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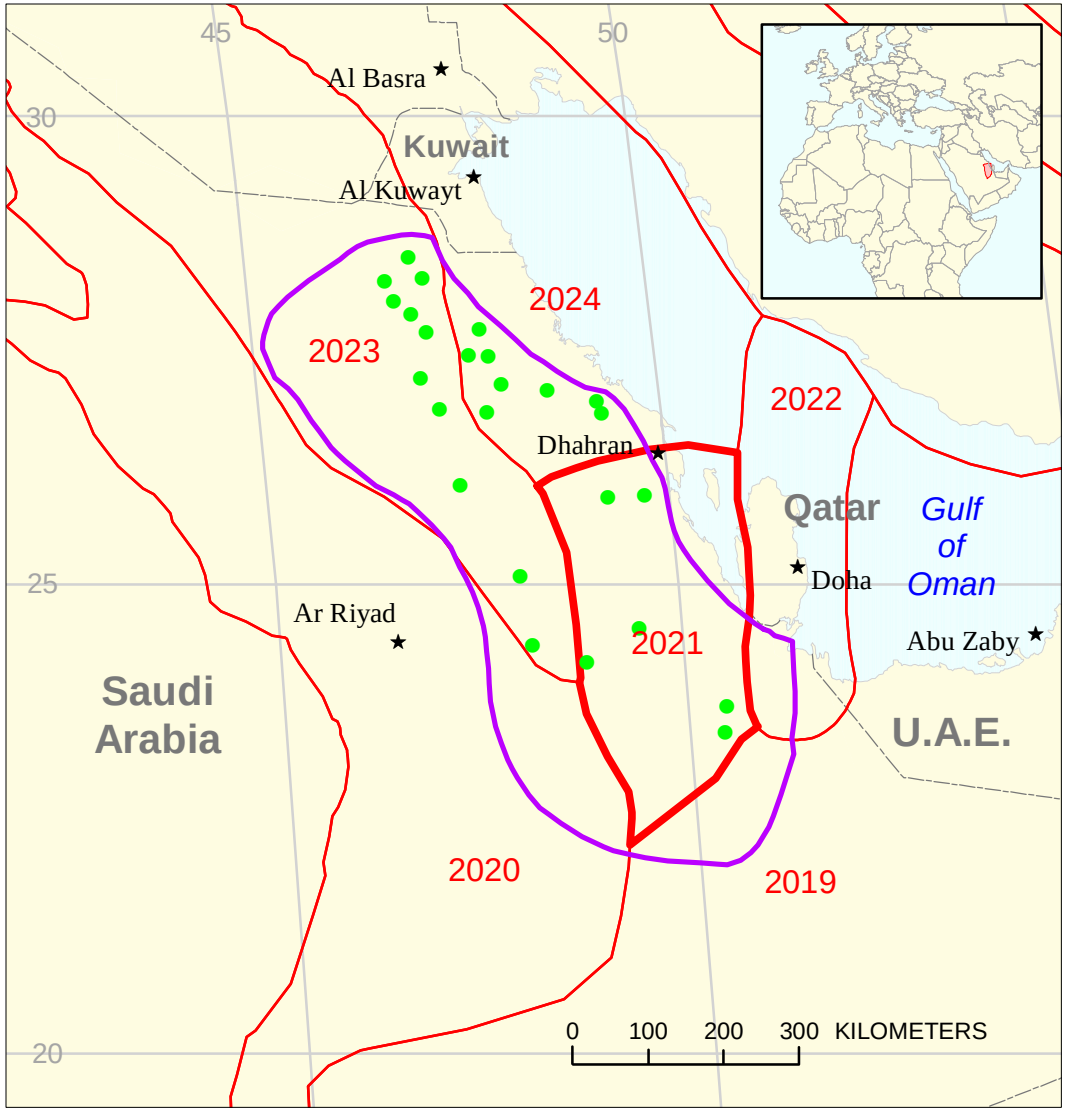
Horst-Block Anticlinal Oil Assessment Unit 20210201



Horst-Block Structural Oil Assessment Unit 20210201
Greater Ghawar Uplift Geologic Province 2021
Other geologic province boundary

Geologic Summary

Detailed map of this assessment unit

Exploration/Discovery-History Data

- Plots of Known Field Sizes
- Plots of Grown Resources
- Tables

Assessment Input Data

Assessment Results

- Assessment Unit Summary
- Detailed Assessment Results
- Undiscovered Field-Size Distributions

USGS PROVINCE: Greater Ghawar Uplift (2021)–Petroleum system is centered at Greater Ghawar province but extends over parts of provinces 2019-Rub 'al Khali Basin; 2020-Interior Homocline-Central Arch; 2022-Qatar Arch; 2023-Widyan Basin-Interior Platform; 2024-Mesopotamian Foredeep.

GEOLOGIST: R.M. Pollastro

TOTAL PETROLEUM SYSTEM: Arabian Sub-Basin Tuwaiq/Hanifa-Arab (202102)

ASSESSMENT UNIT: Horst-Block Anticlinal Oil (20210201)

DESCRIPTION: Assessment unit covers the onshore portion of Central Arabia in the Jurassic Arabian Sub-basin, one of three Jurassic sub-basins; the Jurassic Gotnia sub-basin is to the north and the East Arabian Gulf Sub-basin is to the east. The assessment unit is structurally bounded on the north-northeast by the salt structures of the northern Gulf Salt Basin, south-southeast by the Qatar Arch, on the west by the outcrop belt along the Arabian Shield, and to the north-northwest by the depositional limit of the Tuwaiq/Hanifa source-rock facies. The assessment unit is characterized by a primary north-south structural grain formed by basement fault blocks from island arc accretion (Precambrian Idsas Orogeny). Anticlines formed by draping of sediments over horst blocks having subsequent movement.

SOURCE ROCKS: The organic-rich, argillaceous limestone facies (as thick as 150 m) of the Middle Jurassic Tuwaiq Mountain Formation is the primary source rock; however, the overlying Hanifa Formation is also a significant source. Oil-source correlations classify these oils into one Tuwaiq Mountain/Hanifa family. The Tuwaiq and Hanifa contain Type II organic matter; average TOC of the Tuwaiq and Hanifa is about 3.5 and 2.5 weight percent, respectively.

MATURATION: Tuwaiq/Hanifa source rocks are at marginally mature/early generation stage (Ro = 0.5 to 0.7 percent) for oil along the westernmost third of the assessment unit; however, mature oils of 35° API gravity are produced from Khurais and Majalij fields in this area suggesting some migration. The central and west portions of assessment unit are at mid-mature, main phase oil expulsion stage (Ro = 0.7 to 1.0 percent) at Ghawar, Harmaliyah, and Lughfah. The area immediate east of Ghawar to Qatar is at the end of oil expulsion stage.

MIGRATION: Both vertical and lateral migration has occurred in the assessed area. Mature 35° API gravity oils produced in a marginally mature area of the basin at Khurais and Majalij fields suggest that these oils migrated westward from a more mature eastern source area of the central Arabian basin. Short vertical migration is from the Tuwaiq/Hanifa source into mainly Arab reservoirs.

RESERVOIR ROCKS: Primary reservoirs are the cyclic, shallow-water, carbonate grainstones and packstones of the Upper Jurassic Arab Formation (Arab A, B, C, D). Secondary reservoirs include the high microporous, fine-grained, fractured limestones of the Hanifa Formation, and Middle Jurassic (Dhruma/Tuwaiq Formations) and Lower Jurassic (Marrat Formation) shelf carbonates.

TRAPS AND SEALS: Traps are mainly structural and most are anticlinal (crest and flank traps) formed from draping of sediments over basement horst blocks having subsequent movement. Many of the anticlinal features, such as Ghawar, have multiple structural sub-elements with different growth histories. The primary regional seal is the massive (150 m-thick) evaporites of the Upper Jurassic Hith Formation overlying the Arab Formation. Intraformational seals of the carbonate/anhydrite cycles of the Arab Formation (A, B, C, D) and shales and tight carbonates of the Hanifa, Dhruma, and Marrat Formations are important locally.

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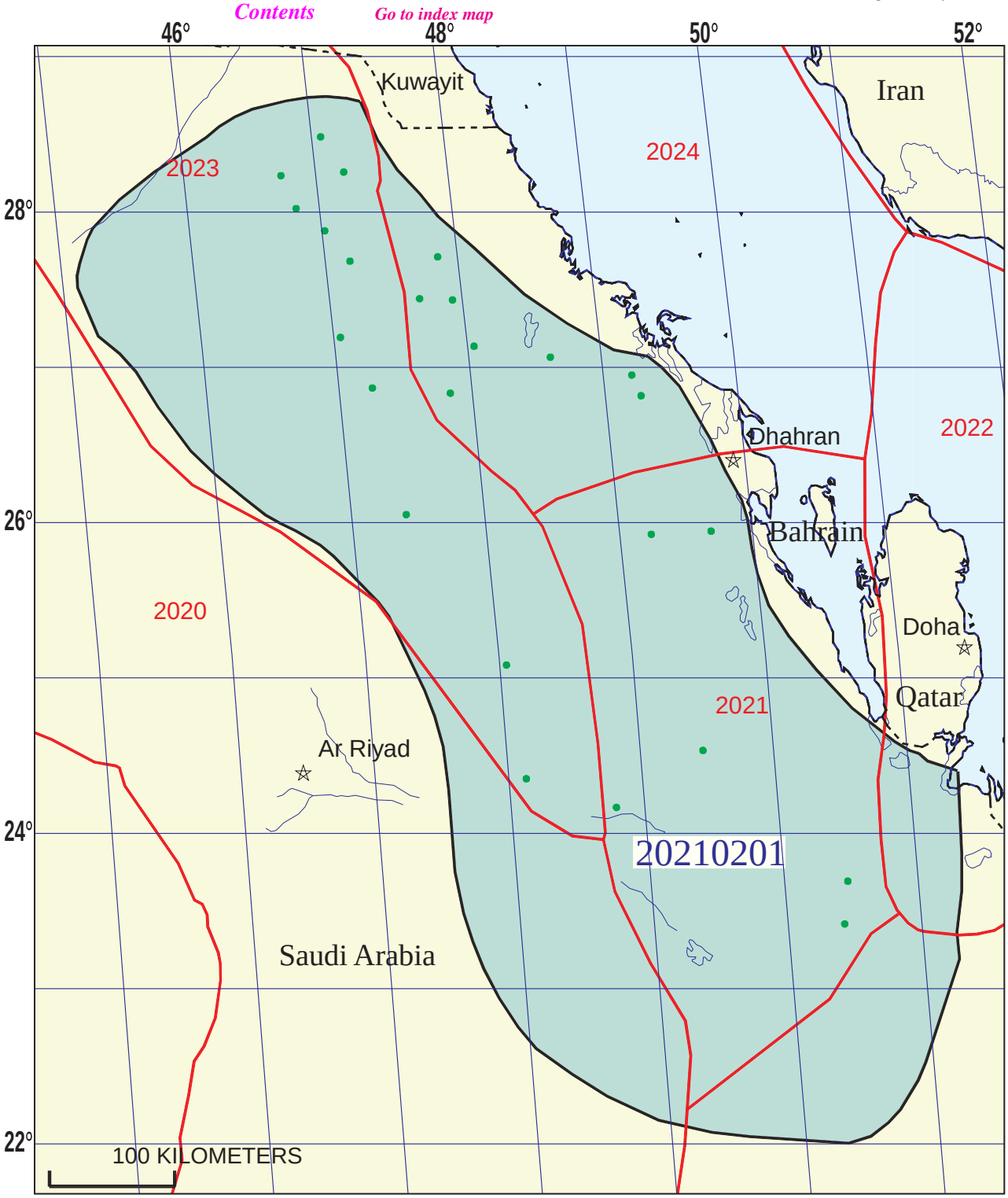
U.S. GEOLOGICAL SURVEY WORLD PETROLEUM ASSESSMENT 2000— DESCRIPTION AND RESULTS
U.S. Geological Survey World Energy Assessment Team



Horst-Block Anticlinal Oil Assessment Unit - 20210201

EXPLANATION

- Hydrography
- Shoreline
- 2021 — Geologic province code and boundary
- Country boundary
- Gas field centerpoint
- Oil field centerpoint
- 20210201 — Assessment unit code and boundary

Projection: Robinson. Central meridian: 0

USGS science for a changing world

SEVENTH APPROXIMATION
NEW MILLENNIUM WORLD PETROLEUM ASSESSMENT
DATA FORM FOR CONVENTIONAL ASSESSMENT UNITS

Date:……..	5/14/99		
Assessment Geologist:……..	R.M. Pollastro		
Region:……..	Middle East and North Africa	Number:	2
Province:……..	Greater Ghawar Uplift	Number:	2021
Priority or Boutique……	Priority		
Total Petroleum System:……	Arabian Sub-Basin Tuwaiq/Hanifa-Arab	Number:	202102
Assessment Unit:……..	Horst-Block Anticlinal Oil	Number:	20210201
* Notes from Assessor	Lower 48 growth factor. Assessment unit involves 6 priority provinces.		

CHARACTERISTICS OF ASSESSMENT UNIT

Oil (<20,000 cfg/bo overall) **or** Gas (≥20,000 cfg/bo overall):… Oil

What is the minimum field size?……. 20 mmboe grown (≥1mmboe)
(the smallest field that has potential to be added to reserves in the next 30 years)

Number of discovered fields exceeding minimum size:…… Oil: 25 Gas: 0
Established (>13 fields) X Frontier (1-13 fields) _____ Hypothetical (no fields) _____

Median size (grown) of discovered oil fields (mmboe):
1st 3rd 1980 2nd 3rd 973 3rd 3rd 1150
Median size (grown) of discovered gas fields (bcfg):
1st 3rd _____ 2nd 3rd _____ 3rd 3rd _____

Assessment-Unit Probabilities:

Attribute	Probability of occurrence (0-1.0)
1. **CHARGE:** Adequate petroleum charge for an undiscovered field ≥ minimum size……	1.0
2. **ROCKS:** Adequate reservoirs, traps, and seals for an undiscovered field ≥ minimum size……	1.0
3. **TIMING OF GEOLOGIC EVENTS:** Favorable timing for an undiscovered field ≥ minimum size	1.0

Assessment-Unit GEOLOGIC Probability (Product of 1, 2, and 3):…….. 1.0

4. **ACCESSIBILITY:** Adequate location to allow exploration for an undiscovered field ≥ minimum size…… 1.0

UNDISCOVERED FIELDS

Number of Undiscovered Fields: How many undiscovered fields exist that are ≥ minimum size?:
(uncertainty of fixed but unknown values)

Oil fields:……min. no. (>0)	25	median no.	120	max no.	215
Gas fields:……min. no. (>0)	_____	median no.	_____	max no.	_____

Size of Undiscovered Fields: What are the anticipated sizes (**grown**) of the above fields?:
(variations in the sizes of undiscovered fields)

Oil in oil fields (mmbo)…… min. size	20	median size	100	max. size	6000
Gas in gas fields (bcfg):…… min. size	_____	median size	_____	max. size	_____

Assessment Unit (name, no.)
Horst-Block Anticlinal Oil, 20210201

AVERAGE RATIOS FOR UNDISCOVERED FIELDS, TO ASSESS COPRODUCTS

(uncertainty of fixed but unknown values)

Oil Fields:	minimum	median	maximum
Gas/oil ratio (cfg/bo)……	400	600	800
NGL/gas ratio (bngl/mmcfg)……	20	40	60

Gas fields:	minimum	median	maximum
Liquids/gas ratio (bngl/mmcfg)……			
Oil/gas ratio (bo/mmcfg)……			

SELECTED ANCILLARY DATA FOR UNDISCOVERED FIELDS

(variations in the properties of undiscovered fields)

Oil Fields:	minimum	median	maximum
API gravity (degrees)……	18	31	44
Sulfur content of oil (%)……	0.5	2	4.6
Drilling Depth (m) ……	1000	2440	4000
Depth (m) of water (if applicable)……			

Gas Fields:	minimum	median	maximum
Inert gas content (%)……			
CO_2 content (%)……			
Hydrogen-sulfide content (%)……			
Drilling Depth (m)……			
Depth (m) of water (if applicable)……			

Assessment Unit (name, no.)
Horst-Block Anticlinal Oil, 20210201

ALLOCATION OF UNDISCOVERED RESOURCES IN THE ASSESSMENT UNIT TO COUNTRIES OR OTHER LAND PARCELS (uncertainty of fixed but unknown values)

1. Saudi Arabia represents 100 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		100	
Portion of volume % that is offshore (0-100%).....		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...			
Portion of volume % that is offshore (0-100%).....			

2. Province 2019 represents 7 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		7	
Portion of volume % that is offshore (0-100%).....		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...			
Portion of volume % that is offshore (0-100%).....			

3. Province 2020 represents 12 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		12	
Portion of volume % that is offshore (0-100%).....		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...			
Portion of volume % that is offshore (0-100%).....			

4. Province 2021 represents 30 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		30	
Portion of volume % that is offshore (0-100%).....		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...			
Portion of volume % that is offshore (0-100%).....			

5. Province 2022 represents 3 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		3	
Portion of volume % that is offshore (0-100%)……		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…			
Portion of volume % that is offshore (0-100%)……			

6. Province 2023 represents 36 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		36	
Portion of volume % that is offshore (0-100%)……		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…			
Portion of volume % that is offshore (0-100%)……			

7. Province 2024 represents 12 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		12	
Portion of volume % that is offshore (0-100%)……		0	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…			
Portion of volume % that is offshore (0-100%)……			

Horst-Block Anticlinal Oil, AU 20210201
Undiscovered Field-Size Distribution