Shale Gas Reserve Potential in the Sedentary Basins of Malaysia and South-East Asia Region

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Received: 8 December 2016 Accepted: 1 January 2017 Published: 15 January 2017

Abstract

Shale gas, which is mostly methane, can be found in any sedimentary basins. The depositional setting directly controls key factors in shale gas, such asorganic geochemistry, organic richness, and rock composition. Shale gas reservoir type is a source rock that has retained gas production potential. Produced gas comes from adsorbed gas in the organic matter and free gas trapped in the pores of the organic matter and in the organic portions of the matrix.The main objective of this study is to discuss the potential of shale gas reserves in Malaysia and South East Asia sedimentary basins. Shale can actually be a game changer in South East Asia and mainly for Malaysia, China, India, Pakistan, Indonesia and Thailand. Malaysia, located within Southeast Asia, has two distinct parts. The western half contains the Peninsular Malaysia, and the eastern half includes the states of Sarawak and Sabah.

Index terms— sedimentary basins, shale gas reserves, south asia region, global shale reserves.

1 Introduction

n the last decade and more, shale gas resources have emerged as a viable energy source. The development of these shales changed the traditional approach geologists had been following-that of the sequence of gas first being generated in the source rock, followed by its migration into the reservoir rock in which it is trapped. The shale layer acts as both source and reservoir rock in gas reservoir, there is no need for migration and since the permeability is near zero, it forms its own seal. Large amount of gas is generated in shale layers by sedimentation of organic matter. It is important for development of shale gas reservoirs to locate such layers where gas can be generated and accumulated in a sedimentary basin as well as the sweet spot with shale gas deposits. To accomplish this, the tectonics of shale sedimentary basins have to be analyzed, along with the sedimentary environment and sequence stratigraphy. As different shale gas reservoirs have different properties, it is imperative to study them before any exploration plan is put in place.

Shale gas consists of 70-90% methane, it is often called unconventional natural gas and is taken from different rock layers than traditional gas. shale gas exploration and exploitation is governed by many factors such as the areal extent of shale layer, thickness, total organiccarbon content, kerogen type, maturity, mineralogy, brittleness verses ductility etc. integrated studies of geological, geochemical, geophysical, petrophysical, geo mechanical can help evaluating all these factors to identify the sweet spots for shale gas exploration and exploitation. The shale itself has very low permeability and, without employing fracturing technology, production well flow rates would be minimal, **??**Satinder et al, 2012 and **??**amada, 2017).

The main method of shale gas production is hydraulic fracturing, which requires a tremendous amount of water. Every shale gas well needs millions of gallons of water. The hydraulic fracturing process shoots out a mixture of water and chemicals at high pressure to extract the gas, inevitably requiring large amounts of water. Thus, the most important issue in developing shale gas in SE ASIA developing the technology to minimize water usage. In summary, it can be stated that the potential for shale gas as a source of energy in Southeast Asia appears to be good. However, more work needs to be carried out to ascertain the exact capacity of this gas in each country mentioned earlier.

For a shale gas reservoir to become a successful shale gas play, the following characteristics need to be considered: organic richness (TOC), maturation, thickness, gas in place, permeability, mineralogy, brittleness and pore pressure. An optimum combination of these factors leads to favorable productivity. Geophysical methods can help in characterizing the shale gas resource plays. However, the methodology adopted is in general quite different from methodologies applied to conventional reservoirs. In addition, the characterization of each shale reservoir could require particular types of tools and approaches to well understand the sedimentation conditions and the petrrophysical properties to meet the growing challenges and expectations of shale gas resources.

Exploration and production activity started in Southeast Asia in the beginning of the last century. Shale gas resources are widely spread across the globe, there is great interest in the economic potential for developing shale gas more widely. The main objective of this study is to discuss the potential of shale gas reserves in Malaysia and South-East Asia sedimentary basins. Shale can be a game changer in South East Asia and mainly for Malaysia, China, India, Pakistan, Indonesia and Thailand. All these countries are big importers of crude oil and shale has the potential to drastically reduce the huge import bills of these nations. However, Southeast Asia has strengthened its important role in the global energy market, due to the growing economies in the region.

2 II.

3 Malaysia Basins And Shale Gas Potential

Malaysia is in rapid economic growth while oil and gas is expected to play an important role in the economy towards the year 2020, when the country is expected to be fully industrialized.

Malaysia is the world's third-largest exporter of liquefied natural gas, and the second-largest oil and natural gas producer in the Southeast Asia. Malaysian sedimentary basins are major areas for potential oil and gas reservoirs as they contain many faults and natural traps, which collects and accumulate hydrocarbons under its impermeable layer. Six major Tertiary sedimentary basins are present in Malaysia: the Malay, Penyu, Sarawak, Sabah, Sandakan and a portion of Tarakan basins (Fig. **??** Peninsular Malaysia region have four main basins, The Malay Basin and the Penyu Basin are located offshore to the east of the peninsula. Other two basins, namely the Central Sumatra Basin and the North Sumatra Basin lie to the west of the peninsula and are mostly offshore with a small portion lying onshore. The Malay Basin contains about 12-km thick Neogene sediments that were deposited within the non-marine to shallow marine environment. In the Penyu Basin, oil has been discovered on horst blocks of Oligocene synrift play consisting of fluvial sandstones reservoirs.

4 III. China Potential And Major Shale Gas Prospects

China is the third country gaining shale gas discovery in the world after the United States and Canada. China has a huge shale gas resources. According to some estimates, it is the world's largest reserve. China possesses 31.6 trillion cubic meters (1,115 trillion cubic feet) of technically recoverable shale gas resources(EIA, 2013).

For geographical distribution, target areas can be divided into four regions (Fig The Sichuan and Tarim Basins are two large organic rich shale plays, and other five less prospective basins are the Songliao, Bohai, Ordos, Tuha and Jungar Basins. The Sichuan Basin is considered as the most promising basin to develop shale gas in short term, because of its well-developed gas pipeline network and mature gas market.

Shale Gas Reserve potential in the Sedentary Basins of Malaysia and South-East Asia Region

5 a)

Sichuan Basin is one of the richest shale gas basins in China. Shale exploration activity in China has been focused on the Sichuan Basin, which contains marine-deposited, dry-gas mature source rock shales that resemble commercially productive shales. The Sichuan Basin covers a large 190,000-km2 area in south central China. The basin currently produces about 1.5 Bcf/d of natural gas from conventional and lowpermeability sandstones and carbonates within the Triassic Xujiahe and Feixianguan formations, from complex structural-stratigraphic traps (mainly faulted anticlines) that are distributed across the basin. Sichuan Basin is the Changning-Weiyuan area, which is found to be high in thermal evolution degree (Ro: 2.0%-4.0%), porosity (3.0%-4.8%), gas concentration (2.82-3.28 m3/t) and the burial depth is relatively moderate (1500-4500 m). **??** The Sichuan Basin, primary focus for shale gas, has multiple shale targets but also significant geologic challenges, such as numerous faults, often steep dips, high tectonic stress, slow drilling in hard formations, and high H_2S and CO_2 in places. Table-1 data provides good control of shale thickness, depth, structural geology, thermal maturity, and organic content.

The Sichuan basin has four tectonic zones: the Northwest Depression, Central Uplift, and the East and South Fold Belts. The Central Uplift, characterized by relatively simple structure and comparatively few faults, appears to be the most attractive region for shale gas development. In contrast, the East and South Fold Belts are structurally more complex, with numerous closely spaced folds and faults.

The four-main organic-rich shale targets in the Sichuan Basin are the Lower Cambrian Qiongzhusi, Lower Silurian Longmaxi, Lower Permian Qixia, and the Upper Permian Longtan formations. (Figure 3). Most important is the Lower Silurian Longmaxi Formation, which contains an average 300 m of organically rich, black, graptolitic-bearing, siliceous to cherty shale. TOC is mostly low to moderate, reaching 4% and consisting mainly of Type II kerogen (Liu et al., 2011). Thermal maturity ishigh and increases with depth, ranging from dry gas prone to over mature (Ro 2.4% to 3.6%).

Another shale gas target in the Sichuan Basin is the Cambrian Qiongzhusi Formation. Even though deeper than the Longmaxi and mostly screened out by the 5-km depth, the Qiongzhusi contains high-quality source rocks that provide stacked shale resource potential. The formation was deposited under shallow marine continental shelf conditions and has an overall thickness of 250 to 600m. The Tarim Basin, located in the Xinjiang Autonomous Region, is China's largest onshore sedimentary basin (600,000 km2, the Tarim Basin produces 260,000 B/D of oil and 1.6 Bcfd of natural gas from conventional reservoirs, which were sourced mainly by organic-rich Cambrian and Ordovician shales. Figure 7 shows the structural elements of the Tarim Basin, and Prospective of shale gas.

The Tarim Basin is sub-divided by fault and fold systems into a series of seven distinct structural zones, comprising three uplifts and four depressions.

6 India Shale Gas Potential

Natural gas is rapidly substituting fuel to suffice the growing energy requirement of today's world. As the consumption of natural gas is increasing rapidly, it is essential to identify and develop the available energy resources. India has the huge prospects of unconventional shale gas resources. Commercial exploration of these shale gas resources can effectively make the global natural gas curve more elastic.

There is a sizeable deposit of shale formations in several sedimentary basins of India with different total organic (TOC) content and maturity history. The Cambay, Krishna-Godavari, Cauvery and Damodar valley are the four major basins of shale gas reservoirs as indicated by considerable thickness of shales; sufficient TOC (2 to 6 wt%) content; and good thermal maturity with vitrinite reflectance of more than 1.0. (Ind., 2014). The reservoir properties and resource potential (290 TCF) of shale gas, estimated by ARI, are shown in Table-3.

According to ARI (American Research Institute), shale gas reserves would be anywhere between 600 Tcf to 2000 Tcf and technically recoverable shale gas resource is estimated as 63 Tcf in spread over many sedimentary basins India. Most of Indian basins especially the Cambay, Krishna-Godavari, Cauvery and Damodar Valley have good prospects of shale gas (Fig. 9). Several other basins such as the Vindhyan, Upper Assam, Pranhita-Godavari and Rajasthan, though show thermal immaturity, contain measurable thickness of shale with good TOC content.

7 b)

It is located on the east coast of India; land part covers an area of 15000 sq. km and the offshore part covers an area of 25,000 sq. km. Shale in the Krishna Godavari Basin is limited to the four grabens (subbasins) where the thermal maturity is sufficiently high for wet to dry gas generation. (Mahto, 2014) Estimated risked shale gas in place is of 136 Tcf, with a risked technically recoverable resource of 27 Tcf.

8 c)

The Cauvery basin covers an area (25,000 sq.km) and shallow offshore areas (30,000 sq. km). The basin contains a thick interval of organic rich source rocks in Lower Cretaceous Andimadam and Sattapadi shale formations. The oldest rocks in the Cauvery Basin : are the shallow marine, late Jurassic sediments and early Cretaceous deposits. Average resource around 43 Tcf of risked shale gas in-place is estimated of which 9 Tcf is considered technically recoverable.

9 d)

The Damodar Valley Basin is part of a group of basins collectively named as Gondwanas. (Pradhan, 2015) The Gondwanas, comprising the Satpura, Pranhita-Godavari, Son-Mahanadi and Damodar Basins. In this basin around 33 Tcf of risked shale gas in-place is estimated of which 7 Tcf is considered technically recoverable.

10 e)

The Southern Indus Basin is in southern Pakistan adjacent to the border with India. Southern Indus Basin has five commercial oil discoveries and one gas discovery in the conventional Cretaceous-age and three gas discoveries and one gas condensate discovery in shallower formations. Moreover, with the help of this technology the well can drain shale gas resources from a geographical area that is much larger than a single vertical well within the same shale formation. The Lower Indus basin has two types of shale formations, which are Sembar and Ranikotformation. Within the overall prospective area of the Lower Indus Basin, the Sembar Shale has risked shale gas in-place of 531 Tcf, with 101 Tcf as the risked, technically recoverable shale gas resource. In addition, prospective area of the Lower Indus Basin, the Ranikot Shale has 55 Tcf of risked shale gas in-place and 82 billion barrels of risked shale oil in-place.

11 Cambay Basin Krishna Godavari Basin

Cauvery

Sembar Formation

? It mainly consists of clastic rocks, typically shale with lesser quantities of siltstone and sandstone in the Lower Indus. The sand content increases towards the Southeast in the Lower Indus Basin. However, in the Middle Indus Basin, the formation is composed of siltstone with few marl and shales.

? Shale in Sembar Formation is basically medium hard, pyritic, moderately indurated and slightly calcareous in the area. The gross thickness varies from >50m to800 m. ? The TOC and thermal maturity (Ro) of Sembar formation as per exploration targets is around 2% and 1%-1.6% respectively. ? The shale in Paleocene Ranikot Formations is primarily upper carbonate unit, which is tailored with fossiliferous limestone inter-bedded with dolomitic shale, calcareous sandstone and abundant bituminous material. ? The prospective area of the Ranikot formation has a thickness of around 1,000-3,000ft with net shale thickness of 200 ft.

12 Ranikot Formation

i.

ii.

13 Lower Indus Basin

Global Journal of Researches in Engineering ( ) Volume XVII Issue IV Version I VI.

14 Thailand

This large Southeast Asian country has significant prospective shale gas potential. Nearly 90% of its current petroleum output comes from offshore fields in the Gulf of Thailand, with only limited production from small onshore fields. Approximately 40% of Thailand's primary energy consumption is supplied by natural gas.

Thailand's greatest potential appears to be shale gas deposits contained in Permian and Triassic shale source rocks in the Khorat, the country's largest onshore sedimentary basin. (Jeenagool, 2015) These shales can be locally thick, organic-rich, dry gas prone, deeply buried, and overpressure.

Thailand has three main onshore sedimentary basins which may have unconventional oil and gas potential, Figure -13. These include the large Khorat Basin in the northeast; a series of smaller, isolated pullapart basins in the Northern Intermontane Basin, where shale oil deposits are being mined; and the similarly complex Central Plains Basin.

The Khorat Basin in northeast Thailand has an estimated 5 Tcf of risked technically recoverable shale gas resources. While no shale gas/oil exploration activity has been reported to date. The structural Khorat Basin depression was initiated during the Middle Paleozoic, with widespread deposition of clastic and carbonate sedimentary rocks, beginning with the Carboniferous Si That Formation. Fluvial and lacustrine deposits of the Triassic Kuchinarai Group also have been identified as petroleum source rocks in the Khorat Basin, with high-TOC intervals. The Kuchinarai Group reportedly averages a prospective 6,500 to 7,000 feet deep within the basin. Thermal maturity modeling suggests it reaches the dry gas window, with no liquids potential (Ro> 2.0%).

15 Indonesia Shale Gas Potential

Indonesia is the world's fourth most populous country (250 million) and a major producer of coal, oil, and natural gas. Indonesia has shale gas and shale oil potential within selected marine-deposited formations, as well as more extensive shale resources within nonmarine and often coaly shale deposits, Estimated 46 Tcf technically recoverable shale gas resources out of 303 Tcf of risked shale gas in-place. in central and western Indonesia. (Fig. 15 shows Stratigraphy of Source Rocks)

16 a)

The Bintuni Basin, located in the eastern side of the Bird's Head region, appears to have the simplest structural conditions and best shale prospectively in the eastern Indonesia region. The stratigraphic section resembles that of the Salawati Basin, with preserved Paleozoic, Mesozoic, and Tertiary units. The prospective areas of the Permian Aifam formation have an estimated 29 TCF of technically recoverable shale gas resources out of 114 Tcf of gas in-place. (Kuuskraa V. S., 2013) This marine-deposited unit could be the best shale gas target in Indonesia. To date No shale gas/oil leasing or exploration activity has been reported in eastern Indonesia.

17 b)

Sumatra has shale oil and gas potential in three deep basin complexes: The North, Central, and South Sumatra basins. The North Sumatra Basin produces mainly conventional gas both onshore and offshore. Central Sumatra Basin one of main resources in Shale gas with technically recoverable resources from the Brown Shale are estimated at 3.3 Tcf out of 42 Tcf shale gas.

South Sumatra Basin, this basin is a significant conventional oil and gas producing area as well as a focus of Shale gas & coalbed methane exploration. The basin contains late Eocene to early Oligocene deposits of clastic sediments in transgressional pull-apart depressions. The Eocene to Oligocene TalangAkar Formation is prospective within a large 15,490-mi2 area and estimated to have a 367-ft thick high-graded zone with average 5% TOC and 0.7% Ro. The pressure gradient is normal and the clay content is considered high. The TalangAkar Formation has an estimated 4.1 of technically recoverable shale gas resources, out of 68 Tcf.

18 VIII.

19 Conclusion

? Shale gas refers to natural gas in organic rich fine grained rocks (shale and/or mud rock). Gas stored in shale as: 1) adsorbed gas attached to organic matter, 2) free gas in matrix pores, micro pores and natural; fractures and 3) solution gas in liquids such as bitumen and oil. For shale gas, hydraulic

Shale Gas Reserve potential in the Sedentary Basins of Malaysia and South-East Asia Region Tarakan basins in Kalimantan; most reserve of shale gas in the eastern part (Salawati, Bintuni, Tomori) but it structurally complex basins. Other basins in Indonesia appear to be less prospective due to low TOC, high clay and CO2 contents Many of Indonesia's organic-rich shales are non-marine coaly deposits that may not be brittle enough for shale development. Their depositional setting ranges from deepwater marine in eastern Indonesia to mostly lacustrine and deltaic environments Indonesia has shale gas within selected marinedeposited formations, more extensive shale resources. The petroleum source rocks in onshore Indonesian basins are relatively young, mostly Eocene to Pliocene. (Rahmalia, 2012) Indonesia have many onshore sedimentary basins (Figure 15) which may have shale gas potential, these include the Central and South Sumatra basins on Sumatra Island; the Kutei and ? The economic feasibility of shale gas as unconventional resources is highly dependent on the price of conventional resources, and the assumption that the price will remain at a certain level for some time to come. Available technology and development plans have great impact on the forecasting of unconventional resources either as complement or replacement of the conventional resources. considered: organic richness (TOC), maturation, thickness, gas in place, permeability, mineralogy, brittleness and pore pressure. An optimum combination of these factors leads to favorable productivity. Geophysical methods can help in characterizing the shale gas resource plays ? Shale gas reservoir to become a successful shale gas play, the following characteristics need to be fracturing of a reservoir is the preferred stimulation method. [1][2][3]

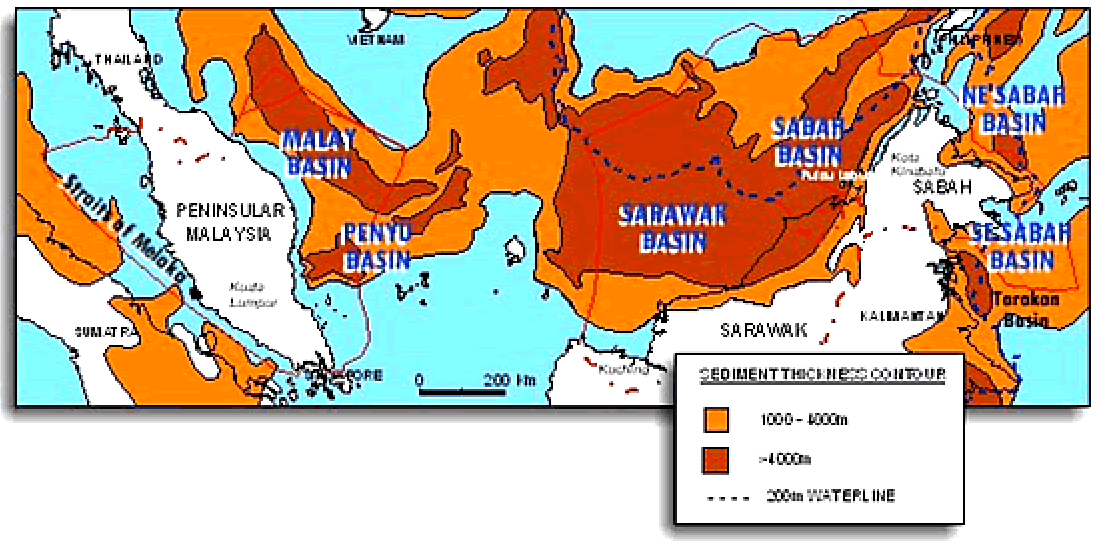

Figure 1:

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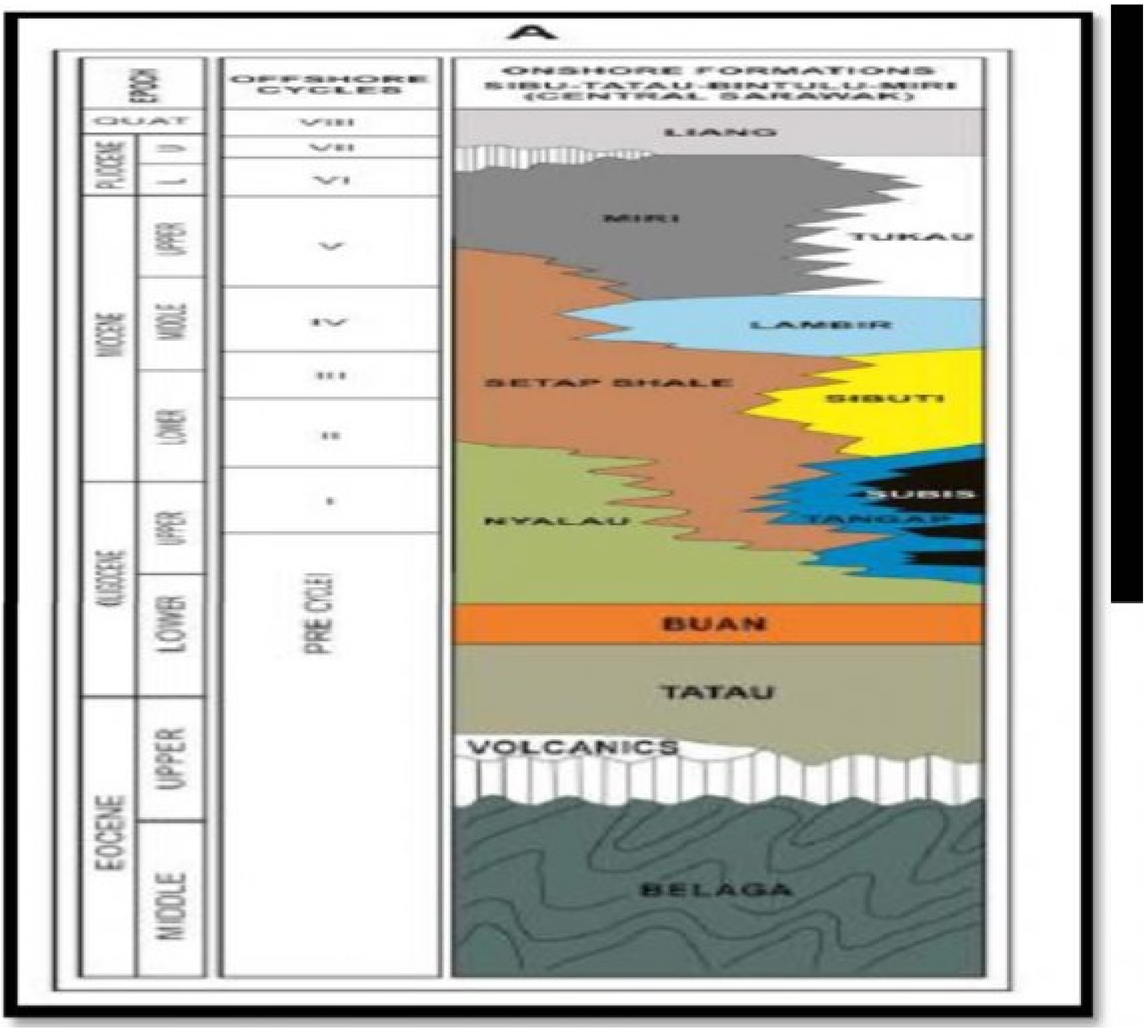

Figure 2: Figure 1 :Figure 2 :

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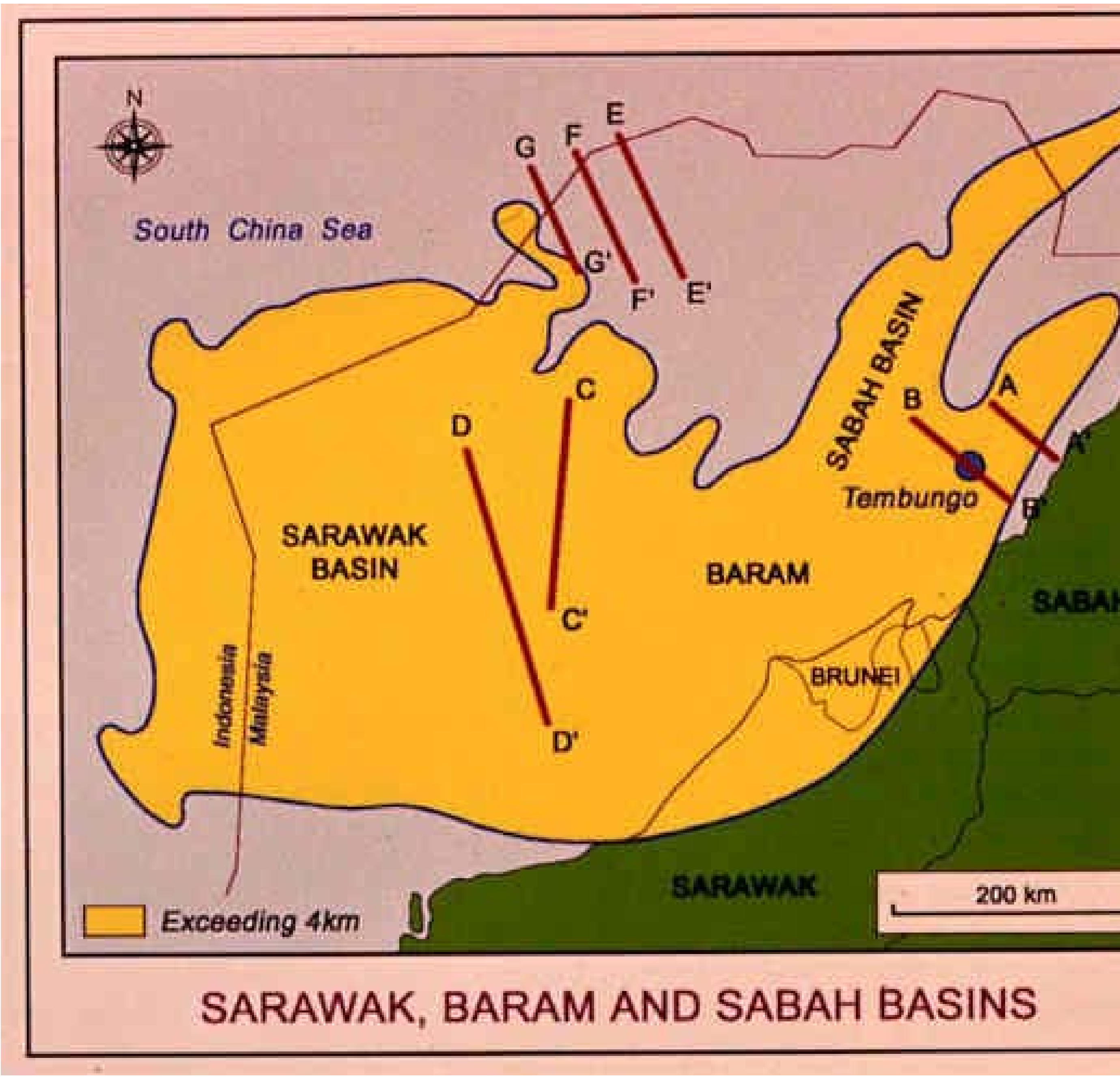

Figure 3: Figure 3 :

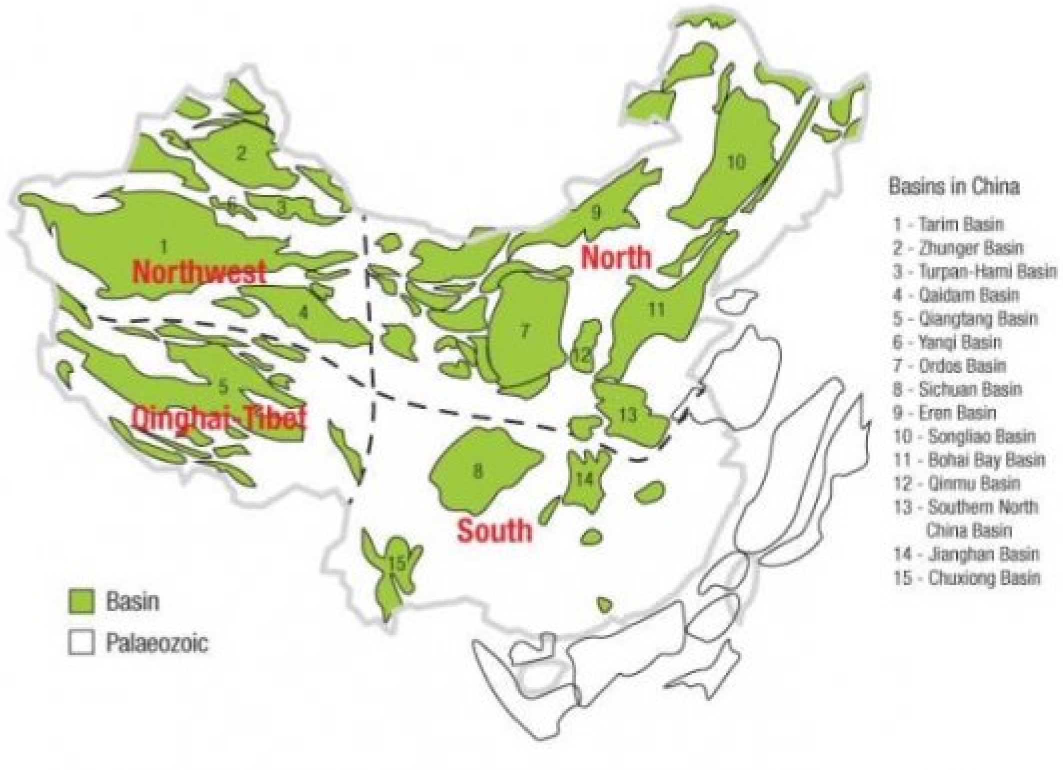

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Figure 4: Figure 4 :

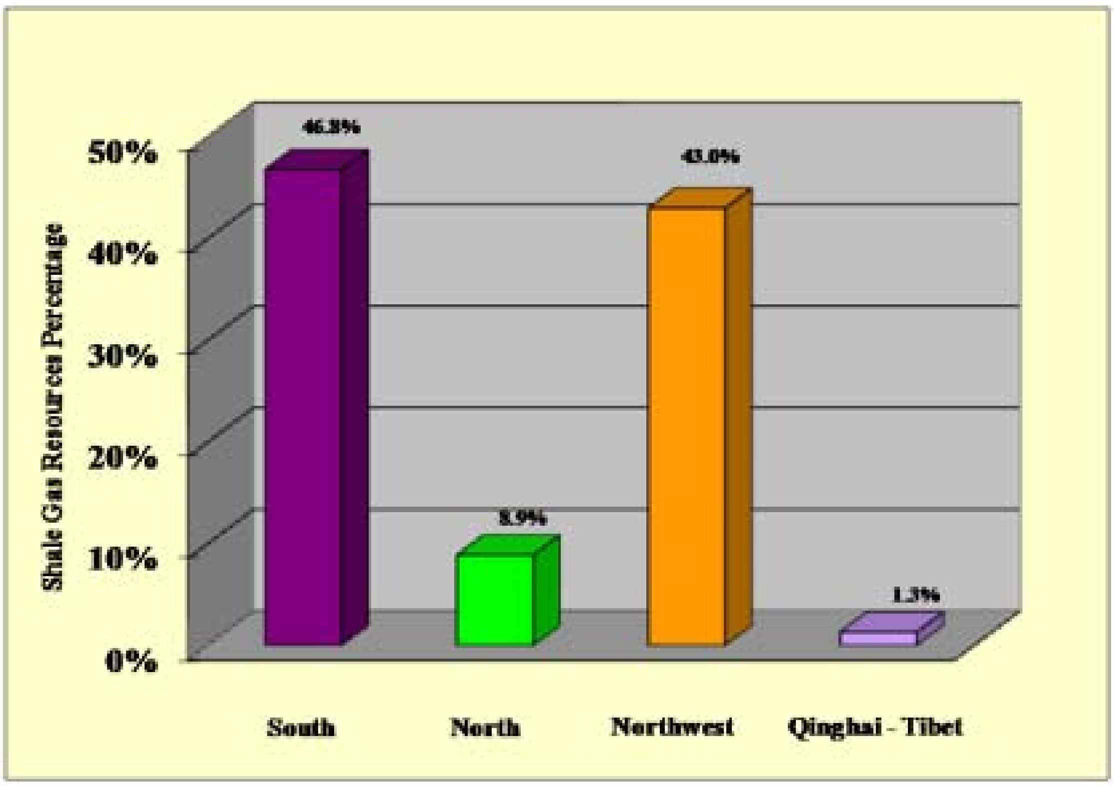

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Figure 5: Figure 5 :Figure 6 :

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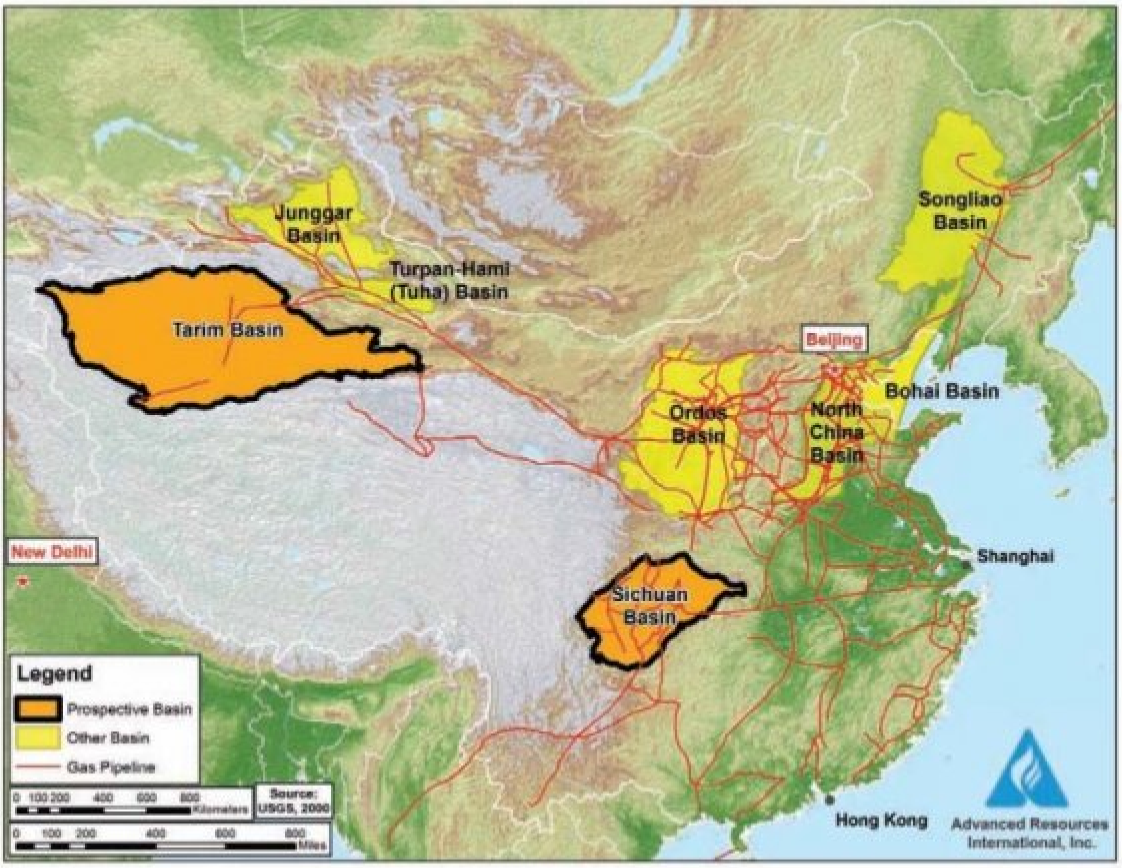

Figure 6: Table 2 :

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System	Series	Formation	Depth	Formation thickness (m)	Shale Thickness (m)	Area ($10^3 km^2$)	Shale Gas Resource ($10^{12} m^3$)
Triassic	upper	Xujiahe	1,870-5,000	1,800-5,100	500-1,860	14-16.5	8.4-33.5
Silurian	lower	Longmaxi	2,300-4,100	200-800	50-500	128.2	4-12.4
Ordovician	upper	Wufengzu	2,300-4,500		2-40	147.3	0.52
Cambria	lower	Qiongzhusi	2,700-3,600	50-500	74-400	184.5	7.14-14.6
Sinian	upper	Doushantuo		25-70	10-40		

Figure 7: Figure 7 :

SICHUAN BASIN					
ERA	PERIOD	EPOCH	FORMATION	AGE (Ma)	THICKNESS (m)
CENOZOIC	QUATERNARY			0 - 3	0 - 380
	TERTIARY	Upper		3 - 25	0 - 300
		Lower		25 - 80	0 - 800
MESOZOIC	CRETACEOUS			80 - 140	0 - 2000
	JURASSIC	Upper	Penglaizhen	140 - 195	650 - 1400
		Middle	Suining		340 - 500
			Shaximiao		600 - 2800
		Middle-Lower	Ziliujing		200 - 900
	TRIASSIC	Upper	*Xujiahe*	195 - 205	250 - 3000
		Middle	Leikoupo	205 - 230	900 - 1700
		Lower	Jialingjiang		
			Feixianguan		
PALEOZOIC	PERMIAN	Upper	Changxing	230 - 270	200 - 500
			Longtan		
		Lower	Maokou		200 - 500
			Qixia-Liangshan		
	CARBONIFEROUS	Mississippian	Huanglong	270 - 320	0 - 500
	SILURIAN	Upper		320 - 570	0 - 1500
		Lower	Longmaxi		
	ORDOVICIAN				0 - 600
	CAMBRIAN	Upper	Xixiangchi		0 - 2500
		Middle	Yuxiansi		
		Lower	Qiongzhusi		
PROTEROZOIC	SINIAN	Upper	Dengying	570 - 850	200 - 1100
			Doushantuo		
		Lower			0 - 400
	PRE-SINIAN			850	

Figure 8:

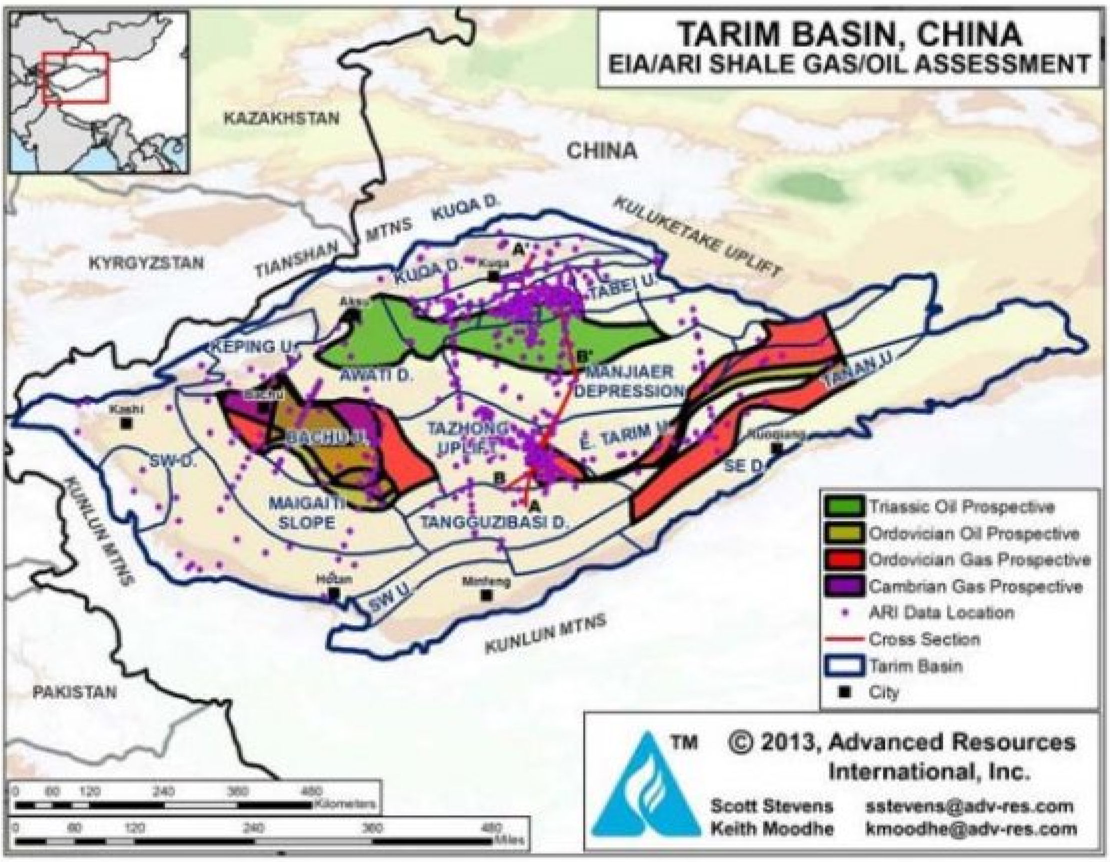

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Figure 9: Figure 8 :

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ERA	PERIOD	EPOCH	FORMATION	AGE (Ma)	THICKNESS (m)
CENOZOIC	QUATERNARY	Q			
	TERTIARY	N_{2a}			
		N_{1w}			
		Eh			
MESOZOIC	CRETACEOUS	K_{2y}			
		K_{1y}			
	JURASSIC	J_{3k}			
		J_{2t}			
		J_{2y}			
		J1k			
	TRIASSIC				
PALEOZOIC	PERMIAN	Upper	Shazijing	290	0 - 780
			Aqiaqun		
		Middle-Lower	Aqiaqun		
	CARBONIFEROUS	Upper-Middle	Xiaohaizi	290 - 355	0 - 691
		Lower	Kalashayi		
			Bachu		
	DEVONIAN			355 - 405	0 - 241
	SILURIAN	Upper		405 - 439	0 - 517
		Middle			
		Lower			
	ORDOVICIAN	Upper	Hetuao (O_{1-2})	439 - 459	0 - 300 org-rich
		Middle	Yijianfan (O_2)	459 - 478	0 - 150 org-rich
		Lower	Lianglitage (O_3)	478 - 505	0 - 50 org-rich
	CAMBRIAN	Upper	Qiulitage	505 - 600	2918
		Middle	Awatage		125
		Lower	Xiaoerbulake		74
PROTEROZOIC	SINIAN			600+	200 - 1100

Figure 10: Figure 9

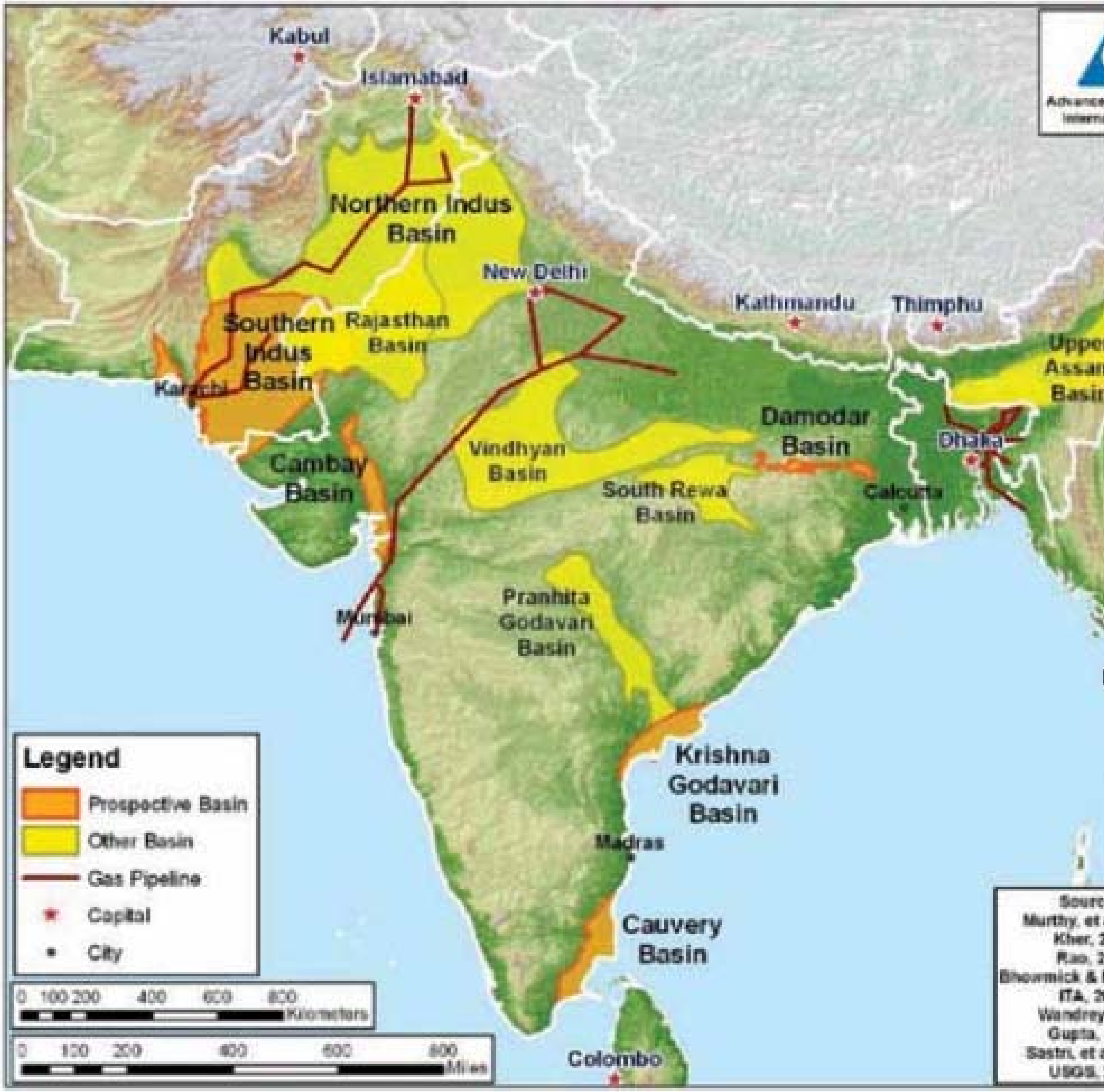

Figure 11: 3 :Figure 10 :

	Basin/Gross Area		Cambay basin (20,000 mi^2)	Damodar Valley basin (1,410 mi^2)	Krishna-Godavari basin (7,800mi^2)	Cauvery basin (9,100 mi^2)
Basic data	Shale Formation		Cambay Shale	Barren Measure	Kommugudem Shale	Andimadam Formation
	Geological Age		Upper Cretaceous/ Tertiary	Permian-Triassic	Permian	Cretaceous
Physical Extent	Prospective Area(mi^2)		940	1,080	4,340	1,005
	Thickness (ft)	Interval	1,600-4,900	0-2,100	3,100-3,500	600-1,200
		Organic Rich	1,500	1,050	1,000	800
		Net	500	368	300	400
	Depth (ft)	Interval	11,500-16,400	3,280-6,560	6,200-13,900	7,000-13,000
		Average	13,000	4,920	11,500	10,000
Reservoir properties	Reservoir Pressure		Moderately Overpressured	Moderately Overpressured	Normal	Normal
	Average TOC (wt. %)		3.0%	4.5%	6.0%	2.0%
	Clay Content		Medium	High	High	High
Resource	GIP Concentration(BCF/mi^2)		231	123	156	143
	Risked GIP (TCF)		78	33	136	43
	Risked recoverable(TCF)		20	7	27	9

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Figure 12: Figure 11 :

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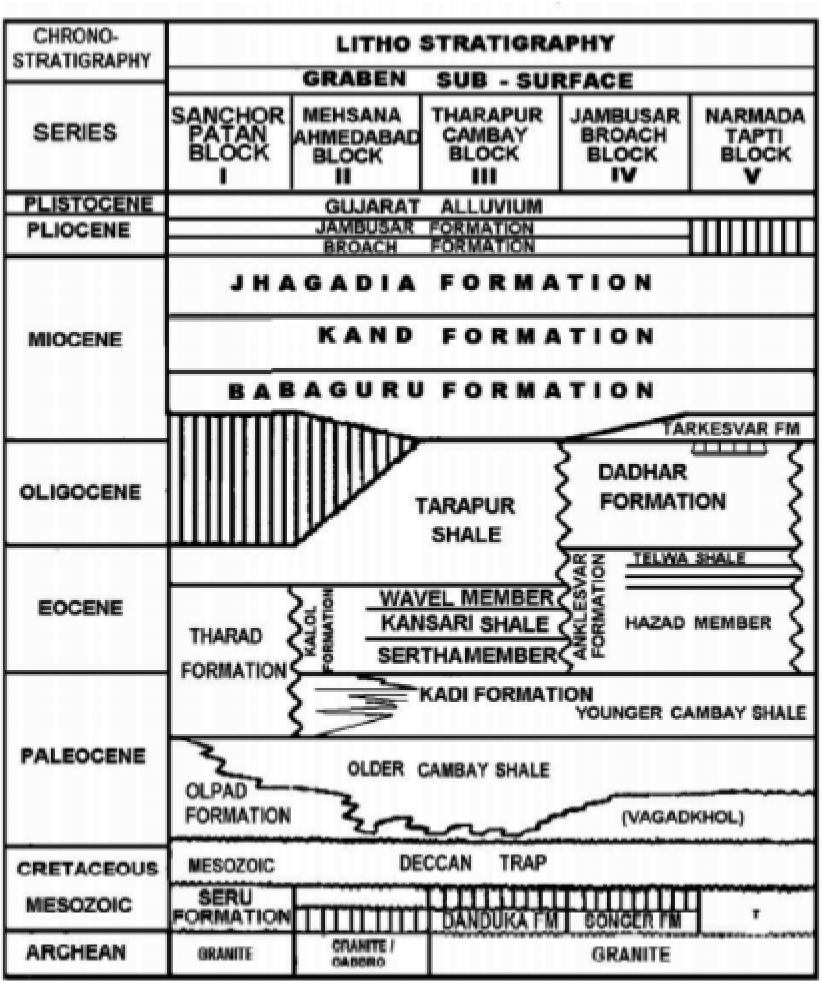

Figure 13: Figure 12 :

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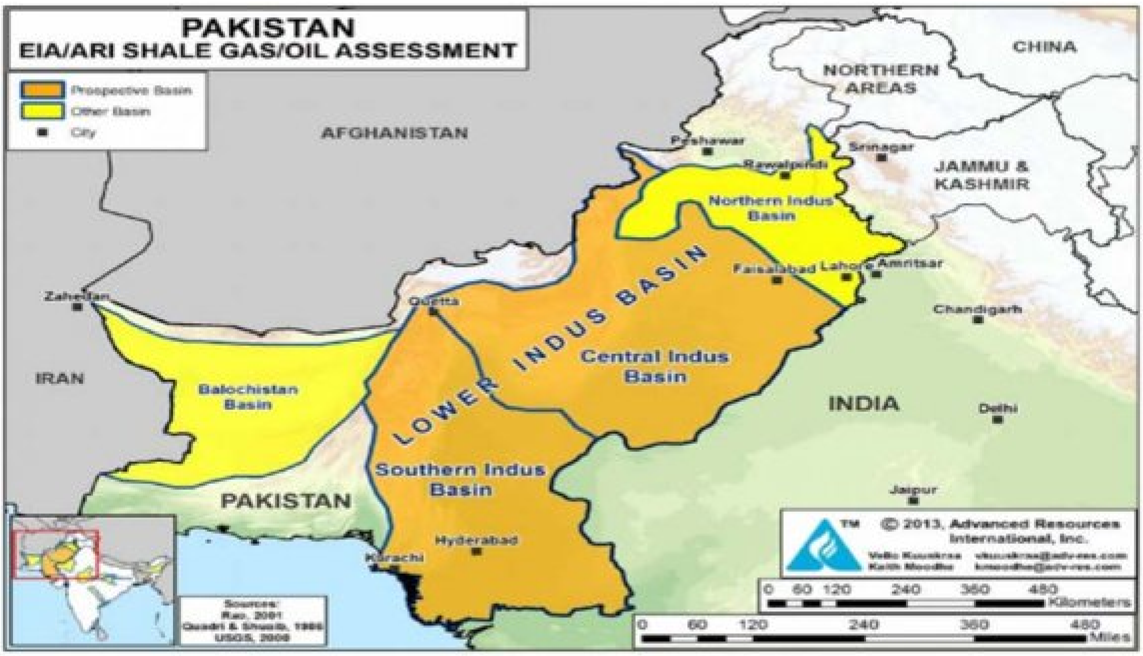
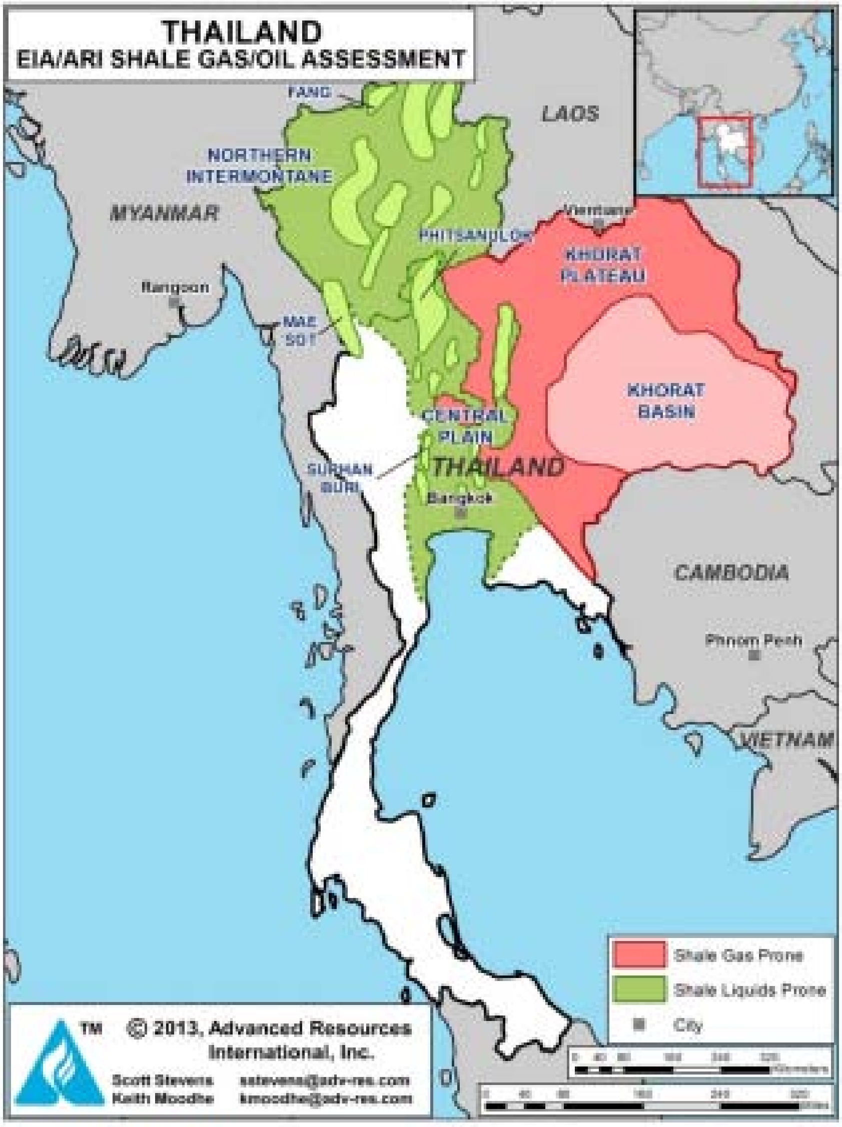


Figure 14: Figure 13 :

			PAKISTAN BASINS			
	BASIN		SOUTHERN INDUS	CENTRAL INDUS	NORTHERN INDUS	BALOCHISTAN
ERA	PERIOD	EPOCH	FORMATION			
CENOZOIC	QUATERNARY	Pleistocene	Siwaliks	Siwaliks		Ormara Chati
	TERTIARY	Pliocene				Talar/Hinglas
		Miocene	Gaj	Gaj	Kamlial Murree	Parkini Panjgur
		Oligocene	Nari	Nari		Hoshab Siahan Amalaf
		Eocene	Kirthar Ghazij/ Baska/Laki	Kirthar Sakaser Nummal	Kohat Kuldana	Wakai Saindak Kharan
		Paleocene	Dunghan Ranikot Khadro	Dunghan Ranikot	Patala Lockhart Hangu	Ispikan Rakhshani
MESOZOIC	CRETACEOUS	Upper	Pab Mughal Kot Parh	Pab Mughal Kot Parh	Kawagarh	Humai
		Lower	Goru Sembar	Goru Sembar	Lumshiwal Chichali	Sinjrani
	JURASSIC	Upper	Takatu/Chiltan	Samana Suk		
		Middle	Lorolai/Datta		Samana Suk	
		Lower	Shirinab	Shinawari Data	Shinawari Data	
	TRIASSIC	Upper	Wulgai/Alozai	Kingriali	Kingriali	
		Middle		Tredian	Tredian Mianwali	
		Lower		Mianwali	Chidru	
PALEOZOIC	PERMIAN			Zaluch Nilawhan	Wargal Sardhai Warcha Dandot Tobra	
	CAMBRIAN		Baghanwala Jutana Kussak	Baghanwala Juttana Kussak	Juttana Khewra	
PROTEROZOIC	PRECAMBRIAN		Khewra Salt Range Jodhpur Basement	Khewra Salt Range Jodhpur Basement	Salt Range Basement	

Figure 15: ShaleTable 4 :



14 Source: ARI, 2013

Figure 16: Figure 14 :

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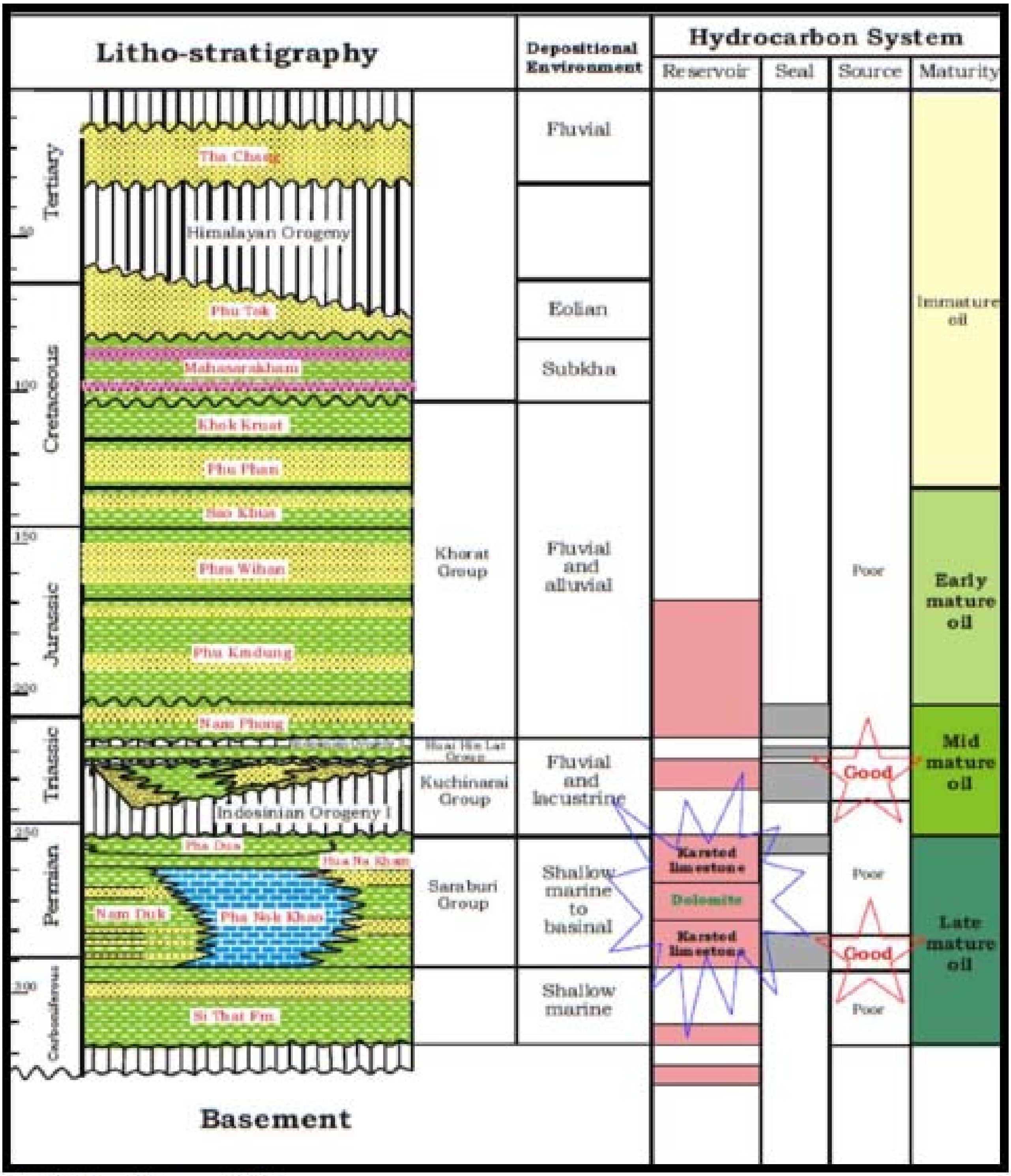
Basic Data	Basin/Gross Area		Khorat (32,400 mi^2)
	Shale Formation		Nam Duk Fm
	Geologic Age		Permian
	Depositional Environment		Marine
Physical Extent	Prospective Area (mi^2)		1,750
	Thickness (ft)	Organically Rich	400
		Net	200
	Depth (ft)	Interval	6,000 - 12,000
		Average	9,000
Reservoir Properties	Reservoir Pressure		Mod. Overpress.
	Average TOC (wt. %)		3.0%
	Thermal Maturity (% Ro)		2.50%
	Clay Content		Low
Resource	Gas Phase		Dry Gas
	GIP Concentration (Bcf/mi^2)		83.0
	Risked GIP (Tcf)		21.8
	Risked Recoverable (Tcf)		5.4

Figure 17: Figure 15 :



Litho-stratigraphy
Depositional Environment
Hydrocarbon System
Reservoir
Seal
Source
Maturity
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Tha Chang
Himalayan Orogeny
Phu Tok
Mahasarakham
Khok Kruat
Phu Phan
Sao Khua
Phra Wihan
Phu Kradung
Nam Phong
Indosinian Orogeny I
Pha Dua
Hua Na Kham
Nam Duk
Pha Nok Khao
Si That Fm.
Basement
Khorat Group
Huai Hin Lat Group
Kuchinarai Group
Saraburi Group
Fluvial
Eolian
Subkha
Fluvial and alluvial
Fluvial and lacustrine
Shallow marine to basinal
Shallow marine
Karsted limestone
Dolomite
Karsted limestone
Poor
Good
Poor
Good
Poor
Immature oil
Early mature oil
Mid mature oil
Late mature oil

Figure 18:

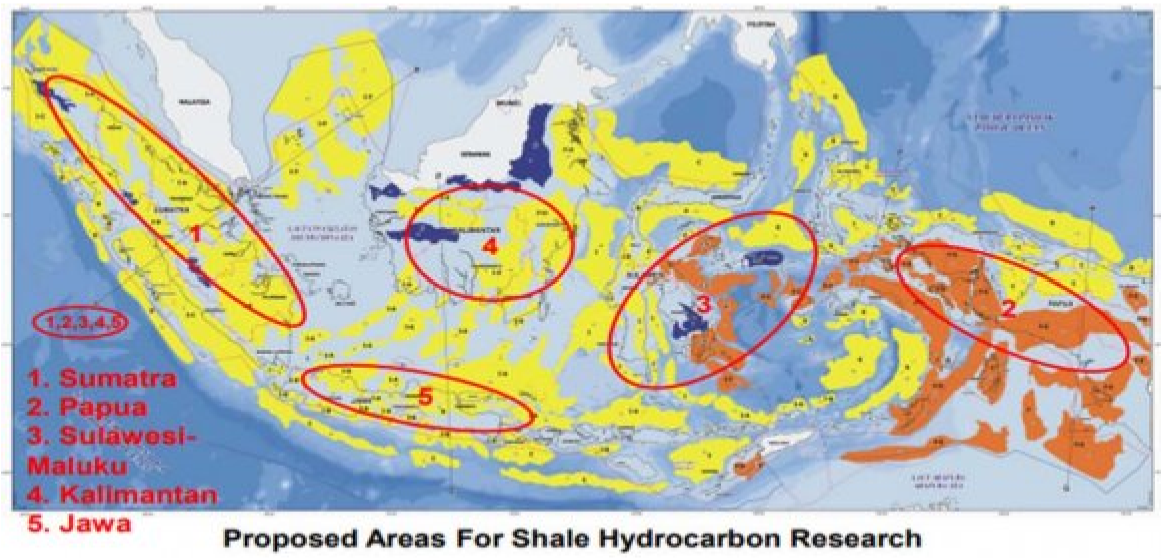


Figure 19:

1

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Sichuan Basin

[Note: Zou C. D., 2010) The EIA shale report assessment said the shale formations in the Sichuan shale are, on average, around 11,000 ft. deep. Sichuan basins technically recoverable resources which are 17. 716 trillion of cubic meters. (Xin-gang, 2015). Some available data on this basin are are summarized in Table1.]

Figure 20: Table 1 :

Country	Basin	Risked Gas in place TCF
Malaysia	Sarawak & Sabah	8.8
	Sichuan	
China	Tarim	1,115
	Ordos	
	Cambay	146
India	Godavari Cauvery	381 30
	Damodar	27
Pakistan	Indus, Balochistan & Pasheen	105
Thailand	Khorat	22
Indonesia	Sumatra Bintumi	68 114

Figure 21: ?

.1 Acknowledgment

The authors would like to address sincere thanks to Shale Gas Research Group, MOREOR, Universit Teknology Petronas for the continuous support for this work.

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