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Chapter R8

REGION 8 ASSESSMENT SUMMARY—South Asia

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INTRODUCTION

South Asia or Region 8, as defined here, includes nine countries, Afghanistan, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan, and Sri Lanka. These countries comprise three priority provinces, Assam, Bombay, and Indus, and four boutique provinces, Ganges-Brahmaputra Delta, Irrawaddy, Sulaiman-Kirthar, and Kohat-Potwar (Region 8 Assessed Geologic Provinces map). In some places, the total petroleum system (TPS) and assessment unit (AU) boundaries extend into other provinces. For example, the Indus province and Sulaiman-Kirthar Province share a composite TPS and AU. Also the Irrawaddy, and North Burma Provinces share composite TPSs and AUs. In Afghanistan, there are two provinces that are shared with Region 1 (the former Soviet Union). They were assessed with Region 1 because the larger portions of those provinces fall within that region.

The U.S. Geological Survey recognizes that there are a large number of known and prospective petroleum provinces in South Asia that are not included in this study such as Baluchistan, Cauvery, and Krishna Godavari. These areas were excluded only because of the time and resource limitations of this study.

Assessed areas of Region 8 contain a mean undiscovered resource of approximately 119,610 BBOE (Region 8 Assessment Results Summary, p. 1). Approximately 110 TCF of gas is included in the mean undiscovered resource.

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REGIONAL GEOLOGIC HISTORY

The TPSs and AUs discussed herein owe their primary structural and stratigraphic features to events associated with continental drift and plate tectonics from the latest Paleozoic Era, to the present. During Permian and Early Jurassic Periods, the Indian plate was located in the southern hemisphere, between the African, Antarctic, and Australian plates, making up part of southern Gondwana. Basal Permian strata containing glacial deposits indicate a much cooler climate during that time. The area that is the Indus Basin today, was a shallow continental shelf on which carbonates were accumulating. This carbonate deposition on the Indus shelf or basin continued intermittently until Early to Middle Jurassic when the interbedded shales and thick limestones of the Springwar Formation were deposited. Carbonate deposition continued during Middle and Late Jurassic with as much as 1400 m of the Sulaiman Limestone Group accumulating. While

Jurassic carbonates were accumulating, Madagascar, India, Australia, Antarctica, and the Seychelles began to break away from Africa, forming the Somali Rift Basin. Late Jurassic rifting also initiated separation of Australia and Antarctica from India.

During Early Cretaceous time the Indian and Seychelles plate drifted northward entering warmer latitudes. Marine shales and limestones of the Lower Cretaceous Sembar and Goru Formations were deposited over a regional erosional surface on the Sulaiman Limestone Group. This shelf environment persisted until late Cretaceous, when regressive sandstones of the Pab Formation were deposited on the Indus shelf. Late Cretaceous rifting between Madagascar and the Seychelles initiated formation of Mascarene Basin. Counter-clockwise rotation of the Indian and Seychelles plate followed, and the Seychelles plate began to break away from the Indian plate (Waples and Hegarty, 1999). Latest Cretaceous time also brought to western India intense volcanism, expulsion of the Deccan Trap basalts and rifting, which began, and then failed, leaving the Cambay and Kutch grabens floored with the Deccan Trap basalts (Biswas and Deshpande, 1983).

From the Late Cretaceous Period through middle Paleocene Epoch, Deccan Trap deposits and basal sands accumulated on the Indus, Bombay, Assam-Arakan and Bengal shelves, and over other parts of the Indian plate, as it continued to move northward at an accelerated rate of 15-20 cm/yr. The eastern edge of the plate passed over the Kerguelen hot spot forming a line of islands near 90° E. The Sino-Burman ranges first emerged and flysch was deposited in what is now the Central Burma Basin. The Assam shelf began to tilt to the southeast and basement-related block faults were reactivated. Basement-related block fault movement also occurred in the Bombay High area and would be intermittently reactivated through at least the Miocene Epoch. Continued northward movement and counter-clockwise rotation of the Indian plate slowly closed the Tethyan Sea and the Sulaiman-Kirthar fold belt began to develop. Uplift and rising mountain ranges on the Eurasian plate created a new dominant sediment source and the predominant sediment transport direction of south to north was reversed. Carbonate platform build up occurred intermittently from the Eocene through Middle Miocene time on the shelves around much of the Indian plate. A trench formed along the subduction zone where the Indian plate began to slip beneath the Eurasian plate. As subduction continued, the Eurasian plate was uplifted and began to shed sediments into the trench. Terrestrial sediment influx from the quickly rising Himalayan, Sino-Burman, and Indo-Burman Ranges and the Deccan plateau, significantly exceeded carbonate accumulation rates on late Miocene platforms (Roychoudhury, and Deshpande, 1982), and smothered carbonate reef formation along the shelf areas. The former shelf areas along these collision zones were either subducted or became emergent and fluvial-deltaic environments developed.

Late Miocene-Pliocene time brought deposition of fluvial shales, sands, and clays into the Indus, Kutch, Cambay, Bengal, and Central Burma Basins and onto the Assam shelf. The proto Indus, Narmada, Ganges, Brahmaputra, Chindwin, and Irrawaddy Rivers developed extensive deltas as the Himalayas, and other ranges continued to shed sediments at a high rate. Today, uplift of the Himalayas and subduction of the Indian plate continues and the growth rate of the Indus, Ganges-Brahmaputra, and Irrawaddy deltas remains high.

REGIONAL ASSESSMENT HISTORY

Many oil and gas assessments have been carried out in Region 8 by government organizations, national oil companies, the United Nations, and private concerns interested in reserves and undiscovered resources. The discussion herein will be limited to the priority and boutique provinces listed above. Previous assessments of some of these areas by the U.S. Geological Survey include those by Yenne (unpub. data, 1980), Kingston (1986), and Masters and others (1998).

Comparisons with previous studies made in this report are generalized, as the areas assessed and the reports produced are not equivalent. Also, there are differences in the definitions and use of the terms, known, discovered, undiscovered, reserves, and resources in the various reports (Region 8, Assessment Results Summary, p. 1).

Assam Province-8034 (priority)

Assam, is an onshore, oil-prone province located in northeastern India. Structurally, it consists of two primary sub-parallel features trending southwest to northeast, which developed as a result of plate collision. The most northerly feature is the Assam shelf, which is being subducted beneath both the Eurasian plate to the north and the Burmese plate to the southeast. The southerly feature consists of the en-echelon folds of the Naga Hills overthrust belt and the northernmost Indo-Burman Ranges which are developing as the shelf is subducted. Presently, most of the hydrocarbon production is in the area northwest of, and parallel to, the Naga thrust.

Total Petroleum Systems and Assessment Units

The USGS recognizes that there are several separate TPSs in this area. For assessment purposes, however, they were combined into a single composite TPS, the Sylhet-Kopili/Barail-Tipam (803401) because few correlations of source to reservoir hydrocarbons were available at the time of the assessment. There are also multiple stacked sources and reservoirs and extensive fault systems allowing mixing of hydrocarbons from multiple sources (Chandra and others, 1995). The TPS of the Assam Shelf most likely is genetically and temporally related to some of the TPSs in the Bengal Basin described later in this report.

The single AU used, the Composite Eocene-Miocene (80340101) resulted from combining the TPS. The rocks that comprise this AU are those of the Eocene-Oligocene Jaintia Group Sylhet and Kopili Formations, the Oligocene Barail Group, and the Oligocene-Miocene Surma and Tipam Groups. These groups include platform carbonates, shallow marine shales and sandstones, and the sandstones, siltstones, shales, and coals of deltaic and lagoonal facies. A second hypothetical structural AU could be added in the overthrust area south of the Naga thrust fault. South of the thrust the rocks of the composite TPS are in the footwall of the thrust and the source rocks are more mature.

Exploration

Oil seeps were reported in the basin as early as 1825 and the first commercial drilled discovery in India, the Digboi Oil Field, was found in the thrust and fold belt of the southeast Assam Basin in 1889. Between 1922 and 1932, Burmah Oil Company (BOC) mapped and drilled 10 structures in the Schuppen Belt with no economic successes (Rangarao, 1983). In 1937, BOC conducted seismic surveys in the area. Although delayed until after World War II, these surveys resulted in the 1953 discovery of Nahorkatiya field and later of other fields in that area. According to Petroconsultants International Data Corp., (1996), there are at least 38 oil fields and 1 gas field with more than 1 MMBOE in cumulative production and proved reserves in the province. There are 89 reservoirs that have produced oil, gas, or condensate. The largest fields are Nahorkatiya discovered in 1953, Moran, discovered in 1956, and Lakwa, the first Tipman reservoir, which was discovered in 1964 (Murty, 1983), each with >0.5 BBOE total discovered recoverable reserves.

Production

On the basis of data from Petroconsultants International Data Corporation, current to 1996, Assam Province (8034) was ranked 83rd in the world, including U.S. provinces. This categorized it as a priority province for the USGS World Petroleum Assessment 2000 (Klett and others, 1997). Known petroleum volumes, are 2.5 BBO and 6.5 TCFG for a total of 3.6 BBOE including natural gas liquids (Petroconsultants, 1996); this volume is approximately 0.1percent of world volume (excluding the U.S.).

Assessment Comparisons

Kingston, (1986) estimated the mode of remaining undiscovered oil at 0.1 BBL and mode of gas at 1 TCF. The 1998 assessment estimate (Masters and others, 1998) for North Assam mean undiscovered oil was 0.1 BBL and mean undiscovered gas was 2.0 TCF. Both previous assessments considered a smaller area than was considered in this report. In this study mean undiscovered resources were estimated to be 0.4 BBO and 1,178 TCFG (Region 8 Assessment Results Summary, p. 2).

Future Prospects

The overthrust area to the south of the Naga thrust fault, while difficult to explore, may contain significant resources. The prospective stratigraphic section to the north of the Brahmaputra River, although thinner and probably containing leaner, less mature source rocks, still has potential, particularly for gas.

The Bombay Province-8043 (priority)

Bombay Province is located on the west coast of India, and includes both onshore and offshore portions. The province includes a large part of the continental shelf to a water depth of 2,000 m on the west. On the east it is bounded by the Deccan Plateau, on the south by the Vengurla arch, and on the north by the Nagar Parkar Ridge. The province contains 4 petroleum basins. These are the Bombay Offshore Basin, Cambay Basin, Kutch Basin, and the Saurashtra Basin.

Total Petroleum Systems and Assessment Units

The USGS recognizes that there are several separate TPSs in this area. For assessment purposes, however, they were combined into a single composite TPS, the Eocene-Miocene Composite TPS (804301), because few correlations of source to reservoir hydrocarbons were available at the time of the assessment. There are also numerous stacked sources and reservoirs allowing possible mixing of hydrocarbons from multiple sources.

There are two AUs. The first of these is the Eocene-Miocene Bombay Shelf unit (80430101), which includes an area of the shelf from the Vengurla arch on the south to the approximate southern edge of the Indus delta on the north. The primary traps in this unit are carbonate reefs on uplifted fault blocks and sandstones draped over these structures. The second AU is the Eocene-Miocene Cambay Deltaic AU (80430102). This unit extends from the shoreward faults bounding the Bombay High landward, and along the Cambay Graben onshore. This unit consists mainly of source and reservoir rocks from lagoonal, deltaic and alluvial environments. There are structural and combination traps in the graben. In the deltaic sequences structural traps have been the primary target, but there have been recent successes in locating stratigraphic traps (Biswas, and others, 1994).

Exploration

Exploration of the area in the late 1950's resulted in the 1958 discovery of the Cambay gas and condensate field. In 1960, the giant Ankleshvar oil and gas field was discovered and through the remainder of the 1960's 11 more fields were discovered in the Cambay Basin (Yenne, unpub. data, 1980). Offshore seismic data collected during the 1960's and early 1970's lead to the discovery of the province's largest field in 1974, the Bombay High offshore oil and gas field. The Bombay High field produces primarily from Miocene limestones and some sandstone reservoirs on a fault bounded block that underwent recurrent uplift from

Paleocene through Miocene time. There are now over 165 fields in the province. Although there are no producing fields in the Kutch Basin, uneconomic quantities of oil and gas have been found there.

Production

Ranked 38th worldwide (Klettand others, 1997), the Bombay oil and gas province contains 8.4 BBL of known oil, 24.2 TCF of gas, and 0.3 BBL of natural gas liquids (Petroconsultants, 1996). The total, 12.7 BBOE including natural gas liquids, is from 165 fields of which 126 are 1 MMBOE or greater in size.

Assessment Comparisons

Kingston (1986) estimated the mode of remaining undiscovered oil in the Bombay province at 1.9 BBL and gas at 8.5 TCF. The 1998 assessment (Masters and others, 1998) estimate for Kutch, Cambay, and Bombay Basins combined mean undiscovered oil was 1.76 BBL and combined mean undiscovered gas was 13.9 TCF. The volumes of oil and gas in the areas previously assessed are difficult to compare with this assessment as the locations and sizes of these areas, including the shelf, are not clear. In this study mean undiscovered resources were estimated to be 2.1 BBO and 12.9 TCFG (Region 8 Assessment Results Summary, p. 3).

Future Prospects

The Kutch offshore and the outer shelf area are only lightly explored and may have potential for significant discoveries. Jurrasic and Cretaceous potential may also exist beneath the trap deposits on the Saurashtra peninsula. Although few stratigraphic traps have been identified in the Eocene-Miocene Cambay Deltaic AU, that area holds good prospects for more stratigraphic accumulations.

Indus Province-8042 (priority) and Sulaiman-Kirthar Province 8025

The area assessed with the Indus Province 8042 includes a large part of the Sulaiman-Kirthar Province (8025). The Indus basin consists of shelf, deltaic, and alluvial sediments that slope gently to the northwest and are being subducted along the Sulaiman-Kirthar foldbelt to the west and Himalayan Ranges to the north. The exposed foldbelt is composed of early Tertiary, Cretaceous, and Jurassic rocks uplifted and folded by the oblique collision of the Indian and Eurasian plates. Also included in the assessed area is the offshore portion of the Indus delta complex to a water depth of 3000 m.

Total Petroleum Systems and Assessment Units

Several TPSs in this area have been combined into a single composite TPS, the Sembar-Goru Ghajiz TPS (804201). The USGS recognizes that there are several separate TPSs in this area. For assessment purposes, however, they were combined into a single composite TPS because few correlations of source to reservoir hydrocarbons were available at the time of the assessment. There are also multiple stacked sources and reservoirs, with fault systems that allow mixing of hydrocarbons from more than one source. While the Sembar Formation is identified as the primary source rock over much of the area, in some places it is missing, overmature or immature, and younger, and perhaps older source rocks may contribute significantly to the total hydrocarbon volume.

The Greater Indus Foreland and Foldbelt AU (80420101) is a composite AU that consists of sediments from several depositional environments, including shallow marine, deltaic, and alluvial. Structural style also varies from foreland basin to foldbelt. The AU encompasses the greater Indus Basin and shelf to a water depth of 200 m, and the Sulaiman-Kirthar foldbelt as far north as the Kohat-Potwar Province (8026). The Indus Fan AU (80420102) is located offshore of southeastern Pakistan between the Murray Ridge and the Indian border from a water depth of 200 m (approximate shelf edge) to 3000 m of water depth (approximate base of the middle portion of the fan).

Exploration

Successful early exploration of the Kohat-Potwar Province (8026) concentrated much activity in the north. The largest gas field, the Sui field with >5 TCF of known gas (Petroconsultants, 1996), was not discovered until 1952. While an anticlinal structure overlies the Sui field and is apparent at the surface, at the Sui

Main Limestone reservoir level the structure is sub-domal and lithologically reeflike. More discoveries followed in that area with the Zin gas field in 1954, the Uch gas field in 1955, and the Mari gas field in 1957. Although there have been significant oil discoveries in the Lower Indus basin, in general it remains a gas-prone province. There have also been several recent encouraging gas discoveries in the lightly explored Sulaiman-Kirthar foldbelt province.

Production

Based on Petroconsultants International Data Corporation data, current to 1996, the Indus Province was ranked 87th, including U.S. provinces. This categorized it as a priority province for the USGS World Petroleum Assessment 2000 (Klett and others, 1997). Known petroleum volumes are 0.2 BBL and 19.6 TCF of gas, for a total of 3.5 BBOE including natural gas liquids (Petroconsultants, 1996); this volume is approximately 0.1 percent of world volume (excluding the U.S.).

Assessment Comparisons

Kingston (1986) estimated the mode of remaining undiscovered oil in the Indus province at 0.2 BBL and gas at 16.5 TCF. The 1993 assessment (Masters and others, 1998) estimate of mean undiscovered oil in the Indus province, both on and offshore combined, was 0.23 BBL, and combined mean undiscovered gas was 29 TCF. The areas assessed by Masters and others (1998) are difficult to compare with the current assessment because it is unknown whether the Sulaiman-Kirthar foldbelt was included in their assessment. This assessment estimates the Sulaiman-Kirthar Province contains undiscovered mean resources of 12.6 TCFG and 12 MMBO. It is also unclear how large an area of the shelf and fan was considered by them. In this study mean undiscovered resources for the Indus Province were estimated to be 100 MMBO and 16 TCFG (Region 8 Assessment Results Summary, p. 2).

Future Prospects

The Indus offshore, both shelf and fan, has seen little exploration. With additional exploration, significant gas resources are likely to be discovered in this area. The Sulaiman-Kirthar foldbelt, also only lightly explored has had significant recent discoveries in a difficult exploration environment. It is highly probable that the largest fields in the foldbelt are yet to be found.

Ganges-Brahmaputra Province-8047 (boutique)

The Ganges-Brahmaputra Province (8047) includes the Ganges-Brahmaputra delta and the Bengal Basin, a region of great tectonic subsidence between the Indian craton on the west and the Indo-Burman ranges on the east. In general, the basin may be divided into a shallow platform and hinge line on the west, and the Bengal foredeep, which contains some 60,000 ft of Tertiary sediments. These Tertiary sedimentary strata are folded on the east where the Indian plate is being obliquely subducted beneath the Burma plate (Pivnik and others, 1998). The province is bounded on the east by the Indo-Burman ranges, and on the north by the Shillong Massif Precambrian continental crust that is thrust southward over the delta.

Total Petroleum Systems and Assessment Units

Permian Coal TPS (804701)

Coalbed Gas AU (80470101)

This AU is in the coal-bearing Permian formations of the Gondwana Supergroup. The coal measures are exposed in grabens and half grabens in the Damodar Valley coalfields on the northeast side of the delta and seismic evidence has verified their extent in the subsurface beneath the western part of the delta. The eastward limit of the Gondwana coal beds is the limit of thinned and extended continental crust is located somewhere beneath the deltaic sediments.

Jalangi-Sylhet/Burdwan Composite TPS (804702)

Western Shelf and Slope AU (80470201)

The AU extends from the western edge of the Bengal fan, where it laps over a basement of Precambrian to Mesozoic igneous, metamorphic, and sedimentary rocks, eastward to the Paleocene-Eocene shelf edge and slope. The eastward extent of the AU is defined by the distribution of the Jalangi Formation (200-1000 m thick), which in part is a source rock of Paleocene and Eocene age. Potential reservoirs occur in the overlying Eocene Kalighat (Sylhet) Limestone (500-1000 m thick) and in sandstones of the Oligocene Burdwan Formation (200-750 m thick). The Burdwan is overlain by the Oligocene/Miocene Diamond Harbour (Pandua) Formation (3500 m thick), which consists mainly of siltstone, sandstone, and carbonaceous shale. The Late Eocene Hoogley (Kopili) Formation (30-3100 m thick) occurs above the Kalighat and locally may serve as a seal.

Jenam/Bhuban-Bokabil TPS (804703)

Central Basin AU (80470301)

This AU is in the axial part of the thick Tertiary deltaic deposits of the Bengal Basin. The delta is located east of the Indian craton of Precambrian crystalline rocks, south of the Himalayan Mountains, and west of the Arakan Yoma. The eastern part of the delta is thrown into a series of plunging folds where it is being subducted obliquely beneath the Arakan Yoma. Overall, the delta is as much as 20,000 m thick in the Patuakhall depression, a depocenter located on the southeastern side of the delta. The strata that comprise this AU are in the Oligocene Barail Group and the Miocene Surma Group and range from about 3000 to 5000 m thick in the northern part of the basin and are at least 7000 m thick in the southern part of the delta. In general, the basin fill consists of sandstones, siltstones, and shales that commonly contain plant-derived organic matter. The stratigraphy of the adjacent Eastern Fold Belt AU (80470302) is well known from exploratory drilling. The Central Basin AU, however, is undrilled and its stratigraphy is extrapolated from the Eastern Fold Belt AU.

Eastern Fold Belt AU (80470302)

This AU is in the thick Tertiary deltaic deposits of the Bengal Basin. The delta is located east of the Indian craton of Precambrian crystalline rocks, south of the Himalayan Mountains, and west of the Arakan Yoma. The eastern part of the delta is thrown into a series of plunging folds where it is being subducted obliquely beneath the Arakan Yoma. Overall, the delta is as much as 20,000 m thick in the Patuakhall depression, a depocenter located on the southeastern side of the delta. The strata that comprise this AU are within the Oligocene Barail Group and the Miocene Surma Group and range from about 3000 to 5000 m thick. In general, the lithologies are sandstones, siltstones, and shales that contain plant-derived organic matter.

Exploration

A British geologist first reported a gas seep in the Chittagong Hill Tract of eastern Bangladesh in 1767 (Ganguly, 1997). Under British rule, the Burmah Oil Company drilled its first well in the Chittagong Hill tract in 1910. Several additional wells were drilled in the ensuing decades, with little success. After independence and partition of Bengal in 1947, Pakistan Petroleum Limited discovered the first commercial gas field, the Sylhet field, in the northeastern part of the country in 1955, followed by the Chhatak gas field in 1959. Shell Oil Company started an extensive exploration effort in the 1960's, when it discovered five gas fields in the Surma sub-basin, the Rashibpur, Kailas Tila, Titas, Habiganj, and Bakhrabad fields. The Pakistan Government established the Oil, Gas & Mineral Corporation in 1961. This national petroleum company drilled the Jaldi structure and, subsequently, completed a discovery well in the Semutang structure in the eastern fold belt in 1967. Following the separation of Bangladesh from Pakistan in 1971, the Union Oil Company discovered the Kutubdia gas field in 1976 after several years of exploration offshore. In the 1980's, the Bangladesh Oil, Gas & Mineral Corporation (BOGMC) discovered new gas-condensate fields at Begumganj, Feni, Beani Bazar, Katma, and Fenchuganj. In 1996, Bangladesh Petroleum Exploration Company (BAPEX), a subsidiary of Petrobangla, found gas at Salda in a structure in eastern Bangladesh that is shared with India. Two pay zones, each 60 to 70 m thick, are reported to produce 15 to 25 MMCFD. In 1998, Unocal discovered the Bibiyana field, which has an estimated 3 to 5 TCF of gas-in-place. The Jalalabad field, which was developed jointly with Occidental, began production in February 1999 at about 60 to 100 MMCFD. More recently, Unocal announced its third major discovery in Bangladesh, the Moulvibazar gas field in the Sylhet region. The discovery well was drilled to 11, 512 ft and encountered 98 ft of sand gas pays in two zones between 7, 074 and 7,225 ft.

Exploration in West Bengal, India, has in general been unsuccessful. From 1949 to 1996 about 47 wells were drilled in the West Bengal part of the basin without the discovery of commercial hydrocarbons (Ganguly, 1997). Of these wells, several appear interesting. The Chandkuri n. 1 well, 60 mi southwest of Calcutta, was drilled in 1990 to a depth of 12,667 ft where it encountered residual oil in Paleocene sandstones. Golf Green, drilled about 12 mi southwest of Calcutta to a depth of 18,368 ft, contained shows of oil and gas in Eocene limestones. The Ichapur n. 1 well, drilled to a depth of 18,410 ft in 1992, some 50 mi north of Calcutta, produced both gas and oil at the surface from a thin Oligocene sandstone. The reservoir occurs at a depth of 14,280 ft in this well.

Production

Based on Petroconsultants International Data Corporation data to 1996, the Ganges-Brahmaputra Province (8047) was ranked 107th in the world (including U.S. provinces). This categorized it as a boutique province for the USGS World Petroleum Assessment 2000 (Klett and others, 1997). Known petroleum volumes are <0.1 BBO and 14.3 TCFG, for a total of 2.4 BBOE including natural gas liquids (Petroconsultants, 1996); this volume is approximately 0.1 percent of world volume (excluding the U.S.).

Assessment Comparisons

For this province, Kingston (1986) estimated the mode of undiscovered oil at 1.9 BBL and gas at 8.5 TCF. Masters and others (1998) estimated that, for all parts of the Bengal Basin and fan the combined mean undiscovered oil was 0.88 BBL and combined mean undiscovered gas was 10.8 TCF. The areas previously assessed by Kingston (1986) and Masters and others (1998) are difficult to compare with this assessment because it is unclear how large an area onshore and offshore they considered. In this study mean undiscovered resources were estimated to be 100 MMBO and 55 TCFG (Region 8 Assessment Results Summary, p. 3).

Irrawaddy Province-8048 (boutique)

The Irrawaddy (8048) and North Burma Provinces (8035) (not assessed) include most of the north-south trending Central Burma Basin, also referred to as the Chindwin-Irrawaddy Basin or the Inner Burman Tertiary Basin. Developed parallel to, and involving obliquely converging marine and continental plates the basin is bounded on the west by the Indo-Burman Ranges and on the east by the Sino-Burman Ranges. The plate boundaries trend roughly south to north within the basin (Curray and others, 1979). The Irrawaddy delta, Gulf of Martaban, and Andaman Basin are also included in the assessed area.

Petroleum Systems and Assessment Units

The USGS recognizes that there are several separate TPS in this area. For assessment purposes, however, they were combined into a single composite TPS, the Eocene to Miocene Composite TPS (804801), because few correlations of source to reservoir hydrocarbons were available at the time of the assessment. There are also multiple stacked sources and reservoirs, and extensive fault systems allowing mixing of hydrocarbons from multiple sources. This composite system includes rocks deposited in alluvial, deltaic, and shallow marine environments. Source rocks include the Upper Eocene-Lower Oligocene shales of the Yaw, Shwezetaw and Okhmintaung Formations and shales of the Pegu Group

There are two AUs in this TPS. The first is the Central Burma Basin (80480101), which is located in the North and Central Burma Basins of Myanmar. This AU is an oil-prone unit consisting of Eocene through Miocene age source rocks and reservoirs. Reservoir rocks are primarily interbedded sandstones of the Oligocene-Miocene Pegu Group. The Eocene Ponduang and Tilin sandstones also have reservoir potential and have a combined thickness of as much as 3500 m including the interbedded shales. The second AU is the Irrawaddy-Andaman AU (80480102) which is located in the southern part of the Central Burma Basin, the Irrawaddy delta, and Andaman Basin. The AU is a gas-prone onshore and offshore basin. Interbedded sandstones of the Pegu Group are the primary reservoirs. The rocks that comprise this AU include Eocene sandstones and shales of the

Oligocene-Miocene Pegu Group, which exceeds 6500 m in places. This group is made up of interbedded, shallow marine shales, limestones, and sandstones, and the sandstones, shales, and coals of deltaic and lagoonal facies.

Exploration

Oil production on the Arakan coast and in the Burma Basin was reported as early as the 13th century from seeps and hand dug wells. In 1864, the first modern discovery was made at Yenangyat. This was followed by a series of discoveries that continued until World War II, when much of the existing oil industry was destroyed. Development and exploration began again in the 1950's and Payagon field was discovered in 1959. This was followed by the discovery of Myanaung (1964), Prome North and South (1965), and Mann (1970) oil and gas fields . In the 1970’s, and 1980's intermittent drilling offshore in the Gulf of Martaban, Irrawaddy delta, and along the eastern edge of the Andaman Sea lead to the discovery of the Yadana and Yetyangun gas fields.

Production

Based on Petroconsultants International Data Corporation data to 1996, the Irrawaddy Province (8048) was ranked 103rd in the world (including U.S. provinces). It was chosen as a boutique province for the USGS World Petroleum Assessment 2000 (Klett and others, 1997). Known petroleum volumes are 0.7 BBO and 10.3 TCFG for a total of 2.5 BBOE including natural gas liquids (

Petroconsultants, 1996); this volume is approximately 0.1 percent of world volume (excluding the U.S.).

Assessment Comparisons

Kingston (1986) estimated the mode of undiscovered oil in the Irrawaddy Province at 1.1 BBL and gas at <2.1 TCF. Masters and others (1998) estimated the mean for undiscovered oil at 1.4 BBL for the Burma Basin and the mean for undiscovered gas at 6.2 TCF for the Burma Basin and Andaman Sea. In this study mean undiscovered resources were estimated to be 725 MMBO and 20.5 TCFG (Region 8 Assessment Results Summary, p. 3).

Future Prospects

Although the offshore area of the Irrawaddy delta and eastern Andaman sea is under-explored, it has shown a good potential for gas. At present the gas is generally uneconomic only because of the temporary lack of large nearby gas markets. The Chindwin Basin also has shown potential for oil production and is underexplored.

Kohat-Potwar Province-8026

This province is located in an intrathrust structural basin in northern Pakistan. It is an oil-prone onshore basin that developed during the collision of the Indian and

Eurasian continental plates. The basin contains rocks with source and reservoir potential ranging in age from Cambrian to Miocene.

Total Petroleum Systems and Assessment Units

The USGS recognizes that there are several separate TPSs in this area. For assessment purposes, however, they were combined into a single composite Eocambrian-Miocene TPS the Patala-Namal TPS (802601), because few correlations of source to reservoir hydrocarbons were available at the time of the assessment. Multiple stacked sources and reservoirs, and extensive fault systems allow the mixing of hydrocarbons from multiple sources. While the Paleocene Patala Formation appears to be the primary source of hydrocarbons, many other potential source rocks may be contributing in different parts of the basin.

The Kohat-Potwar Intrathrust AU (80260101), is also a composite. The rocks of this AU include sandstones, shales, and coals of deltaic to fluvial facies and carbonates and shales of shelf environments, and range in age from Eocambrian to Miocene.

Exploration

The Kohat-Potwar Province is considered a mature oil province, with the first discovery occurring in 1915 when the Attock Oil Company found the Khaur oil field on a faulted anticline. Dhulian oil field, found in 1935, was the next commercial discovery. In 1937, the Eocene Chor Gali limestone reservoir yielded the first significant production from the Dhulian field. By the 1960's oil had been produced from the Jurassic Datta Sandstone, Paleocene Patala limestone, and the Eocene Chor Gali limestone. Other discoveries followed with Joya Mair in 1944, Balkassar in 1946, Karsal in 1956, and Tut in 1967. Recent discoveries have been made in the Attock District southwest of Islamabad. Several prospects unsuccessfully tested in the 1950's and 1960's are now being reexamined with good results (Quadri and Quadri, 1998).

Production

Based on Petroconsultants International Data Corporation data to 1996, the Kohat-Potwar Province (8026) was ranked 174th (including U.S. provinces). It has been chosen as a boutique province for the USGS World Petroleum Assessment 2000 (Klett and others, 1997). Known petroleum volumes are 0.3 BBO and 1.9 TCFG for a total of 0.7 BBOE including natural gas liquids (Petroconsultants, 1996); this volume is <0.1 percent of world volume (excluding the U.S.).

Assessment Comparisons

Kingston (1986) estimated the mode of undiscovered oil in the Kohat-Potwar province at 0.1 BBL and gas at 0.1 TCF. Masters and others (1998) estimated the mean for undiscovered oil in this province as 0.12 BBL and the mean for undiscovered gas as 3.0 TCF. In this study mean undiscovered resources were estimated to be 150 MMBO and 1.4 TCFG (Region 8 Assessment Results Summary, p. 2).

Future Prospects

Although the Kohat-Potwar Basin is a relatively mature basin, recent discoveries, however, indicate that there is still potential in the deeper and older reservoirs.

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