For many years, publications on the geology of the Arabian Intraself Basin area were sparse. That changed dramatically in the early 1990s when Dr Moujahed Al-Husseini left his position as exploration manager in Saudi Aramco in 1992 to establish Gulf Petrolink, whose goal was to facilitate the flow of geologic knowledge in the Middle East region. Gulf Petrolink initiated *Geo94* and published all the papers presented and continued organizing Geos, which still are held biannually in Bahrain. Gulf Petrolink soon afterwards began the rigorously peer-reviewed journal *GeoArabia* (1996–2015) and several special publications. Concomitantly, perhaps inspired by *GeoArabia*, many other papers were published in other journals and special publications. When the price of oil and natural gas fell, industry funding for *GeoArabia* ended and publication ceased in 2015.

This Memoir would not have been possible without the vast data published by Gulf Petrolink. This Memoir began as an article submitted to *GeoArabia*. Three anonymous reviewers (one Saudi, one Dutch and one British) encouraged publication, but first wanted much more in-depth coverage of the topics raised. Their requests required considerable expansion. In 2015, it was on track to be published in 2016 when funding was lost. Moujahed Al-Husseini, however continued to be supportive and helpful, giving specific permission to use any data published by Gulf Petrolink (<https://pubs.geoscienceworld.org/gpl>).

Meanwhile, by personal request in late 2015, David Boote (retired international chief geologist of Occidental who I knew was talented in asking penetrating questions requiring more thought) and former Aramco colleague Martin Ziegler (who published in 2001 a comprehensive summary of Middle East geology) both agreed to read the paper. Martin did so while recovering from a knee replacement, frequently summoning nurses to pick up pages which slid off the bed. Martin proposed a subdivision of chapters, along with other helpful comments. Both recommended an introductory summary, which Chapter 1 in this Memoir supplies. The intent of Chapter 1 is to present the setting and interpretations of this Memoir, so that readers will be able to evaluate these while reading through the data and interpretation chapters.

After *GeoArabia* ceased publication, geologist Peter Dolan suggested to Angharad Hills that the Geological Society of London consider publication. The proposal was accepted, and Mike Simmons and Mike Steensen were chosen for the text-only review. Both recommended publication as a memoir. The full draft, revised to memoir format, was reviewed by Andrew Horbury and Franz van Buchem. Their very helpful suggestions and those of Technical Editor Nick Richardson were addressed, a revision was submitted, which was reviewed again by Horbury, van Buchem and Technical Editor Gabor Tari and accepted.

Working with the Geological Society editors has been a pleasure. Angharad Hills, and after her retirement, Bethan Phillips have been very encouraging and supportive, responding quickly to questions. Production editor Samuel Lickiss has also been very helpful, as well as others who worked behind the scenes. This has been especially impressive because the last few months they have all been working from home during the Covid-19 lockdown.

Professor John McArthur (University College of London) kindly read the section reviewing published $^{87}\text{Sr}/^{86}\text{Sr}$ numeric age dating and made many suggestions providing guidance and references to help evaluate the reliability of the published $^{87}\text{Sr}/^{86}\text{Sr}$ numeric age dating.

Thanks are due to the permissions staff in several organizations and companies who freely granted permission to use published material. These include: *American Association of Petroleum Geologists*, *Society of Sedimentary Geology (SEPM)* and the *Gulf Coast SEPM section*, *Canadian Association of Petroleum Geologists*, *Journal of Petroleum Geology*, *Geological Society of America*, Elsevier, Springer-Verlag, Wiley, Cambridge University Press, Swiss Museum Paleobiologie, *Society of Petroleum Engineers*, Colorado School of Mines, and of course, the *Geological Society of London* Publishing House. Said Al-Hajri, Saudi Aramco Technical Services Manager, approved use of some old photomicrographs representative of facies in the area, but with no specific locations to be given. Dr J. E. de Matos gave permission to use data from his dissertation. (Any further use of data from these sources requires permission from these publishers.)

Gratitude is owed to Roger Alexander, Aramco chief geologist in 1973, who commissioned the source rock study and assigned this author to work with Chevron geochemist Loren 'Slatz' Slentz on that project. Slatz's dedication and practical approach to source rock evaluation made working on the project a pleasure. Walter Dell'Oro encouraged revising a set of regional isopachs building upon a model derived from one interval, which helped in recognizing the existence of the Arabian Intraself Basin. Other Aramco colleagues owed gratitude include Bill Rogers, R.M. Christensen, Sadad Al-Husseini and many others. Earlier inspiration and opportunities were given by my PhD advisor Daniel Textoris at the University of North Carolina (UNC) and Professor John Dennison (first at the University of Tennessee, later at UNC). The good fortune to be one of ten graduate students in 1968 to participate in Robert N. Ginsburg's carbonate research seminar in Bermuda led years later to an invitation by him to write a paper on the Qatif field for the 1985 Carbonate Reservoirs volume, which also provided important data for this Memoir. A nine-month postdoctorate at the Kansas Geological Survey, with Daniel Merriam and Phil Heckel, provided experience with carbonates in Pennsylvania cyclothem and an attempt at modelling repetitive carbonate facies variation in the cycles. My first exposure to the petroleum industry was in a domestic new ventures group in Amerada Hess and being given responsibility for the Basin and Range Province. This led to generation of a high risk prospect in NW Utah, adjacent Permian potential carbonate reservoirs and potential Oquirrh Basin source rocks, which required extensive field work, source rock analyses, aeromagnetics and a later seismic survey in that very remote, unexplored region where only one shallow well had been drilled. (End result was a very dry hole!) That experience with source rock evaluation was why I was hired to work on the Aramco source rock project.

I owe much to my wife Helen, not a geologist, but who in her law career learned to skilfully and meticulously read strange documents. Over the past six years, she has patiently and thoroughly read and reread every draft many times as well as the final proofs, and was always able to find details to be improved and typos to correct.