Chapter R3

REGION 3 ASIA PACIFIC−ASSESSMENT SUMMARY

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Figure R3-1. Pie diagrams showing relative distribution of undiscovered oil and gas resources in the Asia Pacific Region by country. +, some resources from the Gulf of Thailand that belong to Cambodia, Thailand and Vietnam are included in Malaysia; *, some resources from the Zone of Cooperation with Indonesia are included with Australia.

INTRODUCTION

Region 3 for the USGS World Energy assessment consists of countries of East and Southeast Asia, Australia, and the adjoining Pacific Ocean archipelago. Countries of major importance for petroleum reserves and resources are Australia, Brunei, China, Indonesia, and Malaysia. Other countries in this region with significant oil and gas resources include New Zealand, Papua New Guinea, Thailand, and Vietnam.

The Asia Pacific region and its constituent countries, including offshore areas to water depths of 2,000 m, were divided into 256 geologic provinces (Klett and others, 1997; Steinshouer and others, 1999). Several provinces in Region 3 that overlap with Regions 2 on the north and Region 8 on the west were included with those regions. Eighteen of the 256 geologic provinces were assessed for undiscovered conventional oil and gas resources (Region 3 map). The assessed provinces include well-established onshore basins, such as the Bohaiwan (China) and Central Sumatra (Indonesia) Basins; well-established offshore basins, such as the Gippsland Basin (Australia); moderately explored onshore basins with large underexplored areas, such as the Kutei (Indonesia) and the Baram Delta-Sabah (Brunei and Malaysia) Basins; underexplored onshore basins, such as the Tarim Basin (China); and underexplored offshore basins, such as the Northwest Shelf (Australia) and Malay (Malaysia and Thailand) Basins. The assessment was approached by identifying total petroleum systems (TPS) in the geologic provinces (PS), subdividing the petroleum systems into assessment units (AU), and assessing the undiscovered conventional (GL) oil and gas in each assessment unit. Although assessment units for continuous gas accumulations (GL) were defined, where appropriate, their undiscovered resources were not assessed. Heavy oil (15 to ~25 °API gravity) is assessed as conventional oil.

TOTAL PETROLEUM SYSTEMS AND ASSESSMENT UNITS

Thirty four Total Petroleum Systems (TPS) and 49 Assessment Units (AU) have been defined in the 18 assessed geologic provinces (table R3-1) (See also tables of results for AUs and provinces for Region 3). The assessed provinces are located in Australia (4), China (6), Indonesia (5), Malaysia and Brunei (3), and parts of Cambodia, Thailand, and Vietnam (Region 3 map). Geologic provinces selected for assessment have large petroleum reserves and (or) are believed to contain potentially large undiscovered petroleum resources. Certainly, some provinces that were omitted from this assessment such as those in offshore China, Thailand, New Guinea, and Vietnam should be studied at a later date to evaluate more fully the resource base of Region 3. A summary of each TPS and AU with selected references is available in another part of this CD-ROM. Each TPS was identified by its pod of mature source rock(s) and dominant reservoir unit(s) (PS). The AU define areas with similar petroleum habitats and geologic characteristics, such as trap type (for example, pre-Tertiary buried hills; Bohaiwan Basin), depositional environment (for example, Brunei-Sabah turbidites; Baram Delta and Sabah Basin), basin type (for example, Vulcan graben; Bonaparte Gulf Basin, Australia); and accumulation type (for example, basin-centered gas (continuous) (GL) in Ordovician carbonate and Permian sandstone; Ordos Basin, China). Most TPS and AU were identified and defined on data gathered from published literature and commercial databases (DS). In several cases, proprietary industry data and reports were used.

Five types of source rocks prevail in Region 3. (1) *Oil-prone lacustrine shale and mudstone*. Thick and rich lacustrine shale and mudstone constitute the source rocks of major TPS in the Bohaiwan (Paleogene Shahejie Formation), Junggar (Permian Lucaogou Formation), Ordos (Triassic Yanchang Formation), and Songliao (Lower Cretaceous Qingshankou Formation) Basins of China; Central Sumatra (Paleogene Brown Shale) and Northwest Java (Paleogene Banuwati Shale) Basins of Indonesia; and Malay Basin (Oligocene/Miocene strata) of Malaysia and Thailand. Moreover, lacustrine source rocks contribute importantly to TPS in the North Sumatra (Oligocene-Miocene Bampo Formation), South Sumatra (Paleogene Lahat Formation), and Northwest Java (Oligocene-Miocene Jatibarang Formation) Basins where they are mixed to varying degrees with restricted marine shale and (or) coal-bearing strata. (2) *Oil- and (or) gas-prone mudrocks of deltaic and marine condensed intervals that are rich in terrigenous organic material*. Such mudrocks are probably the dominant source rocks for petroleum systems in the Baram Delta/Brunei-Sabah Basin (Miocene-Pliocene deltaics); Greater Sarawak Basin (Oligocene-Miocene deltaics) of Malaysia; and Kutei Basin (Miocene deltaics). (3) *Oil- and (or) gas-prone coal and carbonaceous mudstones*. This is the dominant source-rock for the Bonaparte Gulf (Permian Keyling Formation) and Gippsland (Cretaceous-Paleocene Latrobe Group) Basins of Australia. Terrestrial to lower delta-plain coal beds are the source rock for TPS that involve continuous gas accumulations in the Bohaiwan (Carboniferous-Permian coal), Junggar (Jurassic coal), Ordos (Carboniferous-Permian coal), and Sichuan (Triassic coal) Basins and conventional gas accumulation in the Songliao (Jurassic coal) and Sichuan (Permian coal) Basins. Coals may also be a contributing factor in the TPS of the Baram Delta/Brunei-Sabah Basin (Miocene-Pliocene deltaics); Greater Sarawak Basin (Oligocene-Miocene deltaics) of Malaysia; and Kutei Basin (Miocene deltaics). (4*) Organic-rich mudrocks that accumulated in restricted marine basins*. These constitute the dominant source rock for TPS in the Bonaparte Gulf (Carboniferous Milligans Formation, Jurassic Plover Formation, and Jurassic/Early Cretaceous Flamingo Group), Browse (Jurassic-Cretaceous strata), Northwest Shelf (Jurassic Dingo Claystone and Triassic Locker Shale), and Tarim (Ordovician strata) Basins. (5) *Organic-rich marine argillaceous limestones*. These are important source rocks in the Sichuan Basin (Permian Maokou Formation).

Sandstone reservoirs dominate the TPS in Region 3. They range from nonmarine fluvial-lacustrine deposits in China and parts of Indonesia; to deep-water turbidites in Malaysia/Brunei (Baram Delta/Brunei-Sabah Basin) and Indonesia (Kutei Basin); to coastal marine and deltaic deposits in most of Indonesia, Malaysia, and Australia. In general, the nonmarine sandstone units are low-quality reservoirs because of their arkosic arenite to volcanic litharenite composition. In contrast, marine sandstones are better quality reservoirs because of their quartz arenite composition. Important carbonate reservoirs in the region consist of lower Paleozoic marine platform limestone and dolomite in the Bohaiwan and Tarim Basins; upper Paleozoic and Lower/Middle Triassic limestone and dolomite in the Sichuan Basin; and Cenozoic reefs, commonly perched on high basement-involved fault blocks, in the Greater Sarawak, Northwest Java, and North Sumatra Basins. The best carbonate reservoirs occur where their porosity has been increased by exposure to one or more episodes of prolonged subaerial weathering and dissolution.

The tectonic instability of the Earth's crust in Region 3 for most of the Phanerozoic has clearly impacted the TPS. This instability continues to the present day in most parts of the region as is evidenced by high rates of crustal uplift and subsidence, earthquakes, volcanism, and areas of high heat flow. Sedimentary basins in the region are diverse and complex. They range from moderately stable passive continental margins and post-rift sag basins to unstable foreland basins with marginal fold belts, subduction-accretionary complexes, continental rift basins, back-arc rift basins, pull-apart basins, rifted continental margins, and partially inverted rift basins. Commonly, a given geologic province or sedimentary basin has evolved through several stages and styles of deformation so that its present-day configuration and structural features are a composite of their geologic history.

Global-scale tectonic events have shaped the basins and TPS of Region 3. The prolonged closing of the Tethys Seaway between Eurasia and Gondwanaland from late Paleozoic to early Neogene time was a critical factor in the history of much of the region. In the mid-Paleozoic, Eurasia consisted of the Angaran (Siberian) craton and flanking pre-Tethyan subduction-accretionary complexes (Sengör and Natal'in, 1996). During the closing of Tethys, successive microcontinents collided with and accreted to Eurasia. Most of China was assembled in this manner as well as much of peninsular southeast Asia. Back-arc spreading during Tethyan subduction may have opened large, rapidly subsiding basins floored by oceanic crust in the Tarim and Junggar Basins. The final closing of the Tethys Sea was the India-Eurasia continental collision of the Himalayan orogeny. This collision reactivated earlier suture zones and adjoining structures, initiated marked foreland basin subsidence, and extruded large pieces of the Asian crust along strike-slip faults (escape tectonics) to form new basins and profoundly modify existing ones. Basins formed or modified during Tethyan closing include the Tarim, Junggar, Ordos, Sichuan and the Malay Basins.

Active subduction of the Pacific plate beneath the eastern edge of the Eurasian plate, began in latest Triassic to Early Jurassic time (Watson and others, 1987; Yin and Nie, 1996). Crustal extension accompanying subduction roll back and back-arc spreading opened large rift basins in eastern China, such as Songliao and Bohaiwan.

In contrast to the Far East, where continental accretion and subduction-controlled extension dominate geologic history during the Mesozoic and Cenozoic, the geologic history of Australia and the southern part of the region is tied to the breakup of the Pangea continent. India and Australia rifted apart in the Late Jurassic to Early Cretaceous. At the same time, continental blocks were rifted off the northern parts of Australia (Metcalfe, 1996). Continental-margin grabens of the Northwest Shelf, Browse, and Bonaparte Gulf Basins are associated with these rift events. Triassic basins in the area may be sag basins related to early rift stages. The northwest margin of Australia has been a passive margin since the Late Cretaceous. An earlier, middle to late Paleozoic, failed rift extends southward into the Australian continent and forms a major part of the Bonaparte Gulf Basin. The further breakup of Pangea is seen in the rifting of Antarctica from southern Australia in the Late Cretaceous (Metcalfe, 1996) and the subsequent rifting of parts of New Zealand and Lord Howe Rise from Australia. These events molded the Gippsland Basin that had early rift phases and a later passive margin phase.

Southeast Asia is a complex area of microcontinents and microplates that reflect the interaction of Tethyan closing, and subduction of the Indian-Australian, Philippine Sea, and Pacific plates (Hamilton, 1979). Continental blocks that split from Australia during the late Mesozoic comprise parts of islands such as Sumatra, Borneo, and Sulawesi (Metcalfe, 1996). Sea-floor spreading in the Philippine Sea extended through the Celebes Sea and eventually created a deep rift and oceanic crust between Borneo and Sulawesi (Hamilton, 1979). The Kutei Basin developed in the Oligocene on the Borneo side of that rift. Sea-floor spreading and rifting in the South China Sea was associated with subduction in the Brunei and Sabah area and formation of accretionary prisms (Hall, 1997). Clastics derived from the uplifted accretionary prisms accumulated onshore of the subduction zone as large deltaic and turbidite complexes in the Baram Delta and Sabah area. The compressional event that deformed the upper Kutei Basin and the accretionary prisms in northwest Borneo also supplied ample clastic sediments to the delta and turbidite complex of the Mahakam Delta. The Greater Sarawak Basin is an area of attenuated continental crust of the South China Sea that was accreted onto northern Borneo. The microplates and landmasses of Southeast Asia have experienced significant reorientation through time, notably with counterclockwise rotation in the Miocene associated with changes in the motion of the Indian Plate related to the India-Eurasia continental collision and the northward movement of Australia. Rifting in the Sumatra basins and Northwest Java are associated with this rotation. The Malay Basin was also influenced by this rotation, though its primary origin was related to the tectonic extrusion of Indochina. Subduction of the Indian Plate beneath the Euasian Plate, beginning approximately in the early Paleogene (Hall, 1997), created accretionary prisms on the southern margins of Sumatra and Java and caused compression and partial inversion of the Sumatra and Northwest Java Basins. The uplifted mountains also resulted in a reversal of drainage patterns to the basins. Subduction continues today with extensive island arc development.

ASSESSMENT RESULTS

The assessment of undiscovered conventional oil and gas resources in 18 geologic provinces in the Asia Pacific region is summarized in table R3-1 (see also assessment tables for assessment units and provinces for the region). Estimated undiscovered petroleum resources for the 18 assessed provinces, at a mean value, are approximately 29.8 billion barrels of crude oil (BBO) and 379.3 trillion cubic feet (TCF) of natural gas (table R3-2). Thus, in billions of barrels of oil equivalents (BBOE), about twice as much undiscovered natural gas is expected from the region than crude oil. About 82 percent of the undiscovered gas is expected from Australia (30 percent), Indonesia (29 percent), and China (23 percent) (fig. R3-1). Gas-bearing provinces of major importance are the Bonaparte Gulf, Browse, and Northwest Shelf Basins of northwest Australia; the Kutei, South Sumatra, North Sumatra, and Northwest Java Basins of Indonesia; and the Tarim, Sichuan, and Bohaiwan Basins of China (table R3-1). Also, the Ordos Basin in

China has large gas resources but they are classified as resources in continuous gas accumulations and therefore not included in this assessment. The remainder of the gas is expected from Malaysia (15 percent; Baram Delta/Brunei Sabah Basin and Malay Basin) and Brunei (3 percent; Baram Delta/Brunei Sabah Basin). Approximately 40 percent of the undiscovered oil is expected from China (mainly Tarim, Bohaiwan, and Songliao Basins), followed by 25 percent from Indonesia (mainly Kutei, Central Sumatra, and Northwest Java Basins), 17 percent from Australia (mainly Bonaparte Gulf, Browse, and Northwest Shelf Basins), 12 percent from Malaysia (mainly Baram Delta/Brunei Sabah Basin and Malay Basin), and 6 percent from Brunei (Baram Delta/Brunei Sabah Basin) (fig. R3-1). Offshore areas are estimated to account for approximately 70 percent of the undiscovered gas and 60 percent of the undiscovered oil.

The last USGS assessment of world oil and gas resources was completed in 1993 and was published most comprehensively as Masters and others (1998)(See also (RV)). The results of that assessment are available at <http://energy.er.usgs.gov/products/papers/World_oil/>. The two assessments are not strictly comparable. Major differences include (1) the geographic outline of provinces varies between the two assessments; (2) the earlier assessment included many less significant provinces that were not included in this assessment; and (3) the earlier assessment did not assess natural gas liquids (NGL) and gas in oil fields that are included in the current assessment. A further difference is how reserves have been calculated. The best way to make a comparison between the two assessment figures is to compare the total of known (cumulative production to date plus reserves) and an estimate the undiscovered; this total can be termed the "endowment" of a province, country, or region. Tables R3-2 and R3-3 show comparisons between the current and previous assessments. The known oil and (or) gas is from Klett and others (1997) which is based on the Petroconsultants database (see also (RH) and (DS)) and which was the foundation from which the current assessment started.

If one looks at just the provinces assessed in both studies, the endowment of oil in the Asia Pacific region is slightly less in the current assessment; a 3.6 percent decline. However, that is not a uniform decline. Australia and Brunei are perceived to have about 28 percent and 12 percent more, respectively, than in the earlier assessments, whereas Malaysia is almost 25 percent less. China and Indonesia have also declined. The region as a whole has almost a 35 percent increase in the endowment of natural gas in the current assessment. The endowments of Australia, Brunei, Indonesia and Malaysia have all increased substantially. The estimate of Indonesia's endowment has increased a remarkable 73.6 percent and Australia's by 58.7 percent. In contrast, the estimated endowment of natural gas in China has decreased by about 33 percent. The current assessment also includes 26 billion barrels of NGL in the Asia Pacific region of which 37 percent is in China and 32 percent in Australia. It is worthwhile to point out some of the major changes and known or possible reasons for the differences between the two assessments.

Most of the slight decrease in oil endowment (-4.1 percent) in the provinces of China is caused by decreases in the Tarim, Sichuan, and Junggar Basins (table 2). The results of ongoing deep drilling in the Tarim Basin indicate that the previous assessment was too optimistic for oil. Most of the large anticlines have been drilled with only moderate success with respect to oil discoveries and, to date, just one of the discovered oil fields approaches giant field status. Although large volumes of oil have been expelled and trapped, much of it was exhumed soon after entrapment as indicated by the discovery of deeply buried, giant asphaltic accumulations on the central basin uplift. Numerous smaller structures, yet to be drilled, will yield mostly small to moderate-size fields. Oil in the Sichuan Basin occurs in a rather insignificant Jurassic lacustrine petroleum system near the center of the basin. Anticlinal and stratigraphic-trap oil fields are generally small and most were discovered before the early 1980s. For these reasons, this assessment recognizes only minor undiscovered oil resources there. The net decrease in oil endowment in the Junggar Basin is based on extremely poor-quality continental reservoir rocks and the small number of oil-field discoveries since the previous assessment.

The net loss in gas endowment (-33.1 percent) for the China provinces is distributed among the Junggar, Ordos, Sichuan, and Songliao Basins. All of these basins, except Songliao, have significant volumes of gas in identified continuous accumulations that have not been assessed at this time. Most likely, gas in these continuous accumulations, which is not included in this assessment, will account for much of the loss in gas endowment indicated in the present assessment. For example, the large basin-centered gas field now being developed in the Ordos Basin is identified here as a continuous accumulation whereas it was identified in the previous assessment as conventional. The same can be said for continuous accumulations near the center of the Sichuan Basin, however, the Sichuan Basin's endowment also has decreased in this assessment because all large anticlines have been drilled and the quality of remaining deeply buried reservoirs is questionable. Part of the lower gas endowment for the Junggar Basin is based on the low volumes of associated gas in oil fields and the small number of known gas fields. Apparently, most gas generated from the Permian lacustrine source rock remained in place as a deeply buried, basin-centered (continuous) accumulation rather than migrating into conventional accumulations. The estimate of gas endowment in the Songliao Basin is more pessimistic in this assessment because of the high drilling density in the basin, few recent gas field discoveries, and the high probability that the sparsely drilled gas-prone Jurassic coal TPS is confined to narrow grabens with small traps and thin source rocks. A sizable gain in gas endowment is noted for the Tarim Basin where new basinwide discoveries of gas fields and oil fields with large volumes of gas/condensate indicate that gas is more prevalent than initially believed. In the central uplift and flanking depressions, much of this gas was generated from the same marine Ordovician source rock as the oil but at a much later time (Neogene) when better sealing conditions accompanied structural traps; also important is gas generated from Jurassic coal beds and trapped in Mesozoic and Cenozoic reservoirs along the northern fold belt. Additional gas is expected in the southwestern fold belt where the source is Jurassic and Carboniferous (?) coal and the primary reservoirs are Neogene sandstone.

The geographic limits of the Malay basin are substantially different in the two assessments. The province in Masters and others (1998) includes not only the current Malay Basin (3703) but also much of the Thai Basin (3507) and adjoining areas. However, the more restricted extent of the basin in the current assessment probably does not account for a substantial part of the 47 percent decrease in oil endowment, but it does make the 18.6 percent increase in gas endowment more impressive. All of the large anticlinal structures have now been explored and the basin is now assessed to be considerably more gas prone than was previously assumed. There is also much more interest in exploration for natural gas than a decade ago.

The provinces of North, Central, and South Sumatra and Northwest Java also have less endowment of oil in the current assessment but have significantly higher endowments of natural gas. Unlike the Malay Basin, the geographic limits of the provinces are similar in the two assessments. The remaining reservoirs are seen to be more gas prone than had been thought in the earlier assessment. It should be noted, however, that the substantial increase in endowment of natural gas in South Sumatra is largely because of new markets for gas with high CO_2 to be used in injection in oil fields in central Sumatra.

The Baram Delta and Kutei Basin provinces have substantially higher endowments of oil and gas in the current assessment. This is largely because of the perceived importance of turbidite strata that have the potential for large discoveries. The complex deltaic strata of these areas may also provide many new opportunities for smaller fields. The Kutei Basin in particular is seen as more underexplored than had been thought in the earlier assessment; there is a 48.9 percent increase in oil endowment and a 90.3 percent increase in gas endowment. The Greater Sarawak province is dominated by the gas deposits of Central Luconia TPSand these are also seen to have a markedly higher potential than thought in the last assessment; a 47.6 percent increase in natural gas endowment.

The northern provinces of Australia all have substantial increases in the oil and gas endowment. The Northwest Shelf province has about a 105 percent increase in oil endowment. There are probably lots of untested plays in the area including lowstand deposits and incised valleys. All structures discovered are filled to the spill point and there is an abundance of trap types. The optimism in the current assessment for the Browse Basin was influenced by the large Cornea discovery. The Northwest Shelf, Browse Basin, and Bonaparte Gulf Basin are all seen as having large gas endowments. Exploration since the last assessment has proven more reserves and, though economics have not allowed much development to date, these gas resources could be developed on a large scale over the coming decades. The Gippsland Basin is a relatively mature area for exploration. The current assessment suggests that the previous assessment was overly optimistic in terms of undiscovered oil. However, new exploration on the basin margins and in deeper water suggests that the gas endowment is substantially higher than had previously been estimated (59 percent increase). Furthermore, the infrastructure for gas distribution through much of southeast Australia is being developed which may allow smaller fields to be developed in the future.

SIGNIFICANCE OF ASSESSMENT

A significant result of the assessment is the recognition of larger volumes of undiscovered natural gas in offshore northwest Australia in water depths of as much as 2,000 m where gas fields as large as 5 TCF are expected. Low demand for this gas in the 1980s and early 1990s, in addition to a limited distribution infrastructure, has delayed development of previous discoveries and exploration for new fields. Gas is now regarded worldwide as an economic commodity where previously it had been regarded only as a nuisance. The increased demand for gas has led to new pipelines and exploration drilling. Larger than previously estimated undiscovered gas volumes are recognized in the offshore of Indonesia and Malaysia where fields as large as 5.5 TCF are expected. Parts of onshore Indonesia contain large undiscovered gas resources where the largest expected field size is about 2.4 TCF. Although the growth in demand for gas was diminished by the 1997-98 economic recession in Asia, in the long term, ready markets will exist in China, India, Japan, Singapore, and South Korea (Alexander's Gas & Oil Connection, 1999a; U.S. Energy Information Administration, 1999a, b; Oil & Gas Journal, 1999a, b). Increasingly, this gas may be transported in tankers as liquid natural gas (LNG). The future marketability of gas would be enhanced considerably if an Asian pipeline were constructed to replace the costly LNG mode of transportation and (or) if an efficient and low cost gas-to-liquids conversion process is found.

A modest volume of newly recognized undiscovered oil occurs in the northwest Australia offshore, where fields as large as 400 million barrels of oil (MMBO) are now estimated. Moreover, turbidite sandstone reservoirs in the offshore parts of the Kutei and Sabah Basins offer new potential for moderate oil resources with expected fields as large as 800 MMBO. This oil will ease the growing demand for oil in the Asia Pacific region.

Judging from oil estimates in this assessment, China will be unable to sustain, by domestic supplies, the oil demands of an economy growing at an annual rate of about 6 to 8 percent (U.S. Energy Information Administration, 1999c). Obviously, China must seek other sources of oil to meet increasing demand, which since 1993 has made China a net importer (Drennen and Erickson, 1998). Recent Chinese investments in oil fields of Kazakhstan, Iraq, and Venezuela corroborate this near-term need for imported crude oil (Alexander's Gas & Oil Connection, 1999b; Oil & Gas Journal, 1999c). Oil resources in the remote Tarim Basin, although important, are estimated here to be much smaller than initial expectations and, thus, will not replace declining production from giant fields in the Songliao and Bohaiwan Basins. Natural gas reserves and resources in China are sufficient to accommodate existing demand and short-term surges in demand but the need to import large volumes of LNG and pipeline gas is very probable in the next 10 to 20 years (Paik and Lan, 1998; Logan and Chandler, 1998). Most of China's increasing demand for natural gas is based on the desire to reduce carbon emissions by switching from coal- to gas-generated power (Ellsworth and Wang, 1999; World Oil, 1999).

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Table R3-1. Total petroleum systems and assessment units in the Asia Pacific Region and their estimated undiscovered oil and gas resources. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids; NA, not assessed.

USGS ID Number	Province / *Petroleum System* / Unit	*Total* Assessment	Field Type	Oil Mean (MMBO)	Gas Mean (BCFG)	NGL Mean (MMBNGL)	Mean Largest Field Size
3115	**Junggar Basin**						
311501	*Lucaogou-Karamay/Ulho/Pindequan*						
31150101	U. Paleozoic/L. Mesozoic Nonmarine Coarse Clastics		Oil	467.25	346.41	20.77	92.69
			Gas	NA	0.00	0.00	NA
311502	*Jurassic Coal-Jurassic/Tertiary*						
31150201	Jurassic/Tertiary Fluvial and Lacustrine Sandstone		Oil	96.15	48.05	2.88	34.45
			Gas	NA	901.70	39.70	254.37
311503	*Lucaogou/Jurassic Coal-Paleozoic/Mesozoic*						
31150301	Continuous-Type (Basin-Centered) Gas		Not assessed				
3127	**Bohaiwan Basin**						
312701	*Shahejie-Shahejie/Guantao/Wumishan*						
31270101	Tertiary Lacustrine		Oil	2268.01	1135.03	68.17	285.01
			Gas	NA	3503.90	154.66	755.80
31270102	Pre-Tertiary Buried Hills		Oil	2143.72	1498.06	89.80	348.71
			Gas	NA	2376.87	104.57	632.51
312702	*Carboniferous/Permian Coal-Paleozoic*						
31270201	Continuous-Type Gas		Not assessed				
3128	**Ordos Basin**						
312801	*Yanchang-Yanan*						
31280101	Jurassic/Triassic Fluvial and Lacustrine Sandstone		Oil	138.33	19.99	1.20	18.91
			Gas	NA	0.00	0.00	NA
312802	*Taiyuan/Shanxi-Majiagou/Shihezi*						
31280201	Basin Centered Gas: Ordovician CO_3 and Permian Sst		Not assessed				
31280202	Carboniferous and Permian Coalbed Methane		Not assessed				

USGS ID Number	Province / *Petroleum System* / Unit	*Total* Assessment	Field Type	Oil Mean (MMBO)	Gas Mean (BCFG)	NGL Mean (MMBNGL)	Mean Largest Field Size
3142	***Sichuan Basin***						
314201	*Maokou/Longtang-Jialingjiang/Maokou/Huanglong*						
31420101	Southeastern Fold Belt		Oil	0.00	0.00	0.00	NA
			Gas	NA	4487.57	197.31	580.17
31420102	Northwestern Depression/Foldbelt		Oil	0.00	0.00	0.00	NA
			Gas	NA	1649.64	72.64	449.72
31420103	Continuous Gas in Central Uplift/NW Depression		Not assessed				
314202	*Daanzhai-Daanzhai/Lianggaoshan*						
31420201	Jurassic Lacustrine		Oil	27.45	137.41	8.26	5.86
			Gas	NA	0.00	0.00	NA
314203	*Xujiahe-Xujiahe/Shaximiao*						
31420301	Continuous Gas in NW Depression/Central Uplift						
314204	*Cambrian/Silurian Marine Shale-Dengying/Lr Paleozoic*						
31420401	Leshan-Longnusi Paleohigh		Oil	0.00	0.00	0.00	NA
			Gas	NA	2763.46	121.55	750.16
31420402	Lower Paleozoic of Southeastern Fold Belt		Oil	0.00	0.00	0.00	NA
			Gas	NA	1272.97	55.98	389.36
3144	**Songliao Basin**						
314401	*Qingshankou-Putaohua/Shaertu*						
31440101	Subtle Traps		Oil	735.20	243.15	14.57	73.10
			Gas	NA	1545.52	68.08	173.58
31440102	Anticlinal		Oil	291.07	96.42	5.79	53.29
			Gas	NA	608.87	26.81	96.03
314402	*Jurassic Coal-Denglouku/Nongan*						
31440201	Structural Traps		Oil	0.00	0.00	0.00	NA
			Gas	NA	3212.17	96.47	393.26
3154	**Tarim Basin**						
315401	*Ordovician/Jurassic-Phanerozoic*						
31540101	Tarim Basin Excluding Marginal Foldbelts		Oil	5363.79	16097.51	1207.32	717.50
			Gas	NA	25356.94	1270.40	3965.42
31540102	Kuche (Northern) Foldbelt		Oil	89.05	196.23	11.77	49.45
			Gas	NA	10515.72	463.01	2107.78

McCabe and others Table R3-1 (continued)

USGS ID Number	Province / *Petroleum System* / Unit	*Total* Assessment	Field Type	Oil Mean (MMBO)	Gas Mean (BCFG)	NGL Mean (MMBNGL)	Mean Largest Field Size
31540103	Southwest Foldbelt		Oil	495.21	1090.31	65.38	170.81
			Gas	NA	6682.48	293.74	1456.97
3701	**Baram Delta/Brunei-Sabah Basin**						
370101	*Brunei-Sabah*						
37010101	Brunei-Sabah Deltaics		Oil	2137.41	5988.52	359.28	276.26
			Gas	NA	9988.39	439.51	1728.74
37010102	Brunei-Sabah Turbidites		Oil	1252.40	3508.67	210.50	272.41
			Gas	NA	3740.46	164.31	1182.83
3702	**Greater Sarawak Basin**						
370201	*Sarawak Basin*						
37020101	Central Luconia		Oil	0.00	0.00	0.00	NA
			Gas	NA	15066.89	255.80	1922.89
37020102	Balingian		Oil	529.49	1163.10	69.87	72.29
			Gas	NA	1054.30	46.33	165.52
370202	*East Natuna*						
37020201	East Natuna		Oil	101.82	223.96	13.46	50.76
			Gas	NA	1738.74	76.45	578.47
3703	**Malay Basin**						
370301	*Oligocene-Miocene Lacustrine*						
37030101	South Malay Lacustrine		Oil	1002.98	4810.82	67.27	142.64
			Gas	NA	17123.84	342.64	2266.16
37030102	North Malay Lacustrine		Oil	123.62	594.07	8.33	55.33
			Gas	NA	1167.71	23.32	320.85
370302	*Miocene Coaly Strata*						
37030201	South Malay Coaly		Oil	101.23	485.98	6.80	21.43
			Gas	NA	3282.24	65.63	611.11
3808	**Central Sumatra Basin**						
380801	*Brown Shale-Sihapas*						
38080101	Pematang/Sihapas Siliciclastics		Oil	899.40	539.00	12.92	104.55
			Gas	NA	3539.18	70.84	763.35

McCabe and others Table R3-1 (continued)

USGS ID Number	Province / *Petroleum System* / Unit	*Total* Assessment	Field Type	Oil Mean (MMBO)	Gas Mean (BCFG)	NGL Mean (MMBNGL)	Mean Largest Field Size
3817	**Kutei Basin**						
381701	*Kutei Basin*						
38170101	Kutei Basin Deltaics		Oil	1258.03	3513.65	210.62	243.09
			Gas	NA	32243.05	806.35	5556.85
38170102	Kutei Basin Turbidites		Oil	3569.18	9990.31	598.92	815.49
			Gas	NA	15696.98	392.26	4196.36
38170103	Kutei Basin Fold and Thrust Belt		Oil	317.74	889.88	53.43	92.53
			Gas	NA	2423.01	60.56	629.00
3822	**North Sumatra Basin**						
382201	*Bampo-Cenozoic*						
38220101	North Sumatra		Oil	111.71	223.34	13.40	25.85
			Gas	NA	8894.01	93.75	1437.68
38220102	Mergui		Oil	101.43	202.98	12.17	42.13
			Gas	NA	5802.18	61.22	1714.72
3824	**Northwest Java Basin**						
382401	*Banuwati-Oligocene/Miocene*						
38240101	Sunda/Asri		Oil	462.12	277.45	6.65	91.08
			Gas	NA	596.79	11.93	184.10
382402	*Jatibarang/Talang Akar-Oligocene/Miocene*						
38240201	Ardjuna		Oil	195.47	391.30	23.50	41.95
			Gas	NA	6187.72	65.50	926.05
382403	*Tertiary-Parigi*						
38240301	Biogenic Gas		Not assessed				
382404	*Tertiary-Cenozoic*						
38240401	Billiton Basin Hypothetical		Not assessed				
3828	**South Sumatra Basin**						
382801	*Lahat/Talang Akar-Cenozoic*						
38280101	South Sumatra		Oil	468.82	938.49	56.32	81.99
			Gas	NA	17311.77	182.81	2406.88

McCabe and others Table R3-1 (continued)

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USGS ID Number	Province / *Petroleum System* / Unit	*Total* Assessment	Field Type	Oil Mean (MMBO)	Gas Mean (BCFG)	NGL Mean (MMBNGL)	Mean Largest Field Size
3910	**Bonaparte Gulf Basin**						
391001	*Milligans-Carboniferous/Permian*						
39100101	Barnett		Oil	139.91	307.72	18.49	31.40
			Gas	NA	843.41	37.07	189.58
391002	*Keyling/Hyland Bay-Permian*						
39100201	Petrel		Oil	0.00	0.00	0.00	NA
			Gas	NA	8327.70	366.55	1559.83
39100202	Vulcan Graben		Oil	0.00	0.00	0.00	NA
			Gas	NA	2667.59	117.35	1008.59
391003	*Jurassic/Early Cretaceous-Mesozoic*						
39100301	Malita		Oil	1146.18	2526.76	151.68	255.49
			Gas	NA	8819.25	388.53	2280.85
3913	**Browse Basin**						
391301	*Late Jurassic/Early Cretaceous-Mesozoic*						
39130101	Late Jurassic/Early Cretaceous-Mesozoic		Oil	1055.47	3162.63	189.79	408.38
			Gas	NA	16930.14	744.54	4935.21
3930	**Gippsland Basin**						
393001	*Latrobe*						
39300101	Gippsland		Oil	309.52	866.61	52.00	49.41
			Gas	NA	4791.49	287.11	887.82
3948	**Northwest Shelf**						
394801	*Dingo-Mungaroo/Barrow*						
39480101	Dingo-Mungaroo/Barrow		Oil	2249.08	6744.68	336.57	256.57
			Gas	NA	49635.48	2977.46	4727.03
394802	*Locker-Mungaroo/Barrow*						
39480201	Locker-Mungaroo/Barrow		Oil	131.82	55.49	3.33	47.48
			Gas	NA	8275.26	364.54	2474.64

McCabe and others Table R3-1

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Table R3-2. Change in total endowment (cumulative production to date plus reserves and estimate of undiscovered of oil and gas) by geologic province, between the assessment of Masters and others (1998) and the current assessment. Some geologic provinces are not completely comparable because of differences in the way the province boundaries were selected. Most notable are differences in the Malay Basin (3703) where Masters and others (1998) define a larger area that includes part of the Thai Basin.

Oil in Billions of Barrels

		Masters and others, 1998				2000 Assessment			
		Cumulative Production	Identified Reserves	Mean Undiscovered Resources	Endowment	Known	Mean Undiscovered	Endowment	% Change in Assessed Endowment
3115	**Junggar**	0.79	3.39	4.50	8.68	6.80	0.56	7.36	-15.2
3127	**Bohaiwan**	6.30	13.40	5.40	25.10	24.60	4.41	29.01	15.6
3128	**Ordos**	0.14	0.52	0.70	1.36	0.70	0.14	0.84	-38.2
3142	**Sichuan**	0.06	1.09	1.30	2.45	0.10	0.03	0.13	-94.7
3144	**Songliao**	7.90	9.30	2.30	19.50	25.50	1.03	26.53	36.1
3154	**Tarim**	0.01	0.40	16.00	16.41	0.70	5.95	6.65	-59.5
3701	**Baram Delta**	3.49	2.77	2.20	8.46	6.90	3.39	10.29	21.6
3702	**Gtr Sarawak**	0.10	0.70	0.70	1.50	0.80	0.63	1.43	-4.7
3703	**Malay Basin**	1.10	4.00	4.20	9.30	3.70	1.23	4.93	-47.0
3808	**Central Sumatra**	7.51	6.72	2.10	16.33	13.20	0.90	14.10	-13.7
3817	**Kutei**	2.00	1.40	2.00	5.40	2.90	5.14	8.04	48.9
3822	**North Sumatra**	0.47	0.19	0.27	0.93	0.70	0.21	0.91	-2.2
3824	**NW Java**	1.50	3.20	0.60	5.30	3.20	0.66	3.86	-27.2
3828	**South Sumatra**	1.75	0.91	0.70	3.36	2.40	0.47	2.87	-14.6
3910	**Bonaparte Gulf**	0.07	0.16	0.90	1.13	0.50	1.29	1.79	58.4
3913	**Browse**	0.02	0.26	0.30	0.58	0.00	1.06	1.06	82.8
3930	**Gippsland**	2.60	1.80	0.40	4.80	3.90	0.31	4.21	-12.3
3948	**Northwest Shelf**	0.30	1.10	0.30	1.70	1.10	2.38	3.48	104.7
	Total	**36.11**	**51.31**	**44.87**	**132.29**	**97.70**	**29.79**	**127.49**	**-3.6**

McCabe and others Table2 (continued)

Gas in Trillions of Cubic Feet

		Masters and others, 1998				2000 Assessment			
		Cumulative Production	Identified Reserves	Mean Undiscovered Resources	Endowment	Known	Mean Undiscovered	Endowment	% Change in Assessed Endowment
3115	**Junggar**	0.00	0.03	12.00	12.03	2.40	1.30	3.70	-69.2
3127	**Bohaiwan**	2.00	13.40	8.00	23.40	15.70	8.50	24.20	3.4
3128	**Ordos**	0.00	7.00	33.00	40.00	5.60	0.02	5.62	-86.0
3142	**Sichuan**	4.80	12.40	40.00	57.20	10.80	10.31	21.11	-63.1
3144	**Songliao**	0.10	2.80	13.00	15.90	1.70	5.71	7.41	-53.4
3154	**Tarim**	0.00	1.30	40.00	41.30	5.00	59.94	64.94	57.2
3701	**Baram Delta**	6.51	20.49	15.60	42.60	36.20	23.23	59.43	39.5
3702	**Gtr Sarawak**	2.80	35.00	31.00	68.80	82.30	19.25	101.55	47.6
3703	**Malay Basin**	0.10	30.80	33.00	63.90	48.30	27.46	75.76	18.6
3808	**Central Sumatra**	0.01	2.00	4.60	6.61	3.90	4.08	7.98	20.7
3817	**Kutei**	3.50	43.80	10.80	58.10	45.80	64.76	110.56	90.3
3822	**North Sumatra**	3.44	22.13	9.70	35.27	25.60	15.12	40.72	15.5
3824	**NW Java**	1.00	6.30	0.70	8.00	8.10	7.45	15.55	94.4
3828	**South Sumatra**	0.34	6.37	2.70	9.41	10.70	18.25	28.95	207.7
3910	**Bonaparte Gulf**	0.00	6.68	2.70	9.38	13.30	23.49	36.79	292.2
3913	**Browse**	0.00	18.36	10.00	28.36	18.00	20.09	38.09	34.3
3930	**Gippsland**	1.40	7.60	0.70	9.70	9.80	5.66	15.46	59.4
3948	**Northwest Shelf**	1.00	39.60	7.10	47.70	56.70	64.71	121.41	154.5
	Total	**27.00**	**276.06**	**274.60**	**577.66**	**399.90**	**379.33**	**779.23**	**34.9**

McCabe and others Table2 (continued)

NGL in Billions of Barrels*

		2000 Assessment		
		Known	Mean Undiscovered	Endowment
3115	**Junggar**	0.00	0.06	0.06
3127	**Bohaiwan**	0.10	0.42	0.52
3128	**Ordos**	1.60	0.00	1.60
3142	**Sichuan**	1.90	0.46	2.36
3144	**Songliao**	0.00	0.21	0.21
3154	**Tarim**	1.70	3.31	5.01
3701	**Baram Delta**	0.20	1.17	1.37
3702	**Gtr Sarawak**	0.40	0.46	0.86
3703	**Malay Basin**	0.30	0.51	0.81
3808	**Central Sumatra**	0.00	0.08	0.08
3817	**Kutei**	1.30	2.12	3.42
3822	**North Sumatra**	0.90	0.18	1.08
3824	**NW Java**	0.20	0.11	0.31
3828	**South Sumatra**	0.10	0.24	0.34
3910	**Bonaparte Gulf**	0.40	1.08	1.48
3913	**Browse**	0.20	0.93	1.13
3930	**Gippsland**	0.70	0.34	1.04
3948	**Northwest Shelf**	1.00	3.68	4.68
	Total	**11.00**	**15.36**	**26.36**

*(not assessed by Masters and others, 1998)

McCabe and others Table2 (continued)

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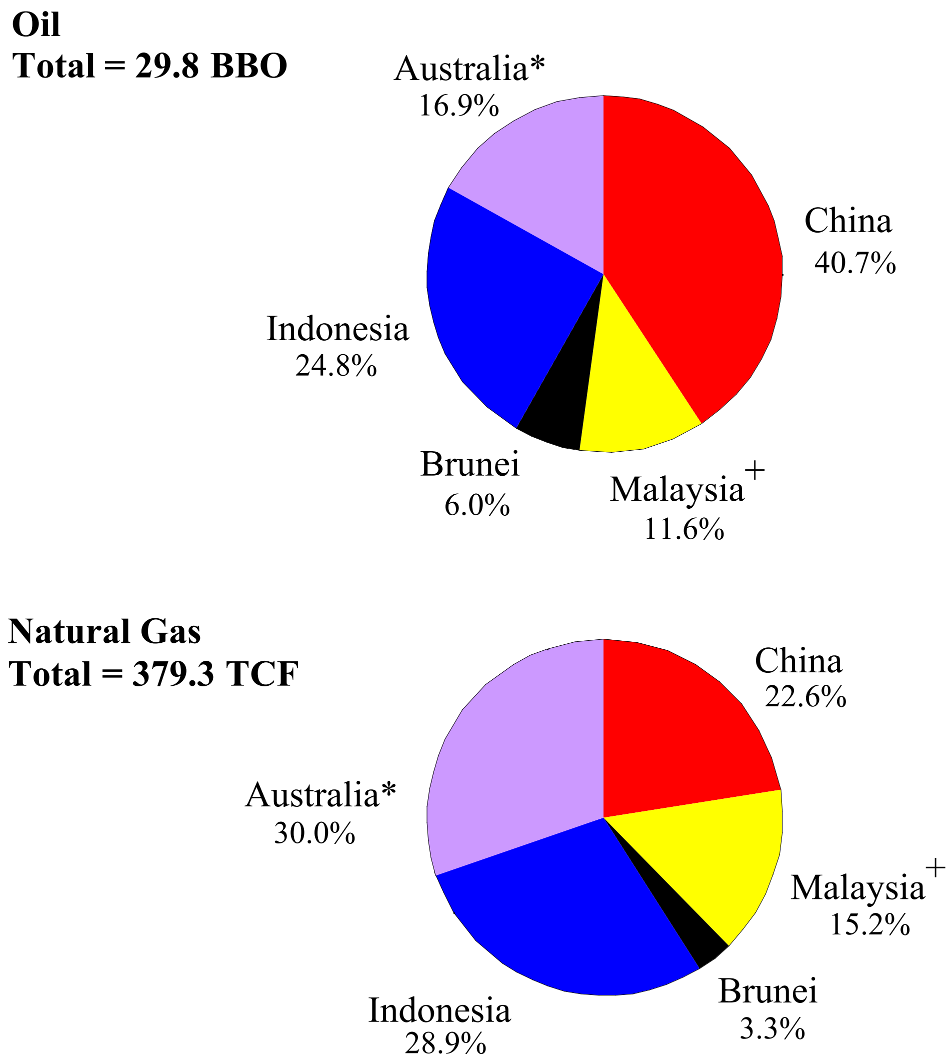
Table R3-3. Change in total endowment for countries between assessment of Masters and others (1998) and current assessment. Does not include natural gas liquids (NGL). Note that some resources from the Gulf of Thailand, that belong to Cambodia, Thailand and Vietnam, are included in Malaysia and some resources from the Zone of Cooperation, that lies between East Timor and Australia, are included with Australia.

	Change in Oil Billion Barrels	***% Change in Oil***	**Change in Gas TCF**	***% Change in Gas***
Australia	+2.32	*+28.3*	+78.29	*+58.66*
Brunei	+0.71	*+12.0*	+7.93	*+26.6*
China	-2.98	*-4.1*	-62.84	*-33.1*
Indonesia	-1.54	*-4.9*	+86.37	*+73.6*
Malaysia	-3.32	*-24.9*	+53.51	*+36.8*

* Not including NGL.



McCabe and others, Figure 1

Figure R3-1. Pie diagrams showing relative distribution of undiscovered oil and gas resources in the Asia Pacific Region by country. +, some resources from the Gulf of Thailand that belong to Cambodia, Thailand and Vietnam are included in Malaysia; *, some resources from the Zone of Cooperation with Indonesia are included with Australia.