International Shale Reservoirs: Tiering Them Into Four Levels*

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Abstract

In previous exploration and development studies performed in various worldwide basins in the 1960s to early 2000s, most of the targeted sandstone and carbonate formations might not have flowed any gas or oil but the underlying Devonian, Silurian or Cretaceous Shale formations did show or might have indicated potential for hydrocarbon. These Devonian, Silurian or Cretaceous age shale formations are very significant laterally and vertically (huge thickness). In some parts of Africa such formations also had tectonic connection to North America in the past. Confirmation of the actual extents will require additional evaluation; appraisal and pilot production to determine if the hydrocarbon trapped in these shale formations (the source rock) can be developed to produce in commercial quantities. Commercial production already exists from such shale gas in the East Coast of US (Marcellus development is a good example).

The purpose of this paper is twofold: (1) develop criteria to identify the various tiers of shale reservoirs (tier I through tier IV where tier IV basins being the most promising) and (2) the second being the identifications of the basins and resource based on the criteria. Examples are presented that use geological, geochemistry, geophysical and petrophysical data to infer potential of shale hydrocarbon in the various basins under consideration.

Website

Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), http://www.eia.doe.gov/iea

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Outline

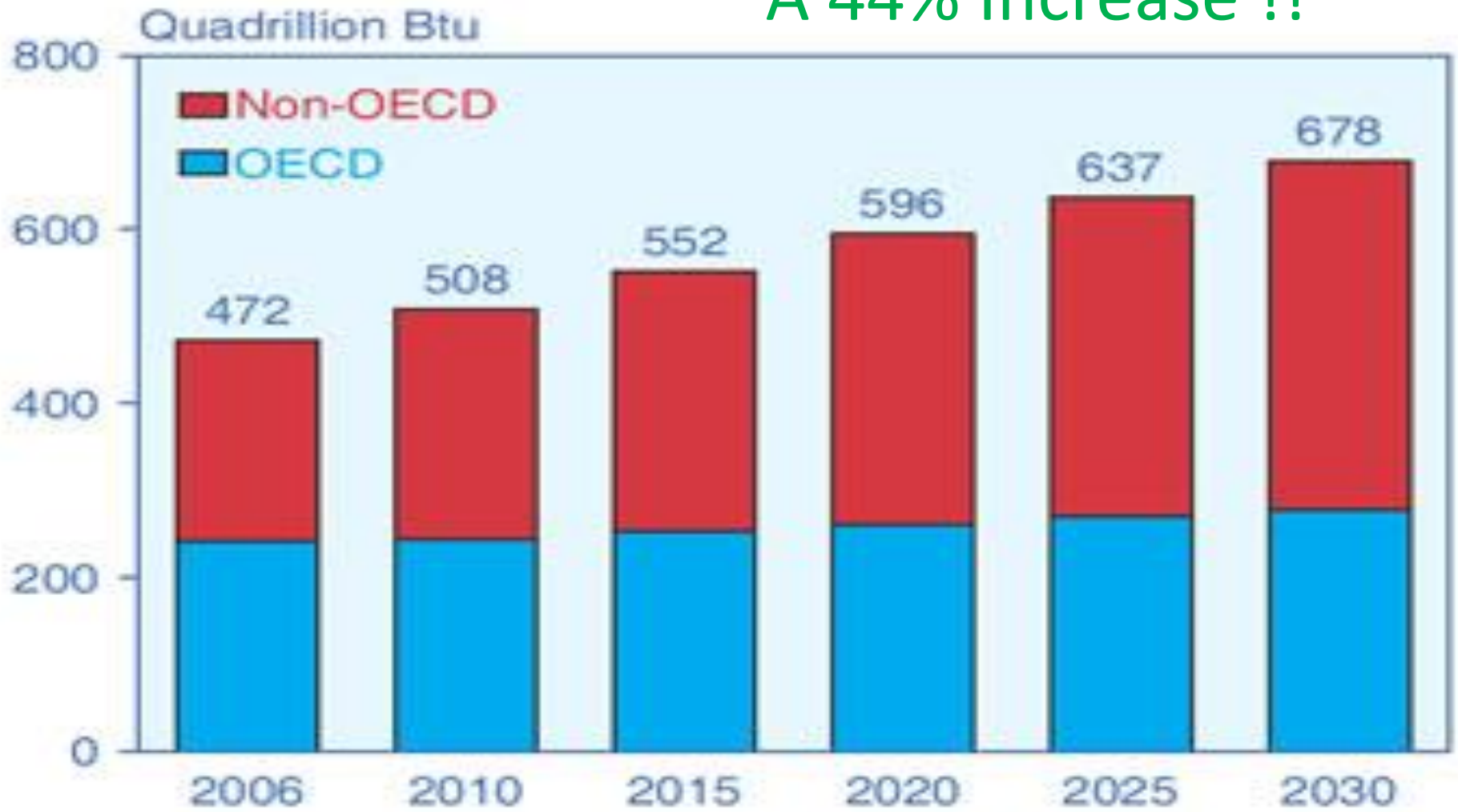
- Future worldwide energy demand and the role of shale reservoirs
  - North America
  - The rest of the world

- Shale reservoirs outside North America
  - Definition of levels
  - Review by Continents

- Conclusions

World Marketed Energy Consumption, 2006-2030

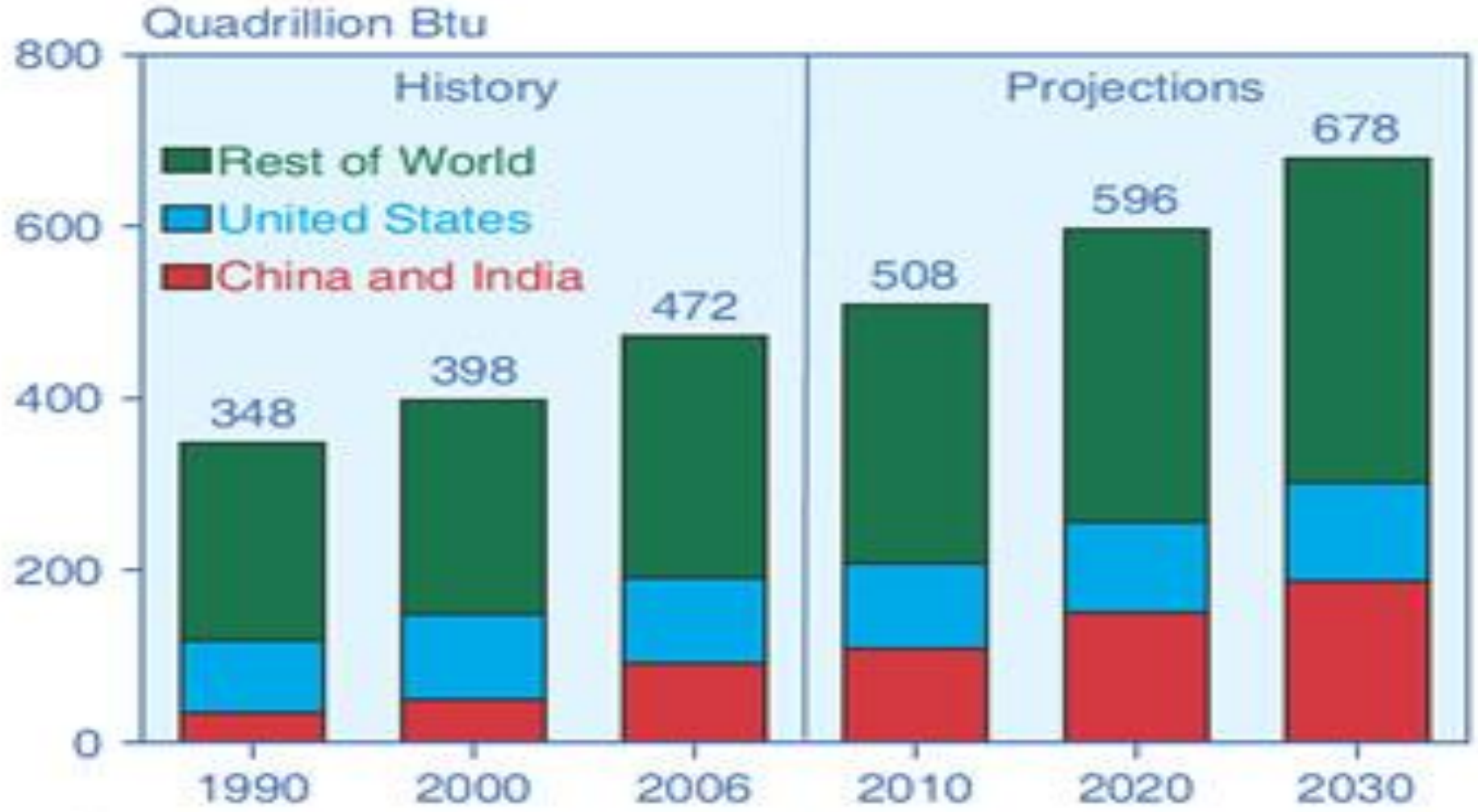
A 44% Increase !!



Sources: **2006:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. Energy Projections Plus (2009).

Reservoir IntelliLogic

Figure 12. Marketed Energy Use by Region, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Chase Manhattan Case Study

- Considering the 2% annual increase in demand and low rate of replenishing produced fluid.
- By 2014 eight (8) more Saudi Arabia will be needed
- By 2024 sixteen (16) Saudi Arabia will be needed
- Where are these Saudi fields going to come from:
  - Unconventional oil and gas (Shale gas & oil)
  - Carbonates
  - IOR and EOR

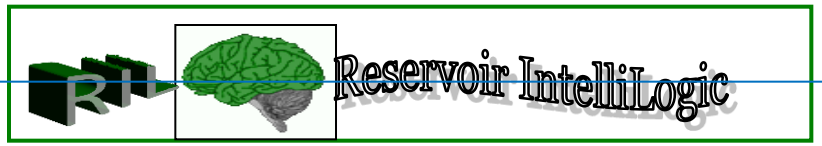
Ranking

- 1st Level Ranking:
  a) TOC (>0.5%)

- 2nd Level Ranking
  a) TOC (>0.5%)
  b) Lateral continuity (min. 20 m thick, 12,500 Km-Sq assuming ¼ Barnett)

- 3rd Level Ranking
  a) TOC (>0.5%)
  b) Lateral continuity (min. 20 m thick, 12,500 Km-Sq assuming ¼ Barnet)
  c) Hydrocarbon window/maturity Level/Kerogen type

- 4Th Level Ranking
  a) TOC (>0.5%)
  b) Lateral continuity (min. 20 m thick, 12,500 Km-Sq assuming ¼ Barnet)
  c) Hydrocarbon window/maturity Level/Kerogen type
  d) Infrastructure - existing and proposed (drilling, production facilities & pipelines)



Africa

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (Km^2)	Kerogen Type	Rating
Nigeria	Bornu State	Cretaceous	680-2840	>1150	23,000	III	3
Niger/Chad/ CAR	WCARS	Cretaceous -Tertiary	1300-5000	610	450,000	I & III	3
Ghana	SE Ghana	Devonian	950-1569	610	2,2000	N/A	1
Mauritania/ Mali	E. Maurit. W. Mali	Middle Infa-Cambrian	1000-6000	450m	2,000,000	II & III	2
Libya	Sirte	Upper Cretaceous	2700-3400	500-700	490,000	II	4
Libya	W. Libya	Lower Silurian	2590-3658	650	20,000	II	4
Libya	W. Libya	Middle-Upp Devonian	2101-2590	650	20,000	II	4
Libya	S-W. Libya	Lower Silurian	2134-3505	305	30,000	II	4

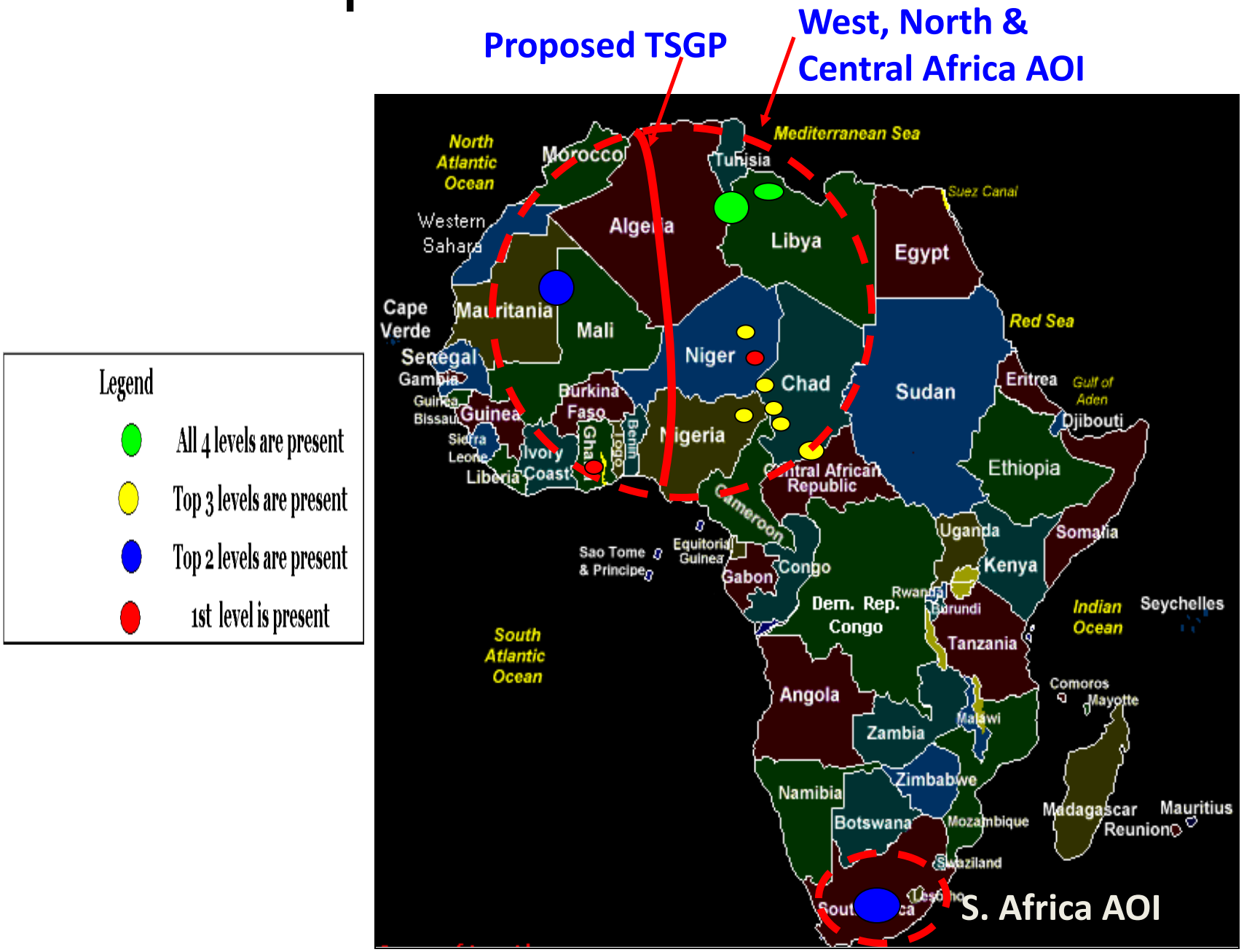
LEGEND: CAR- Central Africa Republic; WCARS - West & Central Africa Rift Systems; N – North; S - South; E – East; W – West; U - Upper

Africa Contd.

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (Km^2)	Kerogen Type	Rating
Algeria	E. Algeria	U. Devonian	3327-4412	120-200	120,000	I & II	4
Algeria	E. Algeria	L. Silurian	2660-4719	120-200	120,000	I & II	4
Tunisia	S. Tunisia	U. Devonian	2000	400	<=120,000	II	4
Tunisia	S. Tunisia	Lower Silurian	3500	300-400	<=120,000	II	4
South Africa	South & Central SA	Carbo-Permian	2563-2612	>46	700,000	III	2

LEGEND: CAR- Central Africa Republic; WCARS - West & Central Africa Rift Systems; N – North; S - South; E – East; W – West; C- Central; U - Upper

Map of Locations in Africa



South America

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (Km^2)	Kerogen Type	Rating
Argentina	Northern Patagonia	Devonian	<3000	30-1200	160,000	II, III	3
Argentina	Western	Carboni-ferous		1000 (max)	140,000	I, II	3
Argentina	Northwest	Devonian		300-4000	400,000	II, III	3
Bolivia		Devonian	2000+	10-1800	57,000	II, III	3
Brazil	Central Southern	Permian	2500+	35-350	1,500,000	I, II	3
Brazil	Southern	Silurian	800-2200	35-250	800	I, II	3
Brazil	Southern	Devonian	2030-2063	20-35	800	I, II	3
Paraguay		Silurian		300-4000	400,000	II, III	3
Paraguay	Eastern	Permian	1500-3500	35-350	1,500,000	I, II	3
Paraguay	Southeastern	Devonian	1200-3200	300-400	240,000	III, IV	3
Uruguay	Northern	Permian	<3200	50	1,500,000	I, II	3

South America (Contd.)

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (Km^2)	Kerogen Type	Rating
Uruguay		Devonian	1000+	150 (max)	400,000	III	3
Mexico	East central	Creta-ceous	3500->5000	2000 (max)	18,000	II, III	
Mexico	South-East	Tithonian	>5000	150-400	12,000	II, III	3
Venezuela	Eastern	Creta-ceous	500	60-740	165,000	I, II	3
Venezuela	Eastern	Miocene	1370-3960	>1830	165,000	II, III	3
Venezuela	Northern Perija	Silurian-Devonian	1220-1525	488	50,000	I & II	4
Venezuela	Western	Turonian-Santonian	1000	195 (max)	50,000	II & III	4

Map of Locations in South America

Australasia

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (Km^2)	Kerogen Type	Rating
Australia	N. Terr.	Pre-Cam		80	7.000	I, ii	4
B'desh	NE	Pliocene		2600	30,000		2
China	NE Depr	Cenezoic	2300-2500	2000	51,000	I-III	4
China	Junnger	Permian		800		III	3
China	Tarim	Paleozoic		1000		II, I	3
India-SE	Cauvery	Mesozoic	3830-5730	80-100		II, III	3
India	Cambay	Eocene	3000-3500	1000	5,400	III, I, II	4
Indonesia	Sumatra	Miocene		100	8,000	III	4
Indonesia	Off(S&J)	Miocene			>2bboe	III	2
Kazak	N. Casp	Devonian	3000+		550,000	I - III	3

Australasia, contd

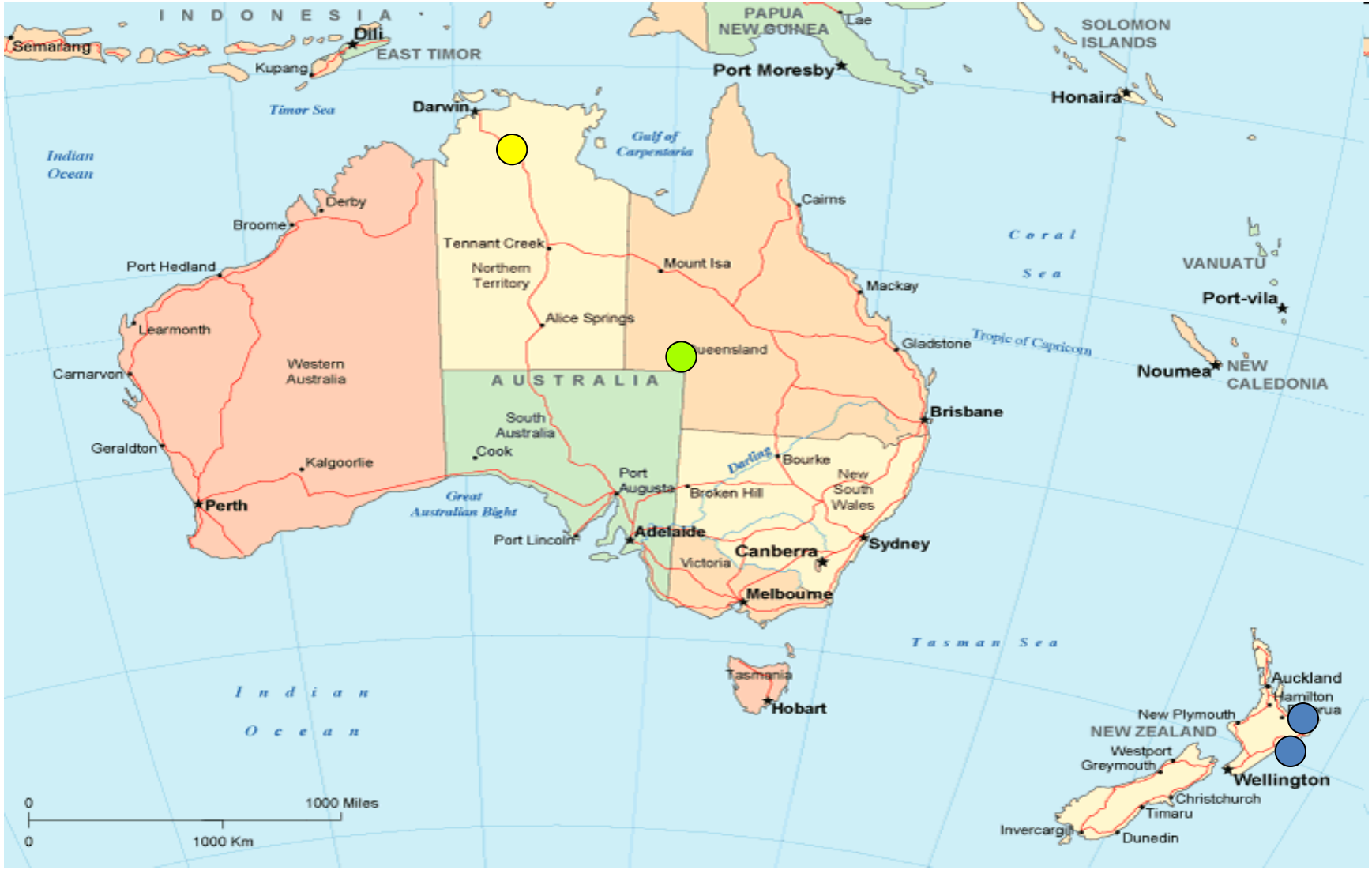
Country	Location	Age or Era	Depth (m)	Thick ness (m)	Field Size (Km^2)	Kero-gen Type	Rating
Malaysia	Offshore				>6bboe	III	1
New Zealand	Eastern North Island	Jurassic	3000-4000	<50	70,000	II & III	2
New Zealand	Eastern North Island	Late Creta-ceous	1600	610	70,000	II & III	2
Thailand	NW				>1bboe		
Sri-Lanka	NE	Mesozoic	3800-5700	20-50		II & III	2

Middle East

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (km^2)	Kerogen Type	Rating
Iran	Gurpi	Cretecs		1750		I-III	1
Iraq	Arab Pla	Silurian	2500+	50-1500	>10tboe	I- III	3
Jordan	Arab Pla	Silurian	2500+	50-1500	"	I-III	2
Kuwait	Arab Pla	Silurian	2500+	50-1500	"	II, III	2
Oman	Arab Pla	Silurian	2500+	50-1500	"	I - III	2
Oman	Arab Pla	Pre-Cam	3000+				1
Pakistan	NE sec	Silurian	2500+	40-200	9,000	I, II	3
Qatar	Arab Pla	Silurian	2500+	50-1500	"	I - III	2
Saudi	Arab Pla	Silurian	2500+	50-1500	"	I - III	2
Syria	Arab Pla	Silurian	2500+	50-1500	"	I - III	2
Turkey	Arab Pla	Silurian	2500+	50-1500	"	I - III	2

Asia including Middle East

Australia


INDONESIA
Semarang
Dili
EAST TIMOR
Kupang
Timor Sea
Darwin
PAPUA NEW GUINEA
Lae
Port Moresby
SOLOMON ISLANDS
Honaira
Indian Ocean
Gulf of Carpentaria
Derby
Broome
Port Hedland
Tennant Creek
Northern Territory
Mount Isa
Cairns
Coral Sea
VANUATU
Port-vila
Mackay
Learmonth
Alice Springs
Gladstone
Tropic of Capricorn
Noumea
NEW CALEDONIA
Carnarvon
Western Australia
Queensland
AUSTRALIA
Brisbane
South Australia
Geraldton
Cook
Darling
Bourke
Kalgoorlie
Port Augusta
Broken Hill
New South Wales
Great Australian Bight
Perth
Adelaide
Port Lincoln
Canberra
Sydney
Victoria
Melbourne
Tasman Sea
Tasmania
Hobart
Auckland
Hamilton
New Plymouth
NEW ZEALAND
Westport
Greymouth
Wellington
Christchurch
Timaru
Invercargill
Dunedin
Indian Ocean
0
1000 Miles
0
1000 Km

Central and Eastern Europe

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (km^2)	Kerogen Type	Rating
Austria	North Eastern	Jurassic	5000	1500	11,500	II & III	3
Germany	Posidoni	Jurassic		25	5.000	III, II	4
Germany	Wealdo	Cretace.		30	3,000	I, II	4
Hungary	Szolnok	Pliocene	2300-4300	1000		III, II	3
Norway	N. Sea	Permian	3300-5000	1000	>6 tboe	II, I	4
Poland	South western	Ordovi-cian-Silurian	2100-3600	150-500	4,050	II	3
Russia	T-Pecho	Permian	3000-3500	75-100	243bboe	III	4
Russia	W.Sibe	Thithoni	1000-3500	35	106,000	I, II	4

Central and Eastern Europe (CONT.)

Country	Location	Age or Era	Depth (m)	Thickness (m)	Field Size (km^2)	Kero-gen Type	Rating
Russia	T-Pecho	Ordovi-cian	3000+	45 - 60	"	II	4
Russia	T-Pecho	Frasnian	3000+	13 - 240	"	II E III W	4
Russia	T-Pecho	Devonian	3000+	25 - 40	"	II	4
Russia	T-Pecho	Devonian	3000+	45 - 60	"	II E III W	4
Russia	T-Pecho	Silurian	3000+	30 - 60	"	II	4
Sweden	Southern	Cambro-Ordovician	260-1315	93	3,035	II	

Map of Locations in Central & Eastern Europe

Conclusions

- Global energy demand continues to grow at a faster pace than the identification of new resource
- Shale reservoir has been identified as a viable source to address the issue and the search for shale needs to go global to address the global need
- Globally, there are significant potential shale resource base as identified; though most need to be further quantified.