[PS]Reservoir Character of Carbonate/Evaporite Oil Fields of the Middle East, a Response to Depositional Setting and Accommodation Space*

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Abstract

Most of the Arabian Gulf major oil and gas fields are from the Permian through Tertiary are sequestered in carbonates and sealed by evaporites formed under arid to semiarid conditions. The field style can be classified based on a sequence stratigraphy framework, depositional setting and facies hierarchies. This framework of erosional and flooding surfaces was formed by base-level change driven by epeirogenetic tectonic movement and eustatic history. This template is populated by a diversity of depositional systems, and facies geometric architecture but interestingly these reservoirs are commonly within wide spread continuous sheets that tend to shoal up on carbonate shelves. These range from grain to muddy carbonates. Reservoir character ranges from depositional fabrics to diagenetic, the latter often related to dolomitization. The porosity may be interparticlal and intercrystalline and/or leached often over 25% with permeabilities of over 100mD related to preserved primary fabrics and early secondary porosity. The seal is nearly always evaporite (e.g. Hith and Lower Fars) or tightly cemented dolomite and limestone, all of which provide a regional caprock on major fields.

Examples include reservoir in fields of Permian, Triassic, Jurassic, and Tertiary of Iraq, Syria, Iran, Kuwait, Saudi Arabia, Bahrain, Qatar, UAE, Oman and Yemen. For instance Kirkuk (bioherm and foreslope), Jambur (shallow marine), Gachsaran (shelf wackestones and packstone), Wafra (shallow water carbonate), Ghawar, Awali, Umm Shaif, Zakum, Yibal, Dukhan, North Field, and South Pars (wackestones, to grainstones often dolomitized), and several others.

References Cited

Al-Husseini, M.I., 1997, Jurassic sequence stratigraphy of the western and southern Arabian Gulf: GeoArabia Manama, v. 2/4, p. 361-382.

Al-Husseini, M.I., 2000, Origin of the Arabian Plate structures; Amar collision and Najd Rift: GeoArabia Manama, v. 5/4, p. 527-542.

Al-Jallal, I.A., A.S. Alsharhan, and H.S. Talu, 1995, Similarities and dissimilarities of the depositional environments between the Permian Khuff Formation over Arabia and the Recent sedimentation over the Arabian Gulf: United Arab Emirates University, Desert and Marine Environment Center Al Ain, United Arab Emirates, p. 60.

Alshahran, A.S., and C.G. St.C. Kendall, 1986, Paleozoic to Early Mesozoic Facies, depositional setting and hydrocarbon habitat in the Middle East: an overview and some play concepts: AAPG Bulletin, v. 70, p. 977-1002.

Al-Sharhan, A.S., and A.E.M. Nairn, 1989, Cretaceous rudist buildup forms giant fields in Arabian Gulf: 28th International Geological Congress, Washington, Abstracts, v. 1, p. 35.

Corrigan, D., and S. Hanmer, 1995, Arc accretion, crustal thickening, post collisional extension and plutonism in the Grenville orogen: constraints from the Mauricie region, south-central Quebec *in* Precambrian 95 Programs and Abstracts: International Conference on Tectonics and Metallogeny of Early-Mid-Precambrian Orogenic Belts, Montreal, Quebec, p. 106.

Edgell, H.S., 1992, Geological evidence of Quaternary climatic change and dune development in Saudi Arabia: International Geological Congress Abstracts, v. 29, p. 410.

Jones, B., and A. Desrochers, 1992, Shallow platform carbonates, *in* R.G. Walker and N.P. James, (eds.), Facies Models: Response to Sea Level Change: Geological Association of Canada, p. 277-301.

Kendall, C.G. St.C., 2012, Stratigraphic controls on carbonate evaporate stratigraphy; importance to hydrocarbon exploration; examples from Middle Eastern oil fields and their response to plate tectonic cycle, climate, basin position and sea-level, *in* Anonymous (ed.), The Permo-Triassic sequence of the Arabian Plate; abstracts; Part II: GeoArabia Manama, v. 17/2, p. 208.

Kingston, D.R., C.P. Dishroon, and P.A. Williams, 1983, Global Basin Classification System: AAPG Bulletin, v. 67/12, p. 2175-2193.

Klemme, H.D., and G.F. Ulmishek, 1991, Effective petroleum source rocks of the world; stratigraphic distribution and controlling depositional factors: AAPG Bulletin, v. 75/12, p. 1809-1851.

Neog, N., N.S. Rao, R. Al-Mayyas, T. De Keyser, C. Perrin, and C.G. St.C. Kendall, 2010, Evaporite Facies: A Key to the Mid Mesozoic Sedimentary Stratigraphy of North Kuwait; Mixed Carbonate/Evaporite Successions (SEPM), *in* R. Gilcrease (compiler), Program of the AAPG 2010 International Conference & Exhibition, Calgary, Canada: published by Pioneer Natural Resources.

Rees, P.M., A.M. Ziegler, and P.J. Valdes, 2000, Jurassic phytogeography and climates; new data and model comparisons, *in* B.T. Huber, K.G. MacLeod, and S.L. Wing, (eds.), Warm climates in Earth history: p. 297-318.

Sharland, P.R., R. Archer, D.M. Casey, R.B. Davies, S.H. Hall, A.P. Heward, A.D. Horbury, and M.D. Simmons, 2001, Arabian Plate sequence stratigraphy: Gulf PetroLink, Manama, Bahrain, 2371 p.

USGS, 2000, U.S. Geological Survey World Petroleum Assessment: CD-Rom: Web accessed July 31, 2013. http://pubs.usgs.gov/dds/dds-060/

van Laer,P., P. Nederlof, S.A. Ahsan and F. Al Katheeri, 2012, Northern Rub Al Khali Upper Jurassic – Lower Cretaceous Petroleum System, Proceedings of EAGE Fourth Arabian Plate Geology Workshop, 9-12 December 2012, Late Jurassic/Early Cretaceous Evaporite-Carbonate-Siliciclastic Systems of the Arabian Plate, Abu Dhabi, United Arab Emirates, EAGE.

Waite, L. (author), and R. Gilcrease (compiler), 2002, Phanerozoic Cycles and Events (NV PXD Global Stratigraphic Chart 02.DSF), March 27, 2002: Pioneer Natural Resources, permission provided by L. Waite.

Weber, L.J., and J.F. Sarg, 2005, Play element prediction; carbonate plays in subaqueous evaporate settings: AAPG Annual Meeting Abstracts, v. 14, p. A150.

Website

Blakey, R., Colorado Plateau Geosystems, Inc., Website accessed July 31, 2013. http://cpgeosystems.com/index.html

Reservoir character of carbonate/evaporite oil fields of the Middle East, a response to depositional setting and accommodation space

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ABSTRACT

Most of the Arabian Gulf major oil and gas fields are from the Permian through Tertiary. They are sequestered in carbonates and sealed by evaporites formed under arid to semiarid conditions. The field style can be classified on the basis of a sequence stratigraphy framework, depositional setting and facies hierarchies. This framework of erosional and flooding surfaces was formed by base-level change driven by epeirogenetic tectonic movement and eustatic history. This template is populated by a diversity of depositional systems, and facies geometric architecture but interestingly these reservoirs are commonly within wide spread continuous sheets that tend to shoal up on carbonate shelves. These range from grain to muddy carbonates. Reservoir character ranges from depositional fabrics to diagenetic, the latter often related to dolomitization. The porosity may be interparticlal and intercrystalline and/or leached often over 25% with permeability's of over 100md related to preserved primary fabrics and early secondary porosity. The seal is nearly always evaporite (eg: Hith and Lower Fars) or tightly cemented dolomite and limestone, all of which provide a regional caprock on major fields.

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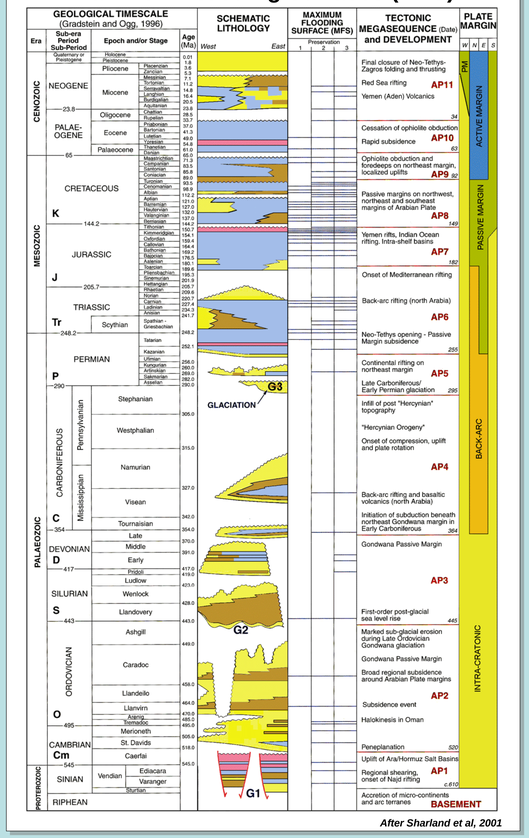
Introductory Statement

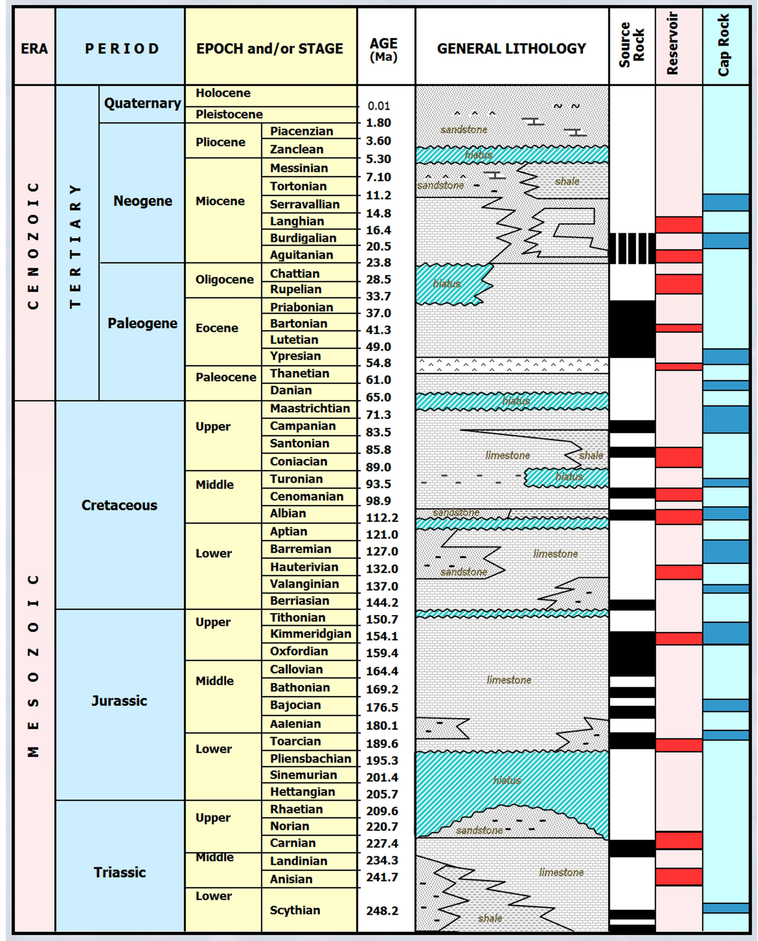
- Framework for hydrocarbon reservoirs, sources & seals of Middle East are expressed by Wilson cycle that tracks Arabian Plate Tectonic history from breakup of Gondwanaland to Iranian collision
- There are 11 major changes in tectonic accommodation, sediment fill and hydrocarbon plays within these low frequency Tectono-Stratigraphic Mega-Sequences
- The mostly carbonate fields & their facies architectures are further subdivided by 63 High frequency Maximum Flooding Surfaces (MFS) that formed in response to the beat of eustasy & structural evolution
- The organic richness of the MFS events in the region has caused the sequestration of source rock since Triassic

High Frequency Beat of Maximum Flooding Surfaces (MFS)

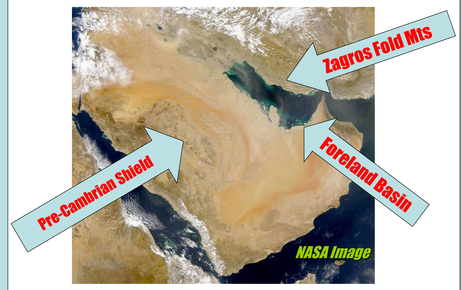


After Sharland et al, 2001

Middle East Source Rocks, Reservoir and Seals



Structural Provinces - Arabian Gulf



Middle East "Cheap" Oil Reserves

Country	Crude		Natural Gas	
Saudi Arabia	263.5	bbs	204.5	tcf
Iraq	112	bbs	109.0	tcf
UAE	97.8	bbs	212.0	tcf
Kuwait	96.5	bbs	52.7	tcf
Iran	89.7	bbs	812.3	tcf
Oman	5.3	bbs	28.4	tcf
Yemen	4.0	bbs	16.9	tcf
Qatar	3.7	bbs	300.0	tcf
Syria	2.5	bbs	8.5	tcf
Bahrain	0.1	bbs	3.9	tcf
TOTAL	**675.1**	**bbs**	**1,748.2**	**tcf**

Most of this oil trapped in carbonates

Low Frequency beat of Tectono-Stratigraphic Mega Sequences

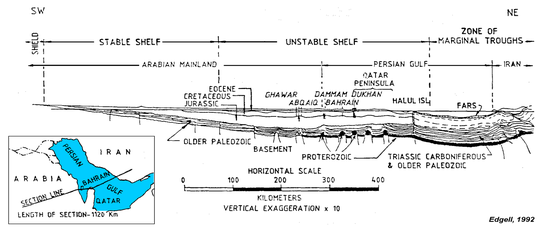
TMS 11	Active Margin	Late Eocene	End of Neo-Tethys & Red Sea rifting
TMS 10	Active Margin	Early Paleocene	End of Ophiolite Obduction
TMS 9	Passive Margin	Middle Turonian	Start ophiolite obduction & inversion
TMS 8	Passive Margin	Early Tithonian	India spreads from SE Oman
TMS 7	Passive Margin	Late Toarcian	Rift of east Mediterranean
TMS 6	Passive Margin	Early Kazanian	Neo-Tethys, passive margin
TMS 5	Back Arc	Late Stephanian	'Hercynian Orogeny' ends
TMS 4	Back Arc	Early Famennian	'Hercynian Orogeny' start rift & Volcanism
TMS 3	Inter Cratonic	Late Ashgill	Uplift (base Zarqu-Sarah Fm
TMS 2	Inter Cratonic	Early Cambrian	Subsidence & pene-planation
TMS 1	Inter Cratonic	Late Pre Cambrian	Najd shearing and rifting

After Sharland et al 2001

High Frequency Sedimentary Framework

Sixty-three maximum flooding surfaces are identified across the Arabian Plate, most ascribed to global eustatic fluctuations. Some surfaces were controlled by regional subsidence that initiated by Sharland et al, (2001) megasequences.
This stratigraphic framework of erosional and depositional surfaces surfaces is used in the Middle East as a template of that enclose and subdivide the sedimentary bodies of the stratigraphic section. It envelopes the sediment geometric end members of the sedimentary stratigraphy, namely sequences, systems tracts and parasequences. It provides a means to extend the interpretation of the depositional setting and predictions of lithofacies' geometries away from the known areas. It also aids prediction of sedimentary rocks likely to contain both hydrocarbon and water resources and what their characteristic fabrics might be.
Sequence boundaries (SB) are identified as significant erosional unconformities and their correlative conformities in the Mega Tectonic Sequences. These boundaries are the products of a fall in sea level that erodes the subaerially exposed sediment surface of the earlier sequence or sequences and low frequency tectonic movement.

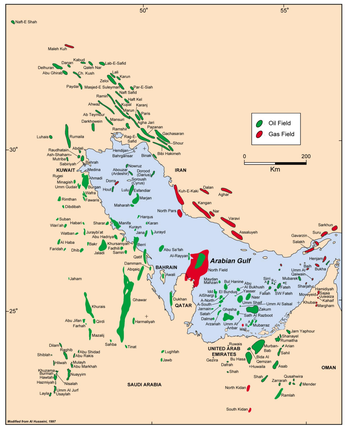
Geologic Cross-Section - Arabian Gulf



Edgell, 1992

Oil fields become younger from West to East

Arabian Gulf Oil and Gas Fields

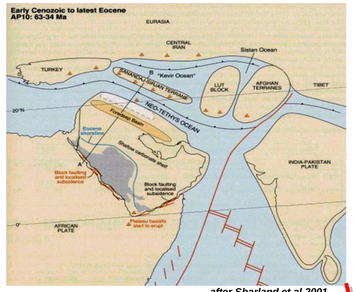


Oil fields become younger from West to East

History of Plate Tectonic movement in Middle East

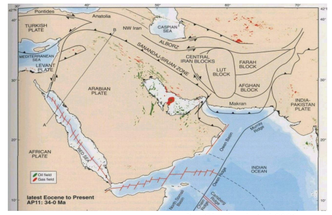
Low Frequency beat of Tectono-Stratigraphic Mega Sequences of Middle East caused by Wilson Cycle of Plate Tectonic Movement & Collision

TMS 10 - Cenozoic - Late Eocene



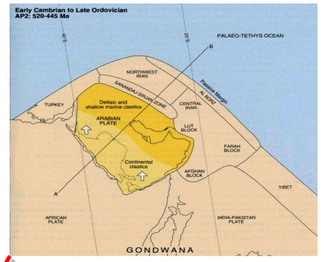
after Sharland et al 2001

TMS 11 - Holocene

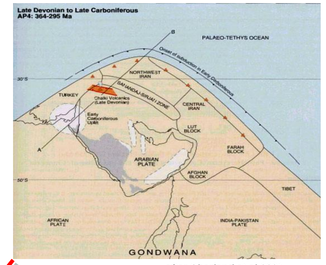


after Sharland et al 2001

TMS 01-3 - Pre-Cambrian - Devonian

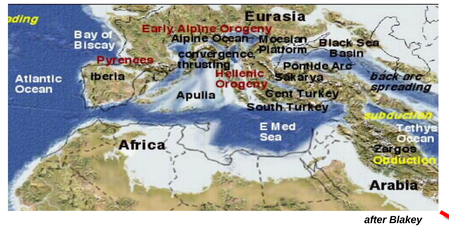


after Sharland et al 2001



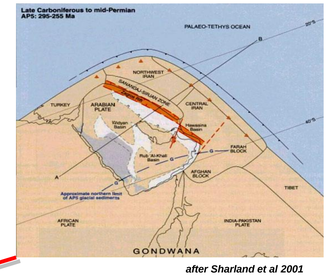
after Sharland et al 2001

TMS 10 – Eocene



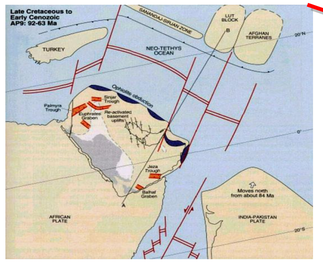
after Blakey

TMS 05 - Late Carboniferous - Permian



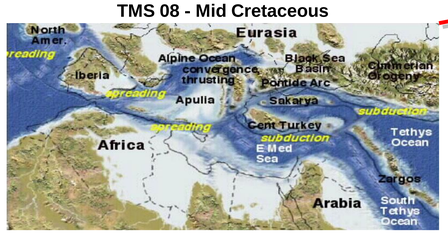
after Sharland et al 2001

TMS 09 - Cretaceous - Cenozoic



after Sharland et al 2001

TMS 08 - Mid Cretaceous

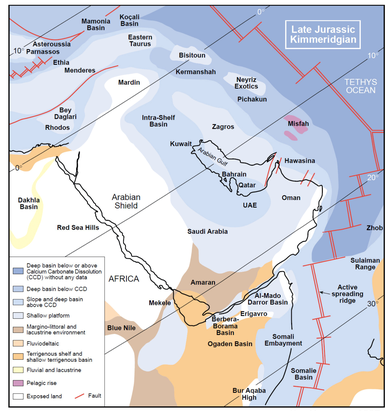


after Blakey

TMS 08 - Early Cretaceous

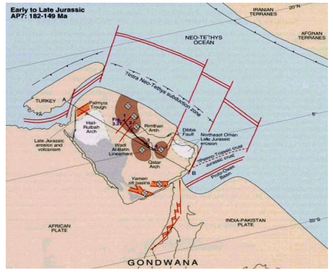
after Blakey

TMS 07 - Late Jurassic



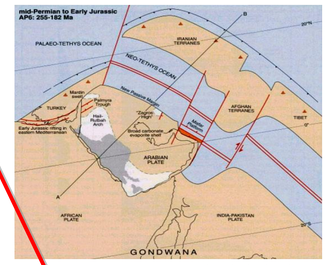
after Husseini. 1997

TMS 07 - Late Jurassic

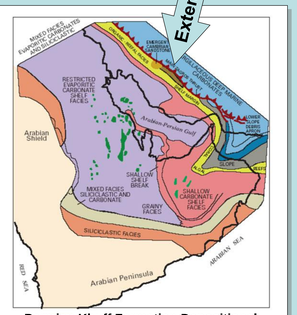


after Sharland et al 2001

TMS 06 - Permian - Early Jurassic



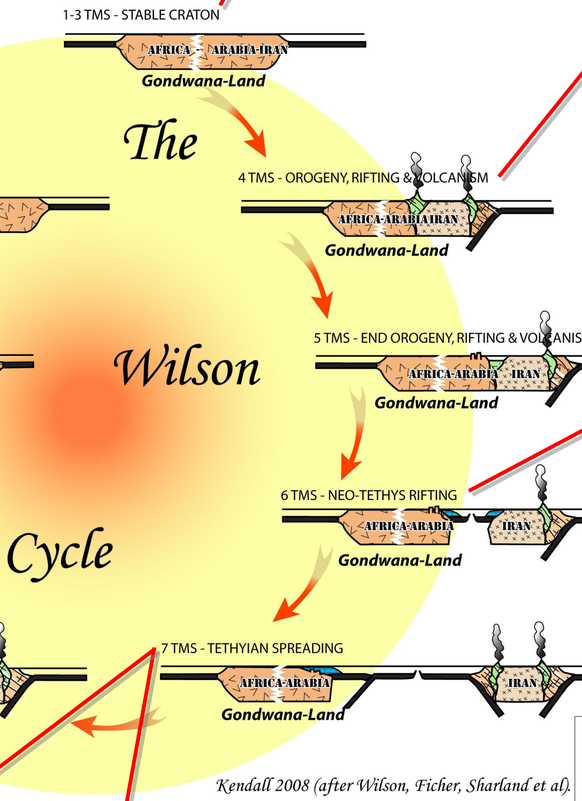
after Sharland et al 2001



Permian Khuff Formation Depositional Settings *after Al Jallal, 1995*

TMS 06 - Triassic

after Blakey



Kendall 2008 (after Wilson, Ficher, Sharland et al).

Tectonic Movement & Plate Movement Produces Simple Plays

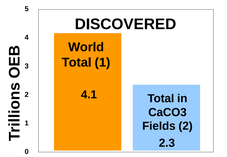
Despite complex history of plate tectonic movement in the Middle East the resulting tectono-megasequences provide a simple low frequency beat to the sedimentary fill and sequestration of organic matter in the rain shadow of the ever present western continental margin. The results are the richest petroleum province in the world!

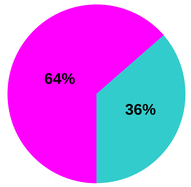
Oil Plays, Evaporites and Carbonates

Character of Jurassic Evaporite & Carbonate Fill of Arabian Basins

There is a strong connection between the style of the evaporite and carbonate fill of the Arabian Basins. This takes the form of open marine high stand conditions for the carbonate production, and the transgressive nature of the lagoonal to salina evaporites that often cap them. In some cases this evaporite takes the form of supratidal high stand accumulations. Both styles results in the richest petroleum province in the world!

Proven Plays with Discovered Reserves Reported (764,000 MOEB)





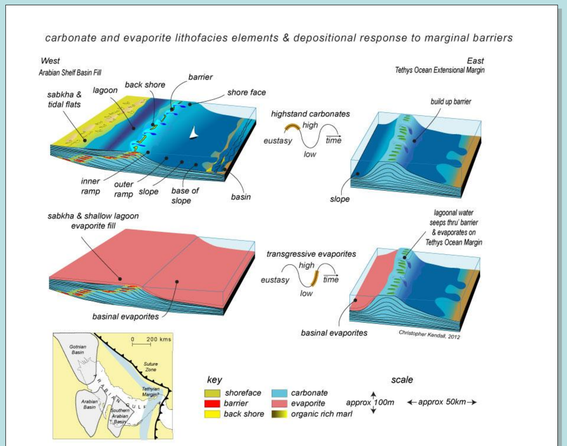
(1) USGS World Assessment (2000)
(2) hMobil CATT Study (1999)

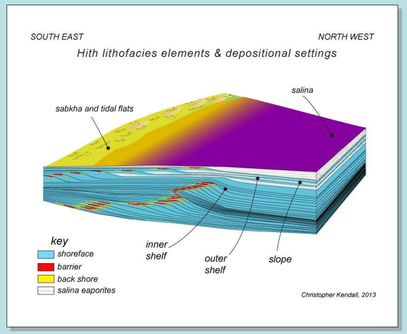
Carbonate Play Association with Evaporite Seal: N = 31

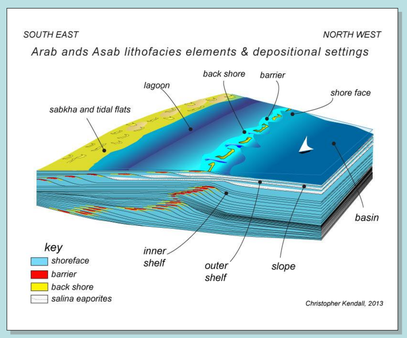
Carbonate Play Association with No Evaporite Seal: N = 45

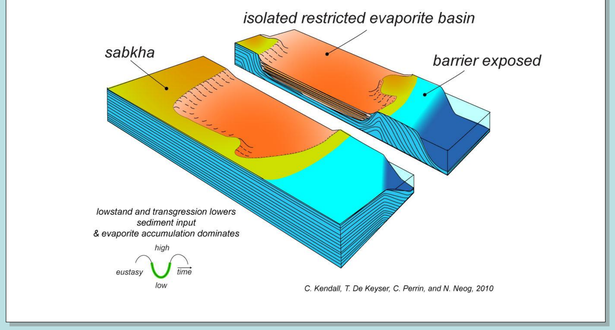
Database captured 33% of total discovered reserves in carbonates
41% of plays exhibit an evaporite seal
64% of discovered reserves trapped under an evaporite seal
So evaporites are important?

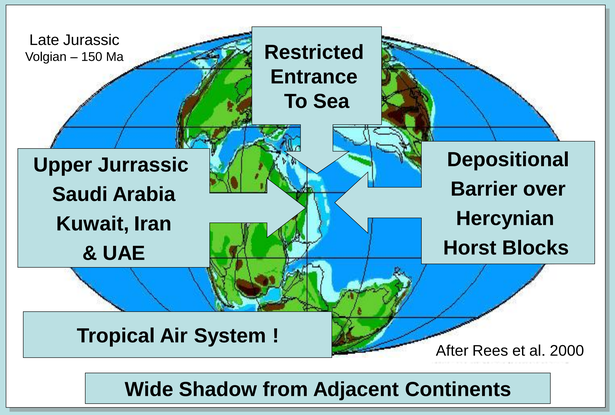
Weber & Sarg, 2005

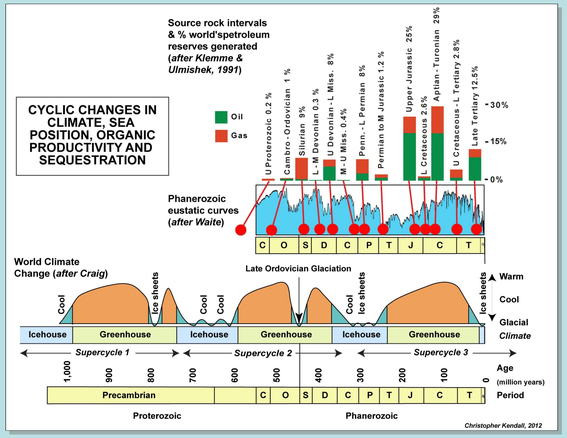


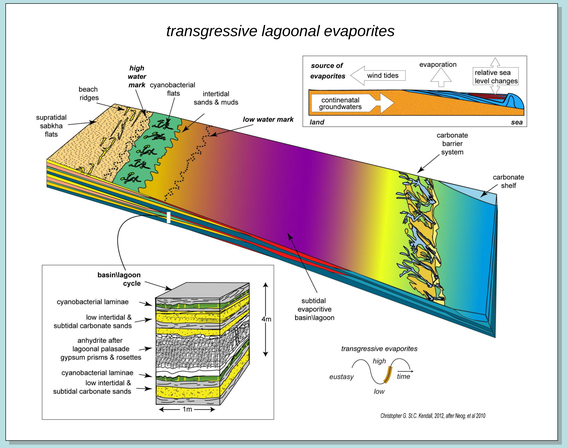


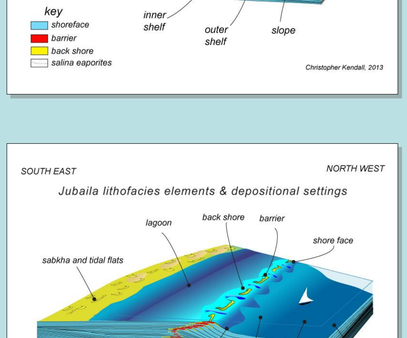


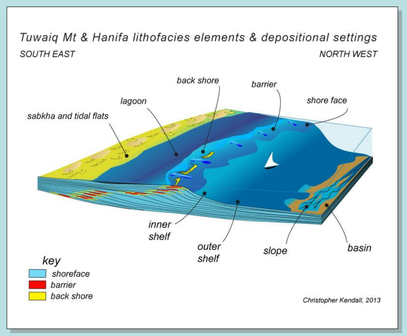


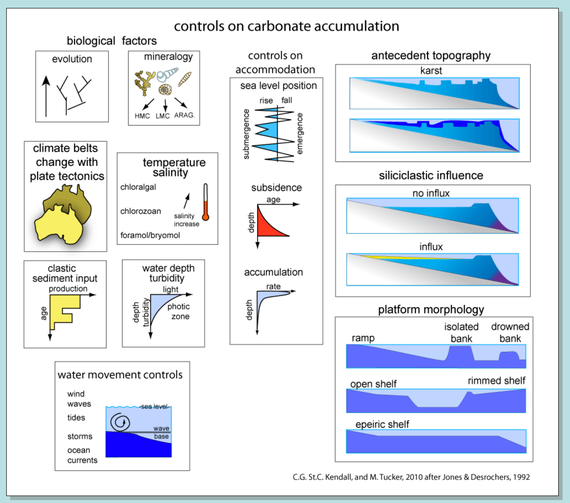


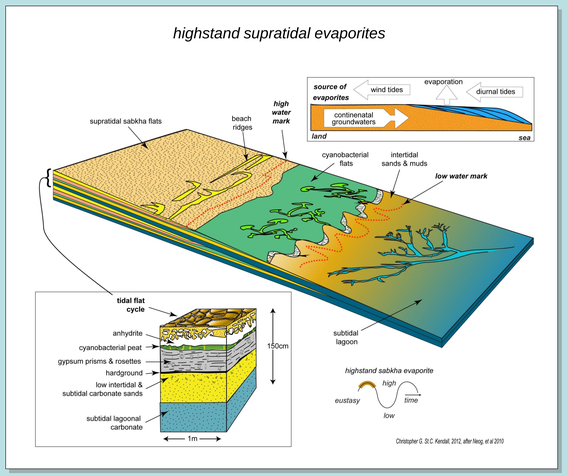


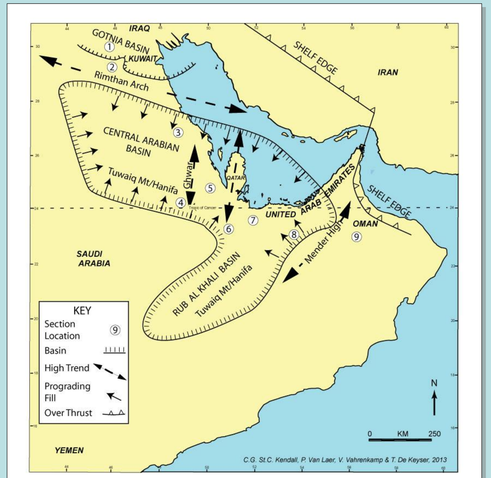




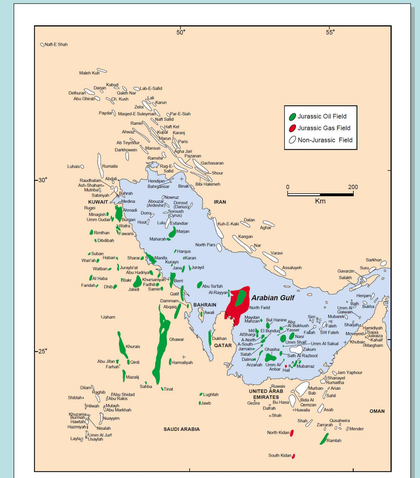








Direction of Middle Jurassic Fill of Central Arabian and Rub al Khali Basins



Jurassic Oil and Gas Fields of Arabian Gulf after Husseini 1997

Oil Field Stratigraphy

Tertiary Oil & Gas Reservoirs

FORMATION	AGE	SETTING	COUNTRY
Aaliji	Paleocene	deep marine pelagic	Syria, Iraq
Asmari	Oligocene - lower Miocene	shallow marine	SW Iran, UAE, Iraq
Chilou	Oligocene	near-shore neritic	Syria
Dammam	Lower and Middle Eocene	shallow marine	Saudi Arabia
Euphrates	Lower Miocene	shallow marine lagoon	Iraq
Habshiya	Paleocene- Eocene	shallow marine restricted	Yemen
Jaddala	Lower-upper Eocene	shallow marine	Syria, Iraq
Bajawan	Middle Oligocene	reef - back reef	Iraq
Jeribe	Middle Miocene	back reef - lagoon	Syria, Iraq
Kirkuk Group	Lower-Middle Oligocene	reef-offshore basin and fringing shoal-slope complex adjoining deep shelf	Iraq
Kalhar	Miocene	shallow-marine lagoon	Iraq
Lower Fars	Miocene	shallow-marine lagoon	Iraq
Radhuma	Paleocene	shallow-marine	Kuwait
Ahmadi	Cenomanian	lagoon	Bahrain, Saudi Arabia, Kuwait

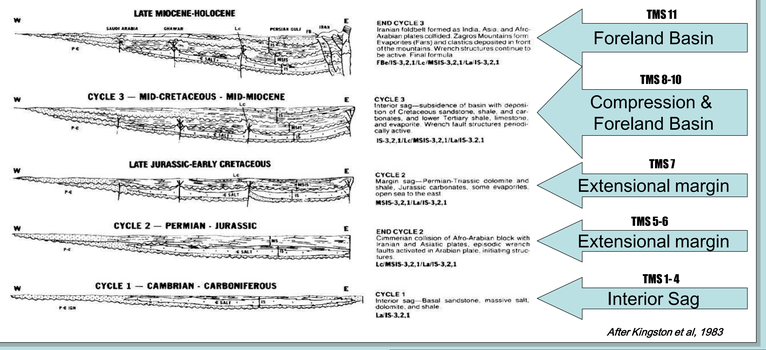
Cretaceous – Jurassic Oil & Gas Reservoirs

FORMATION	AGE	SETTING	COUNTRY
Hummar	Cenomanian	shallow-subtidal lagoon	Jordan
Ilam	Coniacian	shallow marine - slighly deep water	UAE, SW Iran
Judea	Cenomanian	shallow marine	Syria
Karababa	Upper Cretaceous	deep intrashelf	Southeast Turkey
Karabogaz	Upper Cretaceous	deeper shelf	Southeast Turkey
Kharaib	Barremian	shallow marine	Oman, UAE, Qatar, Bahrain
Kometan	Upper Cretaceous	deeper neritic	Iraq
Lekhwair	Hauterivian	Distally-steepened ramp	Oman, UAE,
Massive Limestone	Upper Cretaceous	shallow-slightly deep marine	Syria
Mauddud	Albian	shallow marine	Bahrain, Kuwait, Saudi Arabia, Iraq
Minagish	Lower Cretaceous	low to high energy shoal	Kuwait
Mishrif	Middle Cretaceous Cenomanian	Shoal-rudist complex rimming an intrashelf basin	Offshore Iran, Iraq, UAE, Kuwait. Bahrain, Saudi Arabia, Oman
Mushorah	Upper Cretaceous	shallow marine	Iraq
Natih	Albian-Cenomanian	open marine - shallow shelf	Oman
Naur	Middle Cretaceous	nearshore shallow intertidal	Syria
Qamchuqa	Lower Cretaceous	shallow to slightly deep neritic	Syria, Iraq
Raman	Upper Cretaceous	reefal	Southeast Turkey
Ratawi	Lower Cretaceous	partly euxinic to shallow marine lagoon	Iraq, Kuwait, Saudi Arabia
Rumaila	Cenomanian	tidal flat to slightly deep marine	Bahrain, Iraq, Saudi Arabia
Sabunsuyu	Middle Cretaceous	shallow marine	Southeast Turkey
Khasib	Upper Cretaceous		Iraq
Sarmord	Lower Cretaceous	deeper neritic marine	Iraq
Sarvak	Middle Cretaceous	deep open marine	SW Iran
Shiranish	Maastrichtian	deep open marine	Syria, Iraq
Shuaiba	Aptian	shoal-rudist complex rimming an intrashelf basin	Oman, UAE, Qatar, Saudi Arabia
Shuayib	Middle Cretaceous	open marine outershelf	Jordan
Simsima	Maastrichtian	shallow marine	UAE
Sinan	Upper Cretaceous-Lower Tertiary	shallow marine	Southeast Turkey
Soukhne	Coniacian-Campanian	deep open marine	Syria
Sulaiy	Lower Cretaceous	subtidal to intertidal	Iraq, Saudi Arabia
Tayarat	Maastrichtian	marginal marine	Kuwait
Yamama	Lower Cretaceous	shelf lagoon to open platform	Iraq, Saudi Arabia
Alan	Lower Jurassic	evaporitic lagoon	Iraq
Arab and its equivalent (Qatar and Fahaihil)	Kimmeridgian - Early Tithonian	low to high energy shelf	UAE, Qatar, Bahrain, Saudi Arabia, Offshore Iran

Jurassic – Permian Oil & Gas Reservoirs

FORMATION	AGE	PLATFORM TYPE	COUNTRY
Araej	Middle Jurassic	Low to high energy shelf	UAE, Qatar
Dhruma	Middle Jurassic	tidal flat (shallow to moderately deep marine)	Bahrain, Saudi Arabia
Butmah	Lower Jurassic	lagoon	Syria, Iraq
Chia Gara	Upper Jurassic - Lower Cretaceous	open marine	Iraq
Diyab (Dukhan)	Upper Jurassic Callovian-Oxfordian	moderate-high energy rimming on intrashelf basin	UAE
Gotnia	Upper Jurassic Tiyhonian	supersaline lagoon	Iraq
Hadriya	Middle Jurassic	High-energy shoal rimming an intrashelf basin	Saudi Arabia
Hith (Manifa Member)	Tithonian	Supratidal to lagoon	Saudi Arabia
Izhara	Bajocian	shallow water shelf	Qatar
Jilh	Middle Triassic	shallow marine	Saudi Arabia
Jubailah	Upper Jurassic	shallow water shelf	Bahrain, Saudi Arabia
Madbi	Kimmeridgian	open marine	Yemen
Marrat	Lower Jurassic	tidal flat	Kuwait, Saudi Arabia
Mulussa (Dalan)	Lower-Upper Triassic	Shallow to slightly deep marine	Syria
Naifa	Tithonian	open marine	Yemen
Najmah	Middle-Upper Jurassic	shallow marine/lagoonal neritic	Iraq
Mulussa (Dalan)	Lower-Upper Triassic	Shallow to slightly deep marine	Syria
Naifa	Tithonian	open marine	Yemen
Najmah	Middle-Upper Jurassic	shallow marine/lagoonal neritic	Iraq
Sabatain	Upper Jurassic	shallow marine	Yemen
Hanifa	Upper Jurassic		Saudi Arabia
Sargelu	Middle-Upper Jurassic	euxinic (deep water)	Iraq
Shuqra	Lower-Middle Jurassic	shallow neritic	Yemen
Surmeh	Jurassic	shallow marine	SW Iran
Tuwaiq Mountains	Callovian-Oxfordian	Subtidal to high energy shoal	Oman, Saudi Arabia
Aril	Triassic	shallow marine	Southeast Turkey
Dolaa	Triassic-Jurassic	shallow marine	Syria
Kangan	Lower Triassic	shallow marine	SW Iran
Shuram	Infracambrian	very shallow marine	Oman
Ara	Late Infracambrian	very shallow marine	Oman
Buah	Late Infracambrian	supratidal-lagoon	Oman
Dalan	Permian	shallow marine	SW Iran
Khufai	Late Infracambrian	Shallow to moderate energy (intertidal)	Oman
Khuff	Late Permian – Early Triassic	rimmed epeiric shelf	UAE, Qatar, Bahrain, Saudi Arabia, Oman, SW Iran
Kurra Chine	Middle-Upper Triassic	shallow marine lagoon	Syria, Iraq

Evolution of Arabian Gulf



After Kingston et al, 1983

Cretaceous Oil & Gas Reservoirs

FORMATION	AGE	SETTING	COUNTRY
Ahmadi	Cenomanian	lagoon	Bahrain, Saudi Arabia, Kuwait
Aruma	Upper Cretaceous	shallow marine	Saudi Arabia
Balambo	Lower-Middle Cretaceous	deep marine	Iraq
Bangestan	Middle Cretaceous	shallow marine	SW Iran
Dariyan	Lower Cretaceous	shallow marine lagoon	SW Iran
Derdere	Middle Cretaceous	shallow deep marine	Southeast Turkey
Diban	Middle Cretaceous	open marine	Syria, Iraq
Dokan	Upper Cretaceous	open marine	Iraq
Fahliyan	Lower Cretaceous	shallow marine shelf	Iran
Gadvan	Lower Cretaceous	shallow marine neritic	Iran
Garagu	Lower Cretaceous	lagoon	Iraq
Garau	Middle Cretaceous	deep marine	SW Iran
Garzan	Upper Cretaceous	reef	Southeast Turkey
Germav	Upper Cretaceous- Early Tertiary	shallow to open deep marine	Southeast Turkey
Habshan	Berriasian-Valanginian	tidal flat	UAE
Halul	Upper Cretaceous	low to moderate shallow marine	UAE
Hartha	Upper Cretaceous	marginal marine	Iraq

Hydrocarbon Field Motherhood Statement!

- The framework Arabian Plate Tectonic history provides 11 major low frequency Tectono-Stratigraphic Mega-Sequences of tectonic accommodation, sediment fill & hydrocarbon accumulation within mostly carbonate fields & associated with source rock whose facies architectures are further subdivided by 63 High frequency Maximum Flooding Surfaces (MFS) that responded to beat of eustasy & structural evolution
- The organic richness of regions is related to serendipitous protection behind a wide western continental margin

Arabian Gulf -Cross Section

Structural-stratigraphic section across the northeast Arabian margin and shelf, illustrate trap style variations and role of Precambrian basement and Infra-Cambrian salt

Arabian Gulf Hydrocarbon Fields

Oil fields become younger from west to east

After Al Sharhan & Nairn, 89

Arabian Gulf Fields & the age of their generation

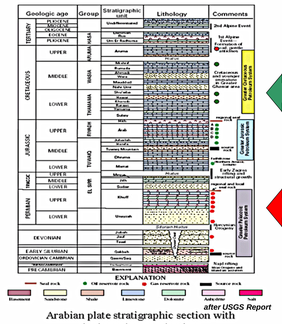
Trap Genesis	Time of Trap Formation	Oil and Gas Fields
Basement	Minor Early Cretaceous and major Late Cretaceous and Tertiary	**Saudi Arabia**: 82. Ramlah, 83. Shaybah/Zarrarah, 45. Abqaq, 46. Ghawar, Mamaliyah, 48. Jawb, 49. Marzalij, 50. Abu Jifan, 51. Qirdi, 52. Khrais, 53. Jahan, 66. Fadhili, 61. Bakr, 55. Wtban, 54. El Haba, 56. Wariah, 62. Juraibiat, 63. Habari, 57. Suban, 58. Dibdibba, 59. Rimthan, 60. Jalada **UAE:** 7. Mender, 8. Shah, 9. Asab, 10. Sahil, 11. Jarn Yaphour, 12. Rumaitha, 83. Zarrah/Shaybah **Qatar:** 39. North Field **Iraq:**101. Luhais. Fields not on map are: Qaiyarah, Najmah, Qasab, Jawan
Basement with Salt Flowage assist	Late Cretaceous and Early Tertiary	**Oman:** 1. Natih, 2. Fahud, 3. Faud West, 4. Yibal, 5. Al Huwiash, 6. Lekhwair **UAE:** 13. Bab, 14. Bu Hasa, 17. Mubarraz, 15. Huwaila **Bahrain:** 41. Awali, 42. Abu Safah **Qatar:** 40. Dukhan **Saudi Arabia:** 42. Abu Safah, 43. Qatif, 68. Berri, 65. Abu Hadriya, 81. Manifa, 64, Sharar, 80. Safaniya/Khafji, 75. Marjan/Fereidoon, 76. Lwah, 79. Ribyan, 78. Zaluf **Kuwait:** 84. Hout, 85. Dorra, 90. Wofra, 92. Umm Gudair, 89. Burgan, 86. Amadi, 88. Magwa, 93. Managish, 80 Khafji/ Safaniya, 94. Khasman, 95. Bahrah, 96. Raudhatain, 91. Fuwairs, 86. Lulu/Esfendiar **Iran:** 139. Ardeshir, 75. Fereidoon/ Marjan, 141. Darius, 138. Nowruz, 149. Pars, 86. Esfendiar /Lulu, 140. Syrus **Iraq:** 98. Zubair, 37. Rumaila, 100. W. Qrnah, 102. Ma'jnoon
Fold Belt (Collision)	Minor Late Cretaceous and major Early Tertiary	**Iran:** 157. Sarkhun, 156. Suru, 155. Qishm, 154. Varavi, 152. Nar, 153. Kangan, 151. Aghar, 148. Kuh-e Maud, 150. Dalan, 147. Bushgan, 146. Nargesi, 142. Binak, 144. Kilur Karim, 145. Bibi Hakimeh, 133. Gacharan, 134. Pazanun, 135. Rag-e-Safid, 129. Paris, 127. Agha Jari, 131. Kuh-i-Rig, 130. Doudrou8, 132. Shurom, 143. Gulkhari, 128. Karanj, 124. Kupal, 125. Haft Kel, 126. Ramshar, 1221. Mansuri, 122. Shadegan,123. Marun, 116. Naft-i-Safid, 115. Par-i-Siah, 117. Mulla Sani, 114. Nadhud-i-Sulaiman, 113. Karun,112. Lali, 118. Ahwaz, 120. Ab-e-Taimur, 119. Susangerd, 111,. Ab-i-Safid, 107. Sarkan, 108. Maleh-i-Kuh, 109. Danan, 110. Chesmeh Khush **Iraq:** 105. Abu Ghirab, 104. Bursurgan, 103. Jabal Fauqis. Fields not shown on this map are: Chme Chemal, Jambur, Chia Surkh, Kirkuk, Baia Hassan, Butamh, Ain Zalah, Pulkana, Mushorah, Naft Khaneh **UAE:** 32. Khuub, 33. Margham, 34. Sajaa, 35. Saleh
Primary salt flowage (on lineament)	Late Cretaceous to present	**UAE:** 16. Umm Ad Dalkh, 18. Hail, 23, Zakum, 22. Sath Al Raazboot, 19. Ghasha, 20. Arzanah, 213. Umm Shaif, 26. Nasr, 21. Sateh, 24. El Buduq, 31. Mubarak, 30. Fateh, 29. SW Fateh, 27. Abu Al Bukhoosh/Sassan, 28. Rashid **Qatar:** 37. Maydan Mahzam, 36. Bul Hanine, 38. Idd El Shargi, 24 El Bunduq **Iran:** 161. Sirri-A, 160. Sirri-C, Sirri-D, 27. Abu Al Sassan/ Bukhoosh, 163 Rostam, 162. Rakhsh, 158. Gavarziq, 136. Hendi jan, 137. Bahrgansar **Saudi Arabia:** 68. Berri, 44. Dammam, 67. Khursaniyah, 69. Kurayn, 77. Maharah **Iraq:** 99. Nahr Umr.
Possible Salt Flowage (On lineament)	Possible Late Cretaceous to Recent	**Saudi Arabia:** 71. Juraid, 70. Jannah, 73. Harkus, 72. Karan, 74. Hasbah

After Al Sharhan & Nairn, 89

Source-rock Formations - Arabian Plate

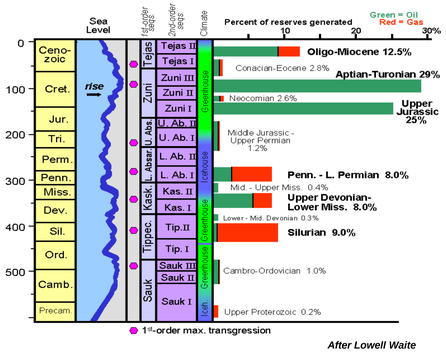
Age/ Country	Yemen	Jordan	Syria	South east Turkey	North Iraq	South Iraq	Iran (Zagros Basin)	Kuwait	Saudi Arabia	Bahrain	Qatar	UAE	Oman
Tertiary	Taqa Jezza	Taqiya	Jaddala Aliji	Sinav	Jaddala Aaliji		Pabdeh		Mansiyah Burqan Yanbu Alwajh Sulaiy				Taqa Andhur
Cretaceous	Mukalla Fartaq Qishn Furt Saar Naifa	Muwaqar Ghareb Wadi Essir Naur	Shiranish Chilou Soukne Qamchuga Rutbah	Germav Beloka Karabogaz Karababa Derdere Sayindere	Shiranish Balambo	Khasib Wara Nahr Umr Ratawi Zubair Chia Gara	Ilam Gurpi Khazhdumi Gadvan	Rumaila Mishrif Ahmadi Wara Maudduud Burqan Zubair Ratawi Minagish Sulaiy		Sulaiy	Mishrif Khatiyah Maudduud Shuaiba Ratawi	Fiqa Shilail/ Khatiyah Shuaiba	Natih Shuaiba
Jurassic	Marib Madbi/ Sabatayn		Sargelu	Aril	Sargelu Naokelekan	Najmah Sargelu	Surmeh	Sargelu Dhruma Najmah	Hanifa Tuwaiq Dhruma Marrat Minjur Jilh	Jubailah Hanifa	Jubailah Hanifa	Diyab/ Dukhan Izhara	Marrat
Triassic			Kurra Chine Mulussa Amanus		Kurra Chine	Baluti					Haushi	Jilh	
Permian				Inbirik Hazro		Beduh			Khuff Unayzah	Basal Khuff		Khuff	
Carboniferous			Najeeb Sawanet										
Devonian				Koprulu					Jauf				Misfar
Silurian		Mudawarra Hiswa	Tanf	Handof Dadas			Gahkum		Qusaiba	Qusaiba	Sharawra	Qusaiba	Safiq
Ordovician			Sawab	Bedinan					Hanadir				
Cambrian				Sosink					Pre-Saq				Haima
Infracambrian													Buah Shuram

Source-rock Formations - Arabian Plate



Arabian plate stratigraphic section with hydrocarbon production

Oil & Gas Sources Through Time



After Lowell Waite

Pre-Cambrian

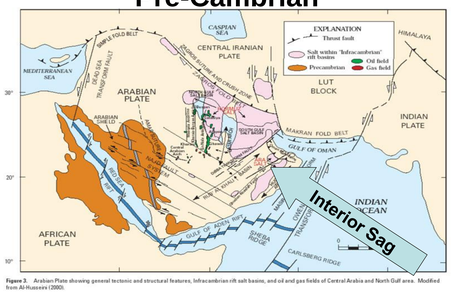


Figure 3. Arabian Plate showing general tectonic and structural features, Infracambrian rift salt basins, and oil and gas fields of Central Arabia and North Gulf area. Modified from Al-Husseini (2000).

Jurassic

Extensional Margin

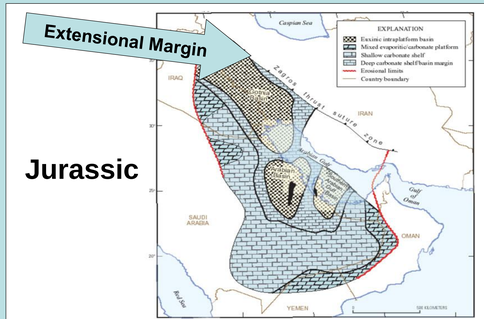
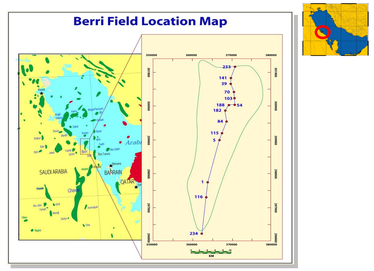
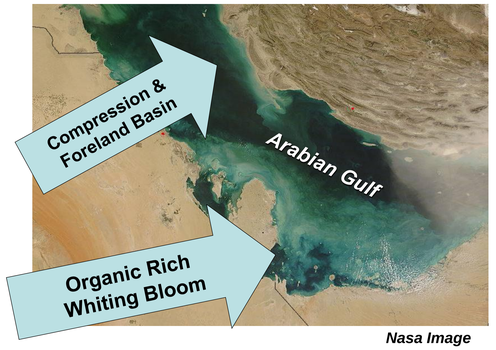


Figure 13. Gotnia, Arabian, and Southern Arabian Gulf Basins in which Jurassic hydrocarbon source rocks accumulated (modified from Alsharhan and Kendall, 1986). Sawtooth on upthrown block of Zagros thrust suture zone.

Hanifa Formation - Berri Field



Organic Sequestration since Trias



Nasa Image

Permian

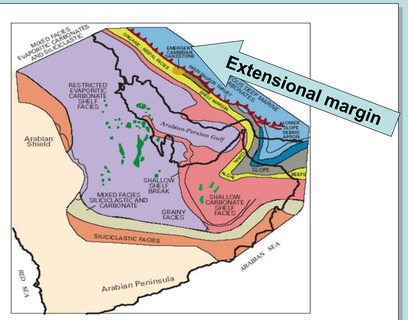
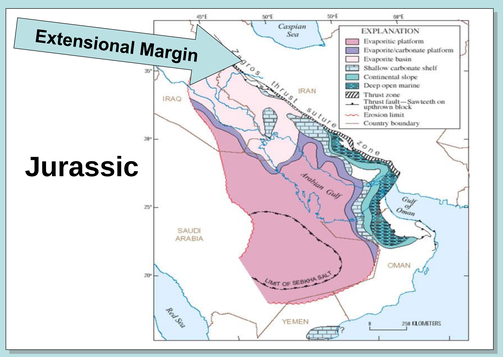


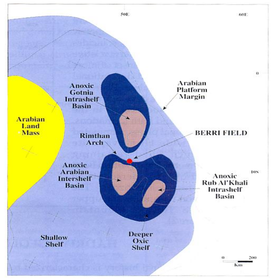
Figure 29. Major environments of deposition and regional facies of the Khuff Formation over the eastern Arabian Peninsula and Zagros Fold Belt. Modified from Al-Jallal (1995).

Jurassic

Extensional Margin



Hanifa Formation Setting



Restricted Entrance To Sea

Permian Khuff
Saudi Arabia
Oman & UAE

Structural & Depositional Barrier over Hercynian Horst Blocks

Arid Tropics Air System

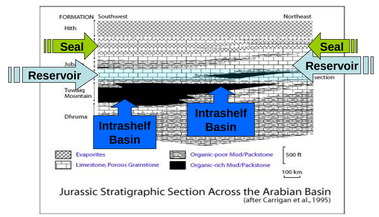
Wide Shadow from Adjacent Continents

Hanifa Formation Characteristics

The basinal lithofacies of the Hanifa Formation provide the hydrocarbon source for the Arab reservoirs up section; these basinal lithofacies are also the seal for the underlying Hadriya reservoir. The shallow shelfal skeletal conglomerates of this formation constitute the bulk of the Hanifa Reservoir of the Berri giant oil field of eastern Saudi Arabia. Both reservoir and source lithofacies were deposited contemporaneously but in a different part of the basin.

The depositional history of the Middle and Upper Jurassic formations of eastern Arabia is best understood when described using a sequence stratigraphic hierarchy that involves the higher order (3rd and 4th order) sequences and their position within the lower-order (1st and 2nd order) sequences.

Reservoir Source and Seal



Jurassic Stratigraphic Section Across the Arabian Basin (after Carrigan et al., 1995)

Source Rock and Organic Matter Sequestration Motherhood Statement!

The organic richness of regions is related to serendipitous protection behind a wide western continental margin; first of Gondwanaland, then Pangaea and finally Africa

The 11 major low frequency Tectono-Stratigraphic Mega-Sequences of tectonic accommodation, sediment fill & hydrocarbon accumulation within mostly carbonate fields & associated with source rock whose facies architectures are further subdivided by 63 High frequency Maximum Flooding Surfaces (MFS) that responded to beat of eustasy & structural evolution

Concluding Statement

The framework for hydrocarbon reservoirs, sources & seals of the Middle East is derived from the Wilson cycle that tracks Arabian Plate Tectonic history & eustatic sea level change

There are 11 major changes in tectonic accommodation, sediment fill and hydrocarbon plays within these low frequency Tectono-Stratigraphic Mega-Sequences

The mostly carbonate fields & their facies architectures are further subdivided by 63 High frequency Maximum Flooding Surfaces (MFS) that formed in response to the beat of eustasy & structural evolution

The Permian, Jurassic and Tertiary fields are largely entrapped beneath evaporite seals

The organic richness of the MFS events in the region has caused the sequestration of source rock since Triassic