Go to Table of Contents

Go to index map

Pre-Tertiary Buried Hills Assessment Unit 31270102

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Bohaiwan Basin Geologic Province 3127

USGS PROVINCE: Bohaiwan Basin (3127) **GEOLOGIST:** R.T. Ryder

TOTAL PETROLEUM SYSTEM: Shahejie-Shahejie/Guantao/Wumishan (312701)

ASSESSMENT UNIT: Pre-Tertiary Buried Hills (31270102)

DESCRIPTION: The assessment unit is characterized by oil and gas fields trapped in buried hills (fault blocks) that largely consist of upper Proterozoic and lower Paleozoic marine carbonate reservoirs. Fields are confined to six sub-basins of extensional origin (Bozhong, Huanghua, Liaohe, Linqing/Dongpu, Jiyang, Jizhong), each having one or more pod(s) of active Eocene source rocks. The Bozhong sub-basin is located in offshore Bohai Bay whereas the Jizhong, Linqing/Dongpu, and most of the Jiyang sub-basins are located onshore. The Huanghua and Liaohe sub-basins have large offshore parts. The giant Renqui field is located in the Jizhong sub-basin. Gas-bearing, pre-Tertiary buried hills sourced by Carboniferous and Permian coalbeds are not included in this assessment unit.

SOURCE ROCKS: Source rocks are deep-water lacustrine shale and mudstone of Eocene and Oligocene age that are draped over the buried hills. The dominant source rock is the upper Eocene part of the Shahejie Formation (Members 3). Additional source rocks are the lower Eocene part of the Shahejie Formation (Member 4), Oligocene part of Shahejie Formation (Member 1), and Eocene Kongdian Formation (Member 2). The thickness of Member 3 of the Shahejie Formation is approximately 1,000 m in each sub-basin and its total organic carbon (TOC) values range from about 1 to 4.5. Oil-source rock correlations clearly demonstrate that oil in the buried hills was derived from adjoining lacustrine shale and mudstone.

MATURATION: The Shahejie Formation (Member 3) has been mature with respect to oil generation since about the middle Oligocene/early Miocene. Member 3 is largely immature with respect to gas generation. In contrast, the Shahejie (Member 4) and Kongdian (Member 2) Formations have been mature with respect to gas generation since about the middle Miocene. The Shahejie Formation (Member 1) is immature with respect to oil and gas generation in most sub-basins. A relatively high geothermal gradient of about 32 to 36°C/km accompanied oil and gas generation.

MIGRATION: Only very local lateral migration of oil and gas occurred in the sub-basins and it was confined to the pods of mature source rocks. Oil and gas migrated directly into buried hills from adjoining and overlying Tertiary lacustrine source rocks. Some migration of oil and gas followed unconformities and normal faults. A limited number of burial/uplift/generation scenarios are critical for the charging and preservation of the buried-hill accumulations.

RESERVOIR ROCK: The best reservoir rocks are shallow marine dolomite and limestone beds of Proterozoic, Cambrian, and Ordovician age that have been exposed to long periods of subaerial weathering, erosion, and karst processes. Solution-enlarged fractures, vugs, and cavities are common features in the better reservoirs. These dolomite and limestone reservoirs occupy the Proterozoic Wumishan Formation and numerous formations of Cambrian and Ordovician age. Local reservoirs consist of Archean crystalline basement, Proterozoic/lower Paleozoic sandstone beds, and Mesozoic volcanic rock and sandstone.

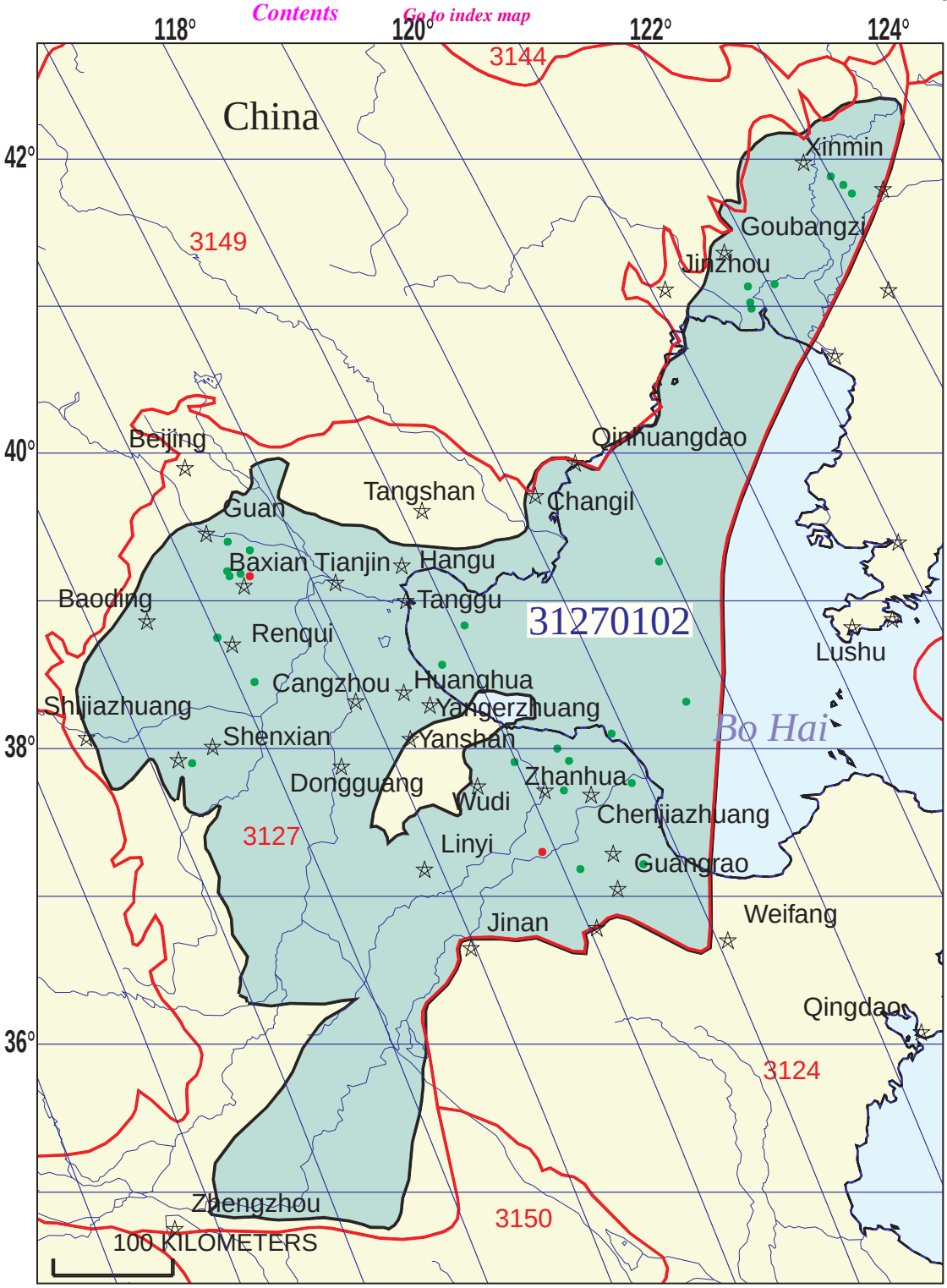
TRAPS AND SEALS: The major traps are buried hills (fault blocks) of extensional origin overlain by seals and source rocks of Tertiary lacustrine shale and mudstone such as the widespread Member 3 of the Eocene Shahejie Formation.

REFERENCES:

Horn, M.K., 1990, Renqui field, *in* Structural traps 2–Traps associated with tectonic faulting: Tulsa, American Association of Petroleum Geologists Atlas of Oil and Gas Fields, p. 227-252.

Zhai G.M. and Zha Q.H., 1982, Buried-hill oil and gas pools in the in the North China basin, *in* Halbouty, M.T., ed., The deliberate search for the subtle trap: American Association of Petroleum Geologists Memoir 32, p. 317-335.

Zheng C.M., 1988, A new exploration method for buried-hill oil fields, the Liaohe depression, China, *in* Wagner, H. C. and others, eds., Petroleum resources of China and related subjects: Houston, Texas, Circum-Pacific Council for Energy and Mineral Resources Earth Science Series, v. 10, p. 251-262.



Pre-Tertiary Buried Hills Assessment Unit - 31270102

EXPLANATION

- Hydrography
- Shoreline
- 3127 Geologic province code and boundary
- Country boundary
- Gas field centerpoint
- Oil field centerpoint
- 31270102 Assessment unit code and boundary

Projection: Robinson. Central meridian: 0

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

Date:……..	4/28/99		
Assessment Geologist:……..	R.T. Ryder		
Region:……..	Asia Pacific	Number:	3
Province:……..	Bohaiwan Basin	Number:	3127
Priority or Boutique……	Priority		
Total Petroleum System:……	Shahejie-Shahejie/Guantao/Wumishan	Number:	312701
Assessment Unit:……..	Pre-Tertiary Buried Hills	Number:	31270102
* Notes from Assessor	MMS growth factor.		

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: 24 Gas: 1
Established (>13 fields) X Frontier (1-13 fields) Hypothetical (no fields)

Median size (grown) of discovered oil fields (mmboe):
1st 3rd 174 2nd 3rd 32 3rd 3rd 60
Median size (grown) of discovered gas fields (bcfg):
1st 3rd 3593 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)	10	median no.	30	max no.	70
Gas fields:……min. no. (>0)	2	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	5	median size	40	max. size	1000
Gas in gas fields (bcfg):……min. size	30	median size	80	max. size	3000

Assessment Unit (name, no.)
Pre-Tertiary Buried Hills, 31270102

AVERAGE RATIOS FOR UNDISCOVERED FIELDS, TO ASSESS COPRODUCTS

(uncertainty of fixed but unknown values)

Oil Fields:	minimum	median	maximum
Gas/oil ratio (cfg/bo)……	350	700	1050
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)……			

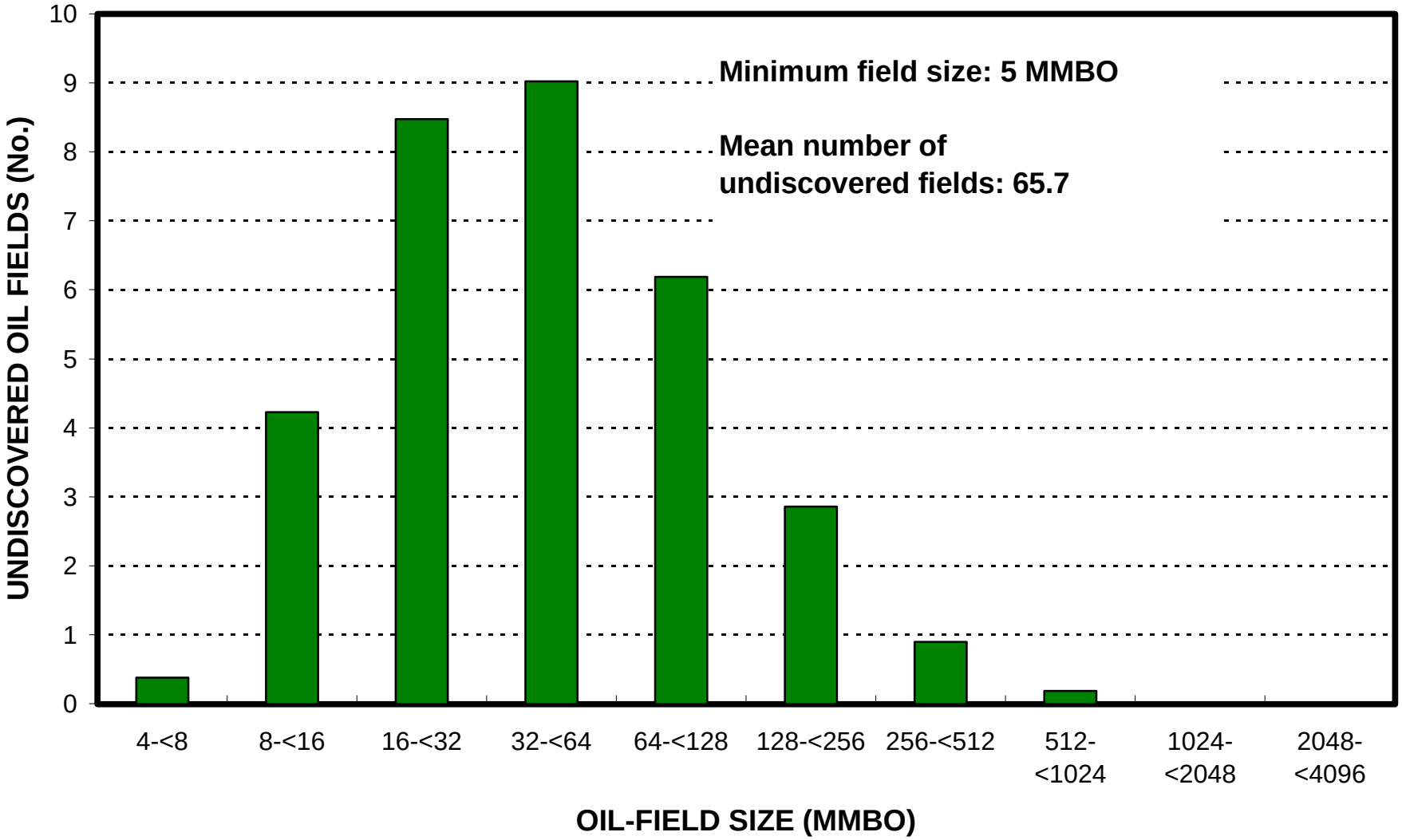
SELECTED ANCILLARY DATA FOR UNDISCOVERED FIELDS

(variations in the properties of undiscovered fields)

Oil Fields:	minimum	median	maximum
API gravity (degrees)……	20	36	50
Sulfur content of oil (%)……	0.05	0.3	1
Drilling Depth (m) ……	1000	3000	4500
Depth (m) of water (if applicable)……	0	20	40

Gas Fields:	minimum	median	maximum
Inert gas content (%)……	0.5	2.5	5
CO_2 content (%)……	0.1	0.5	2
Hydrogen-sulfide content (%)……	0	0.05	1
Drilling Depth (m)……	2000	4000	7000
Depth (m) of water (if applicable)……	0	20	40

Pre-Tertiary Buried Hills, AU 31270102
Undiscovered Field-Size Distribution



Pre-Tertiary Buried Hills, AU 31270102
Undiscovered Field-Size Distribution