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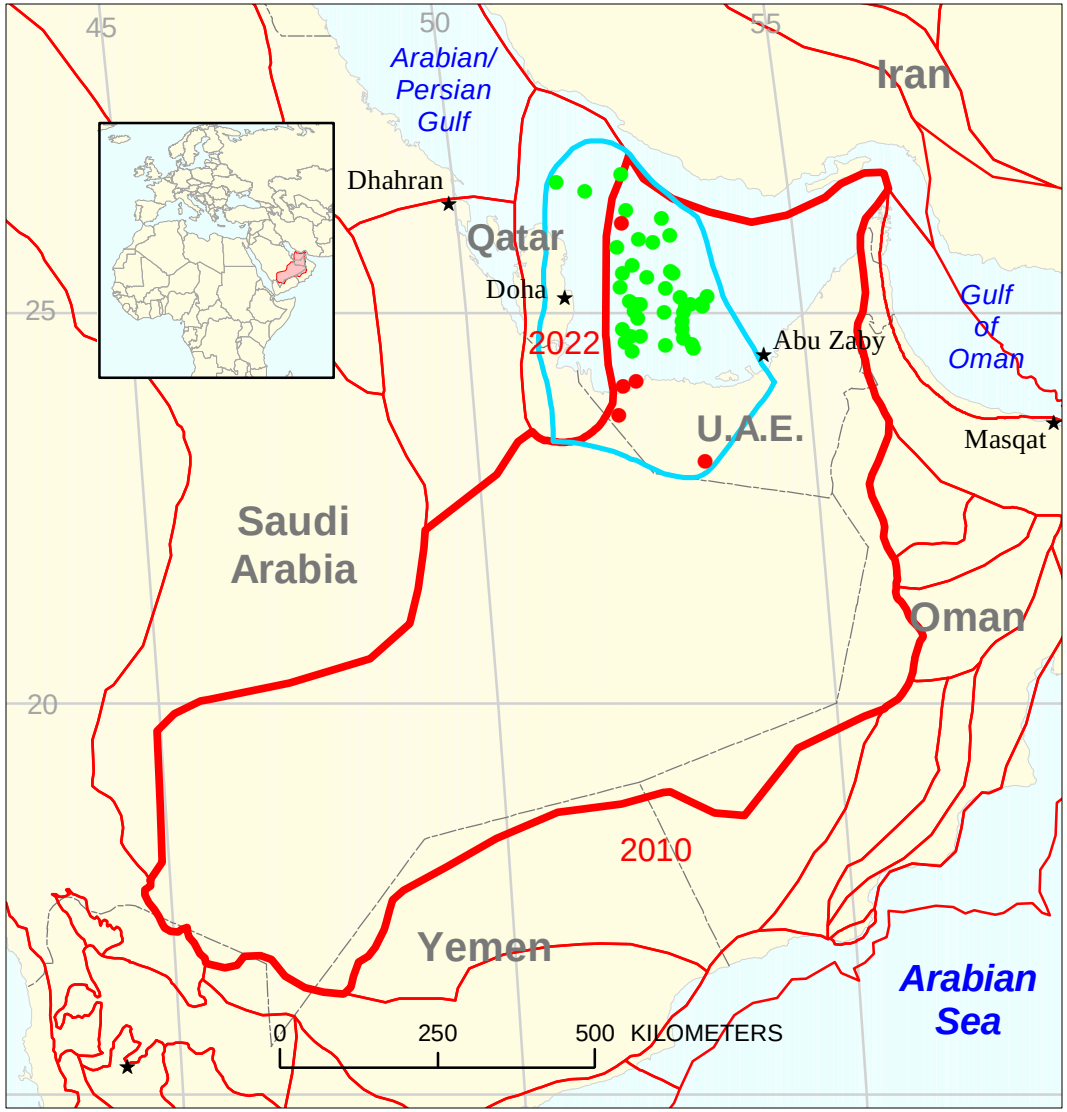
Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural Assessment Unit 20190202



Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural Assessment Unit 20190202

Rub Al Khali Basin Geologic Province 2019

Other petroleum system boundary

USGS PROVINCE: Rub Al Khali Basin (2019)–The petroleum system is centered along the basin's axis and extends over the eastern flank and crest of the Qatar Arch Province (2022). The system is limited to the south-southwest by organic-rich facies deposited in the Jurassic South Gulf intraplatform sub-basin.

GEOLOGIST: R.M. Pollastro

TOTAL PETROLEUM SYSTEM: Jurassic Hanifa/Diyab-Arab (201902)

ASSESSMENT UNIT: Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural (20190202)

DESCRIPTION: The assessment unit covers (1) the eastern offshore portion of the South Arabian-Persian Gulf, (2) onshore eastern flank to crest of the Qatar Arch, and (3) the onshore portions of U.A.E. and Saudi Arabia that are underlain by the Hormuz Salt. The unit is in the Rub' al Khali Basin and in the Jurassic, intraplatform South Gulf sub-basin. It is bounded to the south by the Dibba transform fault and South Gulf Hormuz Salt and is structurally bounded by the Qatar Arch to the west and limited to the east by the geographic extent of source facies and pinch out of the primary Hith evaporite seal. A north-south structural grain is evident from basement- and tectonically formed anticlines. Jurassic reservoirs are assessed separately recognizing possible overlap with Cretaceous and Paleozoic petroleum systems.

SOURCE ROCKS: The organic-rich, argillaceous limestone facies of the Late Jurassic Diyab/Hanifa Formations is the primary source rock. Secondary source rocks include organic-rich beds of the Middle Jurassic Araej/Dhruma Formation and Early and Middle Jurassic Marrat, Hamlah, and Izhara Formations. The Diyab/Hanifa contains Type II organic matter and average TOC is about 2.0 to 3.0 weight percent.

MATURATION: Hanifa/Diyab and Araej/Dhruma source rocks are presently within the mid-to-late-mature (Ro = 0.7 to 1.3 percent) oil window throughout most of the assessment unit where mature oils of 40° API gravity are produced. Jurassic source rocks entered the oil window from Middle Cretaceous to Early Tertiary (100 to 50 Ma). The south-central portion of the unit is within the main gas generation (Ro >1.3 percent) window with some local gas mature areas to the north. Jurassic gas is found in the central part of the unit.

MIGRATION: Some evidence for lateral migration to fields outside the souce rock facies is evidenced to the north. Short vertical migration is from the Hanifa/Diyab source into mainly Arab reservoirs; however, some fields contain Jurassic oil in Cretaceous reservoirs because faulting has breached the main Hith seal.

RESERVOIR ROCKS: Primary reservoirs in this assessment unit are the cyclic, shallow-water, carbonate grainstones and packstones of the Upper Jurassic Arab Formation (Arab A, B, C, D) and also important in the offshore are carbonate shoal deposits of the Araej Formation. Some fields

produce Silurian-sourced gas from the Permian Khuff Formation (for example, Umm Shaif, Bu Haseer 1, Salman, Idd El Shargi North).

TRAPS AND SEALS: Traps are mainly structural and most are anticlinal or salt domes and diapirs (crest and flank traps); some combination structural/stratigraphic traps along a north-southeast trending, secondary leached shelfal limestone. Some anticlines drape basement horst blocks and (or) are faulted due to compression and wrenching from Oman and Zagros Stress. Primary regional seal is the massive Upper Jurassic Hith Formation evaporites overlying the Arab Formation; however, the Hith pinches out to the east, limiting the assessment unit. Intraformational seals of carbonate/anhydrite cycles of the Arab Formation (A, B, C, D) and shales and tight carbonates of the Hanifa/Diyab and Araej Formations are important locally.

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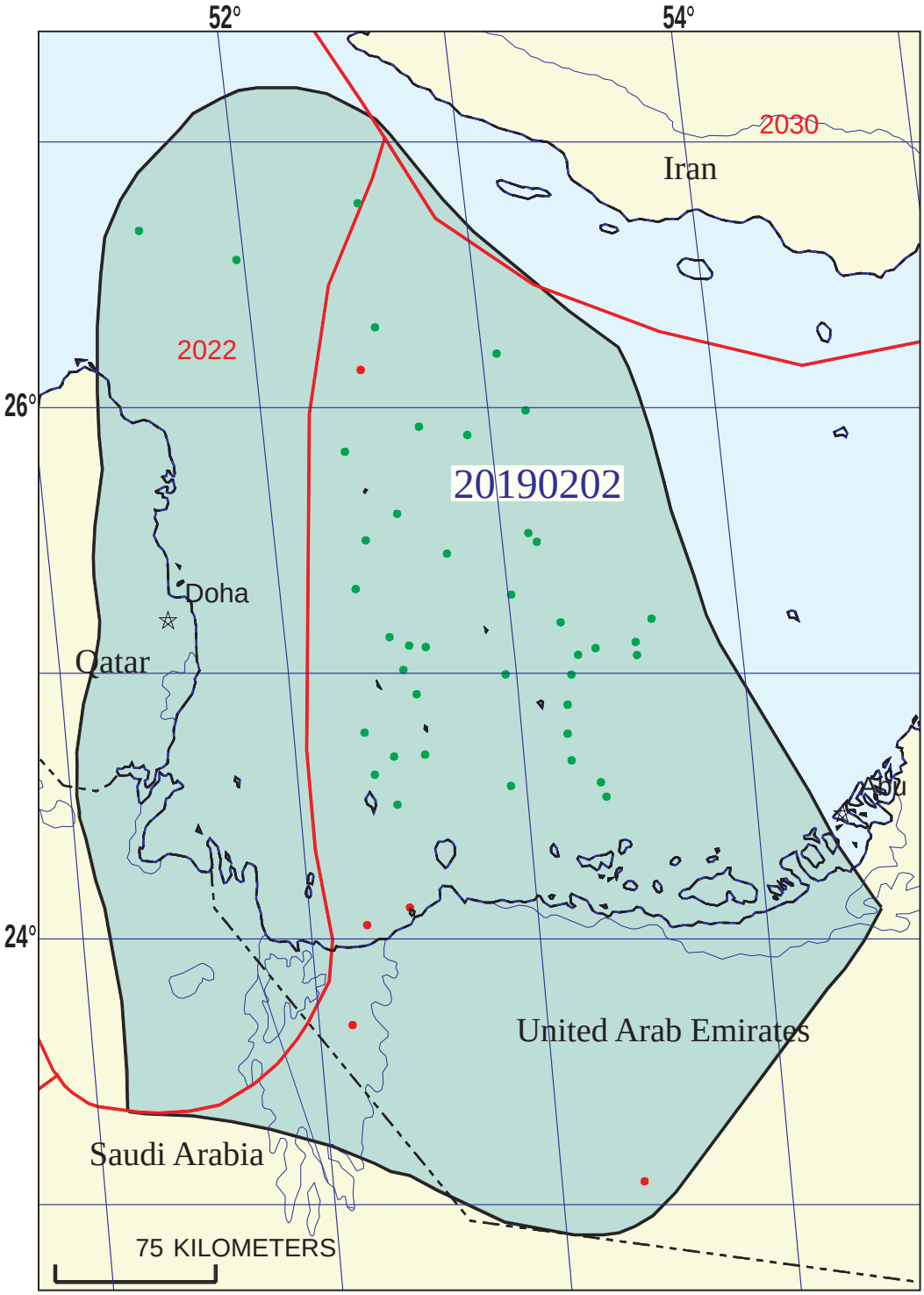


Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural Assessment Unit - 20190202

EXPLANATION

- Hydrography
- Shoreline
- 2019 — Geologic province code and boundary
- Country boundary
- Gas field centerpoint
- Oil field centerpoint
- 20190202 — 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:……..	12/7/99		
Assessment Geologist:……..	R.M. Pollastro		
Region:……..	Middle East and North Africa	Number:	2
Province:……..	Rub Al Khali Basin	Number:	2019
Priority or Boutique……	Priority		
Total Petroleum System:……	Jurassic Hanifa/Diyab-Arab	Number:	201902
Assessment Unit:……..	Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch St	Number:	20190202
* Notes from Assessor	Lower 48-all growth function. This is an assessment of Jurassic reservoirs (assessed separately from other reservoirs), recognizing possible overlap of Cretaceous and Paleozoic.		

CHARACTERISTICS OF ASSESSMENT UNIT

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

What is the minimum field size?……. 10 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: 39 Gas: 5
Established (>13 fields) X Frontier (1-13 fields) _____ Hypothetical (no fields) _____

Median size (grown) of discovered oil fields (mmboe):
1st 3rd 350 2nd 3rd 90 3rd 3rd 84
Median size (grown) of discovered gas fields (bcfg):
1st 3rd 198 2nd 3rd 312 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)	5	median no.	60	max no.	140
Gas fields:……min. no. (>0)	3	median no.	15	max no.	40

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	10	median size	30	max. size	1500
Gas in gas fields (bcfg):……min. size	60	median size	150	max. size	4000

Assessment Unit (name, no.)
Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural, 20190202

AVERAGE RATIOS FOR UNDISCOVERED FIELDS, TO ASSESS COPRODUCTS

(uncertainty of fixed but unknown values)

Oil Fields:	minimum	median	maximum
Gas/oil ratio (cfg/bo)……	1100	2200	3300
NGL/gas ratio (bngl/mmcfg)……	30	60	90

Gas fields:	minimum	median	maximum
Liquids/gas ratio (bngl/mmcfg)……	22	44	66
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)……	15	37	51
Sulfur content of oil (%)……	0.1	1.2	2.8
Drilling Depth (m) ……	500	2700	4000
Depth (m) of water (if applicable)……	0	25	100

Gas Fields:	minimum	median	maximum
Inert gas content (%)……			
CO_2 content (%)……			
Hydrogen-sulfide content (%)……	0.5	2	5
Drilling Depth (m)……	2000	3200	4000
Depth (m) of water (if applicable)……	0	25	100

Assessment Unit (name, no.)
Jurassic Reservoirs in South Gulf Suprasalt/Qatar Arch Structural, 20190202

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

1. Saudi Arabia represents 9 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		9	
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):...		9	
Portion of volume % that is offshore (0-100%).....		0	

2. United Arab Emirates represents 48 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		41	
Portion of volume % that is offshore (0-100%).....		58	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		41	
Portion of volume % that is offshore (0-100%).....		58	

3. Qatar represents 26 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		20	
Portion of volume % that is offshore (0-100%).....		80	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		20	
Portion of volume % that is offshore (0-100%).....		80	

4. Iran represents 17 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%).....		100	

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

5. Province 2019 represents 65 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		65	
Portion of volume % that is offshore (0-100%)……		80	

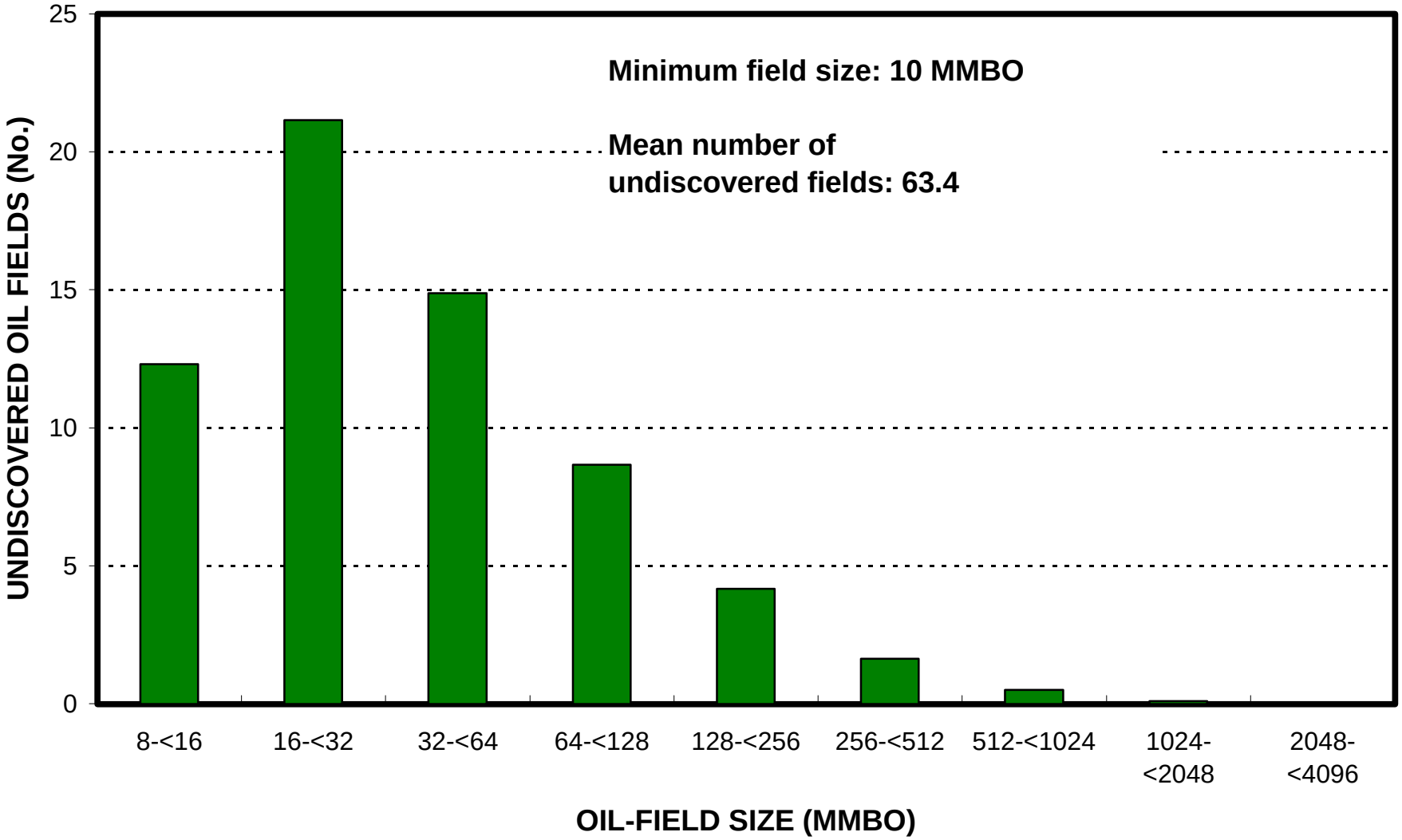
Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		65	
Portion of volume % that is offshore (0-100%)……		80	

6. Province 2022 represents 35 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		35	
Portion of volume % that is offshore (0-100%)……		51	

Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		35	
Portion of volume % that is offshore (0-100%)……		51	

Jurassic Resevoirs in South Gulf Suprasalt/Qatar Arch Structural, AU 20190202, Undiscovered Field-Size Distribution



Jurassic Resevoirs in South Gulf Suprasalt/Qatar Arch Structural, AU 20190202, Undiscovered Field-Size Distribution