CHAPTER 3
WORLD-WIDE CBM EXPLOITATION SCENARIO

In terms of coalbed methane exploration, production and exploitation, USA is considered role model worldwide. The initial exploratory efforts in the coalbed methane in any country tend to draw analogies with the US basins. But detailed analysis indicates existence of a divergent geological settings between the CBM plays of USA and India. In this Chapter, we attempt to depict the present scenario of CBM Exploitation worldwide and technical challenges to achieving it as an emerging energy source. An attempt has been made to draw comparison among some of the US basins , Bowen basin of Australia and Damodar Valley Gondwana basins of India.

3. 1 INTRODUCTION

Recent Coalbed methane (CBM) success in North America has been due to a number of coincidental factors such as the existence of extended coal basins, strong gas prices, a dense distribution network, and little competition with declining conventional gas production.

Strong demand for both oil and gas is pushing the rest of the world (Australia, China and India) to speed up CBM development. However, favourable geological factors such as occurrence of thick gas-rich coal seams with good porosity/permeability characteristics do not necessarily coexist with an ideal business environment in many of these countries. Outside the North America, Australia has the most commercially advanced CBM industry. The country contains about thirty(30) coal bearing basins , mostly Permian and Mesozoic in age. Proven reservoir in Australia have been estimated at nearly 9tcf. In China, an estimate size of CBM resource is very impressive 1200 tcf. India is also making an effort to attract both local and international companies to explore CBM potential in the country. Three bid rounds held in 2001,2003,2006 were successful. West Europe is favourable for CBM development ; however environmental issues and lack of gas-saturated coal seams extended over large areas may slow down full scale production from coal beds. Much less is known about CBM potential in Eastern Europe including Poland, Romania, Ukraine and Bulgaria. In several Latin American countries CBM exploration efforts are in their initial phases. Some countries are offering incentives to CBM investors , which make CBM exploration and production a feasible alternative to conventional gas.

3. 2 SCENARIO IN USA

Drilling activities focusing on unconventional plays is rapidly growing in the U.S. Numbering more than 14,000 these unconventional completions account for about 33%of total 2005 completions. CBM accounts for about 10% of total gas production in the US and this number will continue to grow.

At least five key factors of CBM success in U.S. are listed below:

1) Coal basins, and existence of thick coal seams with high gas content and suitable reservoir characteristics.
2) Historically strong Gas prices in the range from $4/mcf to $10/mcf.
3) Infrastructure and dense distribution network.
4) Little competition from declining production of conventional gas.
5) Water disposal option: via re-injection , allowed to flow into surfacial drainages or is put into evaporation ponds.

3. 2 .1 SAN JUAN BASIN

The San Juan basin is the most prolific coalbed gas basin in the world with proved reserves of over 6tcf. Hydrologic analysis indicates that overpressure in the Fruitland Formation is artesian in origin and represents re-pressuring that developed during the middle Pliocene. Highly permeable ,laterally continuous coal beds override abandoned shoreline .Cliff sandstone extend to the elevated recharge area in the northern basin to form a dynamic, regionally interconnected aquifer system.

Coal rank and basin hydro-dynamics control the composition of Fruitland coalbed gases, which varies significantly across the basin. Chemically dry gases in the north-central part of the basin coincide with meteoric recharge and regional overpressure. Basin hydro-geology, reservoir heterogeneity , location of permeability barriers and the timing of biogenic gas generation and trap development are critical for exploration and development of unconventional gas resources in organic-rich rock.

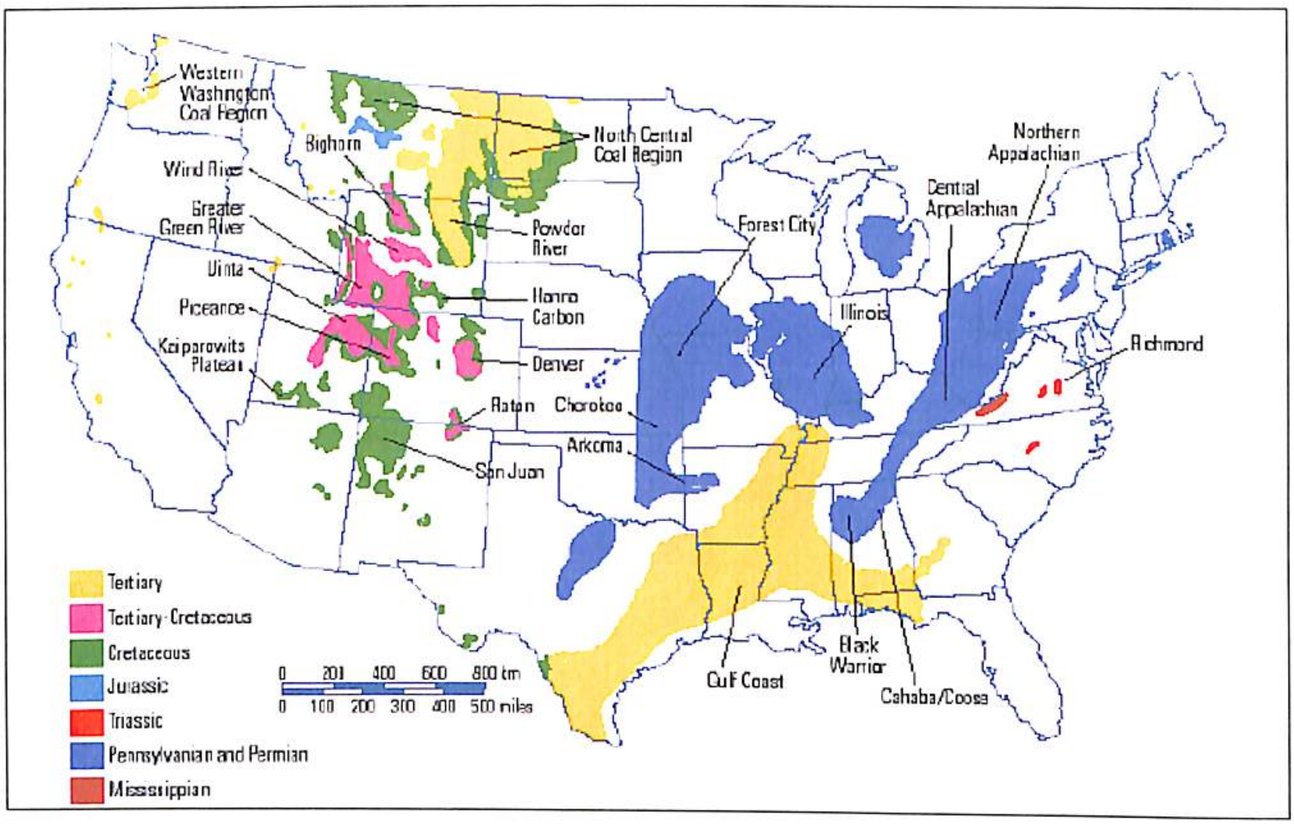
3. 2 .2 POWDER RIVER BASIN

The Powder River Basin, located in northeastern Wyoming and southeastern Montana, is the nation's fastest growing source of Coal Bed Methane. In the next 10 years, natural gas development in the Powder River Basin is expected to increase dramatically. As many as 39,000 additional wells will be drilled with 23,900 of these being on Federal lands. Although more than 12,000 wells have been drilled to date, large areas of the Powder River Basin remain relatively undeveloped.

The Powder River Basin is one of a series of coal-bearing basins along the Rocky Mountains, stretching from northern New Mexico to central Montana. The basin covers approximately 28,500 square miles, with approximately one-half of this area underlain by producible coals. The basin is bounded on the east by the Black Hills uplift, on the north by the Miles City arch, on the south by the Laramide Mountains, and on the west by the Big Horn uplift and Casper arch. The bulk of Coal Bed Methane activity to date has been in the east and central portion of the basin, around the town of Gillette, in Campbell County, Wyoming. To date, nearly 12,000 Coal Bed Methane wells have been drilled in the Powder River Basin, providing a wealth of data for establishing the geologic setting and characteristics of the Wasatch and Fort

Union Formation low rank coals in this basin. The Powder River Basin is filled mainly with thick Tertiary-age marine and fluvial deposits. The different basins in U.S. and their Geological age has been shown by the Figure3.1 below

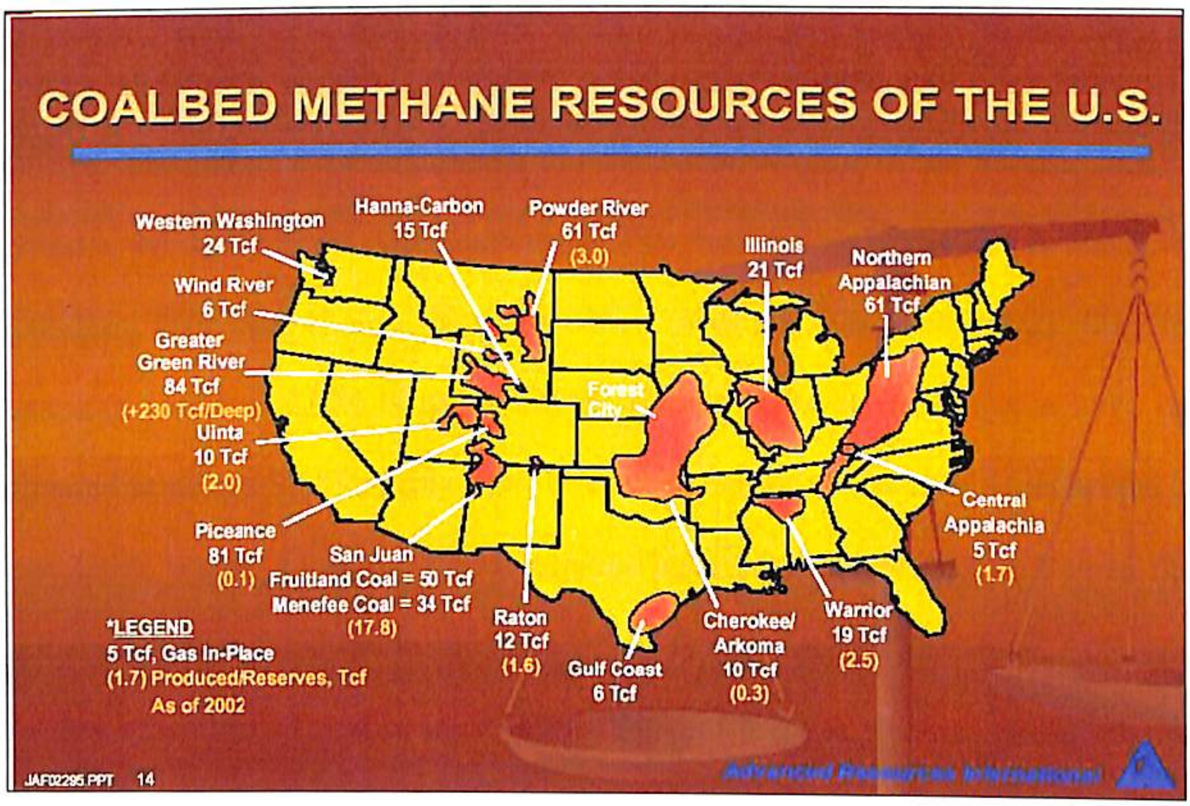
FIGURE 3.1: MAJOR U.S. BASINS AS PER THEIR GEOLOGICAL TIME SCALE.



A series of reservoir properties, including depth, coal thickness, gas content, pressure gradient and gas saturation, were collected and assessed to calculate the gas in-place for each of the major coals. In addition, data on coal fracture and matrix porosity was established to calculate the volume of water in-place for each of the coals. Finally, coal reservoir permeability (for both the cleat system and the coal matrix) was established to calculate the amounts of recoverable methane and water. The coals are fully saturated with methane (at the reduced reservoir pressure conditions that generally exist in the basin) and that modest amounts of free gas exist in the matrix porosity and coal cleat (fracture) seam/partition data sets.

The different basin which are the major contributor as resources of CBM for US is shown by the Figure 3.2 as shown below.

FIGURE 3.2: U.S. CBM RESOURCES SHOWN INDIVIDUAL BASINS WISE



Coal Fracture and Matrix Porosity

1. In general, the coal cleat (fracture) porosity in the coals ranges from 0.1% to 1%.

2. The matrix porosity for these low rank coals varies widely, ranging from 1% to 10%. Matrix porosity tends to increase for the deeper coals, such as the Wall, Pawnee, and Cache. High coal matrix porosities would support the relatively high water production from otherwise thinner (25 to 30 feet) coal seams, such as the Wall.

Coal Permeability In general, the coal cleat (fracture) permeability of Powder River Basin coals is favorable, ranging from 35 to 500 md. Coal matrix permeability's are considerably lower and variable, ranging from 0.001 to 1.0 md. However, even the lower end of the range for cleat and matrix permeability's for the coals in the PRB is sufficient to support reasonable gas recoveries of 50 to 80+% of the gas in-place.

3.3 CBM SCENARIO IN AUSTRALIA

Australia is the world's fourth largest coal producer and world's largest coal exporter. Outside the North America, Australia has the most commercially advanced CBM Industry. The majority of Australia's CBM resources occur in the eastern coasts of Australia, primarily in the Australian state of Queensland and New South Wales. The Australian Gas Association (Gas Statistics Australia,2002) estimates that total Australian resource CBM is about 220tcf, proven reserves in Australia have been estimated at nearly 9tcf.Roughly 60% of recoverable reserves are in Queensland and New South Wales. Most of CBM reserves have been discovered in Bowen-Surat Basins followed by Galilee-Eromanga, Sydney, Otway onshore and Gunnedah basin.

The Baralaba Coal Measures are a substantial coal bed gas resource and account for 14% of the Bowen Basins gas reserves, it contain thickly developed coal with seams up to 6m thick. Coal is characterized by high gas contents, ranging from 9-25m^3/tonne(dry, ash-free) combined with low permeabilities. The Walloon Formation coals had been considered to be of low rank(vitrinite reflectance values 0.44-0.56 Ro)

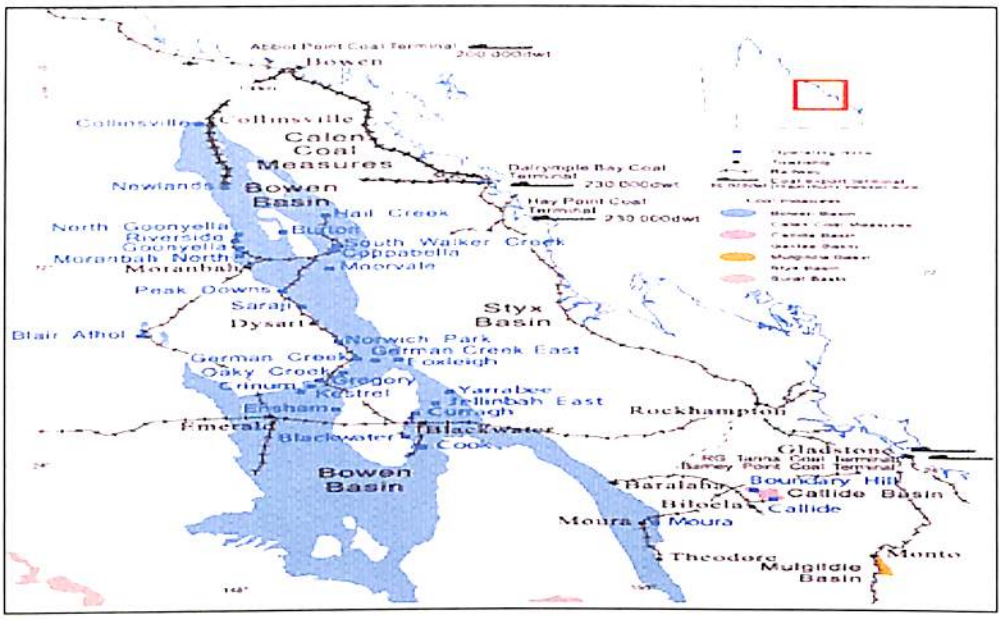
The Jurassic coals of the Surat Basin were not buried as deeply as those in the Bowen Basin and subsequently have lower gas contents.However, the proximity to infrastructure and markets, lower drilling costs, made these biogenic deposits potentially economic. In the main CBM province of the Bowen-Surat Basins average flow rate is about 600mcf/day. The absolute record was registered in the Surat Basin , where the Berwyndale well flowed at 2.3mmcf/day.

The most successful CBM finders are local Australian companies Tristar, Eastern Gas Anglo Coal, Capricorn. Among the top five current owner of CBM reserves are Santos, Eastern Star, Capricorn, Queensland Gas and Arrow Energy. During the last five years, CBM drilling rate in Australia is about 100 wells annually. Most of these wells have been drilled in Bowen, Surat and Sydney Basins. In 2006, considerable drilling activity have been observed in a new area called Kumbarilla Ridge.

CBM is also expanding in West Australia with new exploration blocks awarded in Perth Basin. The majority of CBM supply agreements have been signed with individual power stations, many of which are sited at the CBM project. The gas price is in the range of \$2.8/mcf to \$3/mcf. A typical CBM development requires AU\$200millions to drill 50 CBM wells, build water management facilities, a 100 km gas transmission pipeline, and an expandable gas processing plant with initial capacity of 35MMcf/d.

The major coal basins of Australia is depicted by the Figure 3.3 as shown below.

FIGURE 3.3: MAJOR COAL BASINS OF AUSTRALIA

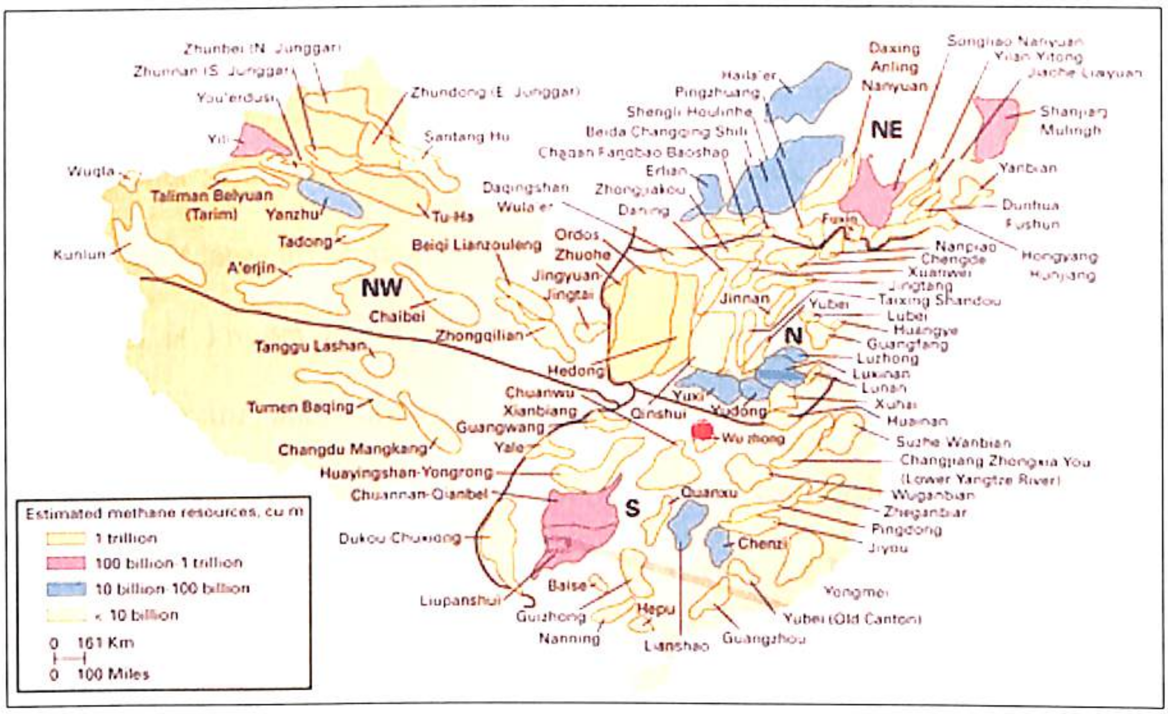


3.4 SCENARIO OF CBM IN CHINA

The Chinese estimate of CBM resources in the country is very impressive at about 1200tcf.Here key players are the local companies like Sinopec and CUCBM. The international community includes Chevron, Greka, BP, Far East Energy, COP and Canadian companies like Terra, Ivana, Verona. Coal Bed Methane Company (CUCBM) is an authority to engage foreign companies in cooperative exploration and production of CBM and to regulate onshore exploration. Here CUCBM is not only the partner, it is very likely that CBM development with international participation will be supervised by the local authorities , who can dictate the gas prices and limit marketing to local consumers.

Most CBM projects in China are in Exploration or initial development phases. As of end-2005,CUCBM and its foreign partners drilled a total o 453 coal bed methane wells, which include the 113 drilled by CUCBM and its foreign partners(at US$ 87.5 million). The CBM scenario in China is shown below by the Figure 3.4.

FIGURE: 3.4: CHINA'S COAL BASINS AND COAL BED METHANE RESOURCES



As of end 2005, CUCBM has started coal bed methane production from phase I of the Panzhuang project, southern Qinshi Basin. The project covering 346 sq. km located around Jincheng city aims to tap 1.42 tcf of CBM reserves. CUCBM also indicated that two pipelines for coal bed methane transmission were planned to be built in next five years. One of the pipelines will link Qinshui, Shanxi province to Boai , Henan province, where it will be connected to the West-East pipeline(WEP). It will have a capacity of 1 bcm/y. The second pipeline will link Songzao, Chongqing Municipality to nearby Chongqing City.

3.5 EUROPEAN SCENARIO OF CBM

In West European countries including France, Germany, Italy, Spain and Swizetzland , CBM exploration activities were known from beginning of nineties. In the UK some of these exploration efforts resulted in the discovery of 15 fields with total reserve size of 120 bcf. Two of them are producing in the Midland Valley Graben. From a commercial standpoint, West Europe is favorable for CBM developments ; however environmental issues and lack of gas-saturated coal seams extended over large areas may slow down full scale production from coal beds.

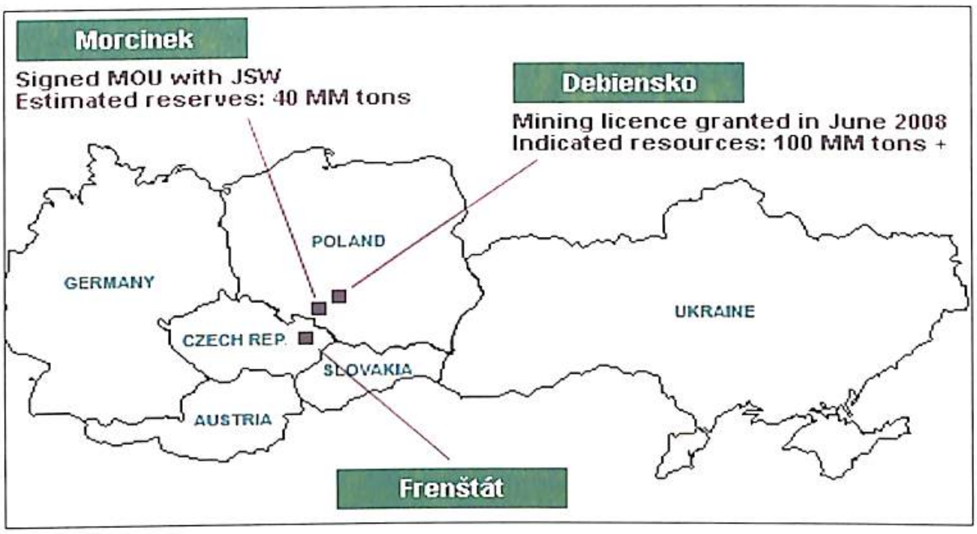
Much less is known about CBM potential in Eastern Europe including Poland, Romania, Ukraine, and Bulgaria. Poland drafted two new concessions for exploration and exploitation of coal bed methane.The new concessions, Pawlowice 1 and Pawlowice 2, are located in Southern Poland within the Upper Silesian Coal Basin. The upside potential within concession areas is estimated at some 1.0 tcf of gas. Favorable fiscal conditions (no royalty, no state participation) as well as proximity to the market and infrastructure are offered to the interested parties.

In 2006, CBM Energy Associates started its CBM exploration during program in Bulgaria(Dobrudzha Coal Basin) in its exploration block 21, which is situated in North-eastern part of Bulgaria and encompasses 440sq.km.

In Romania, Canada-based Falcon Oil & Gas is exploring CBM in Valea Jiului contract. The exploration area encompassing 268sq. km is situated in the Petrosani Coal Basin(Oligocene-Miocene brown coal half graben , developed along a major strike slip fault) in the Hunedoara political province. A significant part of the Valea

Jiului block area includes coal strata containing methane. The prospective acreage contains up to 18 coal seams with a cumulative thickness up to 50m at depths of 300-1000m and the main target seam averages 22m in thickness. The Scenario of Europe has been shown in Figure 3.5 below.

FIGURE 3.5 : SCENARIO OF COAL RESOURCES IN EUROPE



3.6 SCENARIO OF CBM IN LATIN AMERICA

In Chile, U.S. based company Layne Energy is negotiating a special operations contract with the Mining and Energy Ministry and has requested an exploration concession for a 2500sq. km area in the Arauco Basin. The company intends to develop CBM in the under-explored basin of south central Chile.

In Argentina, the Paraguil X-3 is thought to be a coal bed methane exploration well drilled in the Claromeco Basin. The well had a planted total depth of about 600m. In the northern part of the Cesar Basin of Colombia , about eight CBM well were drilled back in 1998-2004 by Andina. About 10bcf of gas has been discovered in the Patilla Field. The field was producing gas at maximum annual rate of 4000mm/cft.

3.7COAL BED METHANE EXPLOITATION SCENARIO OF INDIAN BASINS

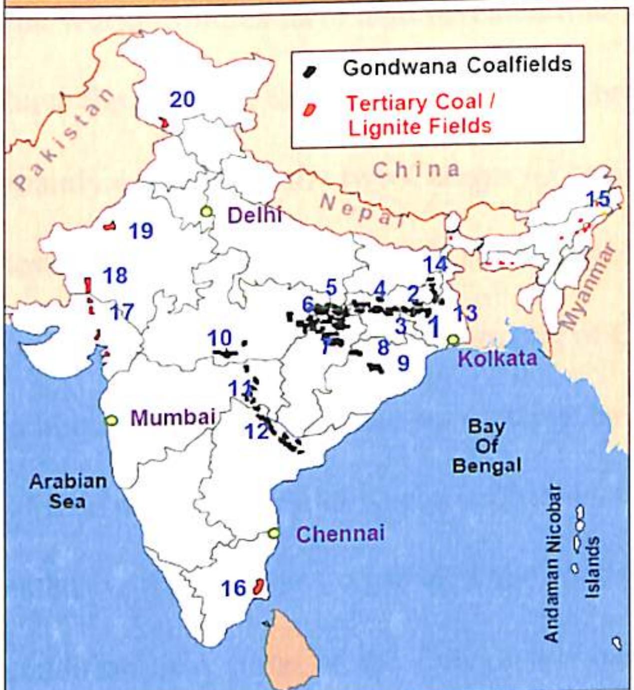
The knowledge of methane occurring with coal beds is as old as the mining itself. However, initially it was treated more as a hazard than a resource. Being highly explosive, coal mines have faced many explosions in the past due to this gas. In China, such explosions are a common occurrence due to lack of proper ventilation in mines. High capacity fans are used to dilute the gas during mining and the mixture is released into the atmosphere. Thus, the resource is not only lost, being a greenhouse gas, it contributes to the global warming. Coal mining is reported to be contributing about nine per cent of the total methane emissions. The total methane emission is 270–449 teragrams

In terms of coal resource India ranks among the top ten countries of the world. Indian coal deposits occur in two stratigraphic groups viz. Gondwana (mainly Permian) and Tertiary (Eocene and Oligocene). The Gondwana coal which constitute about 99% of the total coal resources occur along prominent river valleys viz. Damodar, Sone, Koel, Mahanadi, Pench, Kanhan, Wardha, Pranhita, Godavari and Narmada in the states of West Bengal, Jharkhand, Orissa, Andhra Pradesh, Madhya Pradesh and Maharastra. The Tertiary lignites/coals occur in the states of Tamil Nadu, Gujarat, Rajasthan, J&K, Assam-Arakan and Himalayan Foot Hills. Bulk of the Gondwana coals are distributed over West Bengal, Jharkhand and Madhya Pradesh with suitable grade and type, having high volatile bituminous to low volatile bituminous rank (maturity range VRo:

0.8-1.7), as CBM target. Estimated coal resource of Indian Basins is 211 billion metric tons. The CBM map of Indian scenario has been shown by the Figure 3.6.

Figure 3.6: MAJOR COAL FIELDS AND POTENTIAL CBM

MAJOR COAL & LIGNITE FIELDS OF INDIA



GONDWANA COALFIELDS

Ref. No.	Coalfield/Coal Belt		Ref. No.	Coalfield/Coal Belt	
1.	Raniganj	DAMODAR VALLEY BELT	8.	Ib-valley	MAHANADI VALLEY BELT
2.	Jharia		9.	Talchir	
3.	Bokaro		10.	Satpura	NARMADA BELT
4.	N. Karanpura		11.	Wardha	PRANHITA GODAVARI BELT
5.	Singrauli	SON VALLEY BELT	12.	Godavari	
6.	Sohagpur		13.	Birbhum	
7.	Korba		14.	Rajmahal	

TERTIARY COAL / LIGNITE FIELDS

Ref. No.	Coal/Lignite Field	Ref. No.	Coal/Lignite Field
15.	Assam-Meghalaya	18.	Barmer-Sanchor
16.	Neyveli	19.	Bikaner
17.	Cambay	20.	Jammu & Kashmir

It has been inferred by Biswas (1995), that the range of CBM gas resource of the Gondwana coals in India may be of the order of 1.0 to 2.0 TCM (most likely 1.5 TCM). The maximum density of gas resource is expected in Eastern Coalfields. Moderate density is expected in the North Eastern Coalfields as also in the coalfields of Madhya Pradesh, judging from the chemical and petrographic composition, rank and maturity of the coals.

The coal bearing Indian basins have been subdivided into four categories by James Peters et.al (2001) (explained in Table 3.1) on the basis of rank, physicochemical characteristics, prospective area available, depth of occurrence of coal seams, geological age and present level of knowledge.

The basins under Category-I are considered to be most prospective in terms of higher resource concentration and comparable gas content with some of the producing basins of the world. Studies have also revealed that in terms of producibility, Category-I basins have the potential to provide commercial breakthrough. ONGC's activities since 1995 is mainly confined in the two Category-I basins viz. Jharia and Raniganj. The production testing of multiple coal zones in commingled manner had given encouraging results from one of the wells of Jharia basin. Ranking of Category-II and III basins are mainly based on coal quality and rank, which may change by other favourable factors. For example, coals of Ib-river, Talcher and Korba coalfields, though are quality-wise inferior but possess extensive thickness and occur at shallower depth, which may provide better hydrodynamic condition than some of the Category-II basins. The CBM potential of Tertiary coal / lignite under normal circumstances should be rated as lowest and is placed at Category-IV in the above mentioned classification. However, certain geological factors which have contributed in making Powder River basin, USA with lignite a producing prospect, may be present in some basins under Category-III & IV.

TABLE 3.1 : COALFIELDS OF INDIA & THEIR CATEGORIZATION

Category I	Gondwana Coals ranking high volatile bituminous A and above.	Jharia, Bokaro, Raniganj and North Karanpura Coalfields.
Category II	Gondwana Coals ranking high volatile bituminous A and below.	South Karanpura, Raniganj, Pench-Kanhan and Sohagpur Coalfields
Category III	Low ranking Gondwana Coals	Talchir, Ib, Pranhita-Godavari Valley and Wardha Valley Coal field.
Category IV	Tertiary Coal / Lignite resources.	Cambay, Bikaneer-Nagaaur, Barmer, Assam-Arakan, Cauvery and Himalayan Foot Hills Basins.

3.8 COMPARISON OF CBM RESOURCES – INDIA VS. USA AND AUSTRALIA

In terms of coalbed methane exploration, production and exploitation, USA is considered role model worldwide. The initial exploratory efforts in the field of coalbed methane in any country tends to draw analogies with the US basins, especially San Juan Basin. But detailed analysis indicates existence of a divergent geological settings between the CBM plays of USA and India. An attempt has been made to draw comparison among some of the US basins, Bowen basin of Australia and Damodar Valley Gondwana basins of India

TABLE 3.2 : COMPARISON OF CRITICAL PARAMETERS- INDIA VS USA AND AUSTRALIA

Basin / Parameters	Warrior USA	San Juan (Fairway) USA	San Juan (Non Fairway) USA	Bowen Australia	Damodar Valley (Gondwana) India
Age	U.Carboniferous	Cretaceous	Cretaceous	Permian	Permian
Depth of occ (m)	300-800	300-1000	300-1000	300-1200	400-1200
Thickness (Cum.) (m)	5-8	15-30	9-24	15-30	50-120
Gas content (m^3/ton)	8-18	12-18	9-16	6-12	8-22
Resource Conc. (MMm^3/Km^2)	120	510	310	320	300-1200
Gas saturation (%)	80-100	100	80-100	80-100	85-100
Permeability (md)	1-25	5->50	1-20	<1->50	0.5-2.5 (Source only 4 wells)
Permeability-Thickness Product(md-m)	5-190	75->1500	10-500	<10->1500	5-120
Reservoir Hydrodynamics	Hydro-static to subhydro-static	Artesian condition exists which gives rise to over pressure situation	Hydrostatic to subhydro-static	Hydrostatic to subhydrostatic	Hydrostatic to subhydrostatic
Producibility (m^3/day/well)	2000-15000 (Approx.)	20000 and above	2000-10000 (Approx.)	1200-5500	6000 m^3 stabilized production from 1 well

Australian coal fields are more akin to Indian Gondwana coal fields with respect to Geological and Engineering aspects of coalbed methane exploration. Apart from geological and structural similarity of the coal basins of both the countries, many coal seams of both the countries are affected by extensive igneous activities, which in some cases make the coals unsuitable as CBM prospects.

Worldwide experience of CBM exploration and exploitation lead to realize the basic fact that each CBM play / project is basin specific and demand different kinds of approach for achieving ultimate commercial success.

3.9 CBM ACTIVITIES IN INDIA

The coal-bearing formations of India occur in two distinct geological horizons in the Lower Gondwana (Permian) belts of India and the Tertiary sediments (Eocene-Oliocene) of north-eastern India, Rajasthan, Gujarat, and Jammu and Kashmir. Methane gas is entrapped within these formations at a wide range of sub-surface depths.

In the past, methane had oozed out of the boreholes on several occasions during exploration of coal. Many of the mines in Jharia, Ranigunj, Karanpura, and Bokaro coalfields have been found gassy. The Director General of Mines Safety has categorized these mines based on the quantum of methane given off during the process of mining. A large number of our mines are estimated to produce less than 1 m^3/tonne of coal produced and are defined as Degree I mines; some of them are Degree II mines giving off 1–10 m^3/tonne of output. Only 21 underground mines in

Damodar Valley in Jharia, Ranigunj, and Bokaro coalfields are listed as Degree III mines, where the rate of emission exceeds 10 m^3/tonne of coal output. A few mines also belong to tertiary deposits in Assam. However, such indicative information is highly inadequate to estimate the potential of CBM (coal-bed methane). The estimation of availability of CBM is a complex, time-consuming, and capital-intensive process. For example, the number of drill holes needed for exploring CBM is 10 times that needed for natural gas. The time and cost involved in pumping out the associated water from CBM drill holes are also high. The quantum of gas is dependent on many parameters and some of them are highly variable.

In the last decade, after the realization that methane from coal bed can be gainfully utilized, many agencies and research organizations such as the Central Fuel Research Institute, the Central Mining Research Institute, the Central Mine Planning and Design Institute, the Oil and Natural Gas Corporation, and the Mineral Exploration Corporation have become interested in CBM and are generating useful data. Many private agencies like the Amoco and Reliance also have contributed in this regard.

Investigation on CBM for its commercial exploitation is a comparatively recent phenomenon in India. It was mooted by the Ministry of Coal, Government of India, way back in 1994 when several companies from India and abroad showed keen interest in the subject. The notable ones were Reliance Gas (P) Ltd, Modi Mcenzee, and Amoco, etc. However, though the blocks were allotted to some of them by the Ministry of Coal, it was discovered that the resource came under the preview of the MoPNG (Ministry of Petroleum and Natural Gas). The administrative and bureaucratic wrangle between ministries resulted in a long delay and some of the companies lost interest due to working uncertainty and legal barriers. Finally, the MoPNG was entrusted with the responsibility of framing the policy for the development and use of CBM in India.

Although theoretically CBM potential evaluation in India began in early nineties, it was Essar Oil Ltd. That drilled the first three wells for evaluating the CBM potential of Cambay Basin.(Rao 1997) . This was followed by the drilling of two wells by the ONGC in the Durgapur depression of the Raniganj coalfield.

In the period 1997–2000, the ONGC drilled some test holes and found substantial amount of gas in Bihar in Jharia coalfield. The boreholes were capped after flaring of the gas for some time and search started for the technology for its exploitation and customer for its utilization.

In the mean time, the United Nations Development Programme gave a grant of $9.19 million to the Ministry of Coal for the investigation of CBM in Bihar–Bengal coalfields. The Ministry of Coal has since started the work in several mines and adjoining areas. The total project cost is estimated at $19.226 million. This project generated useful data on CBM and, after successful completion, is likely to generate more confidence in the prospective investors.

After it was decided that the CBM subject will be dealt by the petroleum ministry, a CBM exploitation project was formulated by the Director General of Hydrocarbons with the help of the MoPNG. The project envisaged four phases: Phase I - Exploration, Phase II - Pilot Assessment and Market Confirmation, Phase III - Development, and Phase IV - Production. In the immediate context, only Phase I was to be considered and, to start with, the shallow depth coal-beds of the Lower Gondwana of the eastern and central parts of India was to be offered. The extent of these beds was of the order of 11,000 km^2, made up of:

- 2800 km^2 in the Raniganj, Jharia, East Bokaro and West Bokaro coalfields in the Damodar Valley belt (Jharkhand), and
- 8200 km^2 in the Sohagpur and Satpura coalfields of Central India ,Madhya Pradesh.

Within these areas, it was proposed to outline 10 blocks, varying in size from 200 to 500 km^2, in consultation with the Ministry of Coal and offer them for international competitive bidding. Offers included several fiscal and other incentives for the bidder. However, it took quite some time to do the homework and finalize the project.

Finally, the petroleum ministry recently held the first road show in Delhi, promising expeditious finalization of bids and a time-bound commencement of exploration activities for CBM. This was followed by two road shows in the US. The road shows, it is reported, were attended by a large number of representatives from the public sector and some private sector investors.

The bid has been floated offering 7 blocks (out of the 10 suggested earlier) for exploration of CBM. The total area of these blocks is 2430 km^2 for 6 blocks of Gondwana and 410 km^2 of Tertiary lignite with a total estimated CBM resource of above 280 billion cubic metres. These blocks have an estimated reserve of high grade, high-to-medium volatile bituminous/sub-bituminous coal to the extent of 40.58 billion tonnes and 4.8 billion tonnes of lignite. The depth of burial ranges from 100 to 1500 metres for coal and 100 to 400 metres for lignite. The gassiness is estimated to be a minimum of 4 m^3/tonne and the maximum varies up to 15 m^3/tonne.

The main laws governing CBM exploration and production in India are listed below.

- Oilfields (Regulation and Development) Act, 1948
- Petroleum and Natural Gas Rules, 1959
- Environment Protection Act, 1986
- Arbitration and Conciliation Act, 1996
- Income Tax Act, 1961
- Customs Act, 1962.

The exploration of CBM, as mentioned earlier, is time-consuming and capital-intensive. Unless fiscal and other incentives are in place, the possibility of investors getting interested is remote. Keeping this in mind, many fiscal incentives have been offered in the bid as listed below.

- No signature bonus
- No upfront payments
- No import duties
- Unincorporated joint ventures permitted
- No limitation on cost recovery
- Free to market gas in the domestic market at market-determined prices
- Securitization of participating interests allowed for raising project finance

- No bank guarantee required for work programme at development stage
- 7-year tax holiday
- Liberal set-off and accelerated deductions for income-tax purposes
- No ring fencing.

It was an international competitive bidding where 100% foreign participation had been allowed. The weightages for the main parameters to be used for bid evaluation (under New Exploration Licensing Policy-II) will be based on technical capability (20%), financial strength (10%), work programme (50%), and fiscal package (20%).

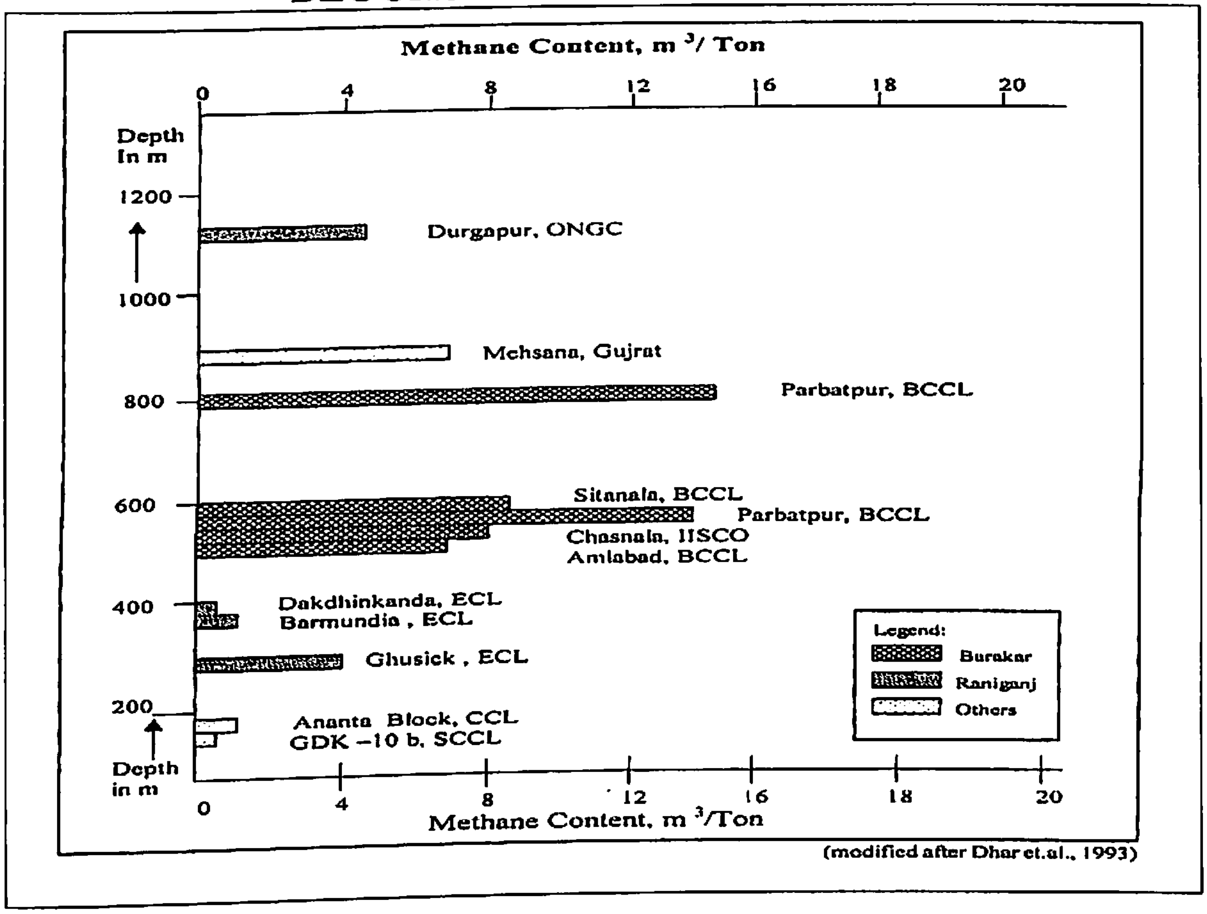
In case of Gondwana coals, their heterogeneity, thick multiple coal seams in a long stratigraphic column combined with hard and abrasive inter-seam partings could cause drilling and completion problems. Since Gondwana coalfields exhibit complex geology because if intricate fault systems, this could lead ultimately correlation and well-spacing problems. The coal with high ash and moisture content adversely affect the storage capacity as these type of coals are allochthonous , while excess igneous activity has de-volatized large areas of Gondwana coals which could result in poor CBM yields.

3.10 CBM RESOURCE AND PRODUCTION POTENTIAL

From the above discussion, it is apparent that only the Category-I basins of India are comparable with the producing basins in USA and Australia in terms of CBM potential. It may be mentioned here that high CBM resource does not necessarily mean high production potential because unlike conventional gas reservoir, the coal reservoir requires high degree of gas saturation. In case of most of the Indian basins, due to low maturity and poor quality, it is expected that the average gas content of most of the coal will be much below the optimum saturation level for achieving producibility. The Category-I basins with huge thickness and high degree of maturity and moderate quality indicated critical saturation level in terms of gas content and adsorptive capacity. The role of permeability in coal for achieving optimum production level is critical and only these coals with moderate permeability and large thickness may provide commercial production of CBM in India. It is unlikely that any other coal basins of India may produce coalbed methane commercially unless certain unique geological conditions may prove otherwise. To identify such unique geological conditions, the dimension of exploratory work that would be required may be tremendous and highly time consuming. So in near future i.e. in coming one decade establishment of CBM as a supplementary source of energy can be thought of in the Damodar Valley Gondwana basins (Category-I) only. This area, being far away from the provinces of conventional natural gas occurrences, may provide indigenous CBM gas at a competitive price. An optimistic estimate indicates that the Category-I basin of Damodar Valley has a resource base of 350 BCM. Taking into account all critical factors viz. quality, gas content, saturation and permeability of these coals, a producible reserve of 85 BCM may be optimistically arrived. This 85 BCM gas from the four Damodar Valley Gondwana basins may be produced in 20-25 years i.e. with an average production of 3-4 BCM per annum.

To achieve this level of production, huge investment spanning over an initial period of 6-10 years will be required with an order of investment of Rs.5000-8000 crore. This level of production is only 10-15% of the present total natural gas production of India. Thus, the realistic picture which emerges from the above discussions indicate that CBM can act as a minor source of supplementary energy to natural gas to the tune of 10-15% only.

FIGURE 3.7 : MAXIMUM VALUES OF METHANE CONTENT IN BLOCKS OF INDIAN COALBEDS



In view of the fact that this energy source would replace the existing feed stock to different industries in the state of Jharkhand and West Bengal and compliment the supply of natural gasin the state of Gujrat, depends on the three critical parameters such as permeability of the coal, Production behavior of CBM wells and marketability of this gas.

Permeability is a critical factor in the extraction of methane from coal seams.It is a combination of micro-porosity(Lamberson and Bustin,1993) of the coal and the porosity generated by fractures or cleats. Megascopic examination of the coal from

Damodar valley grabens show banded coal with thin to thick laminae of vitrain. There appears to be good development of cleat porosity in Category I coalfields. Total core porosity in Middle Barakar coal amd Lower Barakar coals in drilled wells in Jharia vary from 5.82 to 11.30 and 4.74 to 6.94 % respectively. A fairly high value of (1.43 to 4.15%) of matrix porosity has been encountered in Jharia coal. Air permeability is in the range of 0.23to 2.88 and 0.03 to 0.78md for Middle and Lower Barakar seams respectively.

Only a few wells have been tested and produced successfully in Jharia coalfield. Five objects were tested from the Barakar Formation in a depth range of 545-806m.The production profile is similar to a typical CBM well where initially the rate of water production is high with low gas production. With time the gas production increases and water production declines . With CBM activities gaining momentum in the Damodar Valley coalfields in Jharkhand & West Bengal and in the Barmer-Sanchor Basin, North Cambay Basin in the states of Rajasthan and Gujrat CBM may replace conventional fossil fuel like coal. This establishment of CBM as a supplementary source of energy to the tune of 10-15% of present national gas production, may be a realistic goal.