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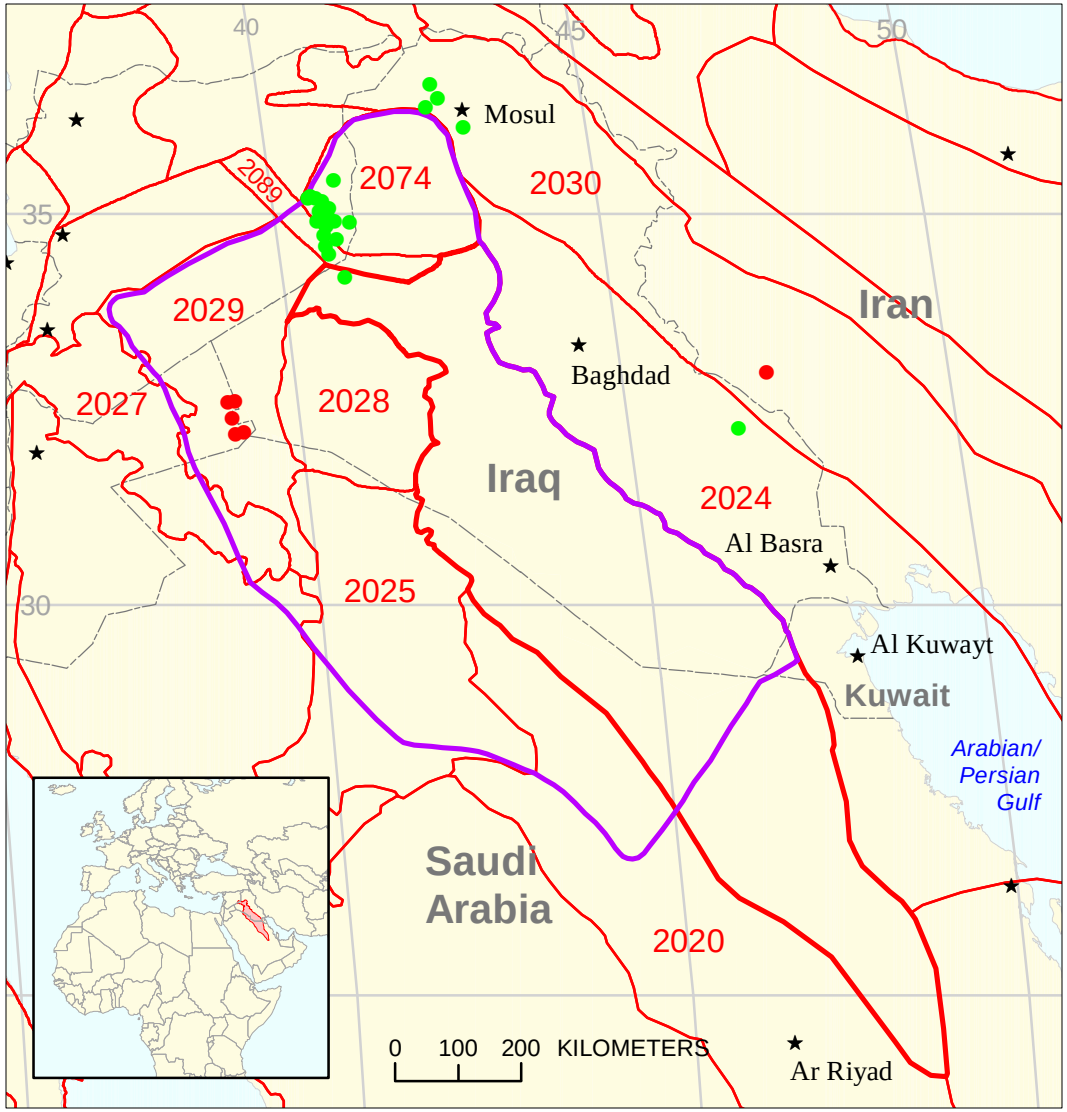
Horst/Graben-Related Oil and Gas Assessment Unit 20230101



Horst/Graben-Related Oil and Gas Assessment Unit 20230101
Widyan Basin-Interior Platform Geologic Province 2023
Other geologic province boundary

USGS PROVINCE: Widyan Basin-Interior Platform (2023) Saudi Arabia and Iraq

GEOLOGIST: J.E. Fox

TOTAL PETROLEUM SYSTEM: Paleozoic Qusaiba/Akkas/Abba/Mudawwara (202301)

ASSESSMENT UNIT: Horst/Graben-Related Oil and Gas (20230101)

DESCRIPTION: "Super Light," high-gravity (43 to 53 degree API) crude with low sulfur content (usually less than 0.07 percent), and natural gas, occur in horst and graben-related traps of Carboniferous-Early Permian Unayzah Formation in Saudi Arabia and the Ordovician Khabour and Silurian Akkas Formation in Iraq. Triassic reservoirs may be charged in part from this source rock.

SOURCE ROCKS: Source of petroleum is organic-rich marine "hot shale" at the base of Silurian strata (Qusaiba, Akkas, Mudawwara, and Abba fms), deposited under dysoxic to anoxic conditions in an intrashelf basin north of the Central Arabian Arch. The source interval generally is richest and thickest (250+ m) in the basin centers. The TOC values are as high as 16.6 percent and hydrocarbon yield is about 49 kg/ton.

MATURATION: The Qusaiba has relatively high maturity (2.29 to 2.47 percent Ro). Onset of oil generation in Iraq began about 250 Ma and in eastern Saudi Arabia about 160 Ma, reaching its peak of maturation and entrapment through the Jurassic. By the Early Tertiary, maturation had largely ceased. The Zagros collision in the Miocene resulted in reactivation of maturation and generation, and increased trap capacity. Major gas yield and entrapment ended in the deep basin by early Neogene; along the basin edge it is still being generated. Gas saturation presumably occurred as the rate of oil generation declined, displacing oil previously reservoired in the deep basin to updip traps.

MIGRATION: Hydrocarbons have migrated vertically along reactivated basement rooted faults or associated fracture zones along the flanks of structures. Pre-Qusaiba reservoirs are charged in structures where they are in direct fault contact with down-faulted blocks of Qusaiba. In both Iraq and northern Saudi Arabia, the general direction of migration is updip towards the west and south.

RESERVOIR ROCKS: In Saudi Arabia, fluvial and eolian quartzose sandstones of the Carboniferous-Early Permian Unayzah Formation overlie the Hercynian unconformity and fill in rifts and half grabens. Thickness is as much as >400 m. In Iraq, reservoirs are in sandstones of the Ordovician Upper Khabour and Silurian Akkas Formations. The Akkas-1 well discovered high gravitiy oil (42 API) in the Silurian Akkas sandstone reservoirs, and sweet gas in the upper sandstones of the underlying Ordovician Khabour Formation.

TRAPS AND SEALS: Structural features that control accumulation of petroleum in Saudi Arabia are moderate-relief, fault-generated structures with 30 to 100 m of closure in north-trending block-faulted anticlines (horsts and grabens) reactivated over pre-Cambrian basement blocks during the Late Devonian to Carboniferous Hercynian Orogeny. Combined stratigraphic-structural traps may exist

where the Unayzah is the reservoir. In the Western Desert of Iraq, about 155 prospects range in size from 1 km to 46 km. Akkas structure is more than 27 km long. Petroleum is sealed in the Unayzah reservoirs by overlying tight carbonate-evaporites within the Late Permian Khuff Formation or in overlying Triassic strata. Lower Silurian shale extends over most of the southwestern desert area of Iraq and acts as a seal for hydrocarbons in the underlying Ordovician Khabour Formation.

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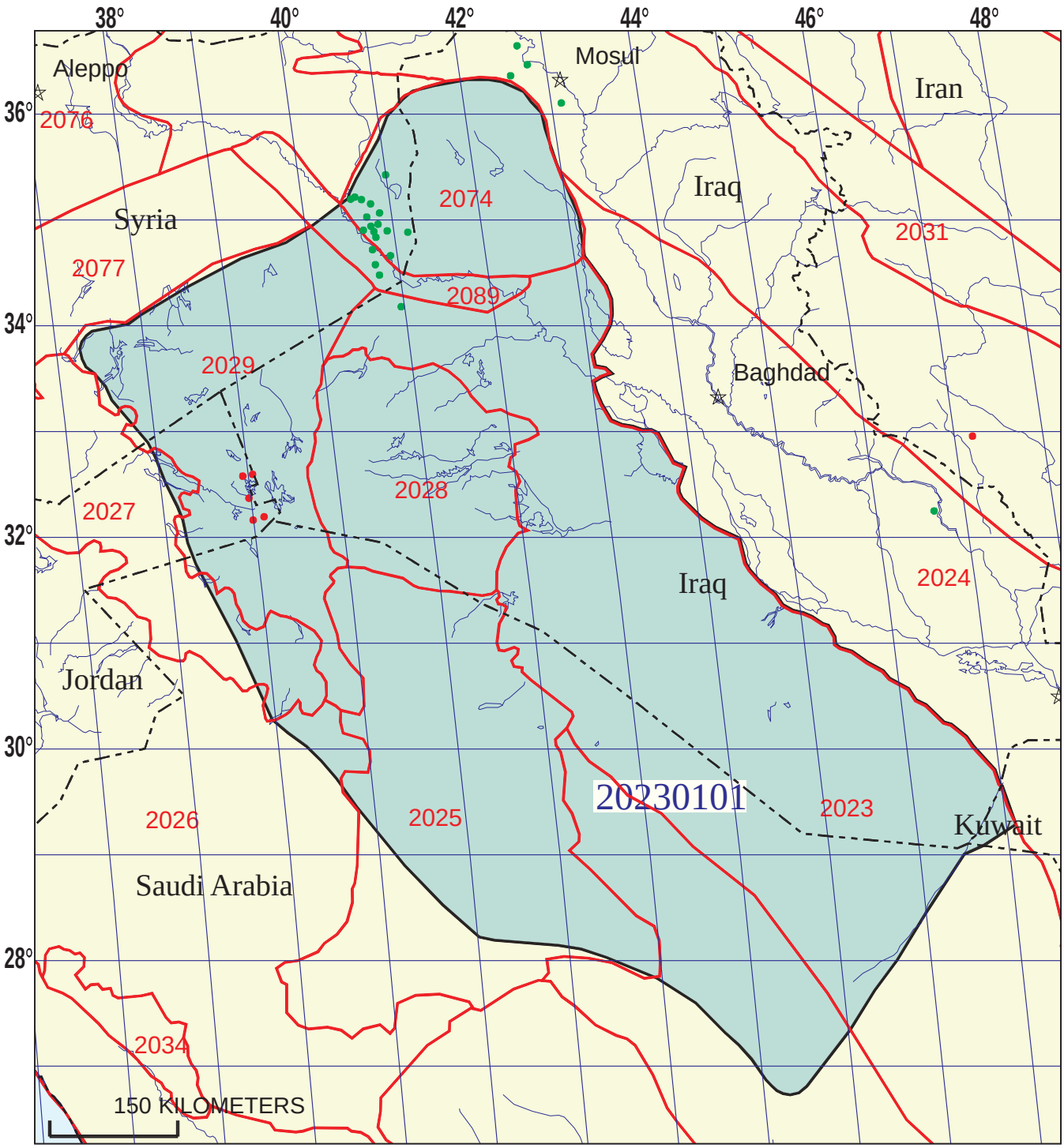


Horst/Graben-Related Oil and Gas Assessment Unit - 20230101

EXPLANATION

- Hydrography
- Shoreline
- 2023 — Geologic province code and boundary
- Country boundary
- Gas field centerpoint
- Oil field centerpoint
- 20230101 — 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:……..	8/26/99		
Assessment Geologist:……..	T.S. Ahlbrandt		
Region:……..	Middle East and North Africa	Number:	2
Province:……..	Widyan Basin-Interior Platform	Number:	2023
Priority or Boutique……	Priority		
Total Petroleum System:……	Paleozoic Qusaiba/Akkas/Abba/Mudawwara	Number:	202301
Assessment Unit:……	Horst/Graben-Related Oil and Gas	Number:	20230101
* Notes from Assessor	Lower 48-all growth function.		

CHARACTERISTICS OF ASSESSMENT UNIT

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

What is the minimum field size?……. 5 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: 21 Gas: 2

Established (>13 fields) X Frontier (1-13 fields) _____ Hypothetical (no fields) _____

Median size (grown) of discovered oil fields (mmboe):
1st 3rd 45.1 2nd 3rd 36.1 3rd 3rd 115.6

Median size (grown) of discovered gas fields (bcfg):
1st 3rd 1286 2nd 3rd 381 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.	40	max no.	90
Gas fields:……min. no. (>0)	10	median no.	170	max no.	360

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	5	median size	25	max. size	2000
Gas in gas fields (bcfg):……min. size	30	median size	150	max. size	10000

Assessment Unit (name, no.)
Horst/Graben-Related Oil and Gas, 20230101

AVERAGE RATIOS FOR UNDISCOVERED FIELDS, TO ASSESS COPRODUCTS

(uncertainty of fixed but unknown values)

Oil Fields:	minimum	median	maximum
Gas/oil ratio (cfg/bo)……	1000	1500	2000
NGL/gas ratio (bngl/mmcfg)……	30	60	90

Gas fields:	minimum	median	maximum
Liquids/gas ratio (bngl/mmcfg)……	60	80	100
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)……	35	44	55
Sulfur content of oil (%)……	0.01	0.1	1
Drilling Depth (m) ……	1500	2500	4500
Depth (m) of water (if applicable)……			

Gas Fields:	minimum	median	maximum
Inert gas content (%)……			
CO_2 content (%)……	1	6	15
Hydrogen-sulfide content (%)……	0	0.03	0.1
Drilling Depth (m)……	1500	2500	6000
Depth (m) of water (if applicable)……			

Assessment Unit (name, no.)
Horst/Graben-Related Oil and Gas, 20230101

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

1. Saudi Arabia 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):...		35	
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):...		31	
Portion of volume % that is offshore (0-100%).....		0	

2. Iraq represents 40 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		60	
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):...		60	
Portion of volume % that is offshore (0-100%).....		0	

3. Syria represents 8 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		5	
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):...		5	
Portion of volume % that is offshore (0-100%).....		0	

4. Jordan represents 4 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		0	
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):...		4	
Portion of volume % that is offshore (0-100%).....		0	

5. Province 2023 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):...		60	
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):...		50	
Portion of volume % that is offshore (0-100%).....		0	

6. Province 2025 represents 20 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		2	
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):...		2	
Portion of volume % that is offshore (0-100%).....		0	

7. Province 2020 represents 16 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		31	
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):...		29	
Portion of volume % that is offshore (0-100%).....		0	

8. Province 2074 represents 10 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):.....			
Volume % in parcel (areal % x richness factor):...		4	
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):...		4	
Portion of volume % that is offshore (0-100%).....		0	

9. Province 2089 represents 1 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		1	
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):…		0	
Portion of volume % that is offshore (0-100%)……		0	

10. Province 2029 represents 13 areal % of the total assessment unit

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

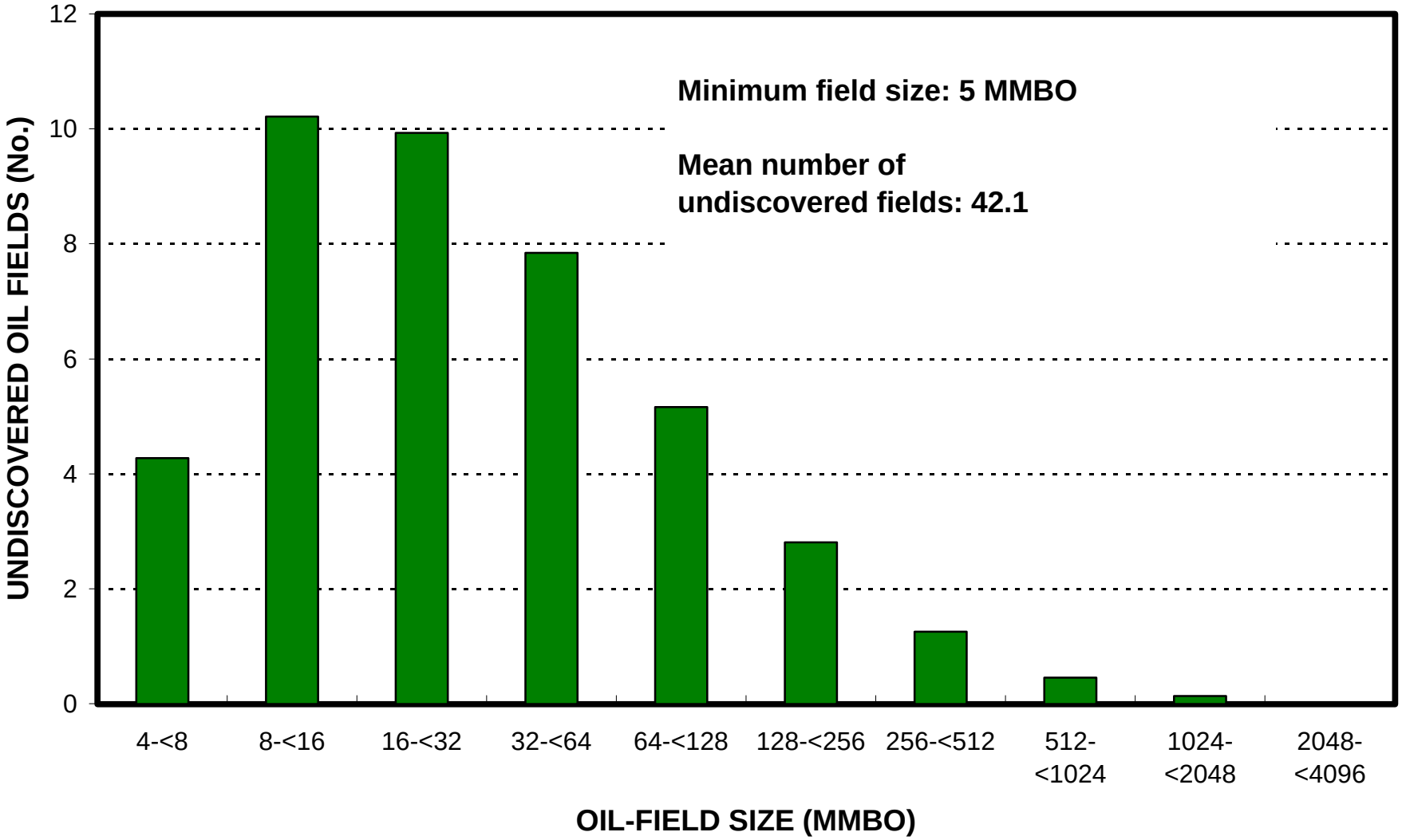
Gas in Gas Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		13	
Portion of volume % that is offshore (0-100%)……		0	

11. Province 2028 represents 10 areal % of the total assessment unit

Oil in Oil Fields:	minimum	median	maximum
Richness factor (unitless multiplier):……			
Volume % in parcel (areal % x richness factor):…		2	
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):…		2	
Portion of volume % that is offshore (0-100%)……		0	

Horst/Graben-Related Oil and Gas, AU 20230101
Undiscovered Field-Size Distribution



Horst/Graben-Related Oil and Gas, AU 20230101
Undiscovered Field-Size Distribution