Petroleum Prospects & Plays in Bangladesh

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BLOCK SYSTEM of Bangladesh

The Block System for offshore areas has been in effect in Bangladesh since 1974.

The Block System was revised in 1988 when onshore areas were divided into 17 blocks, numbered 1-15, 22, and 23, and the offshore areas were consolidated into 06 blocks, numbered 16-21

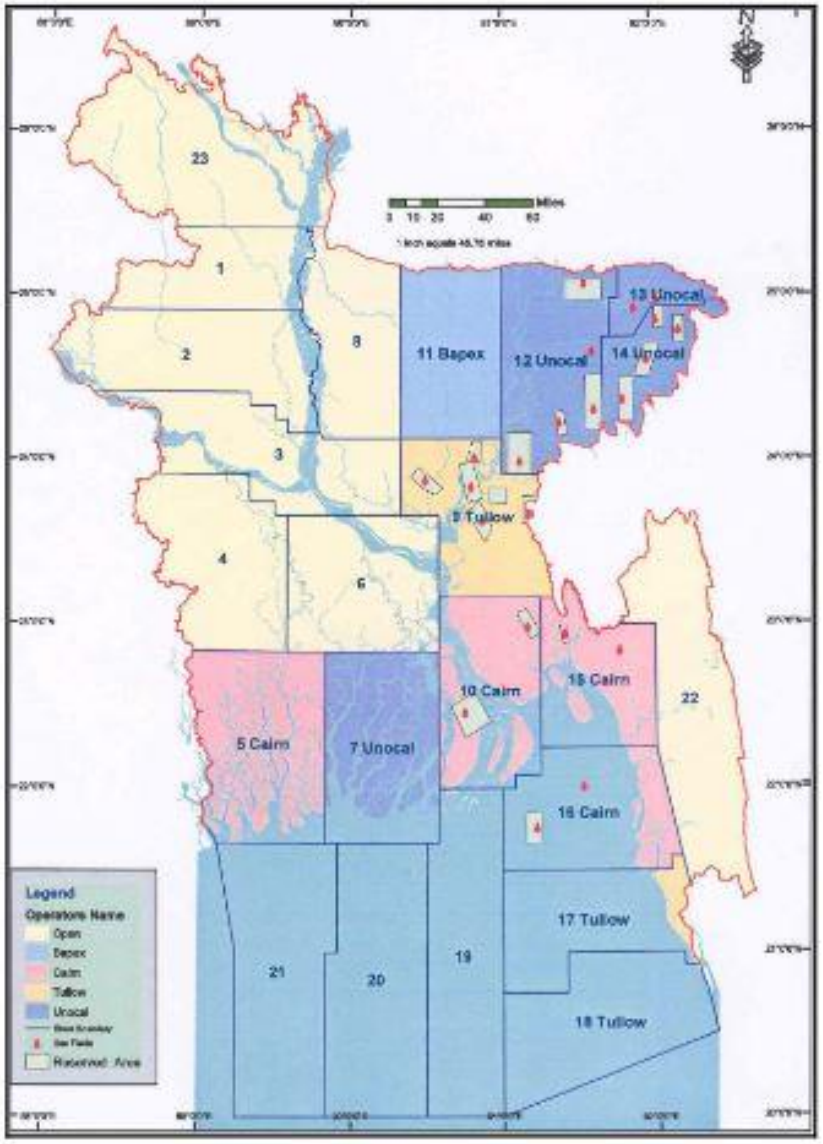


Figure 1-4 Block Map of Bangladesh – 1988 Vintage

Several onshore blocks have been subdivided into two parts, i.e. A and B, or three parts, i.e. A, B, and C resulting in a total of 24 onshore blocks.

The original 06 offshore blocks have been further subdivided, by water depth, into a total of thirty blocks. The subdivision of offshore blocks is based roughly on the 2,000 meter isobath. The shallow water blocks include the original Block 17, a portion of original Block 18 and the eight newly designated blocks SS-08-01 through SS-08-08. The new deep water blocks are designated SS-08-09 through SS-09-28

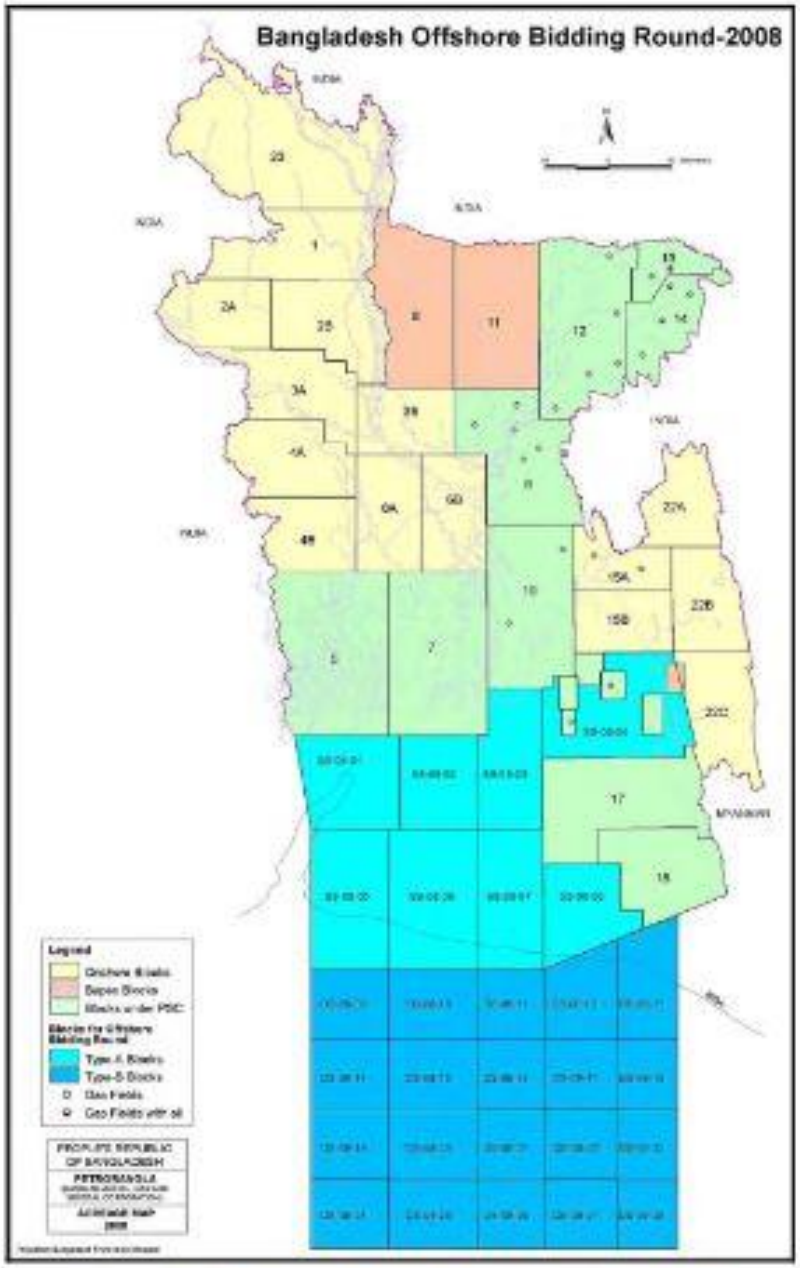
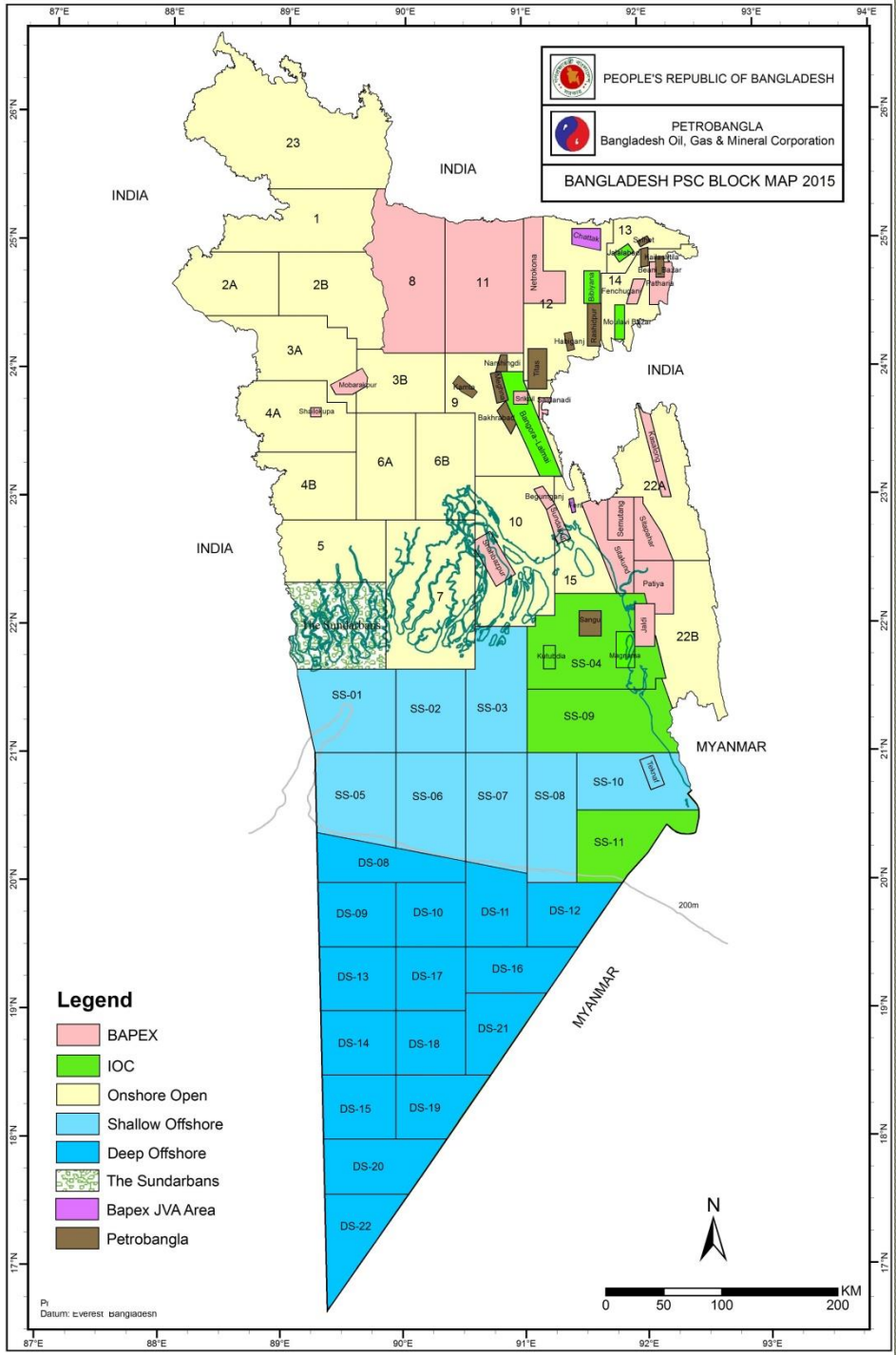


Figure 1-5 Block Map of Bangladesh – Vintage 2008

The Arbitral Tribunal in The Hague, dealing with the Bay of Bengal Maritime boundary Arbitration between Bangladesh and India awarded 19,467 sq-km maritime area to Bangladesh out of disputed 25,602 sq-km area.

The Production Sharing Contracts (PSC's 2012) of the Blocks **SS-04** and **SS-09** were signed by Government of People's Republic of Bangladesh, Bangladesh Oil, Gas & Mineral Corporation (PETROBANGLA), consortium ONGC Videsh Limited (OVL) & OIL India Limited (OIL) and Bangladesh Petroleum Exploration and Production Company Limited (BAPEX) on 17 February, 2014. OVL will act as the Operator of these two Blocks with Participating Interest of 45%, OIL holds 45% PB and BAPEX 10%.



a. Shallow Water Bids :Under this round, the following 3 shallow water PSCs have been signed :

▷ONGC Videsh Ltd. (OVL), Oil India Ltd. (OIL) and BAPEX for blocks SS-04 and SS-09; and
▷Santos, KrisEnergy and BAPEX for block SS-11

b. Deep Water Bid :Three proposals were received for blocks DS-12, 16 and 21 Jointly from ConocoPhillips & Statoil.

However, no PSC was signed for any deep sea block under this bidding round as they asked to improve the terms and condition of the Model PSC.

Operating Fields under PSC in 2018-19

Currently, 4 gas fields are being operated by IOCs under PSC. Of them 3 fields, namely **Bibiyana, Jalalabad** and **Moulvibazar** gas fields are being operated by Chevron and **Bangura** gas field by Tullow/KrisEnergy.

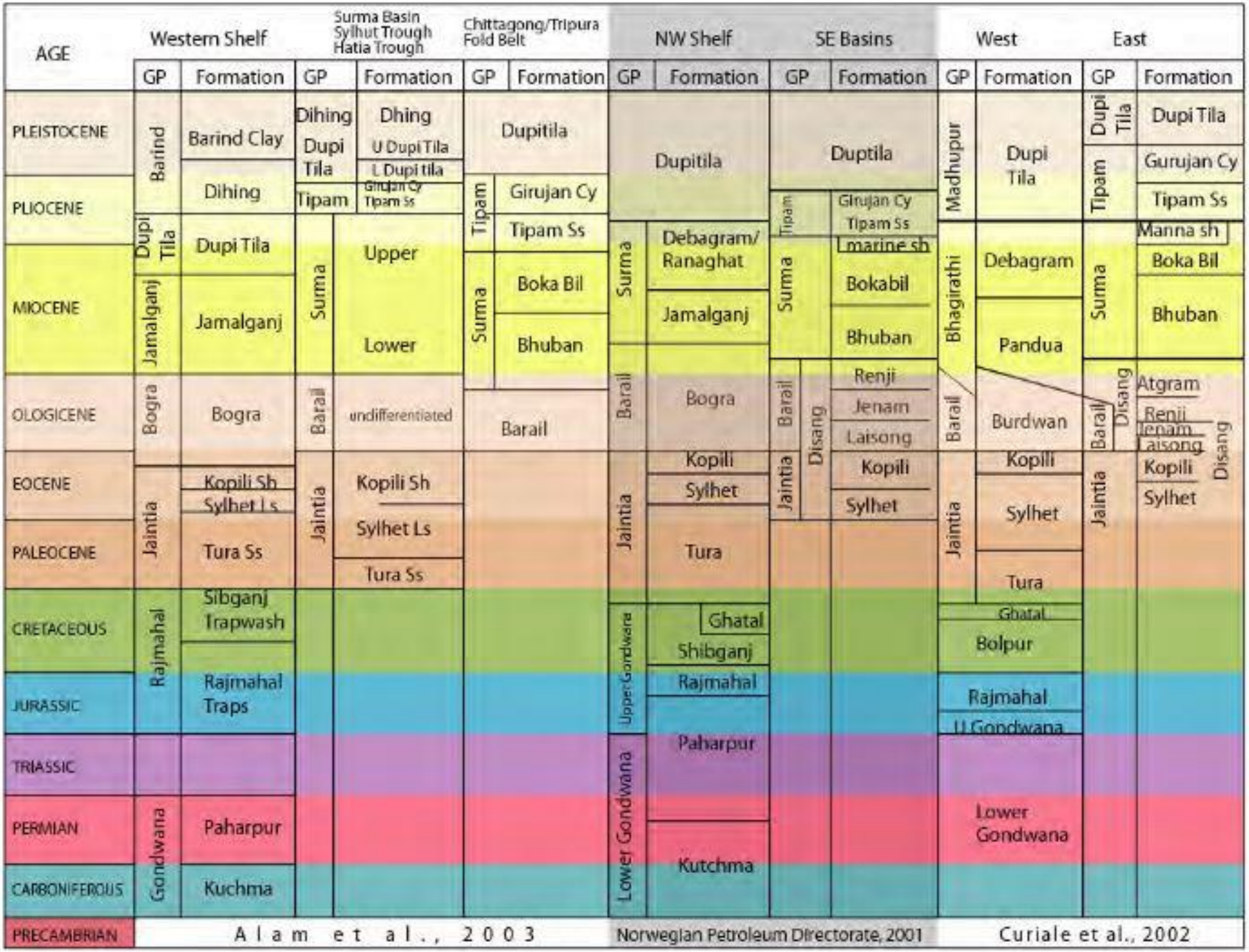
Bibiyana : Bibiyana field is now the largest supplier of gas to the national grid, delivering around 1,314 MMscfd gas and 8,117 bbl/day condensate from 26 wells. The design capacity of the process plant is 1,350 MMscfd. To maintain the current production plateau, few work programs and activities such as thin bed analysis, infill drilling, plant pressure optimization and compression projects are forecasted to execute in future.

Jalalabad : Currently Jalalabad gas field is producing around 213 MMscfd gas and 1,026 bbl/day condensate from 7 wells. The 2015 drilling campaign discovered a new sand layer (BB-20) which indicates further potentiality of the field.

Moulvibazar : Moulvibazar gas field is experiencing natural production decline and currently producing around 19 MMscfd. At present 5 wells are producing out of 9 wells. To increase the field deliverability, it has been decided to supply the produced gas directly to the local distribution line at a lower regulated pressure.

Bangura : The Bangura field started producing in 2006, peaking at 120 MMscfd in 2010 and thereafter declining to 80 MMscfd in November, 2018 from 4 wells. Two development wells were planned to drill to sustain the rate of production.

Petroleum Prospects


AGE
Western Shelf
Surma Basin
Sylhut Trough
Hatia Trough
Chittagong/Tripura Fold Belt
NW Shelf
SE Basins
West
East
GP
Formation
PLEISTOCENE
PLIOCENE
MIOCENE
OLOGICENE
EOCENE
PALEOCENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
PRECAMBRIAN
Barind
Barind Clay
Dihing
Dupi Tila
Jamalganj
Bogra
Kopili Sh
Sylhet Ls
Tura Ss
Sibganj Trapwash
Rajmahal Traps
Paharpur
Kuchma
Jaintia
Rajmahal
Gondwana
Dihing
Dupi Tila
U Dupi Tila
L Dupi tila
Tipam
Girujan Cy
Tipam Ss
Upper
Lower
Surma
Barail
undifferentiated
Kopili Sh
Sylhet Ls
Tura Ss
Jaintia
Dupitila
Girujan Cy
Tipam Ss
Boka Bil
Bhuban
Barail
Tipam
Surma
Debagram/ Ranaghat
Jamalganj
Bogra
Kopili
Sylhet
Tura
Ghatal
Shibganj
Rajmahal
Paharpur
Kutchma
Upper Gondwana
Lower Gondwana
Duptila
Girujan Cy
Tipam Ss
marine sh
Bokabil
Bhuban
Renji
Jenam
Laisong
Kopili
Sylhet
Barail
Disang
Jaintia
Madhupur
Bhagirathi
Dupi Tila
Debagram
Pandua
Burdwan
Kopili
Sylhet
Tura
Ghatal
Bolpur
Rajmahal
U Gondwana
Lower Gondwana
Dupi Tila
Tipam
Surma
Barail
Jaintia
Dupi Tila
Gurujan Cy
Tipam Ss
Manna sh
Boka Bil
Bhuban
Disang
Atgram
Renji
Jenam
Laisong
Kopili
Sylhet
Disang
Alam et al., 2003
Norwegian Petroleum Directorate, 2001
Curiale et al., 2002

SOURCE ROCKS

Source rocks that are mature and capable of generating hydrocarbons have been identified in Eocene and Miocene strata in Bangladesh (Curiale et al., 2002; Hossain et al., 2009; Shamsuddin and Khan, 1991; Manzur Ahmed et al., 1991; Ismal and Shamsuddin, 1991; Islam and Rahman, 2009).

Source rocks from Gondwana Group strata have also been identified (Frielingsdorf et al., 2009).

Table 4-1 Comparison of source rock data, modified from Curiale et al., 2002

Age	Unit	Sample	TOC (%)	Other
Pliocene/late Miocene	Tipam, Boka Bil, U Bhuban	Beani Bazaar-1 well, Rashidpur-3 well	0.2-1.5	HI 104-225 mg/g
Mid-Miocene	L Bhuban	Adamtila-1 well (India)	1.76 (avg)	2-3 mg/g (avg), Rock-Eval S2
Mid-Miocene-Oligocene	Atgram, Renji, U Jenam?	Atgram-1 well plus wells in Surma Basin	0.4-1.2	HI to 155 mg/g, marginally mature
Oligocene	U Jenam	outcrop	1.4-2.7	HI 121-166 mg/g, up to 0.15% extractable hydrocarbons
Eocene/Paleocene	Kopili, Cherra	outcrop	up to 16	gas prone
Tertiary	Undifferentiated	Titas-1 well	0.45-3.60	100% humic organic matter
Mesozoic	Gondwana	surface and subsurface	up to 60	gas prone

Gas, condensate, and oil are present in the Bengal Basin of Bangladesh. Two phases of hydrocarbon generation have occurred.

The **first phase** took place just prior to break up during the Jurassic involving strata of the Gondwana Group and

The **second and current** phase beginning in Paleocene with burial of source rocks in the Sylhet Trough (Surma Basin) and the Hatia Trough.

SOURCE ROCK POTENTIAL

Source rock studies have indicated that there are two primary areas that contain strata that are within the hydrocarbon generating window. One is to the south of the Shillong Plateau and corresponds to the **Surma Basin or Sylhet Trough** and the other is south of the Tangail-Tripura High corresponding to the Hatia Trough (Curiale et al., 2002; Ismail and Shamsuddin, 1991; Shamsuddin and Khan, 1991).

Within these two "kitchen" areas the early mature gas generation window is in the lower portion of the Bokabil Formation. In addition to these hydrocarbon "kitchen" areas, western Bangladesh contains half-grabens located on the rifted margin of the India Plate that contain Gondwana strata that are mature for hydrocarbons.

Studies have also predicted the presence of mature oil windows in Paleocene through Eocene age strata along the Bogra Shelf (Anglo Scandinavian Petroleum Group, 1988). These strata could be both oil and gas prone.

The Gondwana strata in Bangladesh consist of coal and coaly shale sequences that are rich in Type III organic matter. Humic Type III organic matter is generally gas-prone; however, oil is also generated from coals rich in liptinite in many basins. Gondwana strata potential source rocks have TOC values up to 60 percent (Curiale et al., 2002).

VR indicates that in this area Gondwana source rocks entered the oil window in Oligocene to Miocene time and may still be within the oil window.

Mudrocks of the Eocene age Jaintia Group and the Oligocene age Barail Group from the Sylhet Trough contain kerogen derived from land plants that could generate condensate and oil. The TOC values from samples of these strata were 1.0 percent to 1.6 percent

A recent study and modeling of the Kuchma, Singra, and Hazipur wells in northern and western Bangladesh predicted a significant hydrocarbon (predicted to be gas) generation phase for Gondwana strata from Late Triassic through Early Jurassic time (Frielingsdorf et al., 2008).

Another phase of hydrocarbon generation is predicted from these well modeling results in appropriately buried Gondwana strata, particularly basinward of the "hinge zone", from Late Miocene to present day (Frielingsdorf et al., 2008).

Samples of Cretaceous age strata from two wells in West Bengal contain TOC values of 1.04 percent to 1.5 percent. This suggests that the adjacent Natore-Pabna area of western Bangladesh could contain Cretaceous age source rocks capable of generating hydrocarbons.

Paleocene to Eocene strata, particularly the Kopili Formation with TOC values of 5 percent and the Cherra unit with TOC values of 16 percent, have the potential to be source rocks (Curiale et al., 2002).

The transgressive, Kopili Shale covers a large area of the eastern Eocene shelf and the Assam and Surma valleys. The Kopili Shale is known to be a source rock in the Assam area of India and could therefore be a source rock for adjacent northeastern and eastern Bangladesh. This source rock has potential to generate oil and gas.

The Oligocene age Jenam Shale is considered to be a significant source rock for hydrocarbons in the Bengal Basin and one of the major sources of oil in the Assam area of India and the fold belt of Bangladesh.

The Miocene Bhuban Shale is well developed in the Bengal Basin. These strata extend to the fold belt of eastern Bangladesh. The source rock potential is low due to TOC values ranging from 0.2 percent to 0.7 percent and gas is the predicted hydrocarbon from this strata.

RESERVOIR ROCKS

Middle to Late Miocene age sandstones are the primary producing reservoir rocks in Bangladesh and are known mostly from wells drilled in the fold belt. These reservoir rocks include the upper Miocene to Pliocene Boka Bil Formation and the middle Miocene Bhuban Formation (Curiale et al., 2002; Islam, 2009).

The Bhuban Formation produces gas at the Titas Gas Field where the formation represents deposition in prodelta, delta front, paralic and minor marine environments (Islam, 2009).

These reservoir rocks consist of fine- to medium-grained quartz sandstones with siltstone interbeds. Porosity ranges from 5 percent to 28 percent and consists of primary and secondary porosity. Horizontal permeability ranges from 0.5 mD to 490 mD (Islam, 2009).

In other fields in the fold belt, porosity of the reservoir rocks ranges from 15 percent to 33 percent and permeability from 20 mD to 330 mD with permeability found as high as 4 darcies. The depositional environments of these reservoir rocks include fluvial, tidal channel, coastal plain and shallow marine settings.

The equivalent age sequence on the western shelf area may be more argillaceous. Seismic data indicate that the sequence is extensively channeled, which may cut out some potential reservoir strata and add channel fill as a potential reservoir rock.

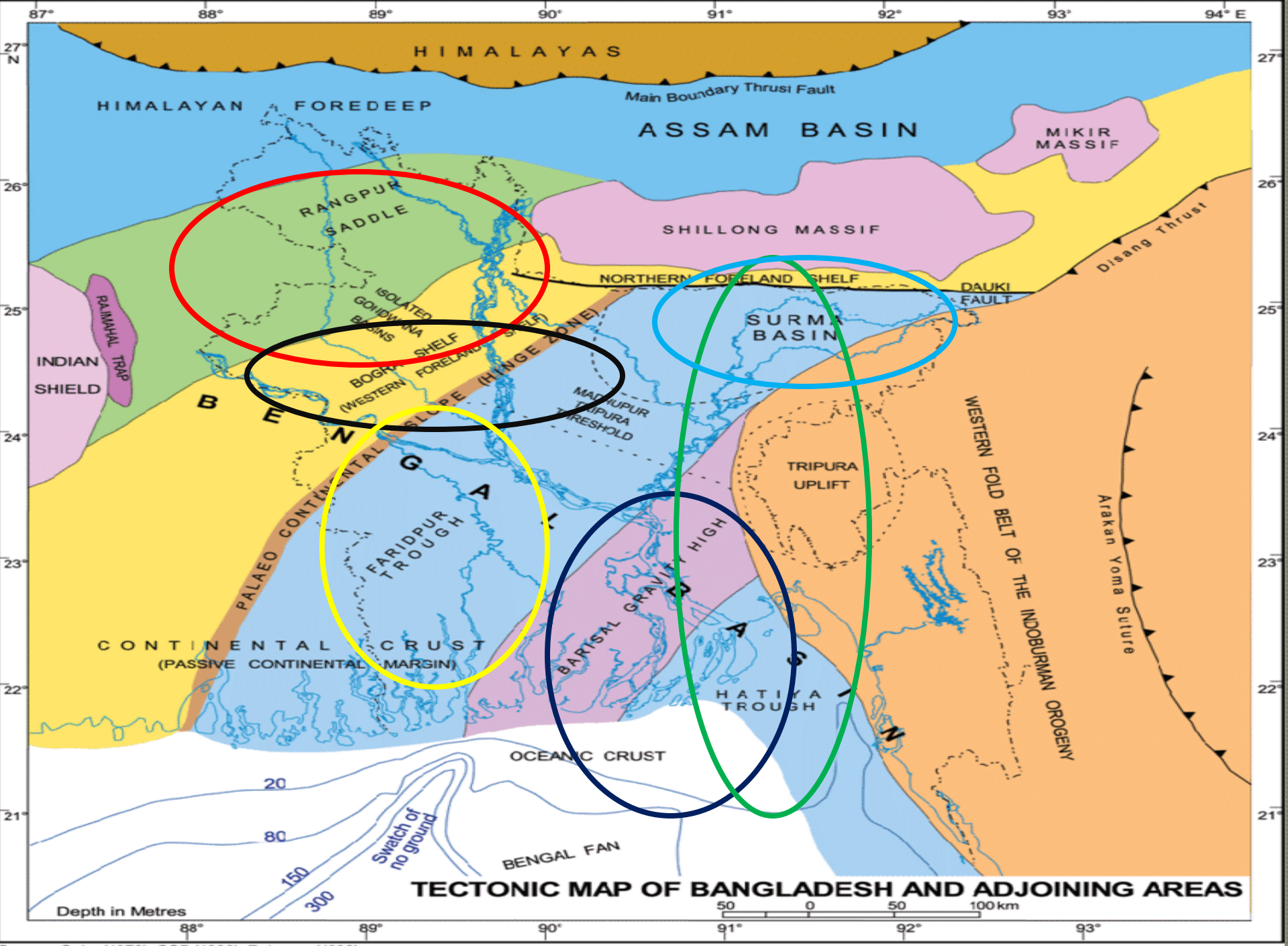
In the western shelf area potential reservoir rocks were deposited in delta front to inner shelf depositional environments. Porosity values of these rocks, measured from conventional core samples, range from 5 percent to 28 percent. The Middle Miocene sequence is absent in many areas in western Bangladesh due to a widespread erosional unconformity.

Syn-rift sandstones of the Jurassic through Carboniferous age Gondwana Group are potential reservoir rocks. These reservoirs are fine- to coarse-grained sandstones deposited in alluvial, fluvial, deltaic, and shallow marine depositional environments. These rocks are restricted half-grabens of the rifted margin of the India Plate.

The Paleocene age Tura Sandstone that has been encountered in the Singra well and the Kutchma well in the area of the western shelf is a potential reservoir rock. Porosity is fair to good, from less than 12 percent to 27 percent.

The platform carbonates and the carbonate buildups that comprise the Sylhet Limestone of the Eocene age shelf are potential reservoir rocks (porosity ranging from tight to approximately 18 percent).

Sandstones and shales of the Oligocene age Barail Group were drilled in wells in the western shelf region and the northern Surma Basin. The sandstone porosity ranges from 10 percent to as much as 18 percent.



Source: Guha (1978), GSB (1990), Reimann (1993)

PETROLEUM SYSTEMS

Bangladesh has been divided into two regions in some schemes and three regions in other schemes.

1. Division into two regions results in the western province, which consists of extensional continental rifting followed by passive margin and partially covered by Tertiary deltaics (includes the western Hatia Trough)
2. the eastern province, which consists of oceanic crust and distal passive margin partially covered by Tertiary deltaics and then folded (includes the Surma Basin or Sylhet Trough).

Division into three regions results in the **Stable Shelf**, **Central Deep Basin** (the Sylhet Trough and the Hatia Trough), and the **Chittagong-Tripura Fold Belt** (Alam, et al., 2003).

Curiale et al., (2002) developed a petroleum system events chart for the Surma basin, Bangladesh. The authors showed the Kopili and Jenam formations as source rock, burial continuous since the middle of the Oligocene, seals within the Kopili and Jenam formation and the Miocene age Bhuban and Boka Bil formations, reservoir rocks from the Eocene age Sylhet Formation up through the Miocene age Boka Bil Formation, trap formation in the Pliocene and Pleistocene, oil generation from late Eocene through middle Oligocene, and gas generation from middle Oligocene to the present.

Another petroleum system was described for northwest Bangladesh (Frielingsdorf et al., 2008) that combined Paleozoic age Lower Gondwana coal, Kopili shale, Jenam shale, and Boka Bil Formation source rocks with Sylhet Limestone and Bhuban/Boka Bil reservoirs.

WESTERN PETROLEUM PROVINCE

Three petroleum systems are suggested within the western province area;

1. the Gondwana composite petroleum system,
2. the Bogra Shelf petroleum system, and
3. the Western Delta petroleum system.

Hypothetical Gondwana Petroleum System

- Location: the rifted margin of the India Plate, now the northwestern part of Bangladesh
- Source Rock: Syn-rift coal-bearing sequences located in half-grabens (up to 45 meters thick) & oil-prone lacustrine shales.
- Resevoir Rock: half-grabens were buried by a passive margin setting, potential traps and reservoir rocks would be expected in Carboniferous through Late Cretaceous age strata and perhaps Tertiary strata
- Trap: Fault block traps would be expected in the syn-rift basins whereas stratigraphic traps in erosional remnants, channels, or stratigraphic pinchouts would be expected targets in this region

Hypothetical Bogra Shelf Petroleum System

- Location: parts of the western shelf and the slope area of the Bengal Foredeep
- Source Rock: The Paleocene age Cherra Shale and the Eocene age Kopili Formation, both part of the Jaintia Group, are dominantly gas-prone with TOC values up to 16 percent (Curiale, et al., 2002)
- Resevoir Rock: Tura Formation, Sylhet Limestone and other clastic strata
- Seal: The Kopili shale and Oligocene through Miocene regional shales could be seals for the hydrocarbon accumulations
- Trap: Stratigraphic traps and carbonate build-ups

Western Delta Petroleum System

- Location: southeast of the Bogra paleo shelf edge in the Bengal Foredeep and the western part of the Hatia Trough

- Source Rock: Oligocene through Miocene age strata of the Barail Group and the Surma Group. One of the source rocks that has been specifically identified as mature in the Hatia Trough is the Bhuban Formation (Shamsuddin and Khan, 1991; Curiale et al., 2002).

This strata is generating hydrocarbons that are expected to migrate up-dip to the west, where the system is unproved, as they have to the east, where the petroleum system is proven.

- Resevoir Rock: Early Miocene through Pliocene age stratigraphic traps in delta front and slope fan complexes are expected exploration targets.

- Trap: Growth faulting associated with deltaic deposition will add fault traps to the target inventory

EASTERN FOLD BELT PETROLEUM PROVINCE

Three areas have proven reserves;

1. the Surma petroleum system,
2. the east delta petroleum system, and
3. the southeastern offshore petroleum system.

Surma Petroleum System

The northeastern area of Bangladesh is characterized by a petroleum system based on the Oligocene age Jenam Formation as a gas-prone and liquid-prone source rock.

Hydrocarbon accumulations have been found primarily in the Oligocene to Miocene age Bhuban and Boka Bil Formations of the Surma Group (Curiale et al., 2002).

The strata is mature in the Surma Trough (Sylhet Trough) and is migrating vertically and horizontally to charge the traps (Shamsuddin and Khan, 1991).

The traps are primarily anticlines and faulted anticlines. Combination anticlines with draped channels have also been proven. Other stratigraphic traps and deeper horizons may be possible future targets

East Delta – Hill Tract Petroleum System

The mature source rock in the east delta area has been identified as the Miocene Bhuban Formation (Curiale et al., 2002).

These strata are mature in the Hatia Trough. Migration is into the fold belt to the east and the Tangail-Tripura High to the north. Migration out of this "kitchen" (Hatia Trough) has also been predicted to the west as reviewed above.

Proven reservoir rocks are primarily Miocene and Pliocene age sandstones deposited in fluvial, nearshore and offshore depositional environments. Traps include anticlines and channels incorporated into anticlines.

Additional exploration targets would include stratigraphic traps and deeper reservoirs.

Southeastern Offshore Petroleum System

This area contains a proven petroleum system that includes the offshore southern and western portion of the fold belt and the offshore portions of the Hatia Trough.

The source rock is the Bhuban Formation that is mature in the Hatia Trough, and perhaps the Kopili Formation.(!?)

The traps are a combination of relaxed folded anticlines of the western part of the fold belt and growth faults related to the delta.

Reservoir rocks include Miocene and Pliocene age deltaic sandstones, and deep-water clastics.

Stratigraphic traps may also prove to be an exploration target.

CONVENTIONAL TRAP TYPES AND PLAYS

The trap types that are proven and expected include:

- Anticlines
- Fault closures or fault traps
- Rollovers and normally faulted anticlines
- Carbonate platforms, carbonate build ups, carbonate debris fans
- Prograding delta plays
- Channels, incised valleys and erosional remnants (“buried hills”), and other stratigraphic plays
- Gondwana fault block, stratigraphic, and inversion plays

HYDROCARBON UNIT

Energy & Mineral Resources Division

FINAL UPDATED REPORT

On

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