Coal Mine Methane (CMM) Resource Assessment and Emissions Inventory Development in Mongolia

Mongolian Nature and Environment Consortium
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Preface

Mongolia is a developing country and is well recognized internationally for efforts to reduce green gas emissions and has consistently demonstrated its strong support of international initiatives in protection of the global climate. The Millennium Development Goals-based Comprehensive National Development Strategy (MDG-based CNDS) of Mongolia, approved in 2010, identifies the need "to exploit the mineral deposits of strategic importance based on advanced technologies, intensify economic development, improve the structure of economic sectors, build financial capacity and the capital accumulation in order to establish a knowledge-based economy." The MDG-based CNDS also identifies the need "to create a sustainable environment for development by promoting capacities and measures on adaptation to climate change, halting imbalances in the country's ecosystems and protecting them." The MDG-based CNDS also includes a Strategic Objective to promote capacity to adapt to climate change and desertification, and to reduce their adverse impacts. In order to address challenges relevant to climate change, Mongolia has developed its National Action Programme on Climate Change and the programme was approved by the State Great Khural (Parliament) in 2000 and updated in 2011.

Mongolia has rich coal resources, with proved reserves over 12 billion metric tons. In recent years, the Mongolian Government and the coal industry have attached great importance on coal methane mine (CMM) and coalbed methane (CBM) development and utilization.

On 27th March 2008 the Government of Mongolia became the 24th member of the Global Methane Initiative (GMI). The Government of Mongolia supports the Initiative by providing financing channels and technical support towards the recovery and utilization of methane. In the framework of the GMI, Mongolia has implemented work such as the Prefeasibility Study of Methane Recovery and Utilization at Nalaikh Mine through the Mongolian Nature and Environment Consortium (MNEC) and a cooperative agreement with the US Environmental Protection Agency (USEPA). MNEC furthers work towards Mongolia's participation in GMI with activities under a second cooperative agreement, entitled Coal Mine Methane (CMM) Resource Assessment and Emissions Inventory Development in Mongolia.

MNEC was established as a non-profit, non-governmental organization to assist decision makers, scientists, and the public and private sector by conducting studies, scientific research and practical activities and by providing information to better understand the environment and natural resources and their sustainable use.

MNEC is an alliance of 14 nature and environment conservation research institutes, centers and non-governmental organizations of Mongolia, committed to joining their efforts and coordinating their activities in all relevant and possible fields of cooperation.

All members of the MNEC are dedicated to fully utilizing their collective expertise and experience to improve the quality of study, research and other activities, and to achieve the highest standard of performance. As inspired by Mongolian nature and environment, the MNEC also seeks to improve the technical and scientific basis for decision making on environmental issues through honest investigations and the application of common sense to problem solving.

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Acronyms and Abbreviations

CBM	Coalbed Methane
CMM	Coal Mine Methane
GMI	Global Methane Initiative
IPCC	Intergovernmental Panel on Climate Change
MDG-based CNDS	Millennium Development Goals-based Comprehensive National Development Strategy
MNEC	Mongolian Nature and Environment Consortium
MW	Megawatt
p10	Indicates a 10% chance that forecast will be ≥ to the p10 amount
p50	Indicates a 50% chance that forecast will be ≥ to the p50 amount
p90	Indicates a 90% chance that forecast will be ≥ to the p90 amount
RRR	Raven Ridge Resources, Incorporated
USEPA	United States Environmental Protection Agency
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Acknowledgments

Sponsor Organizations

The U.S. Environmental Protection Agency's (USEPA) Coalbed Methane Outreach Program (CMOP) is a voluntary program whose goal is to reduce methane emissions from coal mining activities. CMOP promotes the commercial recovery and utilization of coal mine methane (CMM), a greenhouse gas more than 20 times as potent as carbon dioxide. By working closely with mining companies and related businesses, the program helps enterprises to eliminate barriers in utilizing CMM and reduce direct gas emissions to the atmosphere, while improving coal mining safety and productivity, reducing cost and increasing income. USEPA has supported 22 grants for projects promoting coal mine methane recovery and utilization under the Global Methane Initiative (GMI). To date, these projects are located in China, India, Mongolia, Nigeria, Poland, Turkey, and Russia.

Contributors

Work carried out on this project was led by MNEC by Dr. M. Badarch and Ochirsukh Badarch with contributions from Raven Ridge Resources, Incorporated (RRR): Raymond C. Pilcher, Charlee Boger, Candice Tellio, and James S. Marshall. Other contributors include Dr. B. Namkhainyam, professor of heat supply and automation at the Mongolian University of Science and Technology Power Engineering School, and Dr. G. Tulga, consultant with Energy Resources LLC.

Participating Mines

This project was made possible by the cooperation and participation of several coal mines including Naryn Sukhait, Baganuur, Erdenes Tavan Tolgoi, and Khotgor.

Facilities

Gas analysis was facilitated by Dr. Enkhsaruul Byambajav, Director of the Coal Research Center at the School of Chemistry and Chemical Engineering of the National University of Mongolia. Adsorption isotherm testing was performed by Zhang Qingling of the Xian Research institute of the China Coal Technology and Engineering Group Corp.

1. Introduction

1.1. Project Introduction

The coal mining industry in Mongolia commands a dominant role in the developing economy of the country. Mongolia produced almost 33 million metric tons of coal in 2011, almost entirely from surface mines. Mongolia's energy needs are met primarily by coal; however, most coal was exported. Mongolia consumed 9.2 million metric tons of 2011 production to operate seven coal-fired combined heat and power plants, which generated 829 MW from 1062 MW of installed capacity. Mongolia's proven coal reserves are 12.2 billion metric tons, including 2 billion metric tons of coking coal and 10.1 billion metric tons of thermal coal.

Reserves of Mongolia's conventional oil and gas remain largely undiscovered, but coal mine methane (CMM) resources are known to exist based on gas occurrences reported from mining experience, coal exploration, and limited coalbed methane (CBM) exploration and testing. In order to identify prospective CMM project sites, it is important to investigate the distribution and magnitude of methane resources associated with recoverable coal resources. Partnering with RRR and cooperating mines, MNEC set out to provide a CMM Resources Assessment of key coal-producing basins in Mongolia. This project was proposed by MNEC in response to a USEPA Request for Proposals issued in December 2008.

Additionally, as coal production in Mongolia is on the rise with an over three-fold increase in production between 2008 and 2011, quantification of methane emissions as a result of coal mining activity provides a basis for tracking progress towards climate goals achieved by CMM recovery and utilization. MNEC worked to develop a more accurate CMM Emissions Inventory in Mongolia utilizing the data made available during the CMM Resource Assessment; specifically, gas content information for key coal basins. The approach employed by MNEC is prescribed by the Intergovernmental Panel on Climate Change (IPCC)[1]. A basin-specific Tier 2 approach is recommended in Mongolia to reduce uncertainty as mine-specific Tier 3 data are not feasible to obtain for surface mines at this time, which dominate Mongolia's coal production. With widespread coal deposits of varying rank, it is important to develop basin-specific emission factors.

In addition to the CMM Resource Assessment and CMM Emissions Inventory, MNEC worked to build capacity for CMM exploration and project development within Mongolia. As part of the data collection required, MNEC worked with RRR to purchase equipment to measure coal gas content (desorption equipment) for use in Mongolia. Developing the capacity for professional testing services establishes an incentive for testing to continue in Mongolia without the added costs and logistical problems associated with hiring testing companies outside of Mongolia. MNEC also organized several training sessions on data collection and testing procedures, as well as CMM recovery and utilization opportunities. MNEC performed outreach activities such as development of the "GMI in Mongolia" (2012) book in order to promote public awareness of CMM development in Mongolia.

1.2. Project Team and Experts

MNEC is directed by Dr. M. Badarch, who founded the organization in 1999. Before establishing MNEC, he worked in the environment and energy sector for 40 years, including: head of the International Cooperation department of Ministry of Environment, and as the United Nations Development

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 4

Programme (UNDP) team leader on natural resource management and energy. Dr. Badarch has led numerous projects as director of MNEC, including multiple UNDP and Asian Development Bank projects, and a previous USEPA grant, "Prefeasibility Study of Methane Recovery and Utilization at Nalaikh Mine." Through an open solicitation, MNEC acquired the services of RRR, a US-based geologic and environmental consulting firm founded in 1988. RRR has worked on CMM projects and international outreach through contracts with USEPA and private clients for the past 25 years, with specific experience estimating CMM and CBM resources.

MNEC also assembled a team of experts within Mongolia, with members of academia and private consultants, to work on the emissions inventory portion of this grant. This team was headed by Professor B. Namkhainyam, professor on heat supply and automation with the Mongolian University of Science and Technology.

2. CMM Resource Assessment

2.1. Background

To date there has been no commercial CBM or CMM activity in Mongolia; however, there have been CBM exploration and Production Sharing Contracts (PSC), such as that entered into by Storm Cat Energy and the Petroleum Authority in 2004. Thus far, no exploration or PSCs have been negotiated for resources distinguished as CMM; however, members of the Mineral Resources Authority have indicated that there are regulations which require coal lease holders to not only assess the magnitude of coal within their leasehold, but also to estimate the methane resources associated with coal and surrounding strata.

MNEC set out to develop an estimate of CMM resources by basin in Mongolia in order to help focus future exploration activities on basins with the most potential for commercialization of CMM and CBM.

2.1.1. Prior Investigations

Previous work has been done to quantify CBM resources in Mongolia, namely:

- *Tentative Reserves of Coal Bed Methane Gas in Mongolia*, Bazardorj Bayarsaikhan (2012);
- *Mongolian Surface Mines Assessment*, Dr. B. Namkhainyam (2013); and
- *The International Coal Seam Gas Report*, Steve Schwochow (1997) editor.

MNEC and RRR utilized these reports and the following coal resource estimates to evaluate CMM resources in Mongolia:

- *Mongolian coal-bearing basins: Geologic settings, coal characteristics, distribution, and resources*, Bat-Orshikh Erdenetsogt, Insung Lee, Delegiin Bat-Erdene, Luvsanchultem Jargal (2009) and
- *Coal Resources in Mongolia and Some Probable Potential Areas for Coalbed Methane*, Ayurzana Chimiddorj (1995).

The team also utilized *The Geographic Atlas of Mongolia (2004),* D. Dorjgotov editor, for hydrogeologic and precipitation data. Throughout the different data sources, there are varying spellings of the coal deposits and coal basins. For consistency, the team has elected to utilize the spellings from the report done by Erdenetsogt et al.

These resources, along with field visits, coal sample testing, personal communications, and other research, comprise the basis of the CMM resource assessment. The approach to this work is described below.

2.2. Field Investigations

In June of 2012 a team comprised of MNEC and RRR organized and carried out a series of field visits to three surface coal mines: Baganuur, Tavan Tolgoi, and Naryn Sukhait. In preparation for the trip, the project team collected geologic data and information from the three mining areas, specifically, information related to coal rank, coal quality, and depth of occurrence and coal thickness, that helped the team select drilling sites for sample collection. This data and information is used as a basis for preparing a resource assessment for each mining region.

The primary objective of the trip was to collect information and data for the CMM resource assessment, which included coal samples, maps, and other data. Timing of the trip and sample collection was dictated by the drilling being done at each of the mines. **Figure 1** shows the route taken, sites visited, and sampling locations.

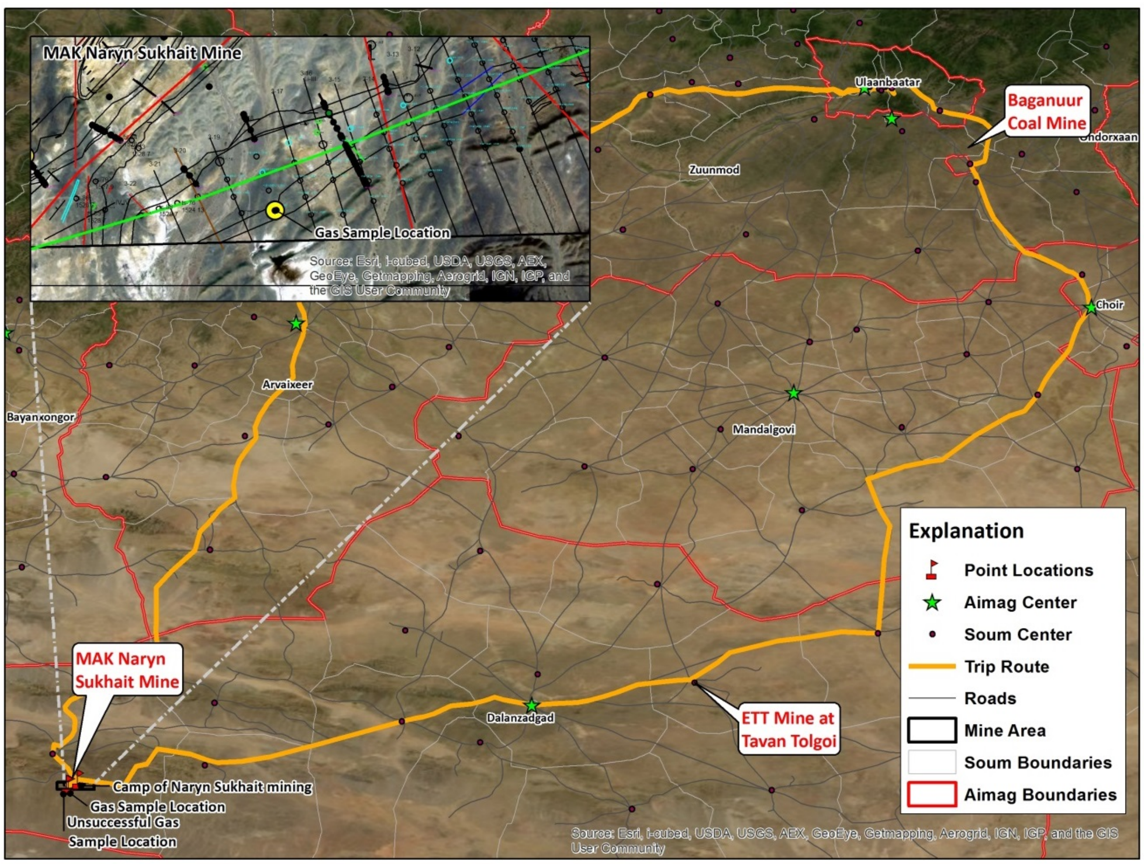

Figure 1: Field Visit Sites

MNEC purchased desorption testing equipment, including canisters and manometers, which were assembled and shipped to MNEC by RRR prior to the aforementioned field visits. MNEC also purchased gas sampling bags and a gas sampling canister with bulb to collect desorbed gas for compositional analysis. This equipment was taken into the field to perform desorption testing at Naryn Sukhait and

Baganuur. Active drilling was not taking place at Tavan Tolgoi; however, a coal sample from previous core drilling was collected by the team for adsorption isotherm testing. Adsorption isotherm testing was coordinated with the Xian Research institute of the China Coal Technology and Engineering Group Corp. Coal samples were shipped by mail to Xian and results were delivered to MNEC and RRR by email.

In May of 2013, coal sample collection was coordinated with Khotgor, a surface mine in Uvs aimag, northwestern Mongolia. Geology staff at Khotgor sent a sample from previous drilling activities to Xian for adsorption isotherm testing.

Table 1 summarizes the sites visited, samples obtained, and testing performed.

Table 1: Sampling and Testing Activity Summary

Site	Owner	Location	Testing Performed
Naryn Sukhait	Mongolyn Alt (MAK) Corporation	Ömnögovi aimag, South Gobi	• 3 coal samples: desorption testing • 1 coal sample: adsorption isotherm • 1 coal sample: proximate analysis • 3 coal samples: gas chromatography
Baganuur	Baganuur JSC	Baganuur düüreg, Ulaanbaatar, 127 km east of Ulaanbaatar center	• 3 coal samples: desorption testing • 1 coal sample: adsorption isotherm • 1 coal sample: proximate analysis
Tavan Tolgoi	Erdenes Tavan Tolgoi	Ömnögovi aimag, South Gobi	• 1 coal sample: adsorption isotherm • 1 coal sample: proximate analysis
Khotgor	Mongolia Minerals Corporation	Uvs aimag, northwestern Mongolia	• 2 coal samples: adsorption isotherms • 2 coal samples: proximate analysis

Following site visits, the team took gas samples from Naryn Sukhait for gas composition analysis using gas chromatography at the Coal Research Center at the School of Chemistry and Chemical Engineering of the National University of Mongolia. Gas chromatography is commonly used in laboratory and field settings to separate constituent chemical compounds in a complexly mixed gas sample. A gas chromatograph uses a flow-through small diameter tube known as the fractionating column, through which a gas sample containing different chemical compounds is carried by an inert gas stream. The gas sample constituents travel through the column at different rates depending on their various chemical and physical properties and interaction with the specific column filling. Depending on the type of chromatograph used, various detectors may be used to identify the time and amount of gas that passes through the column. In order to identify the amount of each expected constituent a calibration gas is injected into the fractionating column. A calibration gas mixture must be chosen which contains the expected gas constituents in order for the chromatograph to detect each constituent and quantify the relative proportions. As a calibration gas mixture passes through the column, each constituent is detected at its arrival time at the end of the column and depicted by a curve reflecting the relative concentration by its height. Thus, a sample of a gas mixture with unknown amounts of the constituent gases can be identified and their relative quantity measured according to their arrival time at the end of the column and the height of the curve traced.

The team tested two gas samples obtained from the manometer during desorption testing in the field at Naryn Sukhait as well as an additional sample directly from the desorption canister that was still producing gas. Unfortunately, although the appropriate fractionating column was used, the calibration gas mixture injected into the system was one that should be used when testing products of a coal gasification reaction; a more appropriate calibration gas was not available in Mongolia at that time. Although some of the constituent gases were the same: methane, water vapor and carbon dioxide, the calibration gas also included hydrogen, and carbon monoxide. The results of the testing verified that methane occurred in high concentration, but quantification was not possible.

2.2.1. Desorption Testing Discussion and Results

Methane desorption tests were conducted at the Naryn Sukhait and Baganuur mines to determine the gas content of coal, which was then used in combination with geologic data such as coal thickness and lateral extent of the coal bed to calculate gas resources contained within coal strata. **Table 2** lists the locations and results of the desorption analyses of the five samples collected at the two mine sites.

Table 2: Desorption Analysis from Mongolian Sampling Locations

Site	Borehole Name	Location	Sample Depth (m)	Gas Content (m^3/t)
Naryn Sukhait	M12-284B	N 43°00'03.0" E 01°10'21.5"	203.0	0.17
			217.4	0.19
			245.0	1.75
Baganuur	91 A	N 57°44'42.2" E 180°18’06.8"	153.0	0.14
			154.9	0.15

Although the gas contents are relatively low at the Naryn Sukhait deposit for bituminous rank coals, the higher ash content recorded there may have affected these results. However, the Naryn Sukhait desorption samples do show an increase in gas content with increased depth, which is expected as the increase in depth of burial of coal correlates to the increase of pore pressure and gas storage capacity. The gas contents recorded at the Baganuur coal deposit are also lower than what is expected from the subbituminous ranked coals, likely as a result of the samples being collected above the potentiometric surface (ground water table) near the highwall of the mine pit. The samples were collected from wells drilled to dewater the highwall in advance of mining. It is likely that the coal from these desorption samples had already begun to release gas while the groundwater was removed by surrounding dewatering wells.

Desorbed gas from the desorption canisters of the Naryn Sukhait samples was tested to determine composition of the gas contained in the coal seam through gas chromatography, as described above. This information is important because the percentage of hydrocarbon versus inert gases is critical for designing potential end use options; and it also indicates the amount of methane that could be released during mining if the gas is released unused.

The results of the adsorption isotherm testing for each of the sampling sites are shown in **Figures 2 – 5**. In order to accommodate the larger gas storage capacity of the higher ranked bituminous coals at Naryn Sukhait and Tavan Tolgoi, the Y-axes are presented on a scale of 0 – 20 m^3/t of volume of adsorbed gas. The lower ranked subbituminous coals of Baganuur and Khotgor are presented on a scale of 0 – 10 m^3/t of volume of adsorbed gas.

Figure 2, which shows the results of the adsorption testing performed on a sample from Naryn Sukhait, shows a large gap between the red dry ash-free curve and the green air dried and blue equilibrium moisture curves. This suggests the coal has considerably larger gas carrying capacity after the moisture and ash have been removed, or simply the coal has a very high percentage of ash. **Figure 3** shows the results of the adsorption testing sample from Tavan Tolgoi and plots the dry ash-free, air dried and equilibrium moisture curves with a tighter distribution. This suggests a large gas storage capacity throughout the three testing bases.

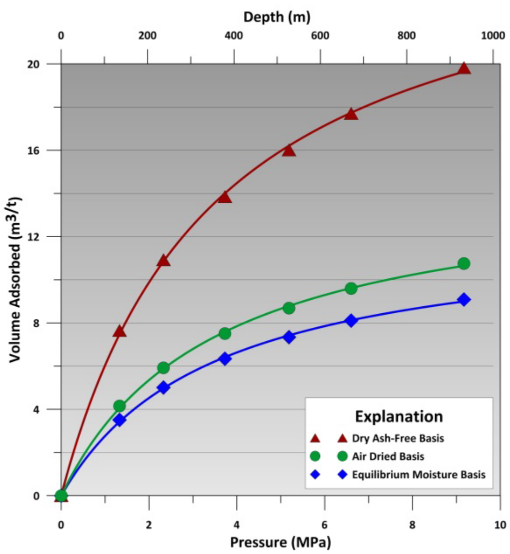

Figure 2: Naryn Sukhait Adsorption Isotherm

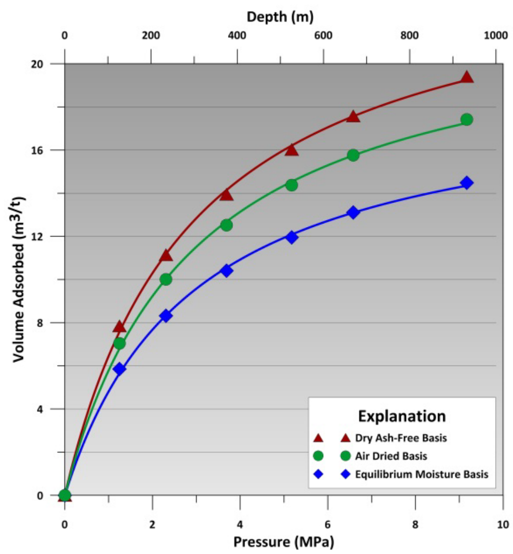

Figure 3: Tavan Tolgoi Adsorption Isotherm

Of the three samples taken from Baganuur (**Figure 4**) and Khotgor (**Figure 5**), the Baganuur coal displays the highest gas storage capacity, as is most apparent on the red curve which depicts the dry ash-free basis. Although the two samples from Khotgor were collected from the same coalbed, the gas storage capacity and the proximate analysis characteristics (**Table 3**) are different. This can be attributed to coal matrix variations within the reservoir.

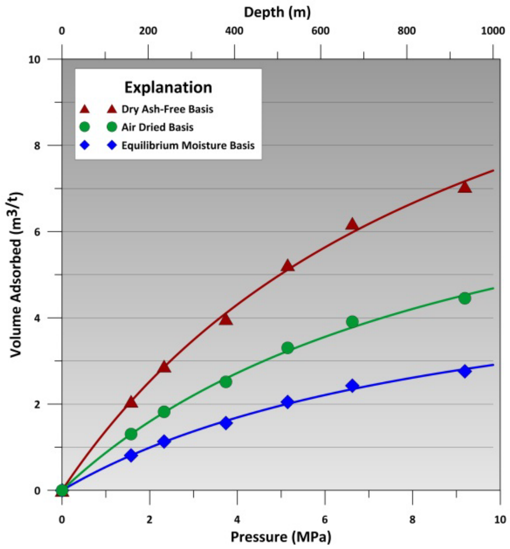

Figure 4: Baganuur Adsorption Isotherm

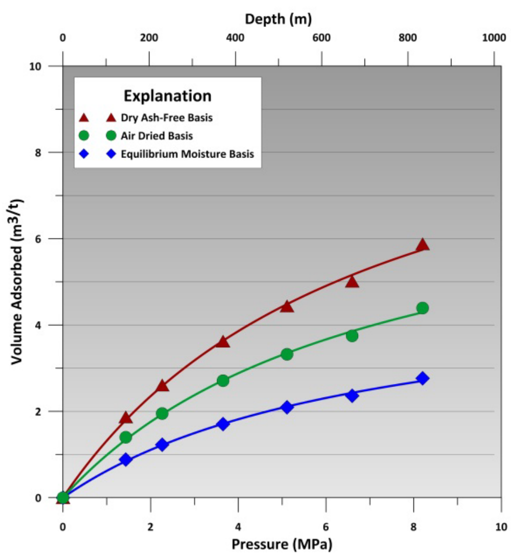

Figure 5: Khotgor Adsorption Isotherm, 13X-160

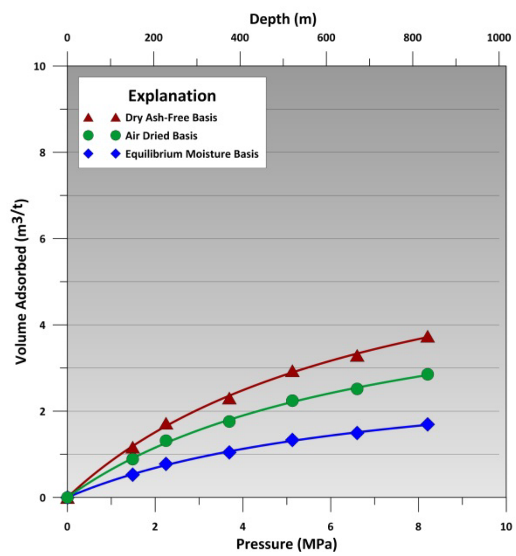

Figure 6: Khotgor Adsorption Isotherm, 13X-161

Table 3 represents the results from the proximate analysis conducted at the mine sites. The values are represented on an air dried basis and were conducted in conjunction with the adsorption isotherm testing.

Table 3: Proximate Analysis from Mongolian Sampling Locations

Site	Moisture % (air dried)	Ash % (air dried)	Volatile Matter % (air dried)	Cinder Characteristics
Naryn Sukhait	1.15	45.16	21.20	4
Baganuur	10.10	29.76	27.94	2

Site	Moisture % (air dried)	Ash % (air dried)	Volatile Matter % (air dried)	Cinder Characteristics
Tavan Tolgoi	0.96	9.46	22.33	6
Khotgor	9.20 10.44	17.71 14.76	26.30 27.69	2 2

2.3. CMM Resource Calculation Methodology

Coal resource estimates served as the basis for calculating in-place gas resources for each Mongolian coal basin. A widely accepted method of estimating the gas resource associated with the coal is to multiply the coal mass by the gas content. The following sections describe the approach and methodology performed during this analysis.

2.3.1. Prior Coal Resource Estimates

Coal resource estimates published in the late 1990s by Chimiddorj (1995) and later reexamined and published by Erdenetsogt et al (2009) were used as the basis for estimating the gas resources. These coal resource estimates were derived from results of early drilling and trenching exploration activities conducted to a depth of 300 m. The exploration activities were conducted to identify minable coal resources and therefore, the authors have assumed that much of the gas associated with these coal resources will be released during mining unless actions are taken to capture the gas. For this reason, CMM is used as the descriptive term for this gas resource rather than CBM. However, if the coal is not mined or the gas is drained prior to development of the coal resource, the gas resource could also be termed CBM.

Coal resources occurring in each basin were assigned a rank according to available proximate analyses. Data for explored coal deposits provided in a unpublished report by Bayarsaikhan (2012) and the published database titled *Chemical Analyses in the World Coal Quality Inventory, Version 1* (2010) completed by the U. S Geological Survey (USGS) was utilized to standardize the coal deposit ranks based on ASTM D388-1977 classification parameters (**Table 21**). Field data collected by the project team and discussed in **Section 2.2** agreed with prior USGS investigations. In basins where multiple coal ranks were observed, it was necessary to determine the percentage of coal of each rank within the basin in order to properly estimate the amount of CMM resources. Bayarsaikhan (2012) provided estimated coal resources for 22 deposits found within 10 of the 15 coal basins. Using the amount of coal resources by rank, the percentage of each rank was calculated for the available basins. In basins where multiple coal ranks were observed and coal deposit data was unavailable, the coal resources were equally divided by the number of ranks within the basin. **Table 5** shows the division of coal resources by rank, according to the methodology described above.

Table 4: Mongolian Coal Basins and Rank of Coal Resources by Percentage

Basin	Reported Rank		Coal Resources (million t)	Percentage of Highest Rank	Percentage of Lowest Rank
	Highest	Lowest			
Kharkhiraa	Bituminous		4,800	-	-
Bayan-Ulgii	Semi anthracite	Bituminous	-	-	-
Mongol-Altai	Bituminous		10,000	-	-
Trans-Altai	Bituminous		3,800	-	-

Basin	Reported Rank		Coal Resources (million t)	Percentage of Highest Rank	Percentage of Lowest Rank
	Highest	Lowest			
Southern Khangai	Bituminous		1,200	-	-
Ikh Bogd*	Bituminous	Subbituminous	200	50%	50%
Ongi River*	Bituminous	Subbituminous	1,500	50%	50%
South Gobi	Bituminous	Subbituminous	13,000	81%	19%
Orkhon-Selenge South	Subbituminous		2,591	-	-
Orkhon-Selenge North	Anthracite	Bituminous	5,109	4%	96%
Choir-Nyalga	Lignite		20,300	-	-
Central Gobi	Subbituminous	Lignite	13,200	35%	65%
East Gobi	Subbituminous		23,500	-	-
Sukhbaatar	Lignite		4,300	-	-
Choibalsan	Lignite		14,900	-	-
Tamsag	Subbituminous		32,000	-	-

*NOTE: Coal resources by deposit and rank were unavailable for this basin, thus basin coal resources were equally divided between the two coal ranks of the basin.

2.3.2. Use of Adsorption Isotherms to Estimate Methane Gas Content of Coal Resources

An adsorption isotherm test mathematically describes the relationship between pressure and gas capacity under equilibrium conditions at a stable temperature, usually chosen to represent the reservoir conditions of the coal seam occurring at the depth from which the sample was taken. RRR compiled a database of isotherms from US coal samples, categorized by rank. Isotherms from China were included to represent anthracite coals as there was a lack of US coal samples to adequately represent the rank. RRR used the available isotherm constants (Langmuir pressure and Langmuir volume) taken from similar coal of similar rank deposited under similar geologic conditions to perform statistical modeling using a Crystal Ball simulation. Analysis of the larger sample set presented the most likely Langmuir pressure and Langmuir volume constants for coal deposits occurring under similar conditions.

The Langmuir equation below was used to generate the rank type curves and calculate the gas content of coal at a given depth.

$$V = V_L * P / (P_L + P); \text{ where:}$$

V = gas content (m^3/t)

V_L = Langmuir volume constant (m^3/t)

P = reservoir pressure (MPa)

P_L = Langmuir pressure constant (MPa)

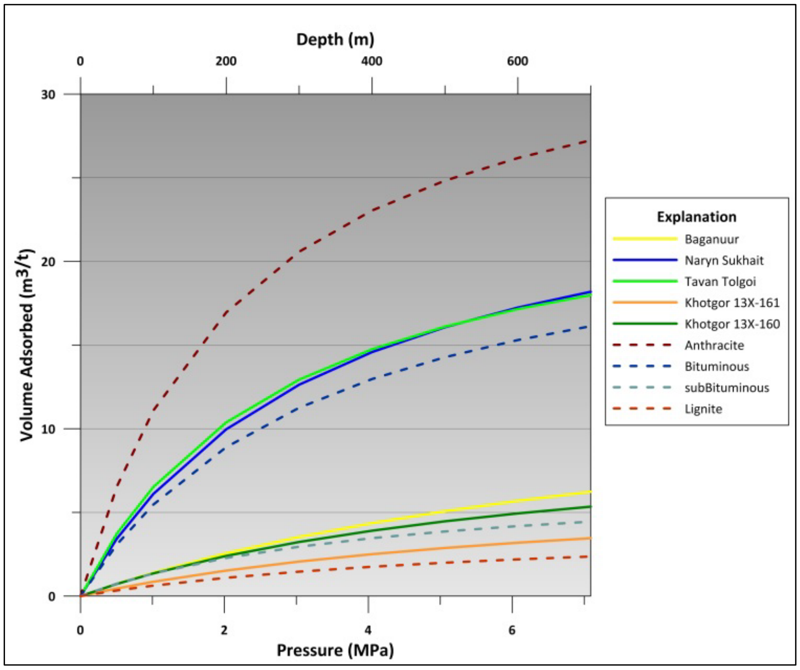

Figure 7: Adsorption Isotherm Type Curves by Rank and Mongolian Coal Deposits

Figure 7 depicts the p50 type curves by rank and the isotherm curves for the Mongolian coal samples collected during the gas sampling activities. Bituminous coals of low-, medium- and high-volatile ranks were combined into one isotherm because the availability of low- and medium- volatile bituminous coals was sparse.

The p10, p50 and p90 rank percentile constants for Langmuir pressure and Langmuir volume constants for anthracite, bituminous, subbituminous and lignite were used to generate a lookup table. A lookup table is a pre-calculated reference table to determine the gas content of a coal at a given depth and rank. The lookup table in this analysis takes the Langmuir volume and Langmuir pressure constants for the p10, p50 and p90 percentile classes and computes the gas content utilizing the Langmuir equation. The table is computed by assuming 1 atmosphere of hydrostatic pressure for every 30 m of depth, for intervals between 0 – 1200 m.

2.3.3. CMM Gas Resource Estimation

In order to estimate gas resources for each of the basins, coal resources were uniformly divided into 30 meter depth intervals. The amount of coal within each interval was multiplied by the gas content value indicated by the corresponding midpoint of the depth along the adsorption isotherm curve. In order to calculate the coal resources between 300 m and 1200 m, it was assumed that the coal resources extended uniformly below the explored 300 m resource estimate depth, CMM resources were calculated for these coal resource intervals (300 – 600 m, 600 – 900 m, and 900 – 1200 m) using the gas content reported from the midpoint depth of each interval and reported in the lookup table (450 m, 750 m and 1050 m, respectively). This yields the original gas in place, or the total CMM resources prior to migration or escape to the atmosphere.

2.3.4. Hydrogeology, Precipitation, and Hydrostatic Gradient Discount Factors

CMM gases are desorbed within pore spaces and within the coal matrix due to hydrostatic pressure exerted on the reservoir through burial below the earth's surface. Non-porous cap rocks, the presence or absence of groundwater fluids, and the hydrostatic pressure exerted upon the coal bed are examples of forces that affect the gas storage and movement characteristics of a potential CBM reservoir. In order to account for the potential loss of CMM resources due to its proximity to the surface and the possibility of migration of gases to the atmosphere, hydrogeologic and precipitation characteristics for each basin were examined to develop discount factors for each basin.

A 1:5,000,000 scale Hydrogeology Map, published in the *Geographic Atlas of Mongolia (2004),* was utilized to determine the percentage of potentially ground water saturated areas within each coal-bearing basin. **Table 5** describes the hydrogeologic classifications presented on the source map and the four groundwater saturation classes utilized in this study. **Figure 8** is a graphic display of the four groundwater saturation classification schemes used in this analysis. The areas classified as intrusive rocks or rocks with limited groundwater resources were placed in the dry class. The areas classified as alluvial sediments, with large pore spaces that likely were either not cemented or poorly cemented were placed in the vadose class. Areas classified as older lithified sandstones to claystones were placed in the potentially saturated class, and the areas classified as highly productive to extensive aquifers were placed in the saturated class.

Table 5: Hydrogeologic and Groundwater Saturation Classification of Mongolian Coal Basins

Hydrogeologic Classification	Groundwater Saturation Classification
Alluvial, proluvial, lacustrine, eolian and glaciofluvial sand, gravel, sandy loam and loam.	Vadose
Sandstone, siltstone, conglomerate, coal claystone	Potential
Acid and intermediate and basic intrusives	Dry
Local, highly productive aquifers or extensive aquifers with low to moderate productivity in karst rocks	Saturated
Rocks with local, limited groundwater resources	Dry
Neogene and paleogene, upper cretaceous sand, sandstone, conglomerate, gravel and clay	Potential
Local, highly productive aquifers or extensive aquifers with low to moderate productivity	Saturated
Highly productive aquifers	Saturated

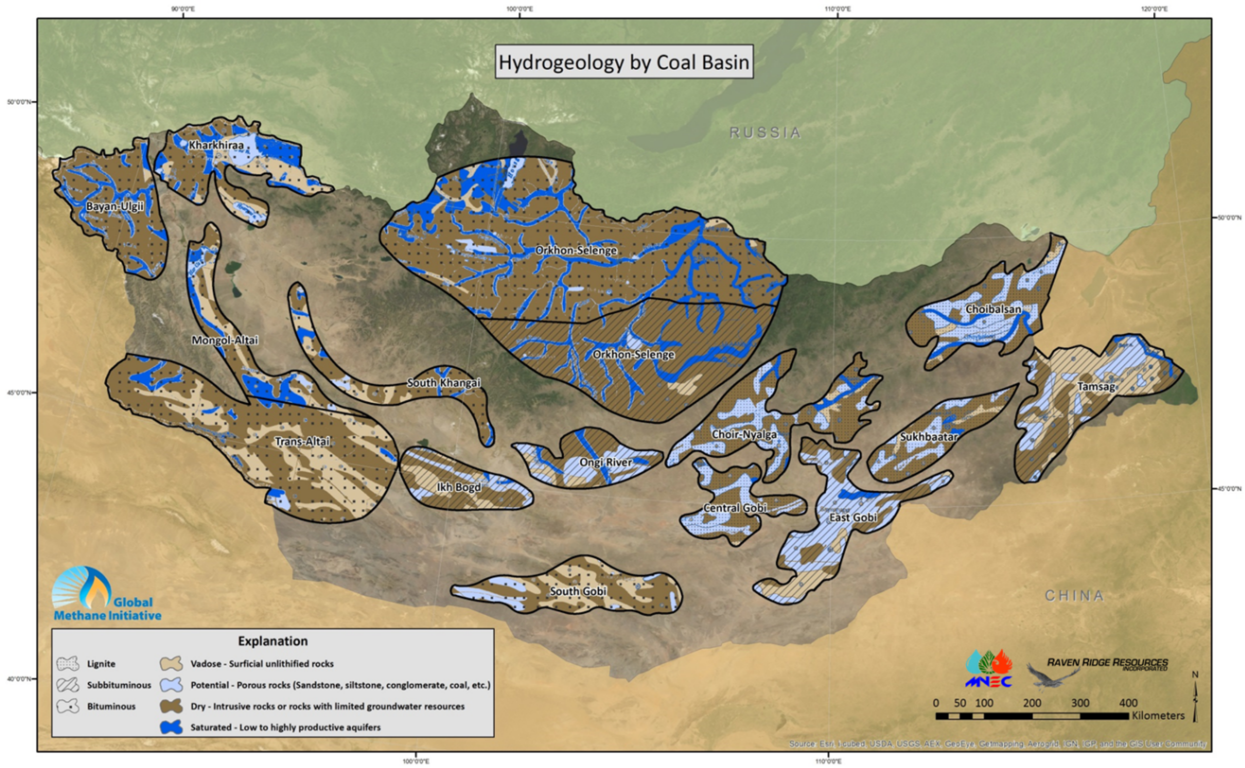

Figure 8: Hydrogeology Classification of Mongolian Coal Basins

A 1:5,000,000 scale Annual Precipitation Map, also published in the *Geographic Atlas of Mongolia (2004),* was utilized to determine the percentage of arid versus semi-arid areas within each coal-bearing basin. Precipitation was incorporated into the potential groundwater saturation classification in order to account for the potential for groundwater recharge. Areas where precipitation ranged between 0 – 250 mm of annual precipitation were designated as arid, and areas where precipitation was greater than 250 mm were designated as semi-arid. **Figure 9** is a graphical representation of the aridity of each of the coal-bearing basins.

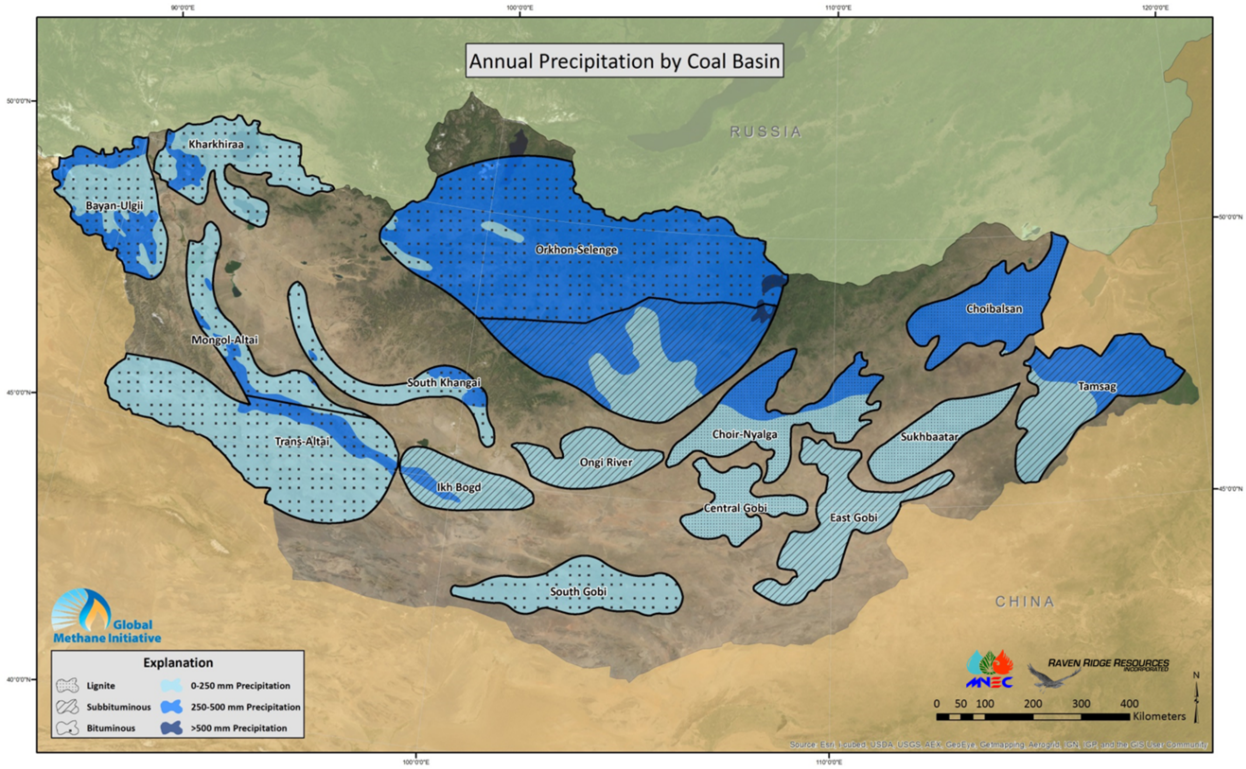

Figure 9: Annual Precipitation of Mongolian Coal Basin

Hydrostatic gradient discount factors were then determined for each basin using the various classifications of groundwater saturation along with the various classifications of precipitation. **Table 6** is a matrix which describes how the hydrogeologic and precipitation classifications influenced the hydrostatic gradient discounts. **Figure 10** is a graphical representation of the hydrogeology of Mongolia overlaid by the precipitation classification for each of the coal-bearing basins.

Table 6: Matrix of Hydrogeology and Precipitation Influence on Hydrostatic Pressure

		Hydrogeology Classes			
		Dry	**Vadose**	**Potential**	**Saturated**
Precipitation Classes	**Arid**	Unsaturated	Unsaturated	Unsaturated	Saturated
	Semi-arid	Unsaturated	Potential	Potential	Saturated

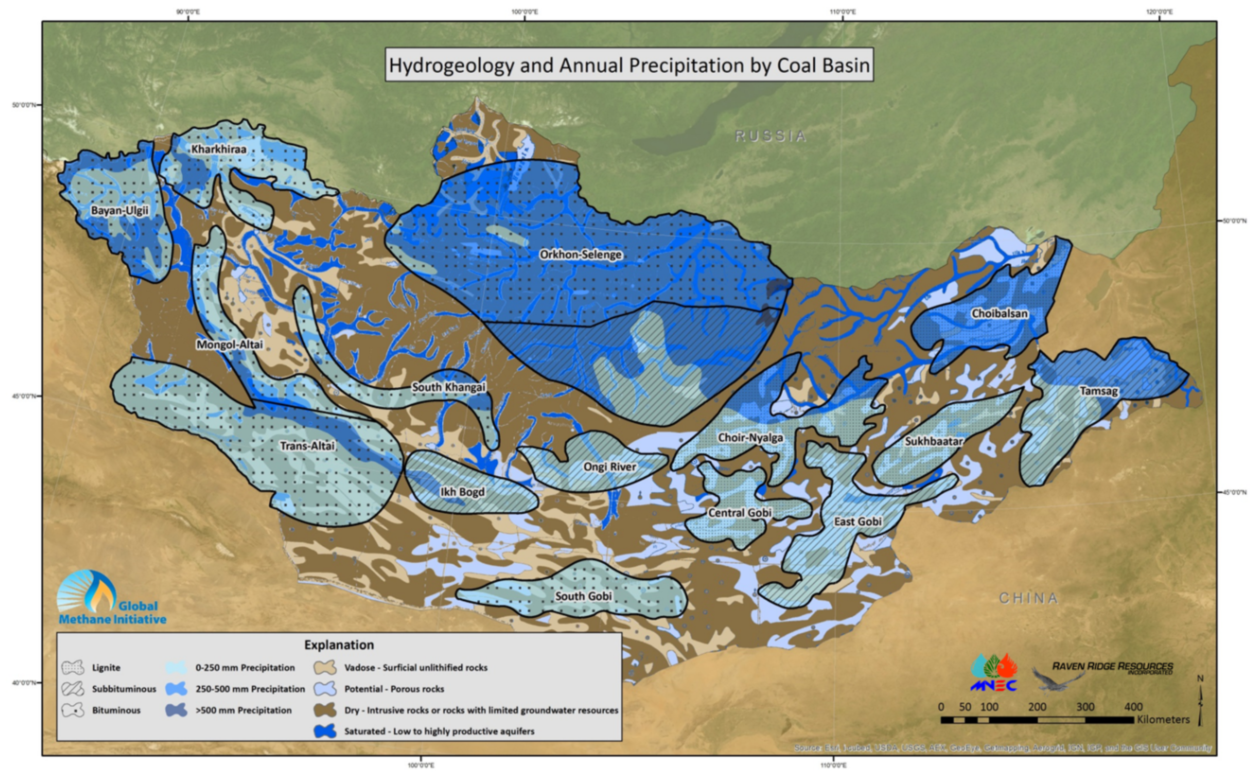

Figure 10: Hydrogeology and Annual Precipitation of Mongolian Coal Basins

As would be expected, the coal basins within the southern half of the country are arid. For semi-arid areas, the discount factor was determined by multiplying the sum of the percentages of vadose and potentially saturated areas by the percentage of the semi-arid areas and adding the percentage of saturated areas. For arid areas, the discount factor was determined by taking the inverse of the percentage which is believed to be saturated. An example of each equation is shown below:

Discount factor (semi-arid) = ((Vadose + Potential) * (Semi-Arid)) + (Saturated)

Discount factor (arid) = 1 – Discount factor (semi-arid)

Table 7 shows the discount percentages for each coal-bearing basin. In predominantly arid coal-basins of the southern region of Mongolia, the discount factors were applied down to a depth of 120 m, whereas in areas of less aridity, the northern coal basins, the discount factors were applied down to a depth of 60 m.

Table 7: Hydrostatic Gradient Discount Factors and Depth of Discount

Coal-Bearing Basin	Discount Factor (%)	Depth of Discount (m)
Bayan-Ulgii	28	60
Central Gobi	8	120
Choibalsan	59	60
Choir-Nyalga	26	120
East Gobi	8	120
Ikh Bogd	12	120

Coal-Bearing Basin	Discount Factor (%)	Depth of Discount (m)
Kharkhiraa	32	60
Mongol-Altai	34	60
Ongi River	14	120
Orkhon-Selenge (North)	34	60
Orkhon-Selenge (South)	25	60
Southern Khangai	18	60
South Gobi	16	120
Sukhbaatar	10	120
Tamsag	36	60
Trans-Altai	14	120

2.4. CMM Resource Assessment of Mongolia's Coal Basins

After applying the hydrostatic gradient discount factors discussed in **Section 2.3.4** to the CMM resources, the estimated p50 CMM resources were depicted by depth within each of the coal-bearing basins (**Figure 11**). **Figure 11** shows that the largest CBM resources are likely found within the South Gobi, Mongol-Altai, Tamsag and Kharkhiraa basins, as was predicted by Chimiddorj in his article titled *Coal Resources in Mongolia and Some Probably Potential Areas for Coalbed Methane (1998)*.

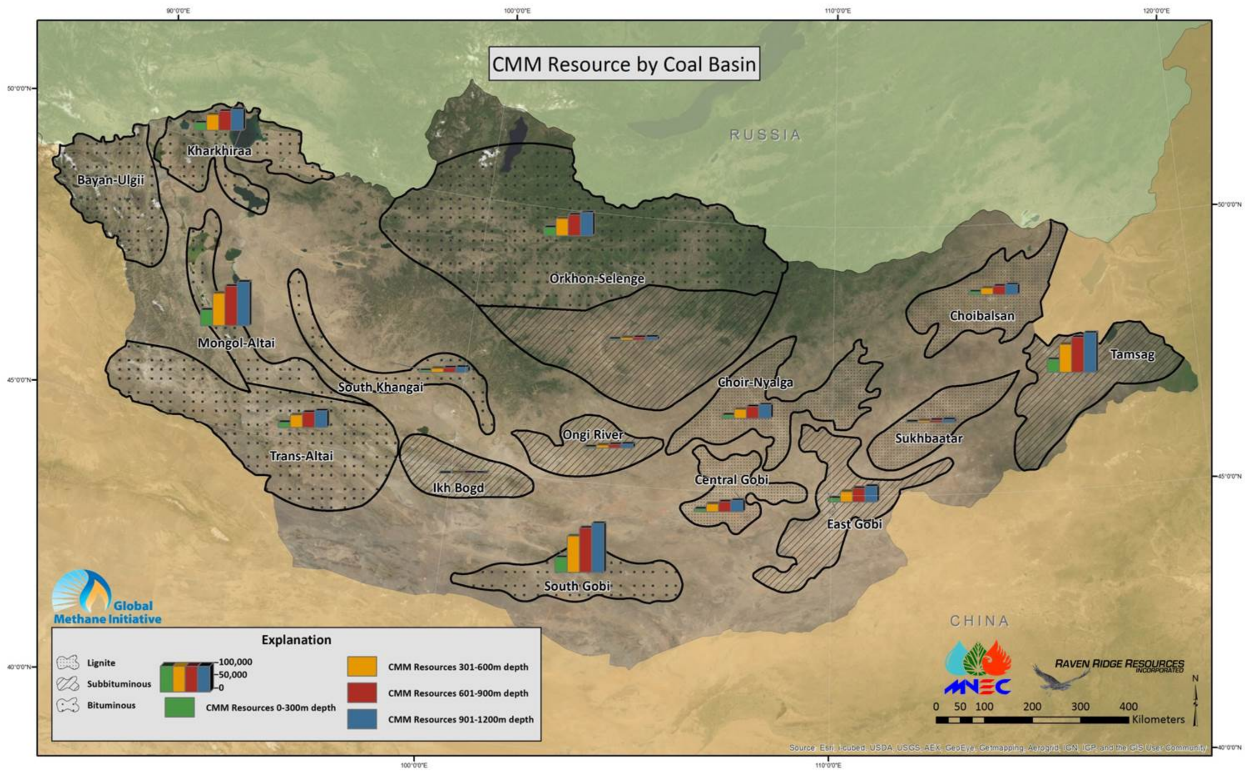

Figure 11: p50 CMM Resources of Mongolian Coal Basins

In summary, basins with the largest amount of higher ranking coal below the groundwater saturation zone contain larger amounts of CMM resources. The basins with the largest coal resources discovered to date in descending order are:

- Tamsag
- East Gobi
- Choir-Nyalga,
- Choibalsan
- Central Gobi,
- South Gobi
- Mongol-Altai basins.

Each of these basins has more than 10,000 million metric tons of resources. Of these basins, the top three with the largest estimated CMM resources in descending order are the Mongol-Altai, South Gobi and the Tamsag basins (**Table 8**). Each of these basins is estimated to contain greater than 50 billion cubic meters of CMM resources.

Table 8: Estimated p50[2] CMM Resources by Coal Basin and Depth

Coal Basin	p50 CMM Resources 0 – 300 m (billion m^3)	p50 CMM Resources 300 – 600 m (billion m^3)	p50 CMM Resources 600 – 900 m (billion m^3)	p50 CMM Resources 900 – 1200 m (billion m^3)
Bayan-Ulgii	-	-	-	-
Central Gobi	12.2	31.9	41.1	46.8
Choibalsan	11.8	26.9	35.5	41.0
Choir-Nyalga	14.1	36.7	48.4	55.8
East Gobi	15.7	42.5	56.0	64.6
Ikh Bogd	0.7	1.7	2.1	2.3
Kharkhiraa	30.8	63.7	77.8	85.8
Mongol-Altai	64.3	132.8	162.2	178.8
Ongi River	5.2	12.6	15.5	17.2
Orkhon-Selenge (North)	34.0	69.9	85.1	93.7
Orkhon-Selenge (South)	4.2	9.2	11.6	13.0
Southern Khangai	7.6	15.9	19.5	21.5
South Gobi	61.8	148.6	181.8	200.7
Sukhbaatar	2.9	7.8	10.2	11.8
Tamsag	52.5	113.8	143.3	160.8
Trans-Altai	20.9	50.5	61.6	68.0
TOTAL	338.7	764.5	951.8	1,061.9

Based on available knowledge, the majority of coal resources within Mongolia are classified as bituminous. **Figure 12** shows the percentage of p50 CMM resources by rank. The majority of CMM resources are contained in bituminous coal (63.9 percent), with subbituminous coal estimated to

[2] Indicates a 50% chance that forecast will be ≥ to the p50 amount.

contain the second largest volume of CMM resources (24.4 percent). Lignite and anthracite contain the least amount of CMM resources with 10.6 percent and 1.0 percent, respectively.

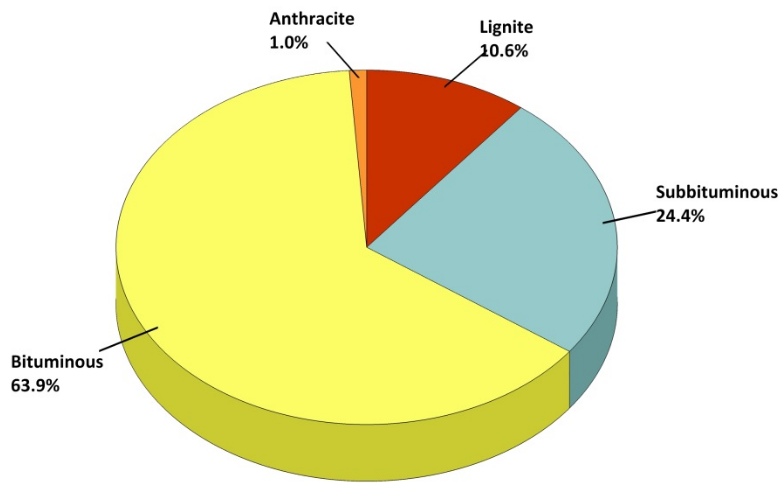

Figure 12: p50 CMM Resources by Rank

2.5. Basin Summaries

The purpose of this study is to provide an estimate of the gas resources associated with the minable coal resources of Mongolia. However, it is important to put any resource calculation into the proper geologic perspective to provide the basis for further exploration and development. In the gas of hydrocarbon occurrence in Mongolia, several researchers have contributed to the overall understanding of hydrocarbon occurrence in Mongolian basins.

Erdenetsogt (2009) states that Jurassic coal samples collected from coal deposits in Mongolia tend to be petrographically distinct from their Permian counterparts as they have higher vitrinite maceral content. Based on research conducted on high volatile B and C bituminous coals during the last three decades, it is now generally recognized that high vitrinite maceral content correlates with increased gas storage. Due to the increased gas storage capacity of high volatile bituminous coalbeds, coal miners in other parts of the world have had to deal with unwanted and dangerous gas emissions into workings where this rank of coal is extracted (USEPA, 2013). Basins in Mongolia that contain Jurassic coal should be carefully developed for CMM capture as the coal resources are developed, if not developed for the coal resources, these Jurassic coal bearing strata are prospective targets for CBM and associated conventional gas resources.

Johnson and others, (2003) have shown that the lower to middle Jurassic coal and coaly mudstone analyzed from samples taken in the South Gobi are important source rocks for hydrocarbon generation. These rocks contain type III and IV kerogen derived from vitrinite macerals which are prevalent in the bright coaly components of the Naryn Sukhait and MAK formation strata. These kerogen types tend toward hydrocarbon gas generation and based on the thermal maturation studies performed on the sediments contained in the foreland basins of the south Gobi, these coal bearing strata are still well within an active hydrocarbon generation stage. Clearly, the coalbeds and surrounding strata occurring at Naryn Sukhait present the potential for generation and storage of hydrocarbons.

Many papers have been written regarding the hydrocarbon generation potential of organic material as it undergoes coalification, some key points related to coal maturation are included as background. During the coalification process much of the water that is contained is expelled and as heat and pressure increase with burial depth, hydrocarbons are liberated, which may then migrate, be adsorbed or otherwise be stored in the source coalbeds and surrounding strata. **Figure 13** shows the relationship of the changes in coal characteristics as coalification proceeds. For reference, labels have been added to show important source rocks and reservoirs in North America; the broad range in rank of the coals occurring in Mongolia is also shown. Additional coal exploration in Mongolia is certain to broaden the range, yet the information that is available on the vitrinite reflectance and maturation of coal occurrences in Mongolia demonstrates ample potential for there to have been hydrocarbons generated during basin filling and ensuing tectonism.

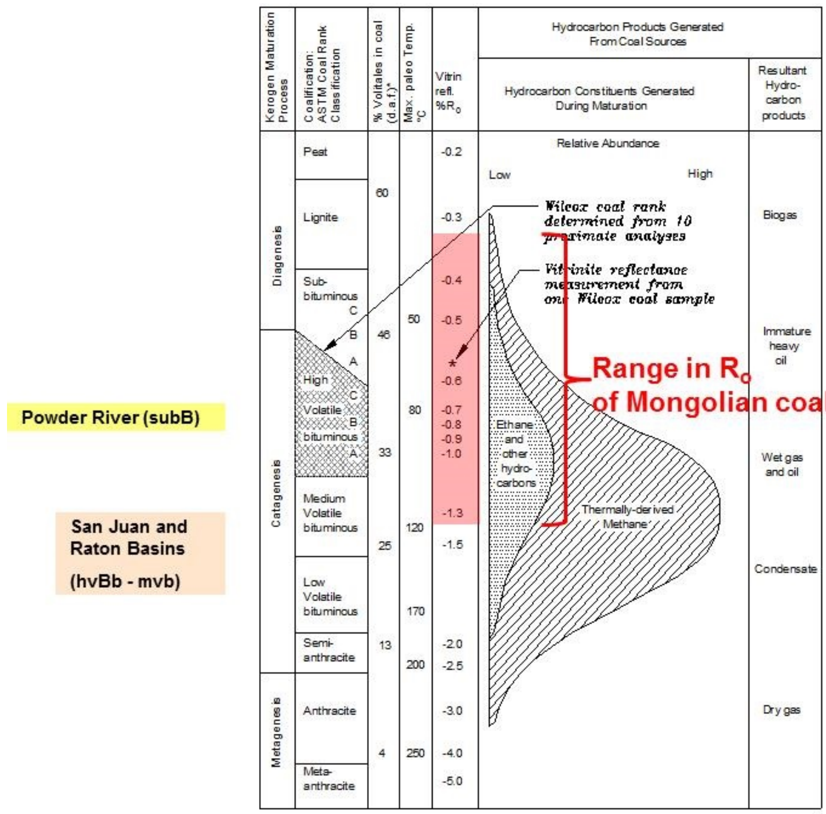

Figure 13: Coal Maturation and Hydrocarbon Generation Potential

The U.S. Geological Survey (2010) published data derived from ultimate analysis of coal samples that were collected by Mongolian scientists and analyzed in USGS laboratories located in the United States. The results of these analyses were used by the authors to develop van Krevelen type diagrams to determine what could be learned about the kerogen types contained in the Mongolian coals and their burial history. The van Krevelen diagram is outlined to show the three types of kerogens, Types I, II, and III with dashed lines showing the processes that have been active since their burial, namely diagenesis, catagenesis and metagenesis. During diagenesis, methane, water and carbon dioxide are released. If the kerogen type is favorable, oil is likely to be expelled during catagenesis. Metagenesis is likely to produce gas from all kerogen types as it occurs at a temperature and pressure that exceeds the hydrocracking temperature of oil.

Figure 14, which displays the data according to the rank of the coal and the basin in which they are found, shows that the subbituminous coal occurring in the Choir-Nyalga basin has been exposed to diagenetic processes, i.e. relatively low heat and pressure caused by relatively shallow burial depths as would be expected from the slowly subsiding lacustrine filled basins of eastern Mongolia. However, it appears that the subbituminous coal found in the Orkhon-Selenge basin has been exposed to high heat and pressure and is approaching the atomic ratios usually associated with catagenesis, suggesting that thermogenic processes were dominant in generating hydrocarbons that may be associated with these coal bearing strata. Bituminous coal bearing strata of the Kharkhiraa, South Gobi and Mongol Altai basins underwent deeper burial and were exposed to the highest temperature and pressure of any of the basins for which the authors have analyses. Not surprisingly, the lignite beds of the Sukhbaatar, Choir-Nyalga, and Cholbaisan basins have undergone exposure at much lower temperature and pressure associated with shallow burial.

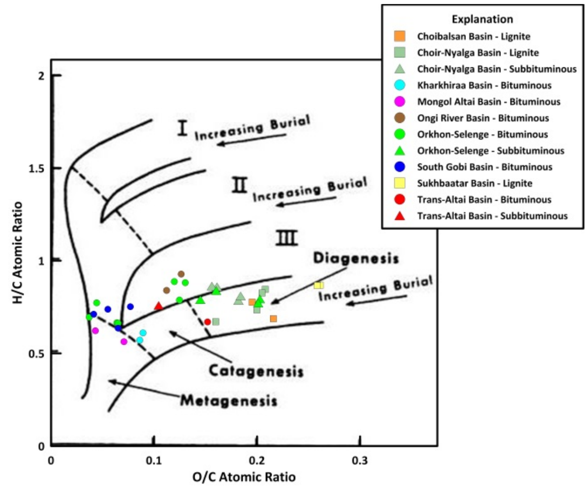

Figure 14: Van Krevelen Diagram of Mongolian Coal Samples by Coal Bearing Basin and Coal Rank

Figure 15 displays the same data but segregated according to the geologic age of the formation in which the coal are found and the rank of the coalbeds. Generally, the younger Cretaceous coalbeds were exposed to less heat and pressure whereas the Carboniferous and Permian coalbeds were exposed to higher heat and pressure.

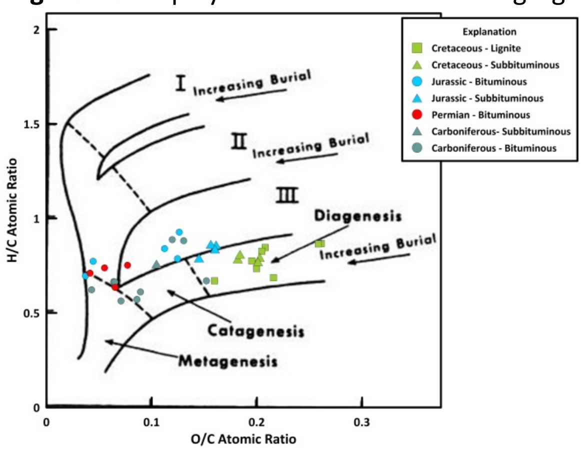

Figure 15: Van Krevelen Diagram of Mongolian Coal Samples by Age and Rank

Most of the samples comprise Type III kerogens, which are derived from woody organic debris occurring in swamps that form in lowland forests, whereas Type II kerogens are derived from a mix of amorphous herbaceous and woody organic debris. These organic materials accumulate in paleoenvironments where woody material, fibrous plants, and amorphous organic material such as algae and spores would accumulate. There is also an intriguing indication that not all of the Carboniferous coalbeds were formed from terrigenous organic material, but that some of the coal has a mixed origin including some marine or lacustrine derived organic material. Based on this data the Permian coalbeds that were sampled are composed of kerogens that have Type II affinity and are in the oil forming window.

2.5.1. Central Gobi

The Khuut and Uvdug Kuhdag coal deposits are located in the Central Gobi coal basin, which lies within the Eastern Mongolian coal-bearing province (Erdenetsogt et al, 2009). The basin covers approximately 25,000 km^2 extending in a northeast to southwest direction. Although many coal deposits and occurrences have been cataloged within the basin, detailed geologic structural knowledge is unknown. The basin is known as a backarc basin, and generally contains monoclines with faulting and synclines. The main coal resources are Lower Cretaceous in age, and are lignite in rank. The hydrogeologic and precipitation discount factor for the Central Gobi basin is eight percent, and the discount was applied to coals down to a depth of 120 m. The basin is in an arid region of the country, and generally contains strata that are not considered good groundwater aquifers near the surface.

The majority of exploration work conducted within the East Gobi basin was done during exploration for oil resources. Little is known about the geologic structure or gas contents of the coal resources within the basin.

The total coal resources of the Central Gobi basin, including the identified coal reserves (104.1 Mt), total 13,200 million metric tons (Erdenetsogt et al, 2009). **Figure 16** shows that the total CMM resources between the p90[3] to p10[4] gas resource forecast range from 8,573 - 202,316 million cubic meters. The p50 CMM resource estimation, which is the mean and most-likely value within the probability based estimate, is 12,175 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 132,072 million cubic meters.

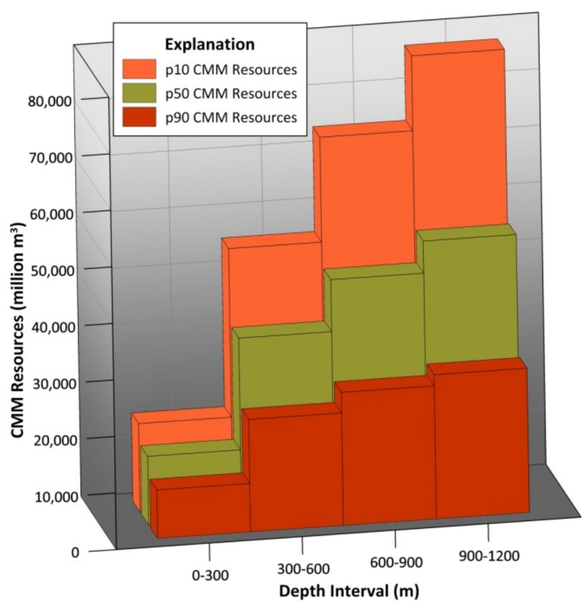

Figure 16: Probability Based Estimation of CMM Resources - Central Gobi Basin

[3] Indicates a 90% chance that forecast will be ≥ to the p90 amount

[4] Indicates a 10% chance that forecast will be ≥ to the p10 amount

2.5.2. Choibalsan

The Choibalsan coal basin, home to the Aduunchuluun coal deposit, lies within the northeast portion of the Eastern Mongolian coal-bearing province (Erdenetsogt et al, 2009). The basin covers approximately 45,000 km^2 of area extending in a northeast to southwest direction. The Choibalsan basin contains more than 20 coal deposits, despite the operation of only the Aduunchuluun deposit. The gentle geologic structure of the backarc basin likely leaves the coalbeds undisrupted; however, the basin contains two depositional centers: North Choibalsan and South Kherlen. The main coal resources are Cretaceous in age, and are lignite in rank. The hydrogeologic and precipitation discount factor for the Choibalsan basin is 59 percent, and the discount was applied to coals down to a depth of 60 m. Although the basin contains a higher percentage of strata with groundwater storage capacity near the surface, the basin is in an arid region of the country, limiting groundwater recharge.

The coal resources of the Choibalsan basin, including the identified coal reserves (213.2 Mt), total 15,113 million metric tons (Erdenetsogt et al, 2009). **Figure 17** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 8,679 - 172,316 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 11,783 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 115,225 million cubic meters.

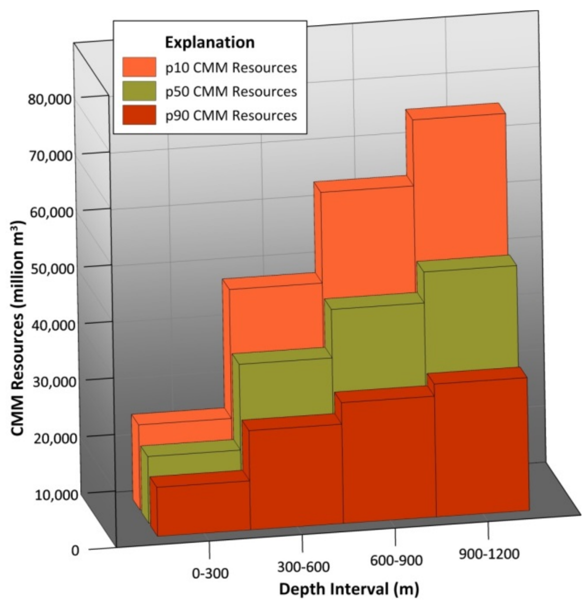

Figure 17: Probability Based Estimation of CMM Resources - Choibalsan Basin

2.5.3. Choir-Nyalga

The Choir-Nyalga coal basin, home to the Baganuur, Chandgan Tal, Shivee-Ovoo and Tevshiir Govi coal deposits, lies within the northwest portion of the Eastern Mongolian coal-bearing province (Erdenetsogt et al, 2009). The basin covers approximately 50,000 km^2 extending in a northeast to southwest direction. The Choir-Nyalga basin is a backarc basin comprised of several smaller fault bounded basins. Displacement along the faults may affect the continuity and thickness of coal seams present in the basin. The main coal deposits are Cretaceous in age, and are lignite in rank. The hydrogeologic and precipitation discount factor for the Choir-Nyalga basin is 26 percent, and the discount was applied to coals down to a depth of 120 m. The basin is in an arid to semi-arid region of the country, and generally contains strata that are not considered good groundwater aquifers near the surface.

The coal resources of the Choir-Nyalga basin, including the identified coal reserves (5,900 Mt), total 26,200 million metric tons (Erdenetsogt et al, 2009). **Figure 18** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 10,279 - 232,446 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 14,127 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 155,057 million cubic meters.

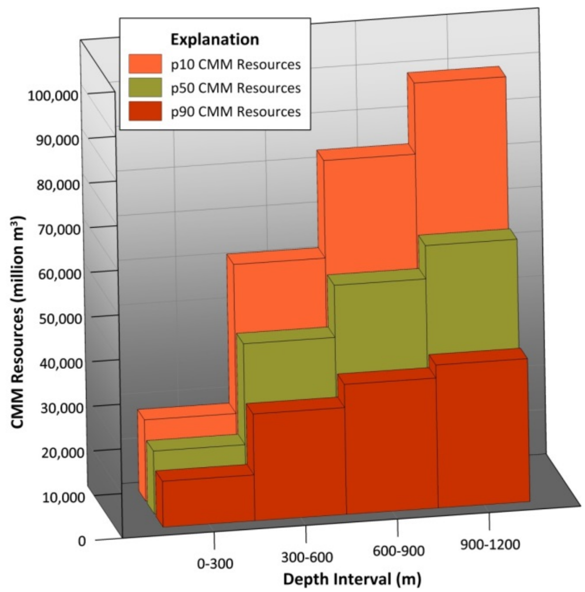

Figure 18: Probability Based Estimation of CMM Resources - Choir-Nyalga Basin

2.5.4. East Gobi

The East Gobi coal basin lies within the southeast portion of Mongolia. The basin covers approximately 60,000 km^2 of area extending in a northeast to southwest direction. The East Gobi basin is a transform-fault-related basin divided into several sub-basins, where complex geologic deformation took place. It is likely that the complex geologic structure of the East Gobi disrupts the continuity of the coal seams, but there is little geologic knowledge of the basin. The main coal resources are Lower Cretaceous in age, and are subbituminous in rank. The hydrogeologic and precipitation discount factor for the East Gobi basin is eight percent, and the discount was applied to coals down to a depth of 120 m. Although the basin contains a higher percentage of strata with groundwater storage capacity, the basin is in an arid region of the country.

The majority of exploration work conducted within the East Gobi basin was carried out during exploration for oil resources. Little is known about the geologic structure or gas contents of the coal deposits within the basin.

The coal resources of the East Gobi basin total 23,500 million metric tons (Erdenetsogt et al, 2009). **Figure 19** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 11,385 - 268,324 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 15,716 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 178,862 million cubic meters.

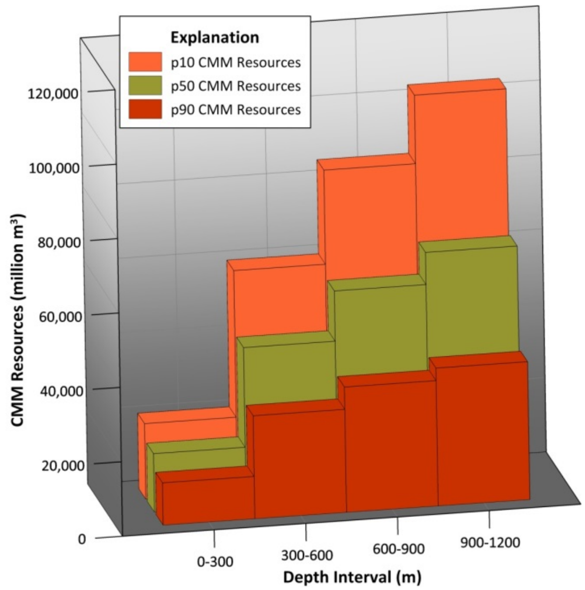

Figure 19: Probability Based Estimation of CMM Resources - East Gobi Basin

2.5.5. Ikh Bogd

The Ikh Bogd coal basin lies within the southeast portion of Mongolia. The basin covers approximately 23,500 km^2 of area extending in an east to west direction. The Ikh Bogd basin is a fault bounded foreland basin near the Valley of Lakes, where complex geologic deformation took place surrounding the basin. Igneous plutonic mountains to the north and intensely folded and faulted rocks to the south surround this coal-bearing area. It is likely that the complex geologic structure of the Ikh Bogd basin disrupts the continuity of the coal seams. The main coal resources are non-marine sedimentary sequences, Upper Permian, Lower-Middle Jurassic and Lower Cretaceous in age, and are lignite to subbituminous in rank. The hydrogeologic and precipitation discount factor for the Ikh Bogd basin is 12 percent, and the discount was applied to coals down to a depth of 120 m. Although the basin contains nearly an equal percentage of strata with and without groundwater storage capacity, the basin is in an arid region of the country.

The coal resources of the Ikh Bogd basin, including the identified coal reserves (5.2 Mt), total 2,005 million metric tons (Erdenetsogt et al, 2009). **Figure 20** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 556 - 8,977 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 689 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 6,732 million cubic meters.

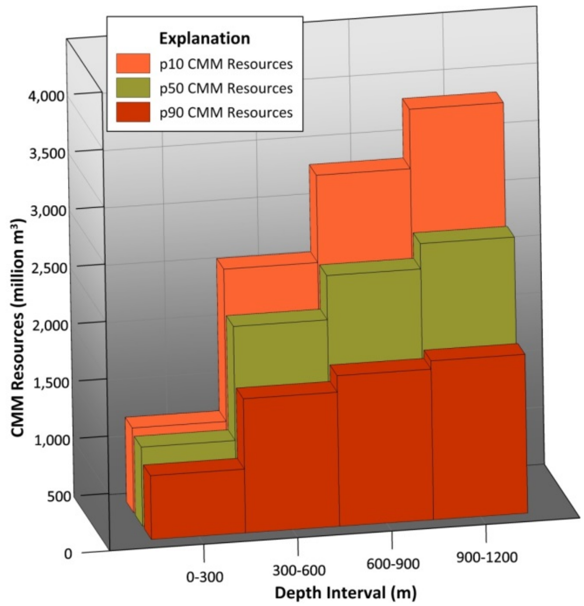

Figure 20: Probability Based Estimation of CMM Resources - Ikh Bogd Basin

2.5.6. Kharkhiraa

The Kharkhiraa coal basin lies within the northeast portion of Mongolia. The basin covers approximately 45,000 km^2 of area extending in an east to west direction. The Kharkhiraa basin is a foreland basin where normal and thrust faulting formed ramps and open thrust and graben like structures. The deformation of the Permian strata is intense and likely disrupts the continuity of the coal seams, but the coals thin toward the edges of the basin. The main coal resources are Carboniferous in age, and are high-volatile bituminous in rank. The hydrogeologic and precipitation discount factor for the Kharkhiraa basin is 32 percent, and the discount was applied to coals down to a depth of 60 m. The basin is in a semi-arid region of the country, and generally strata that are considered good groundwater aquifers near the surface.

The coal resources of the Kharkhiraa basin, including the identified coal reserves (172.5 Mt), total 4,973 million metric tons (Erdenetsogt et al, 2009). **Figure 21** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 26,521 - 326,462 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 30,803 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 326,462 million cubic meters.

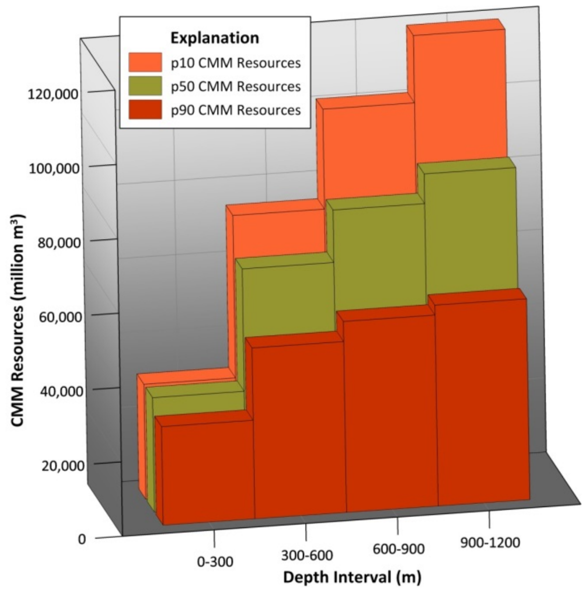

Figure 21: Probability Based Estimation of CMM Resources - Kharkhiraa Basin

2.5.7. Mongol Altai

The Mongol Altai coal basin lies within the northeast portion of Mongolia. The basin covers approximately 60,000 km^2 of area extending in a northeast to southwest direction. The Mongol Altai basin is a foreland basin where Paleozoic normal and thrust faulting formed ramps and open thrust and graben like structures (Erdenetsogt et al, 2009). The basin is surrounded by the Mongol-Altai mountain range to the west and the Valley of Great Lakes to the east. The deformation of the Permian strata is intense and likely disrupts the continuity of the coal seams, but generally the coals thin from the center to the edges of the basin. The main coal resources are Carboniferous in age, and are high to low-volatile bituminous in rank. The hydrogeologic and precipitation discount factor for the Mongol Altai basin is 34 percent, and the discount was applied to coals down to a depth of 60 m. Although the basin contains a higher percentage of strata with groundwater storage capacity, the basin is in an arid region of the country.

The coal resources of the Mongol Altai basin, including the identified coal reserves (49 Mt), total 10,049 million metric tons (Erdenetsogt et al, 2009). **Figure 22** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 55,341 - 680,198 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 64,255 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 538,022 million cubic meters.

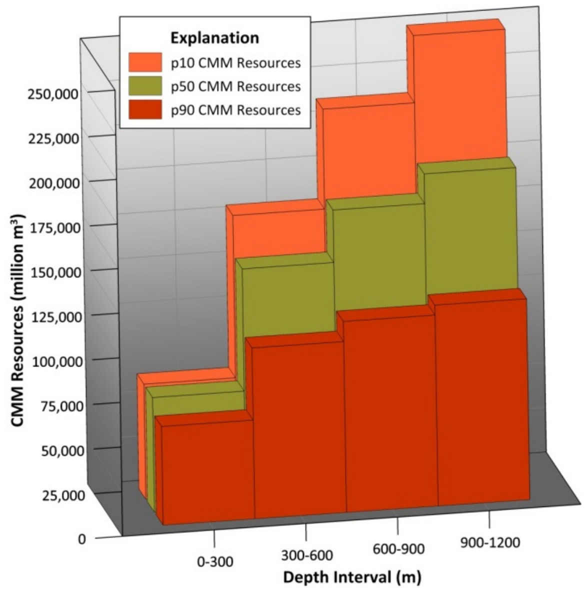

Figure 22: Probability Based Estimation of CMM Resources - Mongol Altai Basin

2.5.8. Ongi River

The Ongi River coal basin lies within the central portion of Mongolia. The basin covers approximately 23,700 km^2 of area extending in an east to west direction. The Ongi River basin is a fault bounded foreland basin near the Valley of Lakes and Gobi ranges, where complex geologic deformation took place surrounding the basin. Igneous plutonic mountains to the north and intensely folded and faulted rocks to the south surround this coal-bearing area. It is likely that the complex geologic structure of the region disrupts the continuity of the coal seams. The main coal resources are non-marine sedimentary sequences, Upper Permian, Lower-Middle Jurassic and Lower Cretaceous in age, and are lignite to subbituminous in rank. The hydrogeologic and precipitation discount factor for the Ongi River basin is 14 percent, and the discount was applied to coals down to a depth of 120 m. Although the basin contains a higher percentage of strata with groundwater storage capacity, the basin is in an arid region of the country.

The coal resources of the Ongi River basin, including the identified coal reserves (42.6 Mt), total 1,543 million metric tons (Erdenetsogt et al, 2009). **Figure 23** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 4,205 - 67,355 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 5,197 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 50,524 million cubic meters.

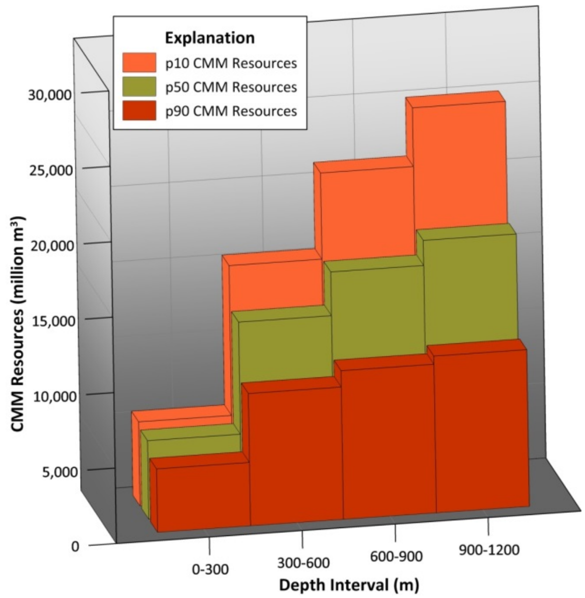

Figure 23: Probability Based Estimation of CMM Resources - Ongi River Basin

2.5.9. Orkhon-Selenge

The Orkhon-Selenge coal basin, home to the Mogoin Gol, Saikhan-Ovoo, Sharyn Gol, Nalaikh and Ulaan-Ovoo deposits, lies in the north central portion of Mongolia. The basin covers approximately 240,000 km^2 of area extending 850 km in an east to west direction. Structurally, this intracratonic basin has a metamorphic basement overlaid by both marine and non-marine sediments. The basin's basement has been extensively faulted and contains about 20 scattered small graben-like basins which contain deposits of Jurassic and Lower Cretaceous aged coalbeds. The northern portion of the basin generally contains higher ranked bituminous coals, while the southern portion generally contains subbituminous coals. For the purpose of this analysis, the basin's coal resources were divided so that amount of the coal resources correlated to the areas within the basin classified as bituminous or subbituminous in rank. The hydrogeologic and precipitation discount factor for the northern portion of the Orkhon-Selenge basin is 34 percent, and the discount was taken down to 60 m depth. For the southern portion of the basin, the discount factor is 25 percent, and is applied to coals down to a depth of 60 m. The entire basin is in a semi-arid region of the country, and generally contains strata that are not considered good groundwater aquifers near the surface.

The coal resources of the Orkhon-Selenge basin, including the identified coal reserves (2,900 Mt), total 15,900 million metric tons (Erdenetsogt et al, 2009). For the bituminous portion of the basin, **Figure 24** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 29,887 - 352,181 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 34,043 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 282,797 million cubic meters. For the subbituminous portion of the basin, **Figure 25** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 2,962 - 59,231 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 4,223 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 38,059 million cubic meters.

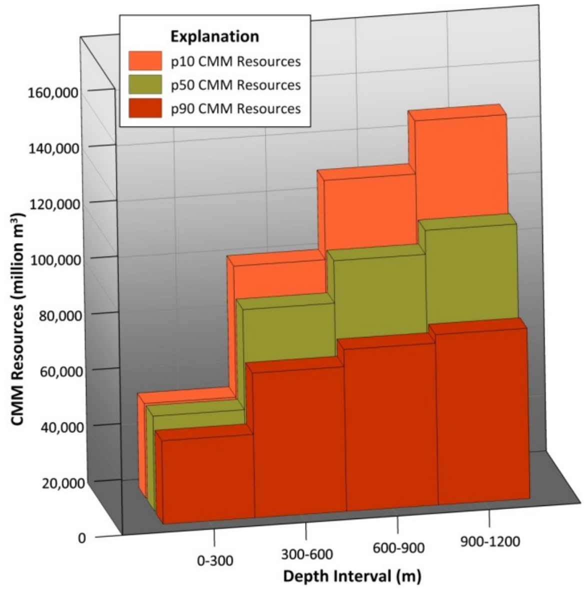

Figure 24: Probability Based Estimation of CMM Resources - Orkhon Selenge Basin Bituminous Region

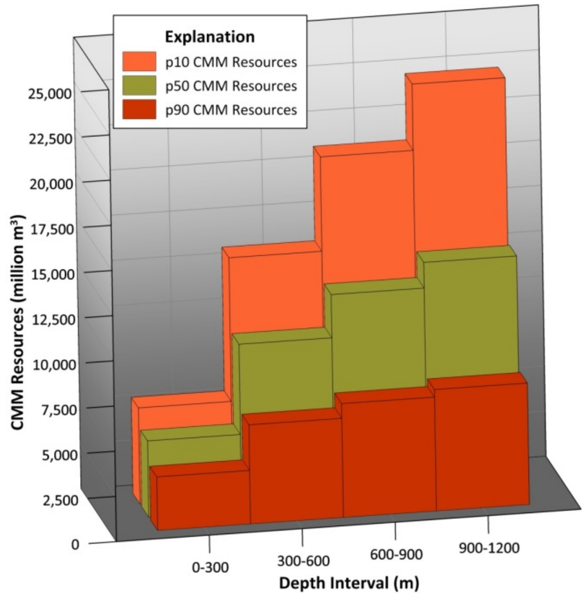

Figure 25: Probability Based Estimation of CMM Resources - Orkhon Selenge Subbituminous Region

2.5.10. South Gobi

The South Gobi coal basin, home to the Naryn Sukhait, Tavan Tolgoi and Aman Gol deposits, is the southernmost Mongolian coal basin. The basin covers approximately 40,000 km^2 of area extending 600 km in an east to west direction. The complex geologic structure of the South Gobi basin disrupts the continuity of the coal seams. Structurally, the foreland basin consists of fold and thrust belts, normal faulting and has experienced continental growth and accretion through erosion of nearby volcanic arc systems. The main coal resources are Permian to Jurassic in age, and generally range in rank between subbituminous to medium-volatile bituminous; however, the majority of the coal resource is high to medium-volatile bituminous. The hydrogeologic and precipitation discount factor for the South Gobi basin is 16 percent, and the discount was applied to coals down to a depth of 120 m. Although the basin contains a higher percentage of strata with groundwater storage capacity, the basin is in an arid region of the country.

CBM exploration work conducted in 2005 by Storm Cat, a coalbed methane exploration and development company based out of the U.S., revealed that the gas content of the coal seams in the Naryn Sukhait area range from 2.4 – 11.8 cubic meters per metric ton (Storm Cat, 2005). The highest gas contents reported by MAK, owner and operator of the Naryn Sukhait coal mine from desorption testing conducted in 2012, was 3.8 cubic meters per metric ton.

The coal resources of the South Gobi basin, including the identified coal reserves (2,900 Mt), total 15,900 million metric tons (Erdenetsogt et al, 2009). **Figure 26** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 51,429 – 763,643 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 61,804 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 592,936 million cubic meters.

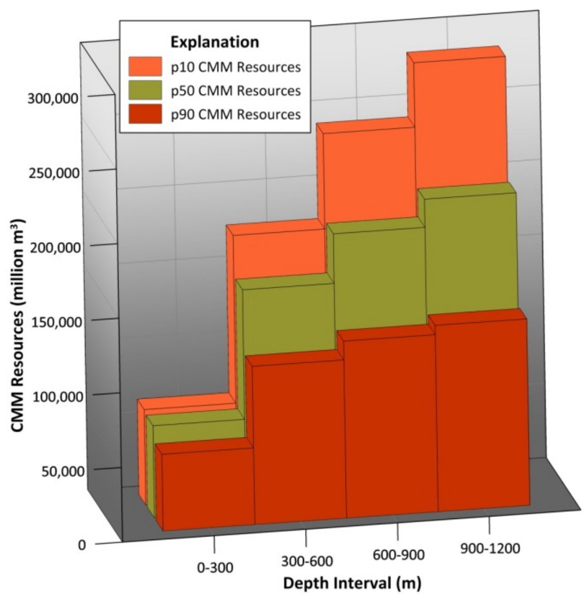

Figure 26: Probability Based Estimation of CMM Resources - South Gobi Basin

2.5.11. Southern Khangai

The Southern Khangai coal basin lies within the west-central portion of Mongolia. The basin covers approximately 25,500 km^2 of area extending in a northwest to southwest direction. The Southern Khangai basin is a fault bounded foreland basin near the Valley of Lakes and Gobi-Altai ranges, where complex geologic deformation took place surrounding the basin. Igneous plutonic mountains to the north and intensely folded and faulted rocks to the south surround this coal-bearing area. It is likely that the complex geologic structure of the region disrupts the continuity of the coal seams. The main coal resources are non-marine sedimentary sequences, Upper Permian, Lower-Middle Jurassic and Lower Cretaceous in age, and are lignite to subbituminous in rank. The hydrogeologic and precipitation discount factor for the Southern Khangai basin is 18 percent, and the discount was applied to coals down to a depth of 60 m.

The coal resources of the Southern Khangai basin, including the identified coal reserves (4.2 Mt), total 1,204 million metric tons (Erdenetsogt et al, 2009). **Figure 27** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 6,560 - 81,562 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 7,638 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 64,490 million cubic meters.

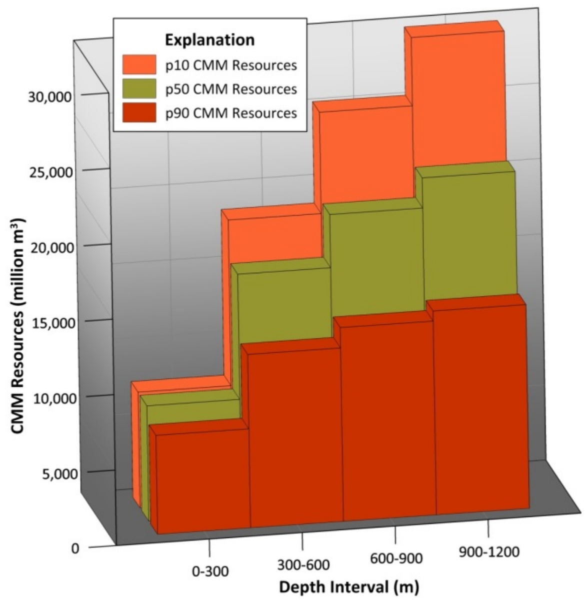

Figure 27: Probability Based Estimation of CMM Resources - Southern Khangai Basin

2.5.12. Sukhbaatar

The Sukhbaatar coal basin, home to the Talbulag coal deposit, lies within the central portion of the Eastern Mongolian coal-bearing province (Erdenetsogt et al, 2009). The basin covers approximately 40,000 km^2 of area extending in a northeast to southwest direction. The occurrence of several graben and half graben structures of this backarc basin likely leaves the coalbeds disrupted. The main coal resources are Cretaceous in age, and are lignite in rank. The hydrogeologic and precipitation discount factor for the Sukhbaatar basin is 10 percent, and the discount was applied to coals down to a depth of 120 m. The basin is in an arid region of the country, and generally contains strata that are not considered good groundwater aquifers near the surface.

The coal resources of the Sukhbaatar basin, including the identified coal reserves (68 Mt), total 4,368 million metric tons (Erdenetsogt et al, 2009). **Figure 28** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 2,095 - 49,115 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 2,890 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 32,743 million cubic meters.

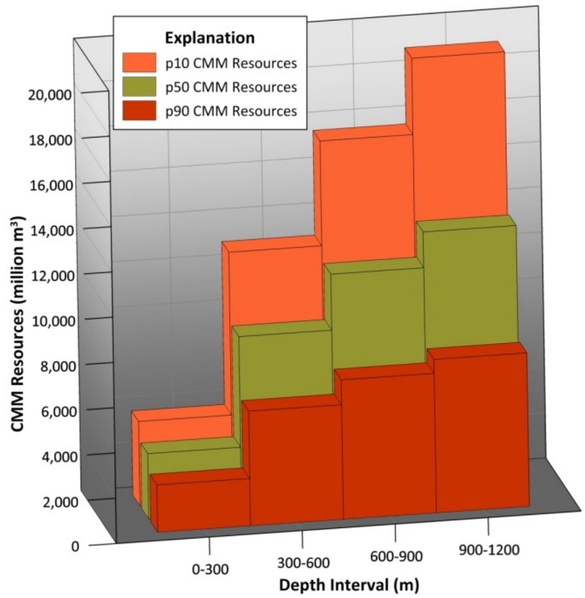

Figure 28: Probability Based Estimation of CMM Resources - Sukhbaatar Basin

2.5.13. Tamsag

The Tamsag coal basin lies within the easternmost portion of the Eastern Mongolian coal-bearing province (Erdenetsogt et al, 2009). The basin covers approximately 32,000 km^2 of area extending in a northeast to southwest direction. The gentle trough structure of this rift basin likely leaves the coalbeds undisrupted. The main coal resources are Cretaceous in age, and are lignite in rank. The hydrogeologic and precipitation discount factor for the Tamsag basin is 36 percent, and the discount was applied to coals down to a depth of 60 m. The basin is in a semi-arid region of the country, and generally contains strata that are considered good groundwater aquifers near the surface.

The coal resources of the Tamsag basin, including the identified coal reserves (190 Mt), total 32,190 million metric tons (Erdenetsogt et al, 2009). **Figure 29** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 36,870 - 731,864 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 52,478 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 470,354 million cubic meters.

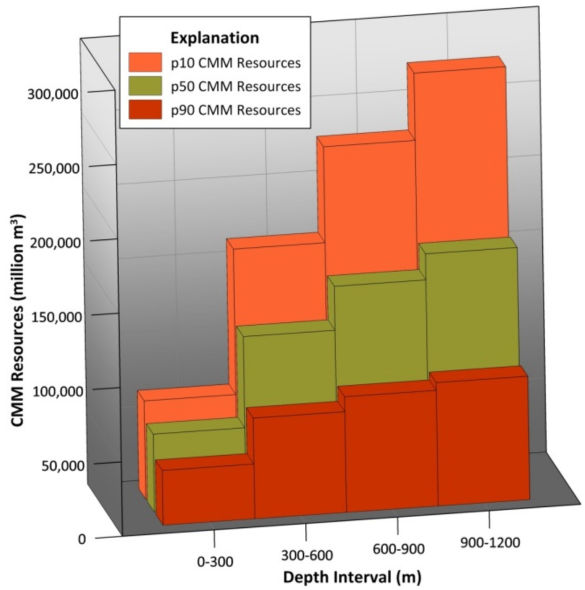

Figure 29: Probability Based Estimation of CMM Resources - Tamsag Basin

2.5.14. Trans-Altai

The Trans-Altai coal basin lies within the southwest portion of Mongolia. The basin covers approximately 72,000 km^2 of area extending in an east to west direction. The Trans-Altai basin is a foreland basin where Paleozoic normal and thrust faulting formed ramps and open thrust and graben like structures. Little is known about the coal deposits within the basin, as geologic surveys for the area are sparse; however, the coalbeds at the Olonbulag deposit have an average net thickness of 42 m (Erdenetsogt et al, 2009). The known coal resources of the Trans-Altai basin are Carboniferous in age, and are low-volatile bituminous to anthracite in rank. The hydrogeologic and precipitation discount factor for the Trans-Altai basin is 16 percent, and the discount was applied to coals down to a depth 120 m. The basin is in an arid region of the country, and generally contains strata that are not considered good groundwater aquifers near the surface.

The coal resources of the Trans-Altai basin, including the identified coal reserves (2.1 Mt), total 3,802 million metric tons (Erdenetsogt et al, 2009). **Figure 30** shows that the total CMM resources between the p90 to p10 gas resource forecast range from 17,568 - 255,313 million cubic meters. The p50 CMM resource estimation, which is the mean and most likely value within the probability based estimate, is 20,919 million cubic meters for the coal resources lying within 300 m depth of the surface of the earth. The p50 CMM resource estimation of the coal resources potentially lying within 1200 m of the surface is 200,951 million cubic meters.

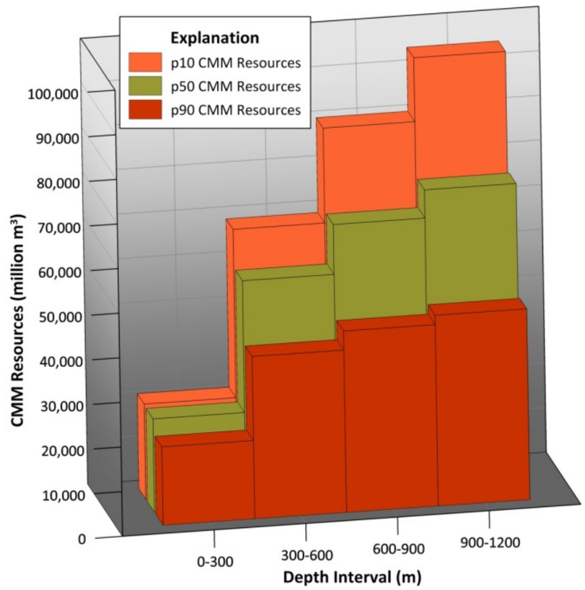

Figure 30: Probability Based Estimation of CMM Resources - Trans-Altai Basin

3. CMM Emissions Inventory Improvement

3.1. Background

Mongolia is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC). As a Non-Annex I Party to the Kyoto Protocol, Mongolia has no official national emissions targets. As a party to the Convention, Mongolia has submitted two National Communications to the UNFCCC; the First National Communication was submitted November 1, 2001, and at that time, a detailed calculation of methane emissions from Mongolian coal mines and coal deposits was not possible, as coal gas investigations had not yet been conducted. Only data for the Nalaikh deposit were available (UNFCCC, 2001). Mongolia's Second National Communication was submitted December 10, 2010, whereas emissions were estimated for 2006. This inventory was completed using an IPCC Tier 1 methodology (UNFCCC, 2010).

As coal mining production has increased with the development of large surface mine operations in several geographically divergent basins, it has become imperative to refine Mongolia's CMM emissions inventory. With activities such as USEPA's "Prefeasibility Study for Coal Mine Methane Recovery and Utilization at Naryn Sukhait Mine," (USEPA, 2013) it is clear that CMM recovery and utilization projects have potential in Mongolia. An accurate CMM emissions inventory is necessary to measure progress against future greenhouse gas emission reduction targets as well as to identify strategic project sites.

3.2. Methodology

The inventory team headed by Professor Namkhainyam developed a report to serve as the basis of CMM fugitive emissions inventory calculations. The report is included as **Attachment 1**. The authors of this report determined that additional information could be incorporated into the emissions inventory by including the methodology used in estimating the CMM (CBM) resources. As discussed in section **2.3.4**, gas content of the coal seams within a basin was modeled using their coal rank and methane isotherms developed from samples taken from coal seams in analogous basins. As was noted in section **2.3.4**, the gas content modeled in coalbeds within a basin was diminished by a drop in hydrostatic pressure associated with the amount of rainfall and hydrogeologic characteristics of the water bearing rocks in each coal basin. The same assumptions were used in calculating emission factors; therefore the emission factor is calculated as follows:

Emission factor *= (Net CMM resources of given depth interval) / (Coal resources of given depth interval)* where the net CMM resources is equal to the original gas in place less that which would have escaped because of reduced hydrostatic pressure caused by climatic conditions that impact evaporation of the water column. The diagram below, **Figure 31**, shows the work flow and logic of developing emission factors.

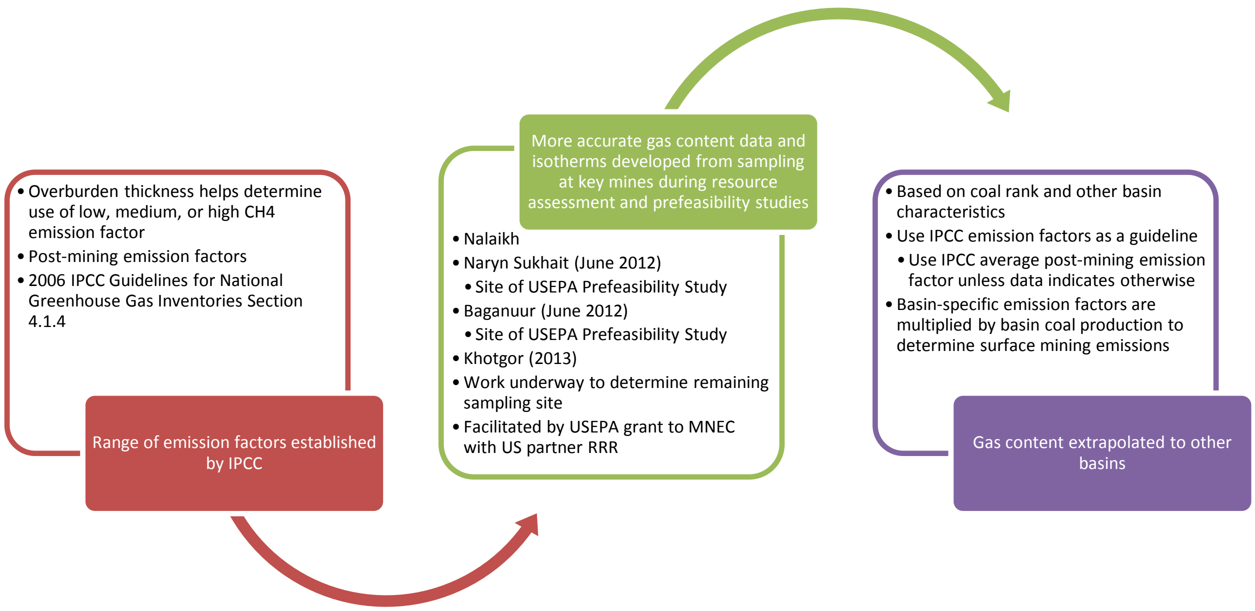

Figure 31: Emissions Factor Workflow Diagram

3.3. Results

Figure 32, below is a map of Mongolia showing the coal basins and the range of emission factors that are predicted using the coal rank and the climatic effects described above. These factors are based on coal resources buried to an average depth of 150 m. As described above, methane gas content was determined using the available isotherm constants (Langmuir pressure and Langmuir volume) taken from similar coal of similar rank deposited under similar geologic conditions to perform statistical modeling using a Crystal Ball simulation to yield expected values for the p10, p50, and p90 percentiles. Each of these gas contents in each basin was used to determine emission factors. **Table 9** below shows the p50 emission factors by depth. Appendix 2: Data Tables shows p10 and p90 emission factors.

Not surprisingly, the higher emission factors are associated with the higher rank coals that occur in wetter environments, where the original gas in place is higher and the higher rainfall recharges near surface strata serving to keep the gas from escaping to the atmosphere.

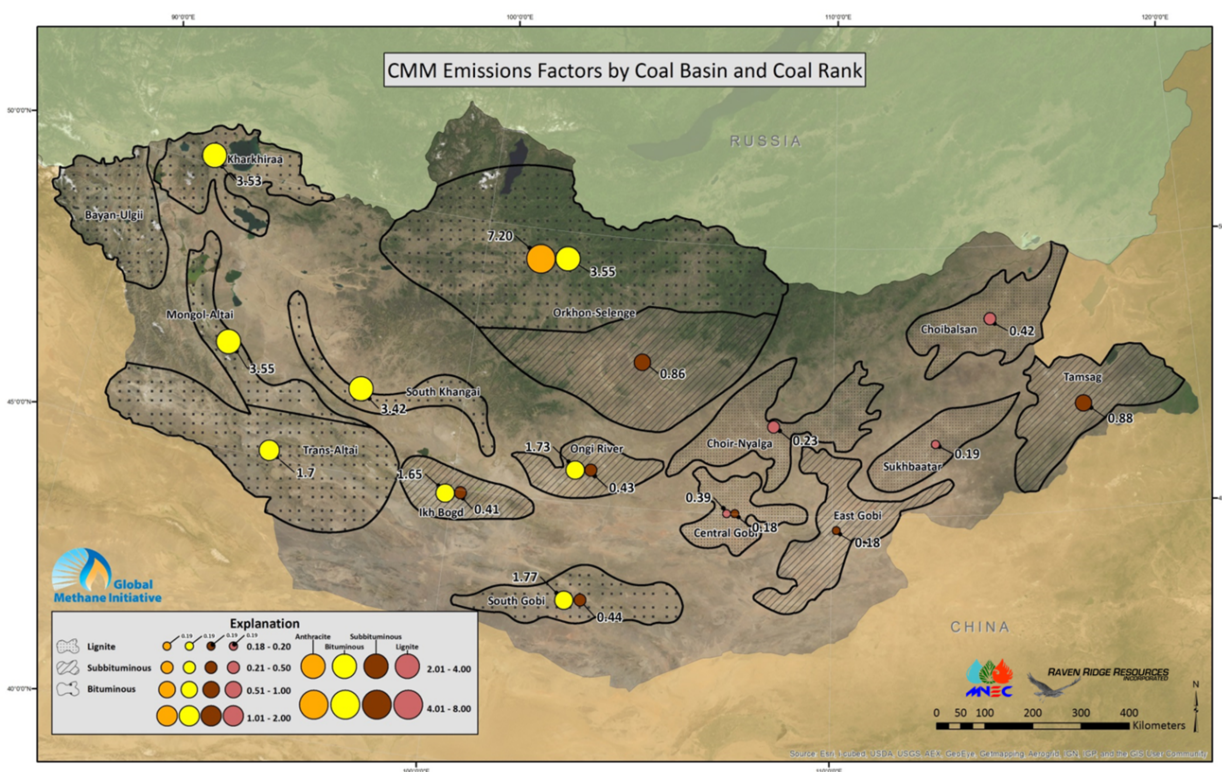

Figure 32: CMM Emissions Factors of Mongolia by Coal Basin and Coal Rank

Table 9: p50 Emission Factors by Depth

Basin	Rank	30 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m
Central Gobi	Lignite	0.01	0.02	0.02	0.03	0.18	0.30	0.41	0.50	0.59	0.67
	Subbituminous	0.02	0.04	0.05	0.07	0.39	0.65	0.87	1.06	1.24	1.39
Choibalsan	Lignite	0.06	0.12	0.24	0.33	0.42	0.51	0.58	0.66	0.73	0.79
Choir-Nyalga	Lignite	0.03	0.05	0.08	0.10	0.23	0.35	0.45	0.54	0.62	0.70
East Gobi	Subbituminous	0.01	0.02	0.02	0.03	0.18	0.30	0.41	0.50	0.59	0.67
Ikh Bogd	Subbituminous	0.03	0.05	0.08	0.10	0.41	0.67	0.89	1.08	1.25	1.41
	Bituminous	0.12	0.22	0.31	0.40	1.65	2.66	3.51	4.24	4.89	5.48
Kharkhiraa	Bituminous	0.31	0.59	1.81	2.74	3.53	4.22	4.85	5.41	5.93	6.42
Mongol-Altai	Bituminous	0.34	0.63	1.84	2.76	3.55	4.24	4.86	5.42	5.94	6.43
Ongi River	Subbituminous	0.03	0.06	0.09	0.12	0.43	0.68	0.90	1.09	1.26	1.41
	Bituminous	0.14	0.27	0.38	0.49	1.73	2.72	3.56	4.29	4.93	5.52
Orkhon-Selenge (North)	Bituminous	0.34	0.63	1.83	2.76	3.55	4.24	4.86	5.42	5.94	6.43
	Anthracite	0.74	1.37	3.84	5.69	7.20	8.49	9.63	10.64	11.55	12.38
Orkhon-Selenge (South)	Subbituminous	0.06	0.11	0.42	0.66	0.86	1.04	1.21	1.36	1.50	1.63
South Gobi	Subbituminous	0.04	0.07	0.10	0.13	0.44	0.69	0.91	1.09	1.26	1.42
	Bituminous	0.16	0.30	0.42	0.54	1.77	2.75	3.59	4.31	4.96	5.54
Southern Khangai	Bituminous	0.18	0.33	1.63	2.61	3.42	4.14	4.77	5.35	5.88	6.36
Sukhbaatar	Lignite	0.01	0.02	0.03	0.04	0.19	0.31	0.41	0.51	0.59	0.67
Tamsag	Subbituminous	0.09	0.16	0.45	0.68	0.88	1.06	1.22	1.37	1.51	1.64
Trans-Altai	Bituminous	0.13	0.25	0.36	0.46	1.70	2.70	3.54	4.27	4.92	5.51

4. Training Activities

A key component of the resource assessment and inventory activities under this cooperative agreement is capacity building. MNEC organized five workshops and training sessions over the two year grant period of performance.

RRR initiated a training program for coal collection, desorption testing, and adsorption isotherm testing in Mongolia. Training sessions were organized at the mine sites of Naryn Sukhait, Tavan Tolgoi, and Baganuur whereas Raymond C. Pilcher from RRR provided a presentation on concepts of CMM assessment and led a discussion and question and answer session at each site. Presentations from this training session can be found in **Attachment 2**. In addition, site training on coal sampling and testing techniques was organized for the management teams of mining companies, geologists, and drillers working at the mine sites.

MNEC also organized training sessions in Ulaanbaatar where decision makers, university teachers, and company directors participated. RRR representatives gave presentations on CMM assessment as well as improvement of Mongolia's CMM emission inventory.

Mr. Ochirsukh, vice director of MNEC, participated and provided presentations at the GMI Coal Subcommittee Meeting held in Sydney, Australia in 2012 and in Geneva in 2013. Dr. Badarch presented at the 2013 Methane Expo.

MNEC prepared a brochure on Mongolian participation in GMI activities which was distributed to the public in order to promote public awareness on CMM and CBM development. This brochure presents activities of GMI worldwide, including Mongolian Government strategies on clean energy and climate change policy and CBM news and presentations of scientists. This brochure includes:

- Millennium Development Goals-based Comprehensive National Development Strategy of Mongolia;
- Climate Change Policy of Mongolia;
- Terms of reference for the GMI;
- GMI partner action plan guidance document;
- Needs to determine methane sources in Mongolian coal mines;
- Overall policy for the coal industry;
- Concepts used for conducting CBM and CMM resources assessment in frontier areas; and,
- Approach for a surface mine methane emissions inventory of Mongolia.

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Appendix 1: Key Coal Deposits

Six mining regions lying within the explored coal basin have been chosen based on publicized plans for coal resource development. The mining areas of Naryn Sukhait, Baganuur, Tavan Tolgoi, Khotgor, Sharyn Gol and Nalaikh are expected to be key areas for Mongolia's coal development in the near future. Sampling was conducted near or within these mining areas and coal mine methane resources were calculated for these basins. In order to obtain the data required to characterize the reservoir properties of the coal seam and assess the gas resource in each of the basins, testing programs were conducted that included desorption testing, adsorption isotherm testing and desorbed gas analysis.

The following sections were developed as background information of the field investigations sites. Coal resources and reserves are listed using terminology provided by reference materials which, in some cases, do not define the basis for the terminology.

1.1. Naryn Sukhait

1.1.1. Location

The Naryn Sukhait coal deposit is located in the territory of Gurvantes Soum, within the Ömnögovi Province, approximately 850 km southwest of Ulaanbaatar city (**Figure 33**).

Figure 33: Location of Naryn Sukhait coal deposit

The center of the deposit is positioned at N 42° 50’ latitude and E 101° 40’ longitude, which is 40 km north of the Chinese border, and 300 km southwest of the capital town of Dalanzadgad, in Ömnögovi Province. The surface elevation of the deposit lies 1,510 – 1,540 m above sea level, atop a flat area of the Gobi Desert.

1.1.2. Geologic Setting and Coal Geology

Table 10: Naryn Sukhait Coal Deposit Exploration History

1991	Reconnaissance survey for the whole deposit and detailed drilling exploration for two mining blocks

The Naryn Sukhait deposit occurs within the South Gobi coal-bearing basin. A reconnaissance survey of the deposit along with detailed drilling exploration first took place in 1991 (**Table 1**). The deposit extends for 90 km east to west and 14 km from north to south. Coal seams occur in the Late Permian coal-bearing Tavantolgoi formation. The Naryn Sukhait deposit lays within a synclinal structure which trends east to west and dips 30-60° to the south (**Figure 34**). The Tavan Tolgoi formation contains five to seven coal seams, of which the mineable seams consist of Seam I in the west block and Seam V in the east block. Both coal seams are approximately 100 m in thickness. Intrusives penetrate the coal bearing formations at the east end of the deposit, and have influenced the coal quality which has been altered to anthracite in that region.

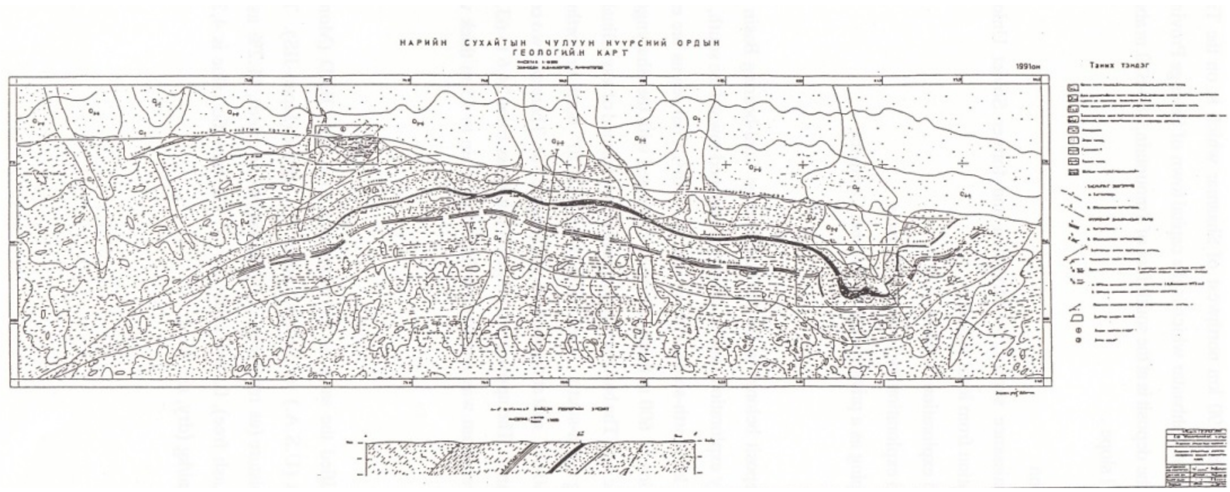


Figure 34: Geological map of Naryn Sukhait Deposit

1.1.3. Coal Resources

Within the two blocks where exploration drilling was conducted, mineable coal reserves (A + B + C1) within 100 m of the surface is estimated to at 40 – 50 million metric tons, with a stripping ratio of 1.2. The total geologic reserves (A + B + C1 + C2 + P) down to a depth of 200 m are estimated at 200 – 250 million metric tons.

1.1.4. Coal Quality

According to the ASTM classification scheme, the Naryn Sukhait coal is classified as high-volatile A bituminous to medium-volatile bituminous in rank. The Mongolian and Russian classification system puts the coal into the GJ classification.

1.1.5. Coal Mining Situation

Presently there are three large scaled surface coal mines operating at the Naryn Sukhait deposit: Naryn Sukhait Mine-1 operated by MAK (**Figure 35**), Naryn Sukhait Mine-2 operated by the Mongolian-Chinese joint venture company, Chinhua-MAK (**Figure 36**), and the Ovoot Tolgoi mine operated by the Australian company, South Gobi Sands (**Figure 37**).

Figure 35: View of Naryn Sukhait Mine-1, Operated by MAK

Figure 36: View of Naryn Sukhait Mine-2, operated by Chinhua-MAK

Figure 37: View of Ovoot Tolgoi East Mine, Operated by South Gobi Sands

Projected production of the Naryn Sukhait Mine-1 for 2013 is 10 million metric tons. The projected production of the Naryn Sukhait Mine-2 is 1.5 million metric tons, while the Ovoot Tolgoi Mine was projected to produce 4 million metric tons in 2013.

1.2. Baganuur

1.2.1. Location

The Baganuur coal deposit is located in the territory of Bayandelger Soum and within the Tuv Province, approximately 125 km southeast of Ulaanbaatar City (**Figure 38**).

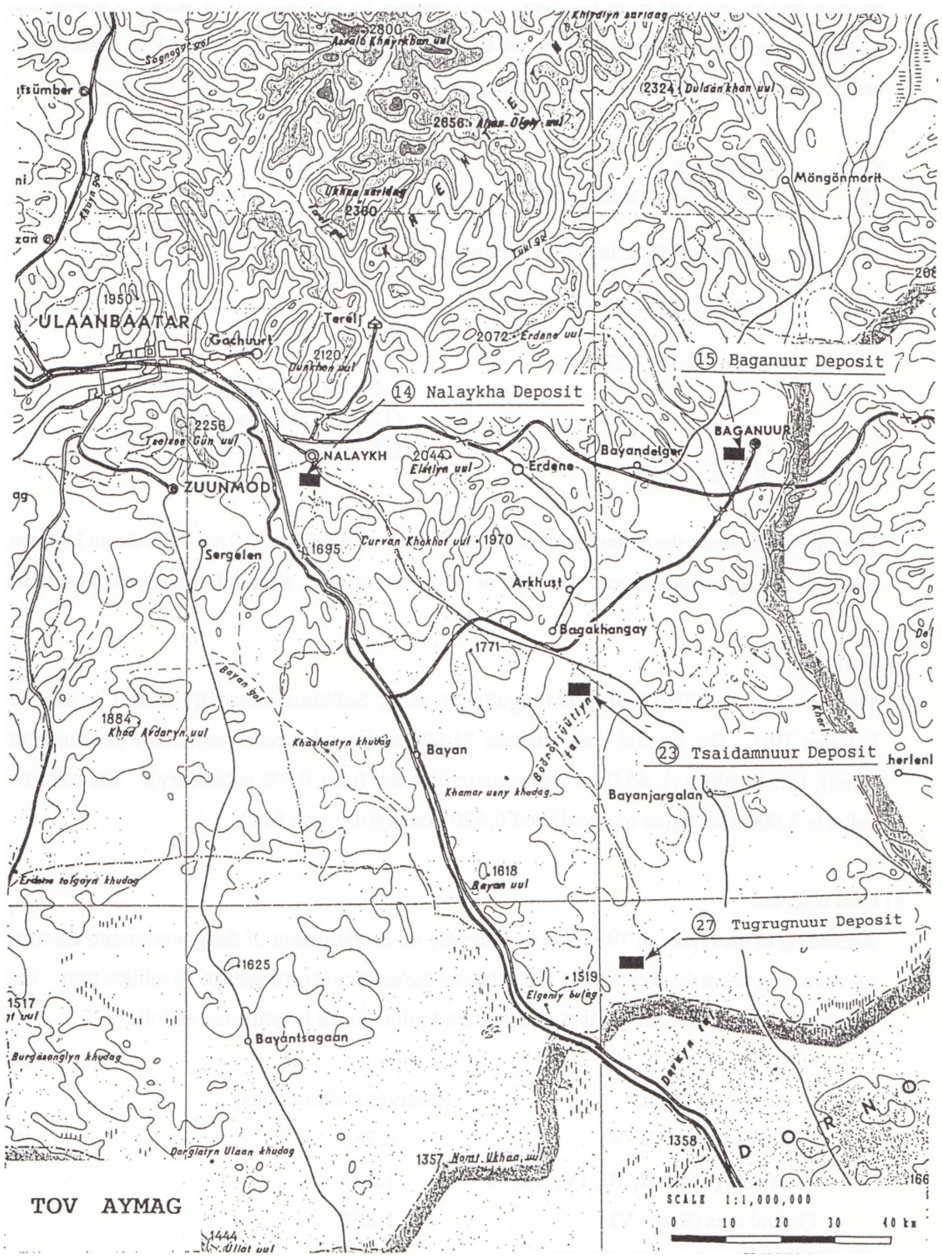


Figure 38: Location of Baganuur Coal Deposit

The center of the deposit is positioned at N 47° 45’ latitude and E 108° 26’ longitude. The surface expression of the deposit forms a steppe at 1,370 m above sea level. The coal deposit plays an important role for the city of Ulaanbaatar, as the Baganuur Coal Mine provides the majority of the coal used to power the city through the Central Electric System network.

1.2.2. Geologic Setting and Coal Geology

Table 11: Baganuur Coal Deposit Exploration History

1925-1926	Deposit first discovered and recorded by team from the former Soviet Union
1931	Initial exploration by former Soviet Union team, who concluded deposit “hopeless”
1964	Drilling and trenching exploration by former Soviet Union team; 7 boreholes, 7 trench sites

with 26 holes; concluded deposit was promising and large

1974-1975 Detailed exploration by former Soviet Union team covering entire deposit with 20 lines of section at 500 m intervals

1988 Additional exploration complete by Mongolian team

The Baganuur deposit occurs within the Choir-Nyalga coal-bearing basin. Discovery and exploration of the coal deposit began in 1925 by a team from the former Soviet Union.

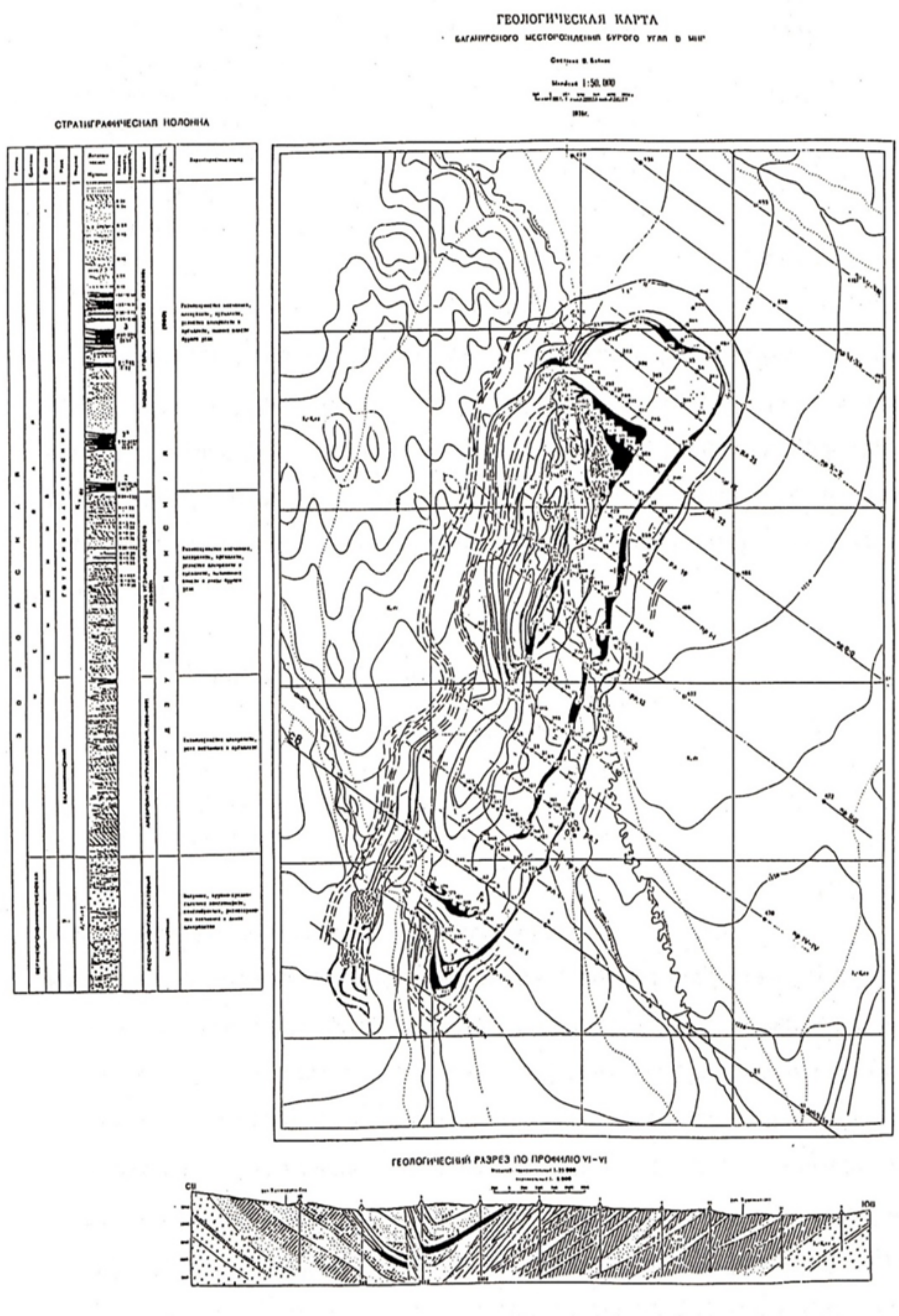


Figure 39: Geologic Map of Baganuur Coal Deposit

The deposit occurs within an elongated basin extending for 12 km north-northeast and 3.5 km west-northwest, over an area of 40 km^2. Coal seams are found in the 500 m thick Early Cretaceous Tevshiingovi Formation of the Dsunbayan Group. The basic geologic structure is a synclinal basin with a north-northeast trending axis (**Figure 39**). There are three main faults trending north-northeast and dipping 60-70° with displacement ranging from 40 to 140 m. The coal seams generally dip 8-10° and 15-20°, and greater than 20° near the faults. The deepest coal seams within the basin are about 350 m below the surface (**Figure 40**). There are a total of 11 coal seams, which characteristically split and vary in thickness. Minable coal seams are identified as

Seam 2, Seam 2a and Seam 3. The lower most seam, Seam 2, is 3.4 – 29.2 meters thick, thickening with depth. Seam 2a, which also thickens with depth, is 2.4 – 52.7 m thick. Seam 3, the upper most seam, contains 25 partings and ranges between 25.0 – 97.8 m in thickness.

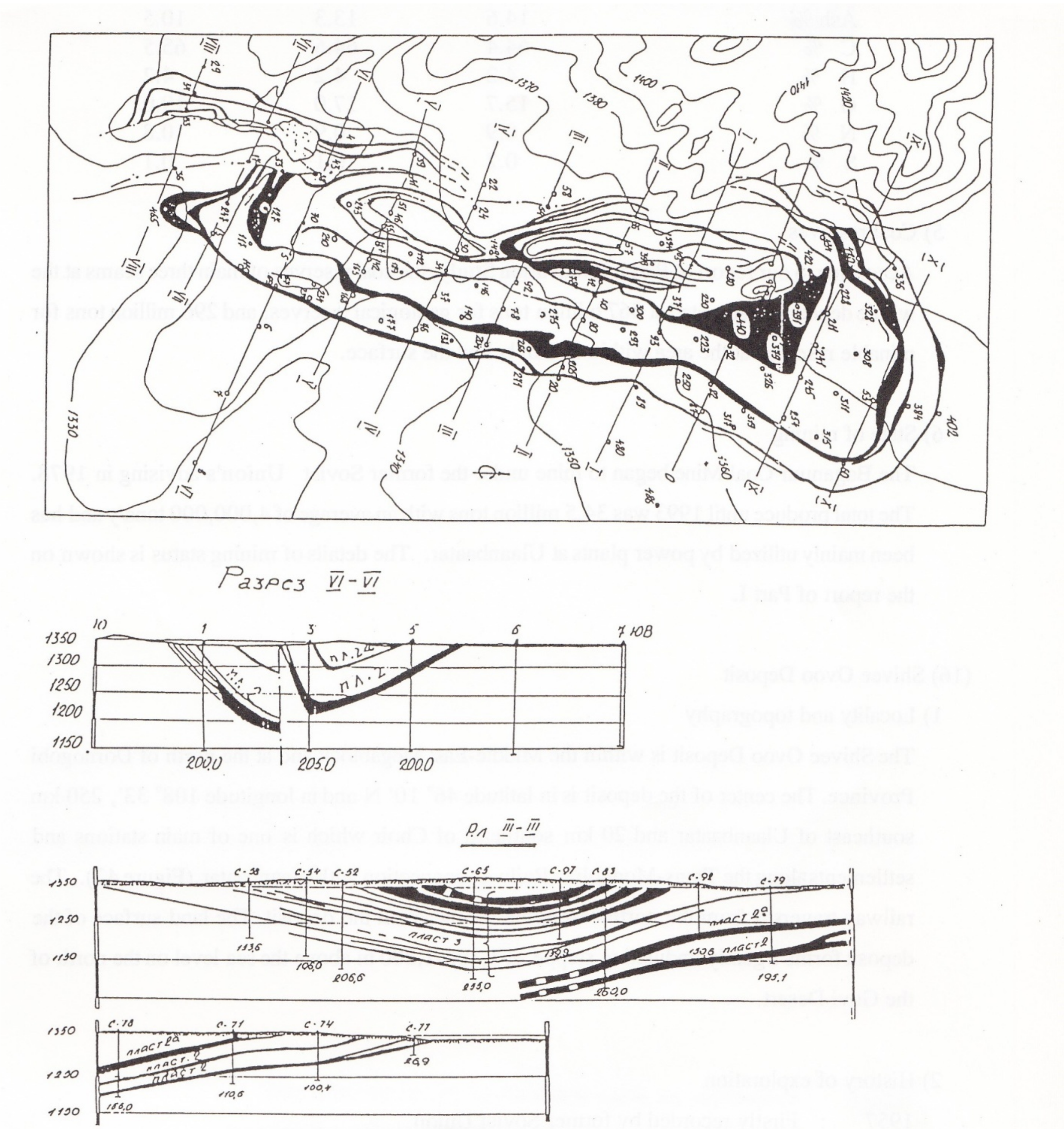


Figure 40: Geologic Structures of Baganuur Coal Deposit

1.2.3. Coal Resources

According to a study carried out by JICA, Japan, the geologic coal reserves of the three main three seams of the Baganuur deposit is estimated at 567 million metric tons. The mineable reserves are 296 million metric tons within 150 m below the surface.

1.2.4. Coal Quality

Various coal quality analyses have been conducted at the Baganuur coal deposit. **Table 12** shows the results of these analyses.

Table 12: Coal Quality Analyses

Analysis	Moisture	Ash	Volatile Matter	Sulfur	Calorific Value	Rank
Japan, 1995	31.0% (as received) 9.2% (air dried)	12.1% (dry)	44.6% (dry, ash free)	0.4% (dry)	3,870 kcal/kg (as received) 7,070 kcal/kg (dry, ash free)	Lignite F (Japan-JIS) B2 (Mongolia, Russia) Subbituminous C (U.S.A.)
Coal Quality Standard (MNS 3818-2001)	≤37.5%	≤17.5%	≤55.0%	≤0.5%	3,360 kcal/kg	

1.2.5. Coal Mining Situation

With assistance from a team from the former Soviet Union, the Baganuur Coal Mine began to mine coal in 1978. The total production until 2013 was approximately 80 million metric tons and has been utilized to generate by power in Ulaanbaatar. **Figure 41** is a photo of the Baganuur Coal Mine.

Figure 41: View of Baganuur Coal Mine

1.3. Tavan Tolgoi

1.3.1. Location

The Tavan Tolgoi coal deposit is located in the territory of Tsogt Tsetsii Soum, within the Ömnögovi Province, approximately 540 km south of Ulaanbaatar City and 96 km west of Dalanzadgad, the capital town of Ömnögovi Province (**Figure 42**).

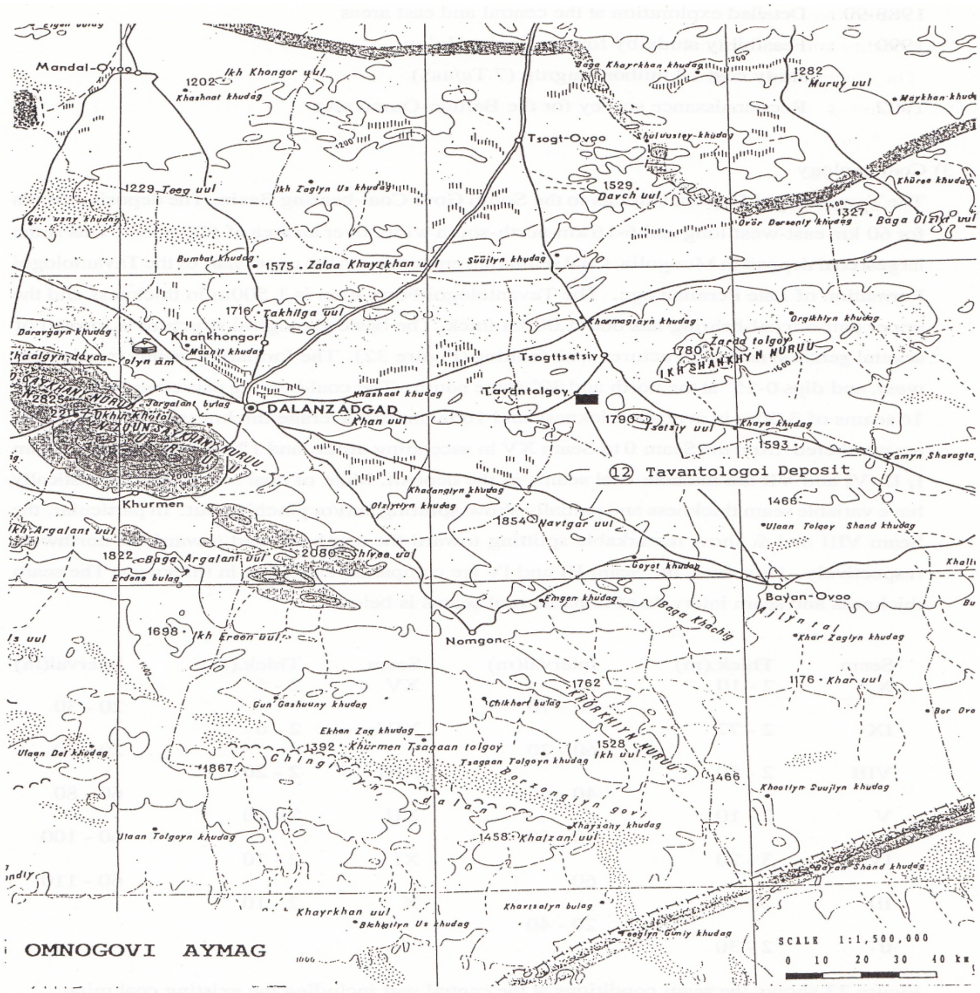


Figure 42: Location of Tavan Tolgoi Coal Deposit

The center of the deposit is positioned at N 43° 35' N latitude and E 106° 30' longitude. The surface expression of the deposit forms a gently undulated semi desert at 1,490-1,560 m above the sea level.

1.3.2. Geologic Setting and Coal Geology

Table 13: Tavan Tolgoi Coal Deposit Exploration History

1890	Deposit first discovered and recorded by team of geologist from U.S. A.
1940-1950	Sampling exploration done by former Soviet Union team who concluded property has coking potential and recommended more detailed exploration
1953-1956	Drilling exploration done by team of geologist from Former Soviet Union confirmed continuity of 18 mineable coal seams, and estimated 950 million t (C1) and 866 million t (C2)
1974-1975	Bulgarian exploration survey sampled 5 tons from 4 seam and determined Seam W best for coking, decided on development at meeting of COMECON
1978-1980	With guidance from former Soviet Union team, Mongolian exploration team spent 150 million Tugrik to drill 2,000 borehole for a total of 200 km, within 90 km^2 area every 1.0 – 1.5 km

1981-1984 Additional drilling exploration of 35 km^2 area, every 700 – 750 m in the northeast and west area

1984-1986 Additional drilling exploration of 10 km^2 area, every 350 m in the northeast area

1984-1987 Additional exploration of northern 10km^2 area

The Tavan Tolgoi Deposit occurs within the South Gobi coal-bearing basin. The deposit extends for 60 km east-west and 6-16 km north-south, over an area of 600 km^2. This is the largest coal deposit in Mongolia. Coal seams are found within the upper part of the Tavantolgoi Formation of Late Permian age. The Tavantolgoi Formation is 1,500m thick, with the upper coal-bearing section ranging in thickness from 600-1,000 m. The basic geologic structure is comprised of several gentle synclinal structures with faulting (**Figure 43**). The formation mainly trends east to west, and dips 0-15° at the north and 30° at the south. The coal-bearing sequence contains a total of 16 seams ranging in thickness from 3 to 30, with an overall average thickness of 165m. The coal seams are numbered from Seam 0 to Seam XV in ascending order, with twelve of the seams of minable thickness. Most of the coal seams vary in thickness laterally, often splitting and/or pinching out. **Table 14** lists the seam thickness and intervals of the mineable coal seams within the Tavan Tolgoi deposit.

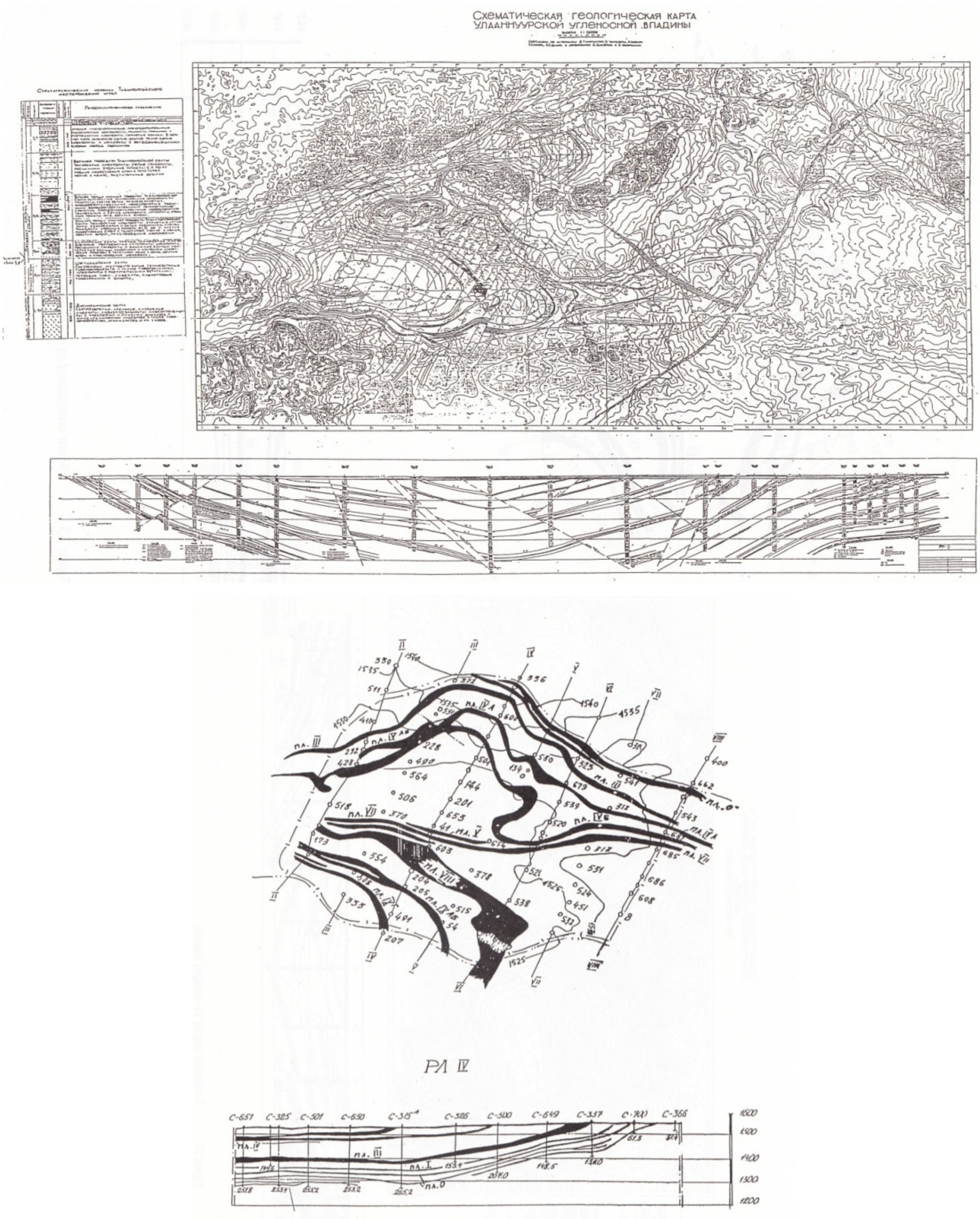


Figure 43: Tavan Tolgoi Geologic Structure

Table 14: Tavan Tolgoi Coal Occurrence and Thickness

Coal Seam	Thickness (m)	Interval(m)	Coal Seam	Thickness (m)	Interval (m)
IX	2 – 72	60 - 70	XV	2 – 5	20 – 30
VIII	2 - 50	40 – 60	XIV	2 – 6	20 – 30
V	2 – 10	40 – 50	XIII	2 – 20	60 – 80
IV	3 – 20	60	XII	2 – 20	60 – 100
III	2 – 15	20 – 40	XI	2 – 10	60 – 110
0	2 – 30		X	2 – 10	50 - 70

1.3.3. Coal Resources

According to estimates completed in 1995 using the Japanese JICA standards, the coal resources contained within the exploration area and within 500 m of the surface are 6,500 million metric tons. However, the resources included in the entire deposit are estimated at 10 billion metric tons. Coal resource estimates of the exploration area down to 300 mare estimated at 3,500 million metric tons, of which 1,000 million tons are coking coal. A feasibility study conducted by Giproshakht of Russia in 1990 reported a total of 1,888.3 million metric tons of reserves to a depth of 300 m; of which 1,016.8 million tons are available as steam coal and 866.5 million tons for coking. **Figure 44** shows the areas for which coal resource assessments were performed.

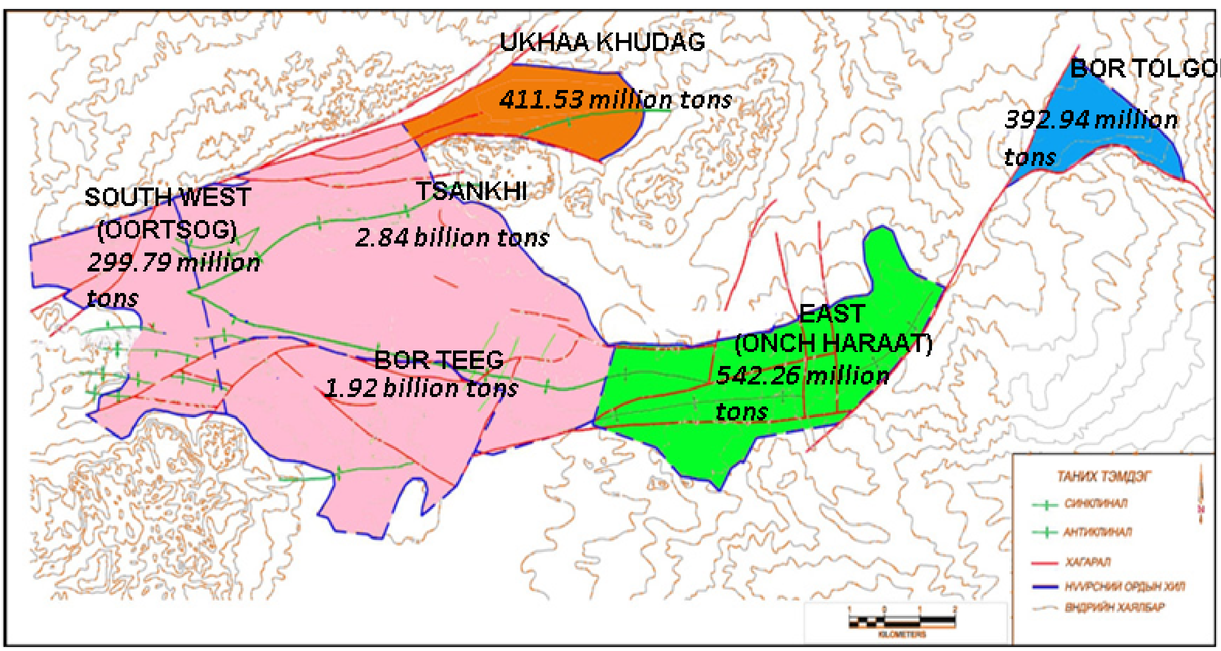


Figure 44: Geologic Coal Resources by Geologic Areas of Tavan Tolgoi Deposit

1.3.4. Coal Quality

The coals have been classified according to the following classification schemes:

- G-KJ (Mongolia, Russia)
- High volatile bituminous C-Low volatile bituminous (U.S.A.)

- Bituminous B- Subbituminous E (Japan-JIS).

The coal seams are then subdivided into two groups based on coal quality. The coals of the upper group, composed of Seam X to Seam XV, are favorable as steam coal, while the coals of the lower group, Seam 0 to Seam IX, show favorable coking properties. Produced coals were analyzed and on average contain 11.5% moisture (as received), 21.2% ash (dry), 25.0% volatile matter (dry, ash free), and 0.7% sulfur (dry). The calorific value averaged 5,110 kcal/kg (as received) and 8,110 kcal/kg (dry, ash free). **Table 15** lists the seams showing favorable coking properties:

Table 15: Coal Analysis Data of Coking Coals at Tavan Tolgoi Deposit

Items	Seam 0	Seam III	Seam IV	Seam VIII	Seam IX
Raw coal-					
- Moisture % (ad)	0.5	0.6	0.7	0.3	0.7
- Ash % (db)	23.6	20.0	21.6	25.4	24.2
- Volatile % (daf)	21.3	25.9	26.1	29.8	30.7
- Sulfur % (db)	0.66	0.67	0.72	0.69	0.59
- Calorific value					
kcal/kg (daf)	7,930	8,820	8,040	8,170	8,220
Clean coal (ash 10%)-					
- Yield %	30-70	52-92	67	40-50	79
- Moisture % (ad)	0.5	0.5	0.6	0.8	1.1
- Volatile % (daf)	22.0	24.4	27.6	31.4	33.7
- Sulfur % (db)	0.6	0.6	0.6	0.6	0.5
- Phosphorus % (db)	0.020	0.074	0.053	0.044	0.034
- Y index mm	11	16	18-20	17	12
-F.S.I.	6	6	6	6	6
-Roga index	42	52	48	51	47
- Gray-King	G2	G6	G8	G8	G4
- Dilatation	T.C	45	120	40	18
- Micum Teet					
M25	85	88-91	87-88	84-85	74
M10	13.8	7-8	8-9	9.5	14
- Vitrinite Ro %	1.2	1.2	1.0-1.2	0.96	0.87
- Inertinite %	45-50	35-40	30-35	30-35	30-35
- Coal Type					
(Mongolia)	KJ,OC	K,KJ	K,KJ	K,KJ	GJ
(ISO)	422,432	433,434	434,435	533,534	633

1.3.5. Coal Mining Situation

Tavan Tolgoi is one of the world's largest untapped coking and thermal coal deposits. It is divided into six coalfields: Tsankhi, Ukhaa Khudag, Bor Tolgoi, Bor Teeg, Southwest and Eastern coalfields (**Figure 45**). A small coal mine within the Tavan Tolgoi coal deposit has been in operation since 1967, which until 2011, has supplied coal directly into the Mongolian domestic market. After 2011, all coal produced is exported to China. This coal mine is owned by the local government (51%) and other private shareholders. The coal production plan for 2013 was 2 million metric tons.

Figure 45: Local Mining Operation at Tavan Tolgoi

Ninety-six percent of the Tavan Tolgoi deposit area is owned by Erdenes MGL (a government owned company), with the exception of the Ukhaa Khudag field which is mined by the Mongolian Mining Corporation (Energy Resources LLC). Erdenes Tavan Tolgoi LLC (Erdenes TT), a subsidiary of Erdenes MGL, is managing the development of the deposit. The Tsankhi field is the largest portion of the entire coal deposit, and is divided into the East and West Tsankhi areas. Recent work has been focused in these two areas. Erdenes TT has chosen the joint venture company of Macmahon Holdings and BBM Operta to operate the min under a five year contract which extends from 2012 – 2017. Production in 2013 from East Tsahkhi mine is expected to be 6 million tons and 1.5 million tons from West Tsankhi.

Figure 46: Mine Operation at East Tsankhi field (ETT)

The Ukhaa Khudag field, located within the Tavan Tolgoi coal formation is mined by Mongolian Mining Corporation (MMC). **Figure 47** shows two views of the Ukhaa Khudag mining operations. The mine is strategically located approximately 240 km from the Mongolian-Chinese border and about 600 km north of Baotou, China, an important railway transportation hub. The hub provides access to the largest steel producing provinces within China.

Figure 47: View of Ukhaa Khudag Mine

MMC began mining operations at Ukhaa Hudag in April of 2009 and became profitable in the first year of operations. MMC's coking coal production has steadily increased from 1.8 Mt in 2009 to 3.9 Mt in 2010, 7.1 Mt in 2011 and 8.6 Mt in 2012, with plans to produce 15 Mt in 2014.

the mine serves as an operational hub for processing ROM coal from Ukhaa Khudag and Baruun Naran mines, complete with all necessary utility infrastructure facilities, including an 18 MW on-site power plant and water supply system.

1.4. Khotgor

1.4.1. Location

The Nuurst Khotgor coal deposit is located in the territory of Bukhmurun Soum, within the Uvs province, approximately 110 km west, southwest of the province center Ulaan Gom (**Figure 48**).

Figure 48: Location Map of Nuurst Khotgor Coal Deposit

The center of the deposit is positioned at N 49° 40' latitude and E 90° 33' longitude, approximately 50 km southeast of the border with Russia. The surface expression of the deposit forms a flat steppe surrounded by mountains and is partially covered with permafrost.

1.4.2. Geologic Setting and Coal Geology

Table 16: Nuurst Khotgor Coal Deposit Exploration History

1927	Deposit first discovered and recorded by Russian geologists
1941-1942	Early exploration work concluded it a mineable deposit
1960	Detailed exploration of 1.0 km X 0.6km area within the northeast by former Soviet Union

	team
1964	Open cut mining began
1990-1991	Mongolian lead exploration team of entire deposit, 10 boreholes revealed western deposit and geologic structure

The Nuurst Khotgor deposit occurs within the Kharkhiraa coal-bearing basin. The deposit occurs within a large basin which extends for 30 km east-west and 15 km north-south, and covers an area exceeding 450 km^2. The coal-bearing Uliastai Formation was deposited during the Middle to Late Carboniferous period. The basic geologic structure is a synclinal basin with an east-west axis (**Figure 49**). The coal seams near the surface dip 45° east at the west area and 11-25° west at the east area.

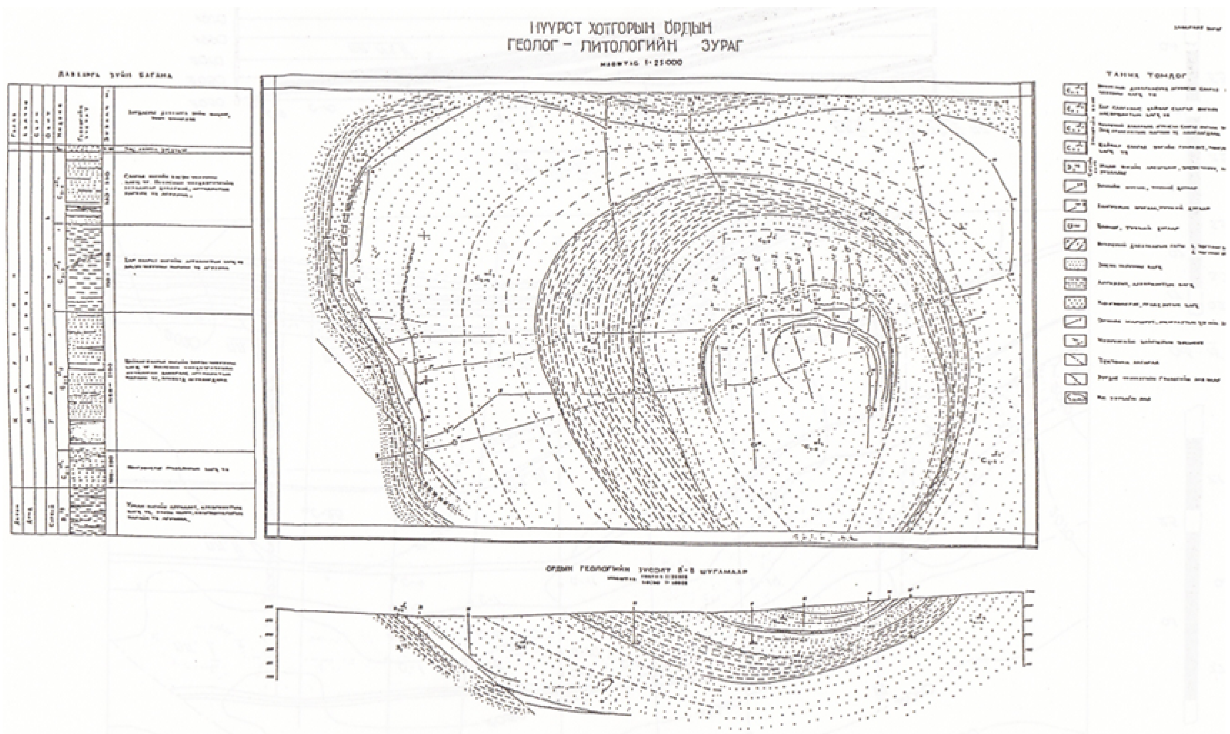


Figure 49: Geologic Map of the Nuurst Khotgor Coal Deposit

There are a total of eight named coal seams, Seam I through Seam VIII, named in ascending order. Seam I and Seam II are restricted within the west area, while Seams III through VIII occur in the east area (**Figure 50**). All the coal seams are characterized by variable thickness and splitting is common. In particular, the seams of the eastern part have a tendency to pinch out towards the south. The ranges of thicknesses of the eight seams are as follows:

Table 17: Nuurst Khotgor Coal Seam Thickness

Coal Seam	Thickness (m)
VIII	2.6 – 5.5
VII	1.1 – 6.2
VI	0.8 – 3.6

Coal Seam	Thickness (m)
V	0.2 – 4.0 (Eastern portion)
IV	1.1 – 24.5
III	1.6 – 7.4
II	12 – 13
I	30 – 50 (Western portion)

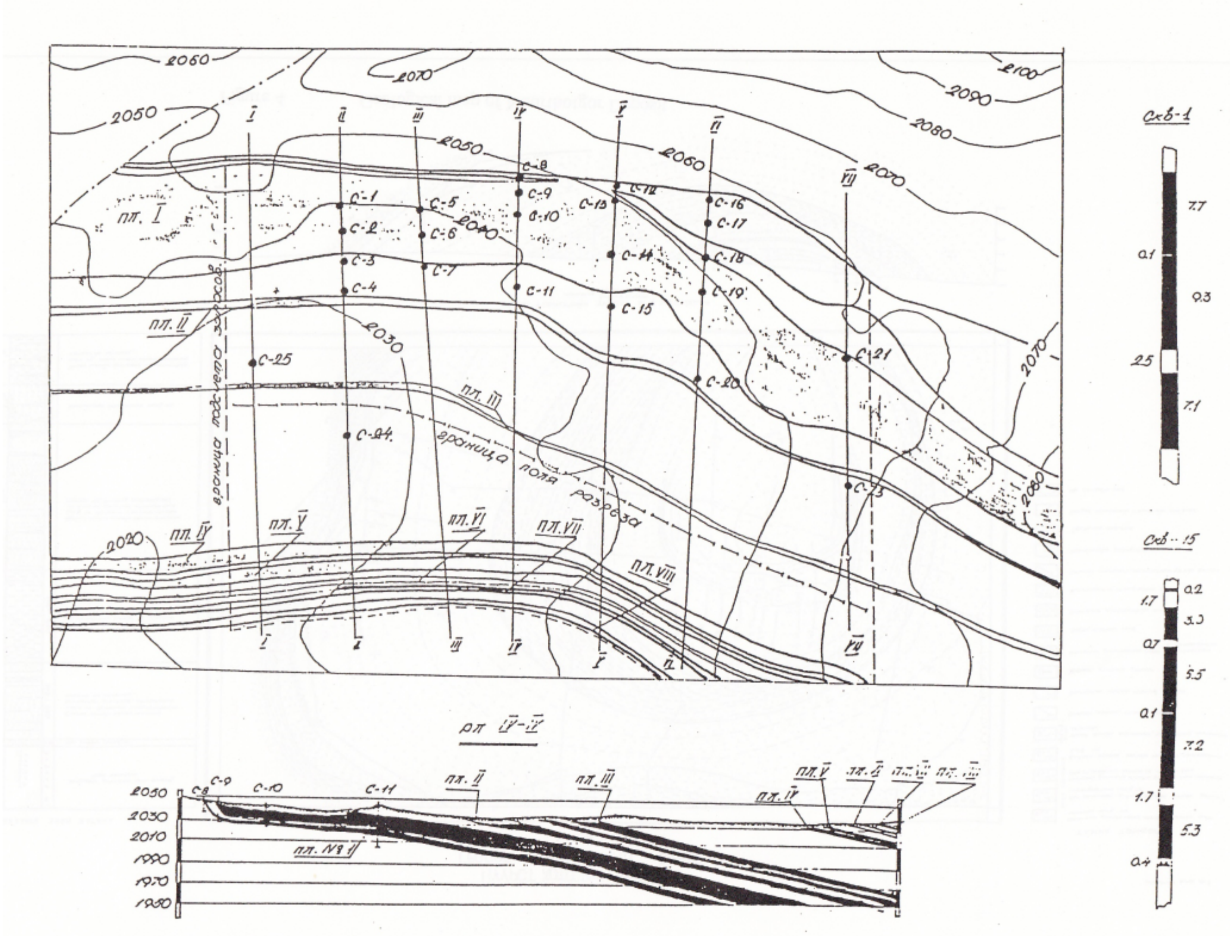


Figure 50: Nuurst Khotgor Coal Deposit Structure

1.4.3. Coal Resources

The mineable resources down to 100 m below the surface are estimated at 142.3 million tons (A + B + C1) and the geologic resources are 166.6 million tons (A + B + C1+ C2). According to a report in 1993, the geologic reserves (A + B + C1 + P1) above 300 m in depth are estimated at 1,918.3 million tons for the entire deposit. Geologic coal reserves within the licensed area (# 12474A) of MCJT Company (by A-B-C1-C2 categories) are estimated to be 64.3 million tons, of which 16.4 million tons are mineable reserves within mine boundary.

1.4.4. Coal Quality

The coals are classified into D-G (Mongolia, Russia), or Subbituminous B to High volatile bituminous C (U.S.A) or Subbituminous E to Bituminous C (Japan -JIS). The coals contain 1.4-2.1% total moisture (as received), 19-36% ash (dry), 31-44% volatile matter (dry, ash free), and 0.3-0.5% total sulfur (dry). The average calorific value ranges from 5,400-6,100 kcal/kg (as received) and 7,560-8,430 kcal/kg (dry, ash free). Most of Nuurst Khotgor coals are regarded as a high quality bituminous coal with high calorific value and low sulfur contents. Average coal quality characteristics within the licensed area (# 12474A) are as follows:

Moisture content (Wa) – 1.8%, Ash content (Ad) – 22.9%, Volatile matter (Vdaf) -31.38%, Calorific value – 6304 kcal/kg.

1.4.5. Coal Mining Situation

The Nuurst Khotgor Coal Mine began operating as an open cut mine in the Khotgor field in 1963. The mine has produced a total of 4.2 million metric tons of coal until it ceased operations in 2013. The coal was utilized by local consumers of the Bayan-Olgii and Uvs Provinces. Presently, mine operations are undertaken in three coal fields (Khotgor, Khotgor Shanaga and Erchim) by different companies. **Figure 51** is a photo of mining operations within the Khotgor field.

Figure 51: View of Mining Operations at Khotgor Field

Korea Coal Corporation (KOCOAL), a state-run coal mine developer, purchased a 51 percent stake in the Khotgor Shanaga coal mine for $10 million US and will invest an additional $18.1 million US in mine operations. The mine has a soft coal reserve of 79 million tons and plans to produce up to 1 million tons of coal annually. The mine, operated by Mongolian-Korean Joint Venture Company, is scheduled to produce 410 thousand tons of coal in 2013. A portion of that production is planned for export to Russia.

KOCOAL was established in 1950 as a government-owned coal company to manage coal mines. Its mission has been further increased with coal export and import businesses, including foreign coal mine development. The company currently operates three domestic coal mines, producing approximately 1.2 million tons annually.

The oldest Khotgor mine will produce 120 thousand tons of coal in 2013 while the Erchim Mine has planned to produce 25 thousand tons.

1.5. Sharyn Gol

1.5.1. Location

The Sharyn Gol coal deposit is located in the territory of Darkhan Soum in Darkhan - Uul Province. The deposit sits approximately 70 km east of Darkhan city, one of the main stations along the Trans-Mongolian Railway (**Figure 52**).

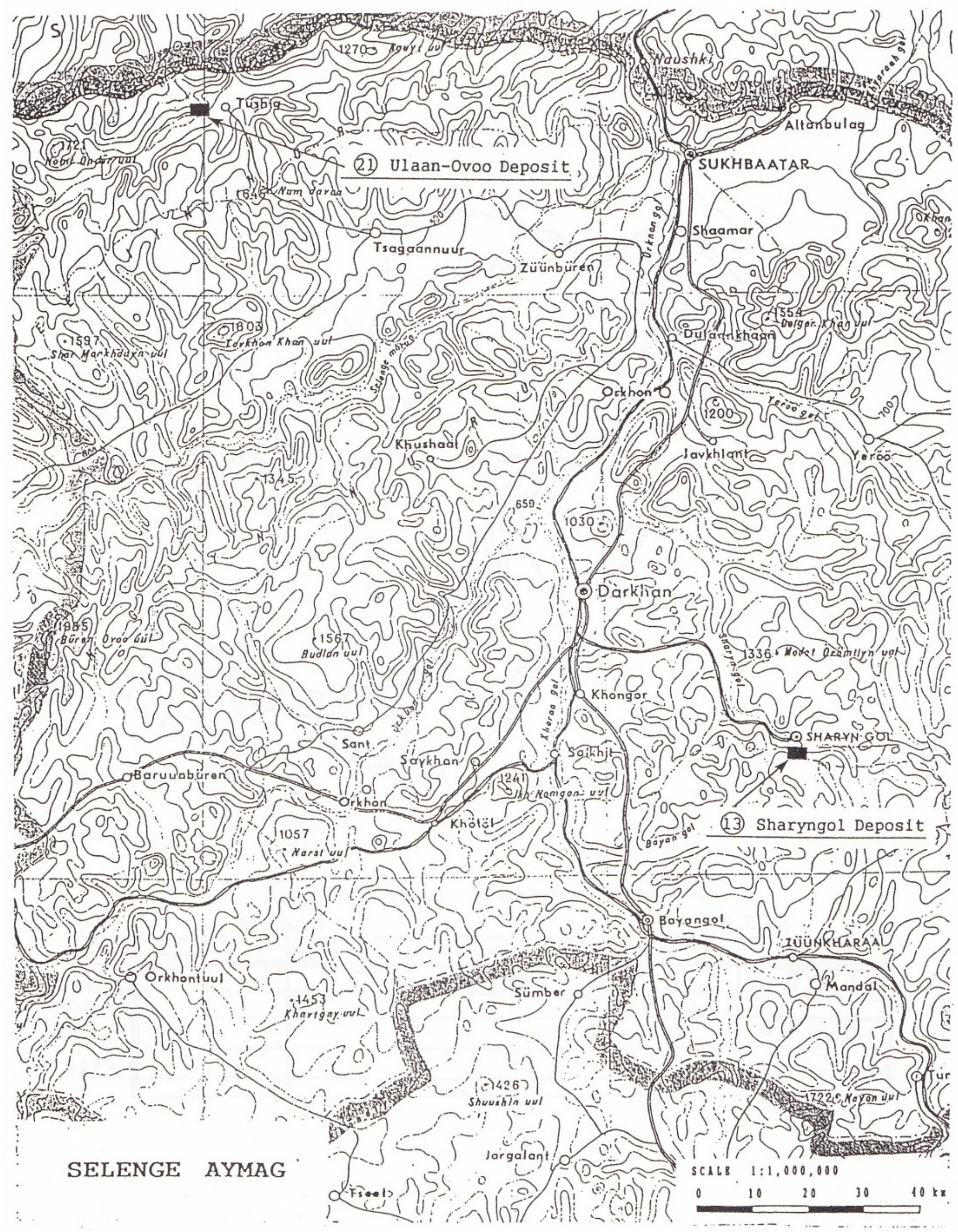


Figure 52: Location Map of Sharyn Gol Coal Deposit

The center of the deposit is positioned at N 49° 12' latitude and E 106° 27' longitude. The surface expression of the deposit forms a forestall hill, where the highest elevation is 975 m above the sea level and the lowest is 790 m.

1.5.2. Geologic Setting and Coal Geology

Table 18: Exploration History of the Sharyn Gol Coal Deposit

1963-1968	Detailed drilling exploration, 59 boreholes for a total of 9,280 m
1965-1974	Additional detailed drilling exploration, 157 boreholes for a total of 10,741 m
1976-1978	Additional detailed drilling exploration, 59 boreholes for a total of 8,237 m

1984 Coal prospecting conducted in Sharyn Gol area

2010-2011 Completion of operational exploration and evaluation of Micromine company at Shaazgait field. 15.5 Mt of B coal reserves, 63.9 Mt of C coal reserves, 44.9 Mt of P coal reserves were evaluated. Mineable coal reserves of 23.1 Mt within the licensed area.

The Sharyn Gol coal deposit occurs within the Orkhon Selenge coal-bearing basin. The deposit extends for 3 km northeast and 1.5 km northwest and covers an area of about 4.5 km^2. The coal bearing formation is the Sharyngol Formation of Middle-Late Jurassic age, which lies on the basement of Carboniferous sediments. The Sharyngol Formation has ranges in thickness from 420-500 m and contains six coal seams (**Figure 53**). The deposit is divided by faults into three areas: the main area which has been mined, the northeast area, and the west area. The basic geologic structure is a gentle monoclinal structure. The coal seams strike N 60° W and dips 6-9° SW at the main and northeast areas. At the west area, the seams trend east-northeast and dip southeast.

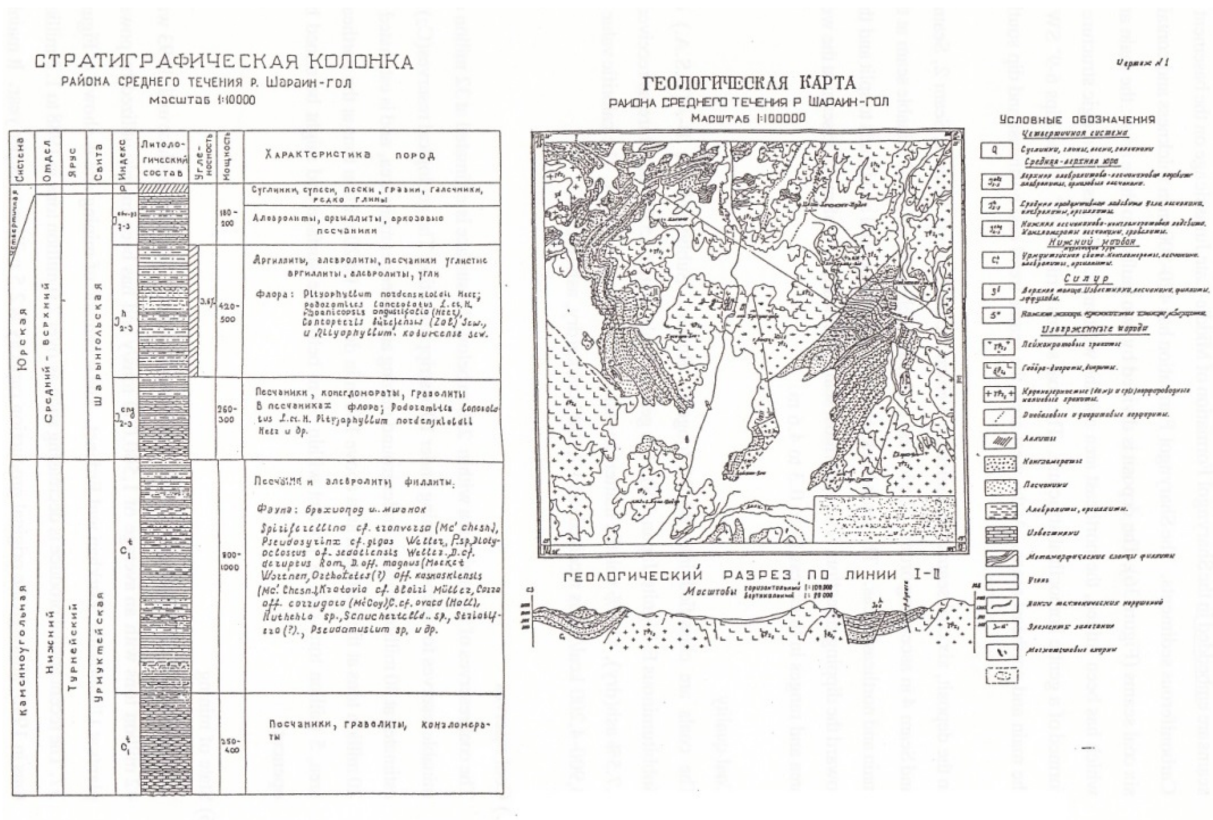


Figure 53: Geologic Map of the Sharyn Gol Coal Deposit

The deposit contains six named coal seams, the Velikan Seam, Seam 0, Seam 1, Seam 2, Seam 3 and Seam 4. The lowest seam, the Velikan Seam, is mineable in the main and northeast areas. In general, the seam ranges in thickness from 30-40 m and tends to split and thin down dip (**Figure 54**). The uppermost seam, Seam 4, is mineable in the west area and ranges in thickness from 0.3 to 4.6 m.

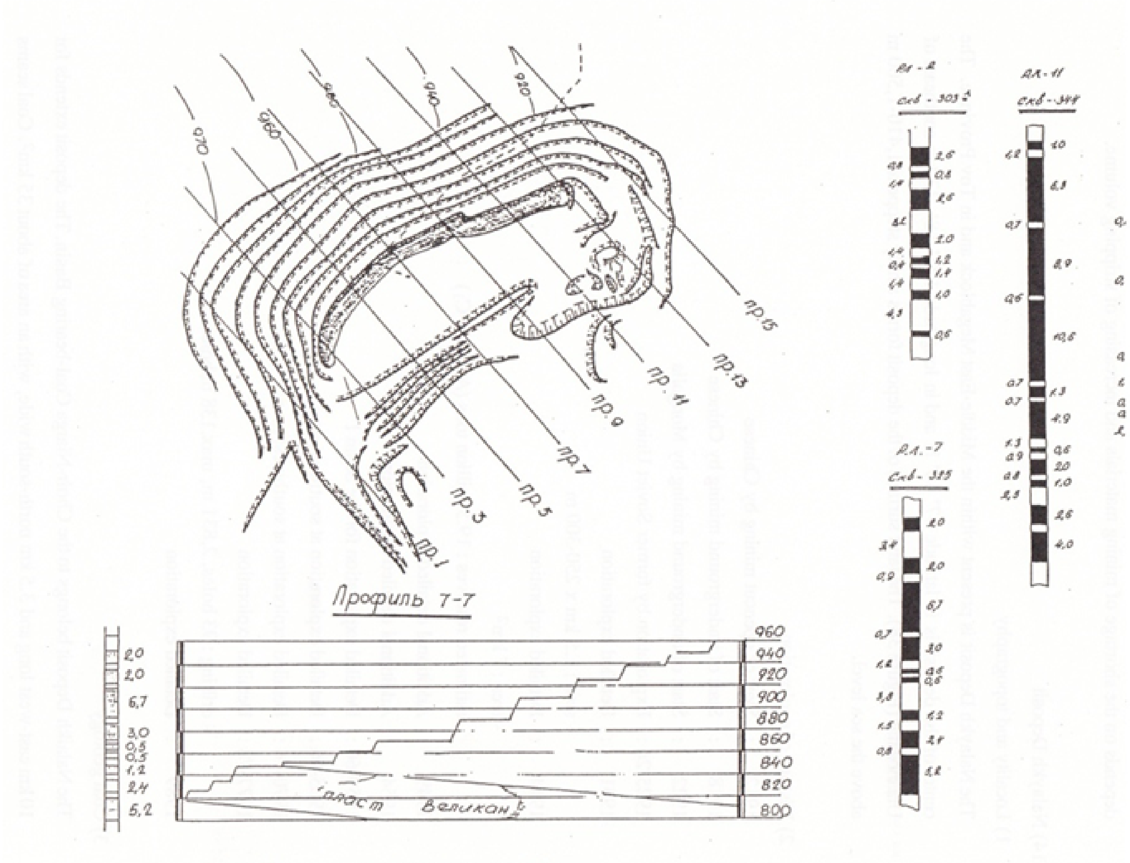


Figure 54: Coal Seam Structure of Sharyn Gol Coal Deposit

1.5.3. Coal Resources

The mineable coal reserves found in the main area, down to a depth of 250 m below is estimated to be 32 million metric tons. For underground mining at the deeper main area, the geologic reserves (C2) are estimated at 30 million tons, and estimated at 20 million tons at the northeast area above 150 m of depth. Of 20 million tons in the northeast area, 5 million tons of coal are present to a depth of 50 m and have the potential to be mined using surface mining methods.

1.5.4. Coal Quality

The coals are classified into B3-D (Mongolia, Russia), Subbituminous B-A (U.S.A.) or Subbituminous E-Lignite (Japan-JIS). Generally, the coals contain 15.0% moisture (as received), 17.5% ash (dry), 41.0% volatile matter (dry, ash free), and 0.6% sulfur (dry). The calorific value ranges between 3,900-4,200 kcal/kg (as received) and 7,200 kcal/kg (dry, ash free).

1.5.5. Coal Mining Situation

The Sharyn Gol mine is the oldest coal mine in Mongolia, with over 45 years of continuous production history. The mine began its open pit operation in 1965. Produced coal has been utilized mainly by power plants in Ulaanbaatar, Darkhan and Erdenet. Although the original production capacity was 2.5 million tons per year, the recent annual production has been on the decline, with 465 thousand tons produced in 2012, and a production plan for 2013 of 900 thousand metric tons. **Figure 55** is a photo of the operations at the Sharyn Gol mine.

Figure 55: View of Mining Operations at Sharyn Gol Mine

The Sharyn Gol mine was privatized on the Mongolian Stock Exchange in 2003. Firebird acquired a controlling position in 2010 and led a complete overhaul of the company, including a 17,000 meter drilling program, resulting in the identification of 374 million tons of coal resources in a JORC-compliant resource statement. Recently, Sharyn Gol JSC received the government approval required for the launch of operations at its planned new open pit.

Sharyn Gol is strategically situated on a rail spur connecting to the Trans-Mongolian Railway. As the only significant supplier of high quality thermal coal, Sharyn Gol can take advantage of growing domestic demand in the Darkhan province and throughout the region. The rail connection also offers the company the option to consider exports to Russia and into the international market through Russian ports. Laboratory tests demonstrated that Sharyn Gol coal can be washed efficiently into a premium export quality coal.

1.6. Nalaikh

1.6.1. Location

The Nalaikh coal deposit is located in the territory of Nalaikh District of Ulaanbaatar City. Nalaikh is one of nine districts of Ulaanbaatar City and is located approximately 36 km east of Ulaanbaatar (**Figure 56**).

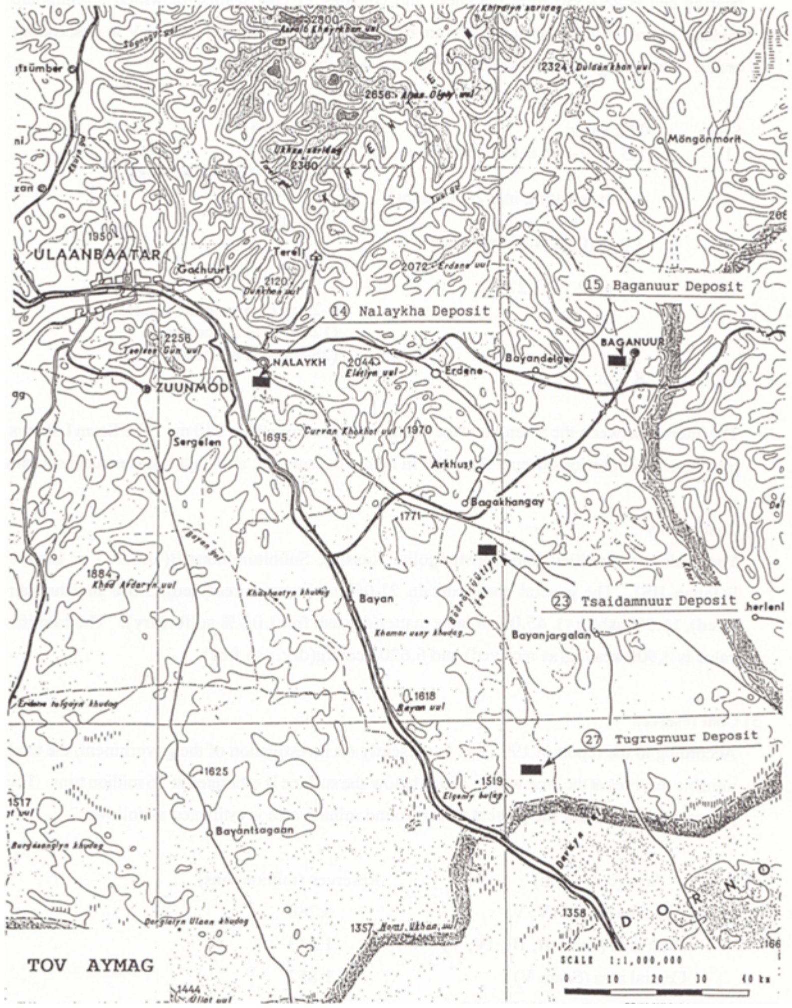


Figure 56: Location Map of Nalaikh Coal Deposit

The Nalaikh coal deposit lies within the forest steppe region, where the average winter temperature ranges between -20C and - 26C and the average summer temperature ranges between 23C and 26C. The Nalaikh District borders the Bayanzurkh District, Sergelen and Erdene Soums in the Tuv Aimag. The total population is 27,000 making it the seventh largest district by population size. The total area is 68.7 thousand square hectares, where 41.1 percent of its area is classified as state special protected area. The coal deposit is connected to Ulaanbaatar by paved road and the network of the Central Electric System.

1.6.2. Geologic Setting and Coal Geology

Table 19: Exploration History of the Nalaikh Coal Deposit

1925-1926	First geologic exploration and 1:10,000 scale mapping conducted by Russian geologist, Lokeshev
1931	Russian geologist, Maklelader, conducted drilling exploration of 2 boreholes, totaling 99.6 m and 132.6 m
1945-1948	Additional Russian exploration of 1:5,000 scale geologic mapping covering 14 km^2 areas, with 5 boreholes

1952-1954	Additional exploration work conducted by Mongolian team
1954	Report of preliminary exploration by Volokiv
1955	Report of all join exploration by Nikolaev
1959	Drilling of 27 shallow (10-50 m) exploration boreholes
1965-1966	Additional drilling exploration with hydrogeological and geophysical surveys
1970-1976	Additional detailed drilling exploration, 97 boreholes, hydrogeological surveys and 1:5,000 scale topographic mapping
1991-1992	Detailed exploration by Central Geological Expedition, Mongolia

The Nalaikh coal deposit occurs within the Orkhon Selenge coal-bearing basin. Its surrounding sediment deposits comprise Devonian, Carboniferous, and lower Cretaceous, Tertiary and Quaternary stage deposits. The Devonian stage sediments are outcropped in the east, and the rimming hills that surround the Nalaikh basin on the south. The total thickness of these interbedded siltstone and sandstone sediments are 2,500 to 3,000 meters. The Carbonaceous sediments are found along the hills that of the western and northern portion of the basin. Theses sandstone to argillaceous schist sediments range from 1,500 to 2,500 meters in thickness. The Cretaceous stage sediments, deposited atop an angular unconformity, are broken into the lower argillaceous schist and the upper coal bearing zone. The lower zone sometimes contains thin coal beds toward the top of the deposit, and ranges in thickness between 300 to 350 meters. The upper Cretaceous sediments are composed of conglomerates and gravely sandstones near the base, with some coaly lenses present in the middle of the course grained sediment. The sediments fine upward, and 12 coal seams are found in the deposit. The II, III, IV and V coal seams are the main coal beds that contain production resources. The total thickness of the upper coal-bearing zone of the Cretaceous sediments are 280 to 350 meters. The Nalaikh basin is an intermontane depression, where the basin structure was developed during the middle Paleozoic and filled by coal-bearing sediments during the Cretaceous. The coal-bearing sequence has a monoclinal structure which stretches in a SE to NW direction, dips to the SW and is sheared by numerous tectonic faulting.

Nalaikh is an old mining area of Mongolia, which dates back to the 1900's. An underground coal mine was operated for many years there (**Figure 57**).

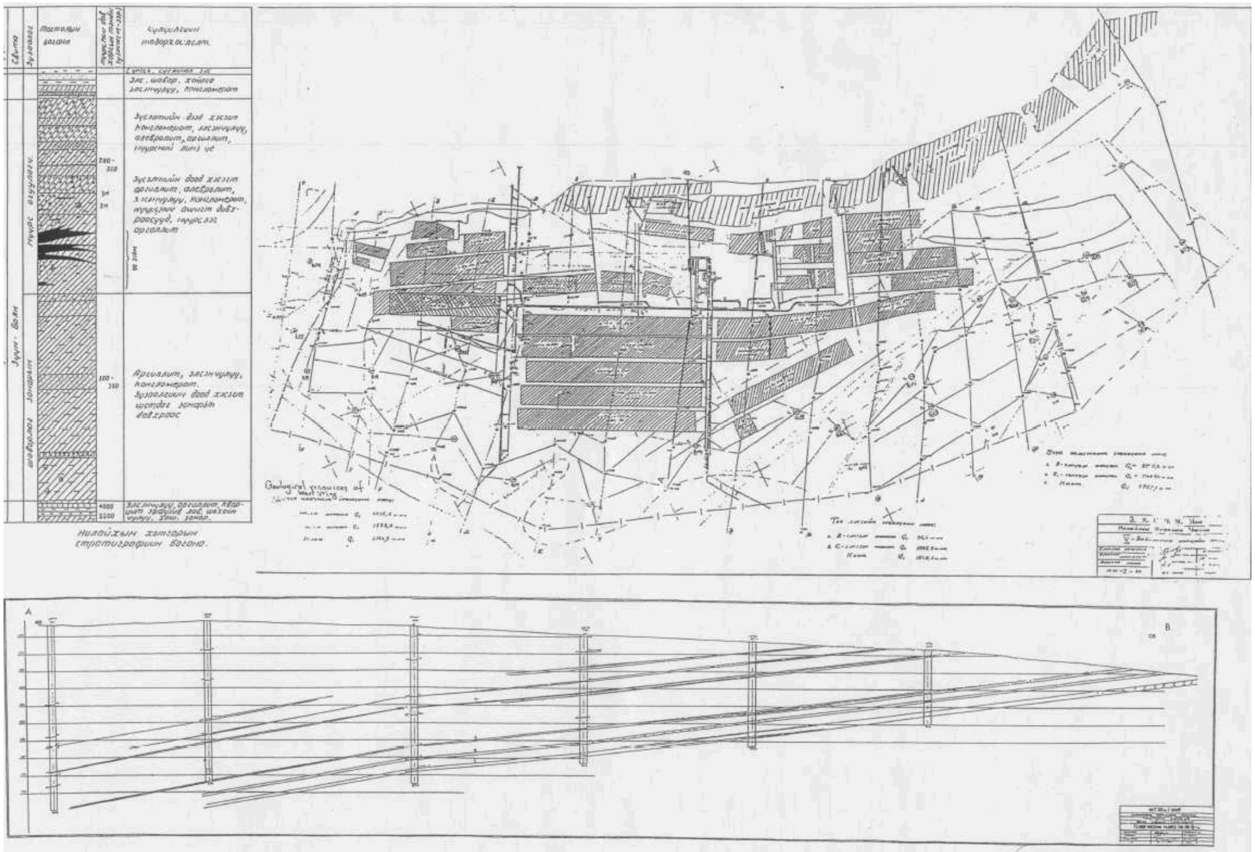


Figure 57: Former Underground Mining Plan of the Nalaikh Deposit.

1.6.3. Coal Resources

According to the latest detailed exploration of 1991 – 1992, the total coal resources within the deposit were estimated at 76.2 million metric tons, of which 21.5 million tonnes within the A + B categories, and 54.7 million tonnes in the C_1 category. According to the Russian and Mongolian classifications, the total coal resources are divided into two groups: the balance and non-balance resources. All balance resource total 58.8 million tonnes, comprising 20.5 million tonnes within the A + B categories and 38.4 million tonnes in the C_1 category. Resources within the mine boundary comprise 32.3 million tonnes of reserves, including 18.7 million tonnes within the A + B categories and 13.5 million tonnes in the C_1 category. The non-balance resources total 17.3 million tonnes, of which 1.0 million tonnes are from the B category and 16.3 million tonnes are from the C_1 category. Forty-three percent of coal resources of the Nalaikh deposit are within the II, IV and V coal seams.

1.6.4. Coal Quality

According to the laboratory analyses carried out during the latest exploration (1991 – 1992) as well as other research performed, the average coal quality characteristics are shown below in **Table 20**.

Table 20: Coal Quality at Nalaikh Mine

Source	Ash	Total Moisture	Volatile Matter	Sulfur	Calorific Value
1991-1992 Exploration	**18%**	**24.6%**	**47.3%**	**0.75%**	**6535 kcal/kg**
Other Research	**21.1% (As received)**	**17.9%**	**45.7%**	**0.9%**	**6620 kcal/kg**

The chemical composition of the coal was also sampled during other research analyses, and is as follows:

- Hydrocarbons (C) 71.6%
- Hydrogen (H) 4.8%
- Nitrate (N) 1.1%
- Oxygen (O) 22.5%

1.6.5. Coal Mining Situation

Small shallow depth mining at coal outcrops at Nalaikh began in 1922, for the purpose of supplying coal to customers of the capital city of Ulaanbaatar. In 1954 – 1958, the larger underground mining operations were established with the production capacity of 600 thousand tonnes annually. By 1987, the mine reached full capacity, producing 800 thousand tonnes per year. Mining operations ceased in 1993, due to economic difficulties.

After the formal closure of the underground mine, the masses of freshly unemployed and skilled miners turned to illegal mining of the Nalaikh deposit. With nearly 200 shafts and five to ten workers per shaft, there are roughly 2,500 miners working the area during the peak season between September and May. The shafts are dug haphazardly, with little to no coordination between shafts. Mining dangers, such as cave-ins, are becoming more frequent. **Figure 58** depicts some of the small coal mines at the Nalaikh deposit. **Figure 59** and **Figure 60** show the entryway and mining tunnel at one of these mines.

Figure 58: Small Coal Mines at Nalaikh

Figure 59: View of Mine Shaft

Figure 60: View of Shaft Face

With the concern over the increased number of accidents, the government has attempted to regain some control over operations, and is contemplating declaring a freeze over all coal mining at Nalaikh. However, miners are unlikely to abandon their sites, unless they are given a viable alternative to earning a living.

Appendix 2: Data Tables

2.1. Coal Deposit Proximate Analysis

Deposit	Fixed Carbon % (d.m.m.f.)				Volatile Matter % (d.m.m.f.)				Calorific Value - BTU (m.m.m.f.)				Rank			
	USGS		Bayarsaikhan		USGS		Bayarsaikhan		USGS		Bayarsaikhan		USGS (A.S.T.M.)		Bayarsaikhan	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Aduunchuluun	52.0	52.7	51.9	51.9	47.3	48.0	48.1	48.1	5,594	7,426	5,129	5,132	ligB	ligA	ligA	ligA
Baganuur	53.6	54.0	55.4	55.4	46.0	46.4	44.6	44.6	8,479	8,590	6,983	7,642	subC	subC	subC	subC
Bayanteeg	50.2	53.5	48.1	48.1	46.5	49.8	51.9	51.9	13,477	13,541	11,070	11,072	hvBb	hvBb	subB	subA
Chandgan	52.8	53.9	53.5	53.5	46.1	47.2	46.5	46.5	7,316	7,640	6,049	6,867	ligA	ligA	subC	subC
Khartarvagatai	72.6	74.1	54.3	60.7	25.9	27.4	39.3	45.7	13,472	13,514	11,745	13,322	mvb	mvb	subB	hvCb
Khusheet	80.4	81.7	75.8	77.5	18.3	19.6	22.5	24.2	13,474	14,456	10,931	14,800	lvb	lvb	subB	hvCb
Khuut	-	-	57.0	57.0	-	-	43.0	43.0	-	-	8,620	8,623	-	-	subB	subA
Mogoingol	66.3	67.6	65.2	65.6	32.4	33.7	34.4	34.8	15,041	15,173	11,706	12,345	hvAb	hvAb	subB	hvCb
Nalaykha	50.4	53.3	55.0	55.0	46.7	49.6	45.0	45.0	8,741	8,820	8,440	8,442	subC	subC	subB	subB
Naryn uhait	62.3	75.1	60.8	71.3	24.9	37.7	28.7	39.2	14,494	14,548	14,266	14,266	hvAb	mvb	hvCb	an
Nuurst khotgor	-	-	58.8	66.5	-	-	33.5	41.2	-	-	9,137	14,666	-	-	subB	hvCb
Saihan Ovoo	53.5	54.7	69.0	82.6	45.3	46.5	17.4	31.0	12,912	13,477	14,350	13,844	hvCb	hvBb	mvb	an
Sharyngol	51.9	60.4	55.0	55.0	39.6	48.1	45.0	45.0	10,571	11,114	9,115	9,821	hvCb	hvCb	subB	subA
Shivee Ovoo	50.0	53.0	54.3	54.3	47.0	50.0	44.0	45.7	6,490	6,652	5,854	7,083	ligA	ligA	subC	subC
Talbulag	50.9	51.2	53.0	53.0	48.8	49.1	47.0	47.0	6,257	6,337	5,921	5,924	ligB	ligA	ligA	ligA
Tavantologoi	64.3	69.8	66.7	67.7	30.2	35.7	32.3	33.3	14,914	14,959	10,941	11,748	hvAb	mvb	hvCb	lvb
Tevshiin govi	-	-	54.5	54.5	-	-	45.5	45.5	-	-	7,575	7,579	-	-	subC	subC
Ulaan-Ovoo	-	-	54.0	54.0	-	-	46.0	46.0	-	-	8,650	8,651	-	-	subB	subA
Uvdug khudag	-	-	54.5	55.5	-	-	44.5	45.5	-	-	6,362	6,348	-	-	subC	subC
Uvurchuluut	-	-	51.4	62.4	-	-	37.6	48.6	-	-	6,668	8,311	-	-	subB	hvCb
Zeegt	62.1	63.7	65.7	70.3	36.3	37.9	29.7	34.3	11,429	13,198	10,955	10,609	hvCb	hvBb	hvAb	hvAb

Table 21: Mongolian Coal Deposit Proximate Analyses and Rank (USGS and Bayarsaikhan)

2.2. Emission Factor Tables

Table 22: p10 Emission Factors by Depth

Basin	Rank	30 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m
Central Gobi	Lignite	0.01	0.02	0.03	0.04	0.22	0.38	0.52	0.64	0.76	0.86
	Subbituminous	0.02	0.04	0.06	0.08	0.46	0.79	1.07	1.32	1.56	1.78
Choibalsan	Lignite	0.07	0.14	0.28	0.40	0.52	0.62	0.72	0.82	0.92	1.01
Choir-Nyalga	Lignite	0.03	0.06	0.09	0.12	0.29	0.43	0.56	0.68	0.79	0.90
East Gobi	Subbituminous	0.01	0.02	0.03	0.04	0.22	0.38	0.52	0.64	0.75	0.86
Ikh Bogd	Subbituminous	0.03	0.06	0.09	0.11	0.49	0.81	1.09	1.34	1.58	1.79
	Bituminous	0.10	0.19	0.27	0.36	1.56	2.55	3.42	4.20	4.92	5.59
Kharkhiraa	Bituminous	0.26	0.50	1.59	2.47	3.25	3.97	4.63	5.26	5.86	6.44
Mongol-Altai	Bituminous	0.28	0.54	1.62	2.49	3.27	3.98	4.64	5.27	5.87	6.44
Ongi River	Subbituminous	0.04	0.07	0.10	0.14	0.51	0.83	1.10	1.35	1.59	1.80
	Bituminous	0.12	0.23	0.33	0.43	1.62	2.61	3.47	4.24	4.96	5.62
Orkhon-Selenge (North)	Bituminous	0.28	0.54	1.62	2.49	3.27	3.98	4.64	5.27	5.87	6.44
	Anthracite	0.60	1.12	3.23	4.85	6.21	7.40	8.46	9.43	10.31	11.13
Orkhon-Selenge (South)	Subbituminous	0.06	0.12	0.48	0.76	1.01	1.24	1.46	1.67	1.86	2.05
South Gobi	Subbituminous	0.04	0.08	0.12	0.15	0.52	0.84	1.11	1.36	1.59	1.81
	Bituminous	0.13	0.25	0.37	0.48	1.66	2.64	3.50	4.27	4.98	5.64
Southern Khangai	Bituminous	0.14	0.28	1.45	2.36	3.16	3.89	4.57	5.21	5.81	6.39
Sukhbaatar	Lignite	0.01	0.02	0.03	0.05	0.23	0.38	0.52	0.64	0.76	0.87
Tamsag	Subbituminous	0.09	0.18	0.51	0.79	1.03	1.26	1.48	1.68	1.88	2.06
Trans-Altai	Bituminous	0.11	0.22	0.32	0.41	1.60	2.59	3.45	4.23	4.95	5.61

Table 23: p90 Emission Factors by Depth

Basin	Rank	30 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m
Central Gobi	Lignite	0.01	0.01	0.02	0.02	0.14	0.23	0.31	0.37	0.43	0.48
	Subbituminous	0.02	0.03	0.04	0.05	0.29	0.48	0.63	0.75	0.86	0.96
Choibalsan	Lignite	0.05	0.10	0.19	0.27	0.33	0.39	0.45	0.50	0.54	0.58
Choir-Nyalga	Lignite	0.02	0.04	0.06	0.08	0.18	0.27	0.34	0.40	0.46	0.51
East Gobi	Subbituminous	0.01	0.01	0.02	0.02	0.14	0.23	0.31	0.37	0.43	0.48
Ikh Bogd	Subbituminous	0.03	0.05	0.06	0.08	0.31	0.49	0.64	0.76	0.87	0.97
	Bituminous	0.14	0.24	0.33	0.40	1.54	2.41	3.10	3.68	4.17	4.60
Kharkhiraa	Bituminous	0.37	0.66	1.87	2.72	3.40	3.95	4.43	4.84	5.20	5.53
Mongol-Altai	Bituminous	0.40	0.70	1.90	2.75	3.41	3.97	4.44	4.85	5.21	5.53
Ongi River	Subbituminous	0.17	0.30	0.40	0.49	1.61	2.47	3.15	3.73	4.21	4.63
	Bituminous	0.03	0.06	0.08	0.10	0.33	0.50	0.65	0.77	0.88	0.97
Orkhon-Selenge (North)	Bituminous	0.40	0.70	1.90	2.74	3.41	3.97	4.44	4.85	5.21	5.53
	Anthracite	0.92	1.64	4.48	6.53	8.16	9.52	10.69	11.71	12.62	13.44
Orkhon-Selenge (South)	Subbituminous	0.05	0.10	0.35	0.52	0.67	0.79	0.89	0.99	1.07	1.14
South Gobi	Subbituminous	0.19	0.33	0.45	0.55	1.66	2.50	3.18	3.75	4.24	4.65
	Bituminous	0.03	0.06	0.09	0.11	0.33	0.51	0.66	0.78	0.88	0.98
Southern Khangai	Bituminous	0.21	0.37	1.67	2.58	3.28	3.86	4.34	4.77	5.14	5.47
Sukhbaatar	Lignite	0.01	0.02	0.02	0.03	0.14	0.23	0.31	0.38	0.43	0.49
Tamsag	Subbituminous	0.08	0.14	0.37	0.55	0.69	0.80	0.91	1.00	1.08	1.15
Trans-Altai	Bituminous	0.16	0.28	0.38	0.47	1.59	2.45	3.14	3.71	4.20	4.62

Attachment 1: CMM Emissions Inventory Working Group Report

By Dr. Namkhainyam, Mongolian University of sciences and technology
Dr. M. Badarch, Mongolian nature and Environment consortium

MONGOLIAN SURFACE MINES EMISSIONS ASSESSMENT

2013

ACKNOWLEDGEMENT

Executive Summary

A history of coal mining sector has begun its development since 1935, in Mongolia. Then, an annual coal production was about only 10.4 thousand tones. The annual coal production was relatively stable, about 7.0-8.0 million tones between1980-2006. онд харьцангуй тогтвортой дундажаар 7.0-8.0 сая тонн байсан. The coal production has been increasing sharply since 2006. A bituminous type of coal was exported first time in 2001 and it leads to expansion of coal production by 4 times during 2006-2012.
There's almost 100 percent of coal mining is registered to open-pit (surface) coal mines. According the statistics, only 2.2 percent of total coal production is mined by underground mining (in Sharyn gol coal mine) in 2011.

There were conducted National Greenhouse gas Inventory 2 times (*ALGAS,1996; Mongolian Second National Communication, 2011*). GHG emissions are only estimated in these inventories until 2006. The coal production was low at that time. Methane emissions from activities of open-pit coal mines were too low and it was about 2 percent of total methane emissions.

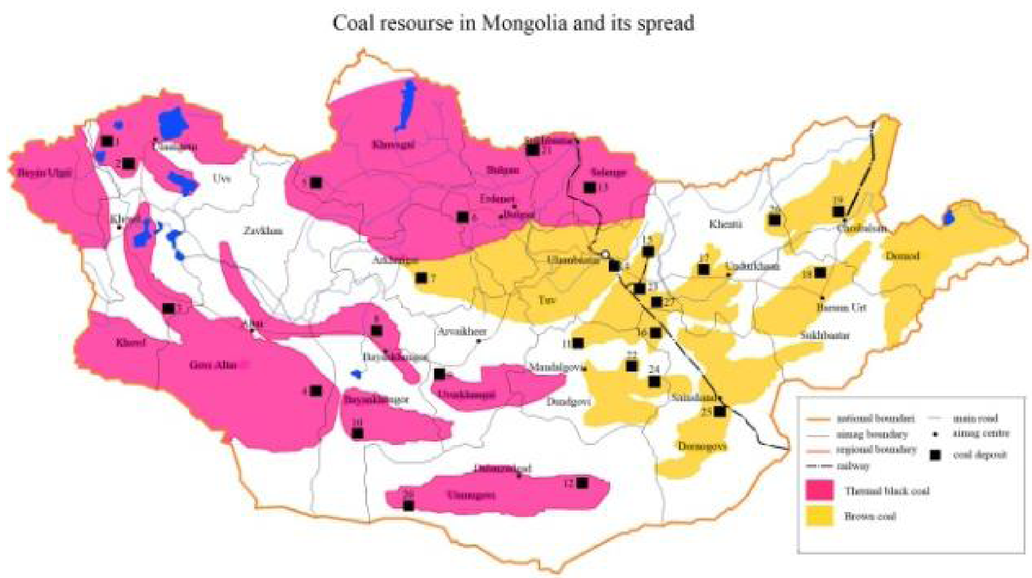
CH_4 emissions from coal mining and post-mining activities (underground and surface mining) – ыг Greenhouse Gas Inventory Guidelines, Workbook, Vol. 3, 1996-ын methodology ашиглан тооцсон.

The emission factors (m^3 CH_4/t) for Fugitive emissions from coal mining and handling are not clear in Mongolian present conditions. It's necessary to study and determine the emission factors (m^3 CH_4/t) for fugitive emissions from Mongolian surface (open-pit) coal mines, due growth of coal mining production. This project had a purpose to carry out them. The methane content of bituminous, sub-bituminous and lignite type of coal were estimated and these results were used in estimation of fugitive methane emission during the project.

1.1 COAL DEPOSITS AND ITS RESERVE IN MONGOLIA

Coal is the main energy source in the country. Mongolia is one of the ten countries in the world with the most coal reserve, and further exploration could increase its reserves. Mongolia has geological coal reserves of 150 billion tons in 300 deposits and occurrences in 15 coal basins, falling in 3 major regions. The preliminary and detailed exploration activities resulted in 22.3 billion tons of coal reserves. The proven coal reserves are 12.2 billion tons including 2 billion tons coking coal and 10.1 billion tons of brown coal.

Figure 1.1. Coal resource in Mongolia and its spread



1-Nuurst khotgor, 2-Khartarvagatai, 3-Khushuut, 4-Zeegt, 5-Mogoingol, 6-Saikhan ovoo, 7-Bayantsagaan, 8-Uvurchuluut, 9-Bayanteeg, 10-Shinejinst, 11-Tevshyngovi, 12-Tavantolgoi, 13-Sharyngol, 14-Nalaikh, 15-Baganuur, 16-Shivee ovoo, 17-Chandgan tal, 18-Talbulag, 19-Aduunchuluun, 20-Nariin sukhait, 21-Ulaan ovoo, 22-Khuut, 23-Tsaidam nuur, 24-Uvdug khudag, 25-Sainshand, 26-Khulst nuur, 27-Tugrug nuur [4]

The Mineral Resources Authority has revealed that around 50 organizations currently exploit coal in 36 mines. Two of these are state owned, three are owned by province administrations, and the remaining 45 are private companies.

1.2. Coal production of Mongolia

Монгол улсын нүүрсний олборлолтыг Figure 1.2 үзүүлэв Mongolia also has substantial proven reserves of coal, and annual coal production is presently about 7 million metric tons, almost all of which is used for steam and electricity generation.

Figure 1.2. Coal production, export and consumption by country, mln ton

Last years, the export of coal is growing. The export volume reached 70 percent of total coal mining production in 2011.

There are 12 basins of coal resources in Mongolia and their coal production is shown in table 1.1 and figure 1.3.

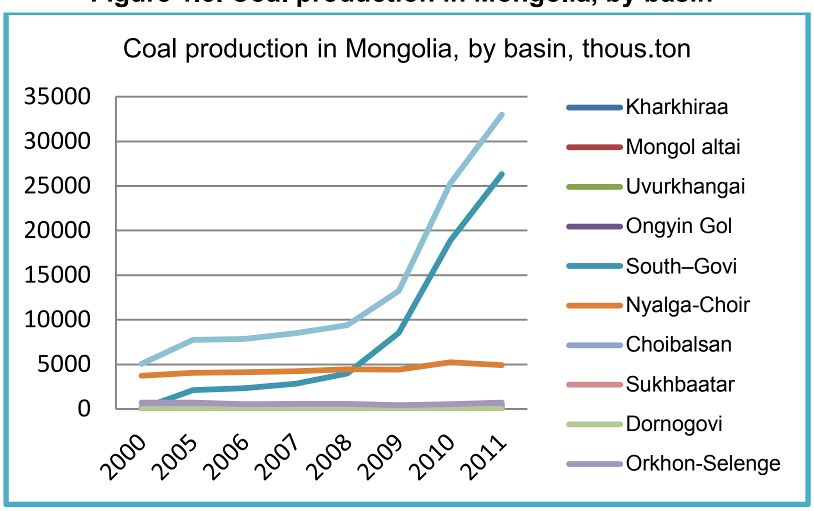
Table 1.1. Coal production, thousand MT

	5. Coal basins	Coal minies	Name of companies	2000	2005	2006	2007	2008	2009	2010	2011
1	Kharkhiraa	Nuurst khotgor Khartarbagatai	Nuurst khotgor, Ltd. Khartarbagatai Ltd	54.2 28.2	43.7 36.0	37.9 36.0	16.4 36.5	45.0 54.4	58.0 53.0	52.0 55.3	74.7 53.7
	total			**82.4**	**79.7**	**73.9**	**52.9**	**99.4**	**111.0**	**107.3**	**128.4**
2	Mongol altai	Khesheet Zeegt	Mo En Co Ltd.	0.0	13.5	0.0	0.0	0.0	0.0	0.0	435.4
3	Uvurkhangai	Uverchuluut	Baylag Ord Co Ltd.	0.0	0.0	0.0	0.0	12.0	36.0	0.0	4.2
4											
5	Ongyin Gol	Bayan-teeg	BayanTeeg LTD.Co	40.0	43.7	26.0	36.5	16.1	36.5	47.0	55.3
6	South–Govi	Tavantolgoi[5] Nariinsukhait Ovoo tolgoi Khotgor Erdenebulag	MAK + Sousgovi Ltd. Govi coal, Energy Bold Fo Ltd.	26.1 0.0 0.0 0.0 0.0	404.6 1724.3 0.0 0.0 0.0	787.1 1547.9 0.0 0.0 0.0	1686.2 1146.0 0.0 0.0 0.0	2174.3 1821.0 0.0 0.0 0.0	4564.9 2630.2 1327.6 0.0 1.7	9154.0 7254.6 2457.9 0.0 11.9	14215.5 7513.2 4574.7 5.3 23.0
	total			**26.1**	**2128.9**	**2335.0**	**2832.2**	**3995.3**	**8522.7**	**18866.5**	**26331.7**
7	Nyalga-Choir	Tevshiingovi	Tevshiingovi Ltd.Co	18.0	15.4	15.1	15.4	12.0	13.3	33.5	15.5

[5] Energy Resource LTd.Co+Erdes Tavan tolgoi+Tavan Tolgoi

		Baga-nuur Chandgan-tal Zaidam nuur Tugreg nuur Shivee Ovoo	Baganuur Ltd.Co Chandgan-tal Ltd.Co Tugreg nuur Ltd.Co Shivee Ovoo Ltd.Co	3066.0 30.7 0.0 603.3	2811.4 29.2 0.0 1200.3	2804.4 0.0 0.0 1306.7	2794.3 0.0 0.0 1415.0	3000.4 0.0 0.0 1450.6	3005.0 0.0 0.0 1403.2	3394.8 0.0 0.0 1807.2	3253.3 28.7 17.9 1586.3
	total			**3718.0**	**4056.3**	**4126.2**	**4224.7**	**4463.0**	**4421.5**	**5235.3**	**4901.7**
8	Dundgovi	Uvdeg Khudag Kheet	Buman elzii Ltd	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.0
9	Choibalsan	Aduun chuluun Khulst nuur		238.6	226.1	241.3	254.3	276.3	314.0	350.0	344.1
10	Sukhbaatar	Talbulag	Talbulag Ltd.Co	0.0	36.5	38.5	39.3	41.3	46.3	**47.2**	**49.5**
11	Dornogovi	Alag tolgoi	Chines Khar Alt	0.0	0.0	0.0	0.0	0.0	0.0	27.6	5.4
12	Tamsag										
13	Orkhon-Selenge	Ulaan ovoo Shariin-gol Saikhan ovoo Mogoin gol Nalaikh	Redhill Mongol Ilchit metal LTD.Co Mogoin Gol Ltd.Co	0.0 709.0 0.0 13.8 0.0	0.0 710.0 0.0 13.5 7.1	0.0 505.0 0.0 16.6 6.2	0.0 545.0 0.0 15.0 5.7	0.0 548.3 0.0 15.3 4.8	0.0 420.6 0.0 14.0 0.0	47.1 422.1 45.0 35.0 0.0	299.2 375.2 28.8 23.0 0.0
	Total			722.8	730.6	527.8	565.7	568.4	434.6	**549.2**	**726.2**
	TOTAL			**5067.3**	**7765.3**	**7863.9**	**8493.3**	**9409.2**	**13232.1**	**25296.6**	**32994.4**

Figure 1.3. Coal production in Mongolia, by basin



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The south govi coal basin produces 80 percent of total coal production.

The coal production is classified by its coal type and shown in tables 1.2 and 3, and figures 1.4 and 1.5. A bituminous type of coal was exported first time in 2001 and it leads to expansion of coal production by 4 times during 2006-2012.

Table 1.2. Coal production of Mongolia by type, thous.tn

	Type of coal	2000	2005	2006	2007	2008	2009	2010	2011
1	Bituminous	26.1	2128.9	2335	2832.2	3995.3	8522.7	18866.5	26331.7
2	Sub-Bituminous	845.2	867.5	627.7	655.1	695.9	618.1	703.5	1349.5
3	lignite	3956.6	4318.9	4406	4518.3	4780.6	4781.8	5660.1	5300.7

Now exported high quality, Sub-Bituminous and Bituminous from TavanTolgoi, Ukhaa Khudag and Nariinsukhait deposits to China. The government is projecting an expansion of coal export and development coal processing industry because of high quality, bituminous demand is low in Mongolia. Mongolia coal exported since 2003 and reached to 23.0 million tons in 2011.

Figure 1.4. Coal production in Mongolia, by type coal

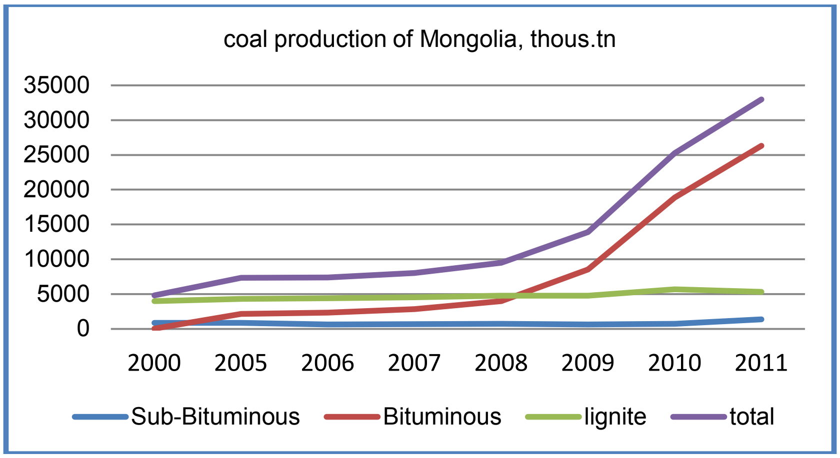

Figure 1.5. share of total coal production, by type 2011

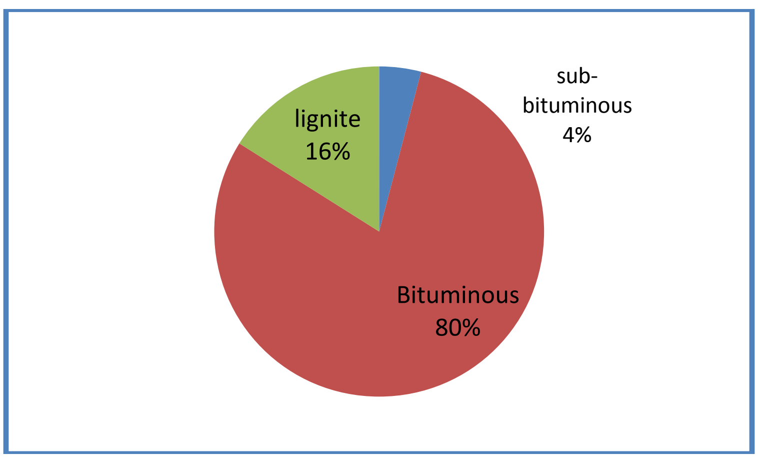

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Table1. 3 Coal production of Mines by type, thous.tn

	Coal basins	2000	2005	2006	2007	2008	2009	2010	2011
	Sub-Bituminous								
1	Kharkhiraa	82.4	79.7	73.9	52.9	99.4	111	**107.3**	**128.4**

2	Mongol altai	0	13.5	0	0	0	0	0	435.4
3	Uvurkhangai	0	0	0	0	12	36	0	4.2
5	Ongyin Gol	40	43.7	26	36.5	16.1	36.5	**47**	**55.3**
13	Orkhon-Selenge	722.8	730.6	527.8	565.7	568.4	434.6	**549.2**	**726.2**
	TOTAL	**845.2**	**867.5**	**627.7**	**655.1**	**695.9**	**618.1**	**703.5**	**1349.5**
	Bituminous								
6	South-Govi	**26.1**	**2128.9**	**2335**	**2832.2**	**3995.3**	**8522.7**	**18866.5**	**26331.7**
	Lignite								
	Nyalga-Choir	3718	4056.3	4126.2	4224.7	4463	4421.5	**5235.3**	**4901.7**
9	Choibalsan	238.6	226.1	241.3	254.3	276.3	314	350	344.1
10	Sukhbaatar	0	36.5	38.5	39.3	41.3	46.3	**47.2**	**49.5**
11	Dornogovi	0	0	0	0	0	0	27.6	5.4
	TOTAL	**3956.6**	**4318.9**	**4406**	**4518.3**	**4780.6**	**4781.8**	**5660.1**	**5300.7**

The bituminous and sub-bituminous type of coal production is 84 percent of total production. Also this trend will dominate in the future.

2. The methane volume in the coal mines in abroad[6]

Literature regarding gas contents of surface mined coal was researched for several countries and coal was distinguished by rank. (Figure 2.1). The U.S. average falls close to but below the overall average factor for each coal rank and appears low when plotted on the range of factors (Figure 2.2).

This parameter is not available for Mongolia.

Figure 2.1 - CH_4 Gas Contents by Country and Coal Rank

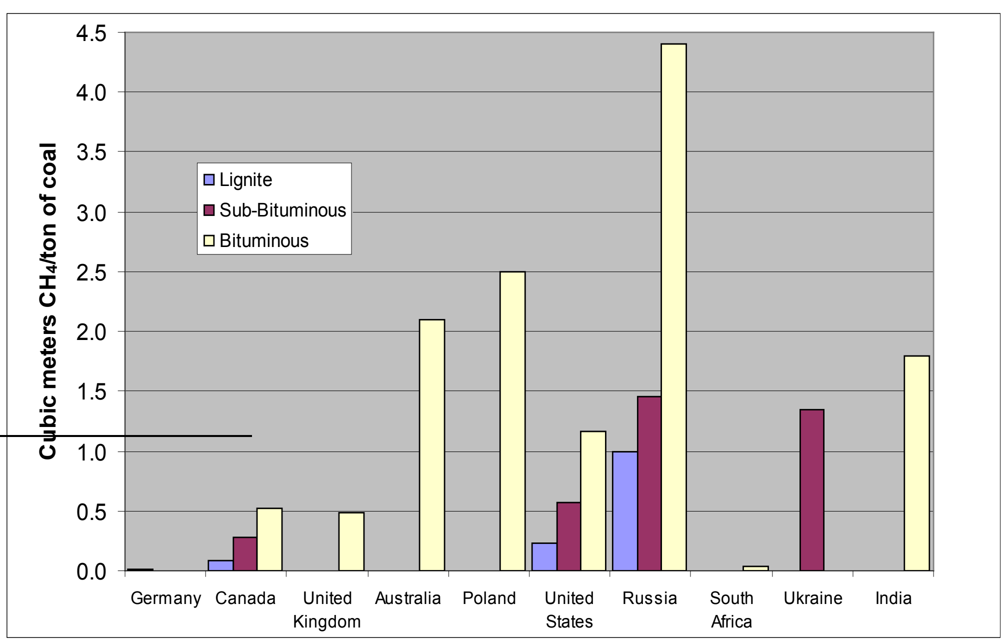


Figure 2.1 compares several average surface mining gas content values including the U.S. average based on new gas content values. Most emission factor data was obtained from National Communications to the UNFCCC. The range of values for South Africa was obtained from Lloyd, et al. Data for Russia was obtained by applying the appropriate coal ranks to the gas contents found in Izrael, et al. Kazakhstan information was taken from KazNIIMOSK, 2002.

Figure 2.2 - Range of Worldwide CH_4 Gas Contents by Coal Rank

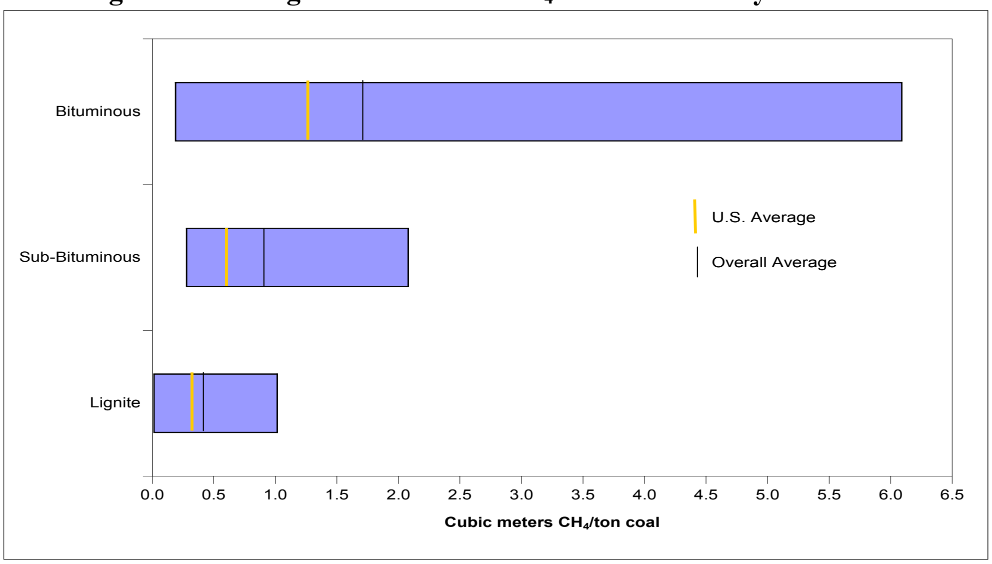


Figure 2.2 shows where the U.S. average surface mine gas contents fall within the range of worldwide gas contents for each coal rank. For all three coal types, the U.S. gas content is lower than the overall average. The ranges of gas contents by coal rank are shown in **Table 2.1**

Table 2.1 - Ranges and Values of CH_4 Gas Contents in m^3 CH_4 / ton of coal

	Lignite	Sub-Bituminous	Bituminous
Germany	0.015		
Canada	0.088	0.28	0.19 - 0.85
United Kingdom			0.49
Australia			1.0 - 3.2
Poland			2.5
United States	0.16 - 0.31	0.57	0.21 - 2.11

Russia	1.0	1.1 - 1.8	2.9 - 5.9
South Africa			0.002 - 0.064
Ukraine		1.35	
India			1.8

3. FUGITIVE METHANE EMISSIONS FROM COAL PRODUCTION OF MONGOLIA

7.

8. 3.1. Methane emissions from coal mining and handling activities

Coal mining and post-mining activities contribute to methane emissions as methane contained in the coal is released during coal mining activities. However, these emissions are not significant compared to methane emissions from agriculture, comprising only 1.6-3.5 per cent of all methane emissions.

Activity data: In Mongolia, working approximately 18 coal mining from where produced 5-6 million tones of coal per year. Most of the coal produces from surface and only 5% of total coal is mined as a underground. The mines are located 50-250 km far from main consumers and therefore, coal stored before delivery to consumers by train and car. Activity data are available from Statistical Year Book of Mongolia. However, separate data of underground and surface mining data were supplied from Energy Authority of Mongolia.
Methodology: The structure of the CH_4 emissions from coal mining (underground and surface mining) and post-mining activities (underground and surface mining) is (Greenhouse Gas Inentory Guidelines, Workbook, Vol. 3, 1996):

CH_4 emissions (Gg) = Coal production (10^6 t) x CH_4 Emission Factor (m^3 CH_4/ton coal) $\times$ Conversion Factor (Gg/10^6 m^3)

Emission factors: The emission factors (m^3 CH_4/t) used for coal mining and handling are selected as an average value given in IPCC guidelines.

Table 3.1. Emission factor in coal mining and handing

Category	*Methane Emission factor used for National inventory*			*Emission factor given in IPCC guidelines*
	Bituminous	***Sub-Bituminous***	***Lignite***	
Underground Coal: Mining: Post-mining:				 10.0-25.0 0.9-4.0
Surface coal: Mining Post-mining:	 2.2 0.1	 1.8 0.1	 1.4 0.1	 0.3-2.0 0.0-0.2

The methane emission from coal production is calculated with annual coal production of Mongolia (Table 1.2) and emission factor in coal mining and handing (Table 3.1).

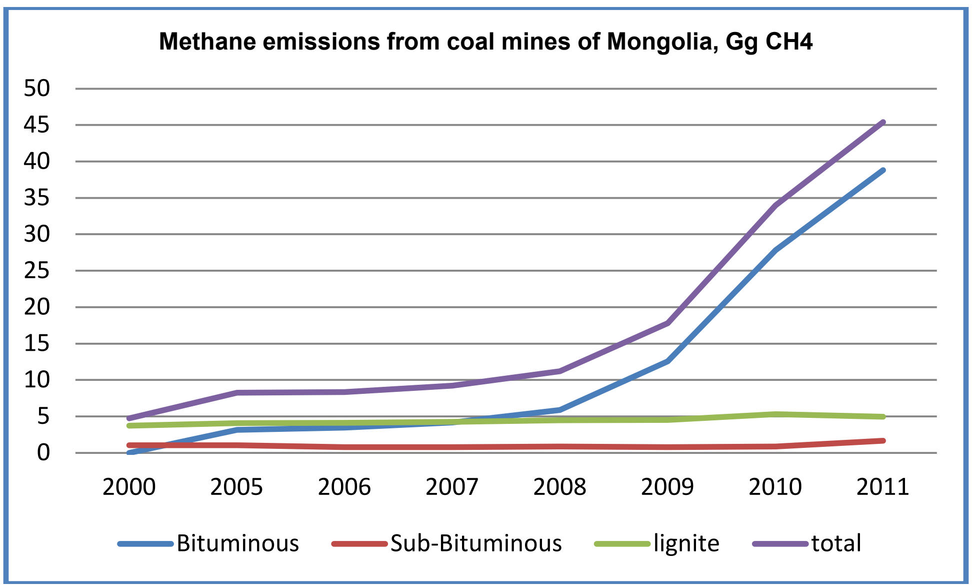
When methane emission factor of Mongolian coal mines to be defined, the values in table 3.2. can be calculated more accurately.

Table 3.2. Annual Methane Emission from Coal production of Mongolia, Gg CH_4

Draft

	Type of coal	2000	2005	2006	2007	2008	2009	2010	2011
1	Bituminous	0.00	3.14	3.44	4.17	5.89	12.56	27.81	38.81
2	Sub-Bituminous	1.02	1.05	0.76	0.79	0.84	0.75	0.85	1.63
3	lignite	3.71	4.05	4.13	4.24	4.48	4.49	5.31	4.97
	Total	4.73	8.24	8.33	9.20	11.21	17.79	33.97	45.41

Figure 3.1. Methane emissions from coal mines of Mongolia



Please send your suggestions about defining of methane emission factor of from surface coal mines of Mongolia (table 3.1.), based on your study findings.

Attachment 2: Presentations Given During Training Activities

Concepts Used for Conducting CBM and CMM Resource Assessment in Frontier Areas

25 June 2012

Ulaanbaatar, Mongolia

Raymond C. Pilcher, Candice Tellio, Charlee Boger, and James S. Marshall

MNEC

Global Methane Initiative

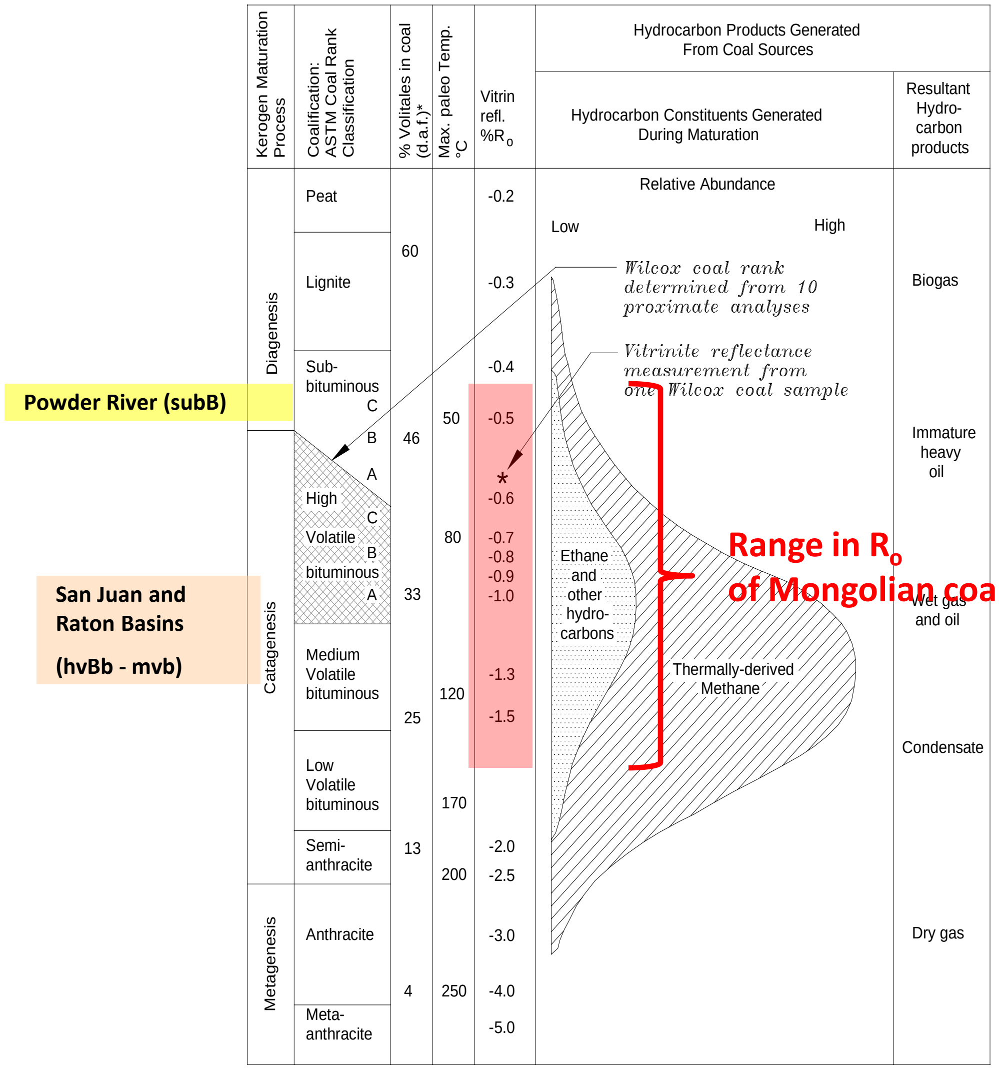
RAVEN RIDGE RESOURCES INCORPORATED

Presentation Outline

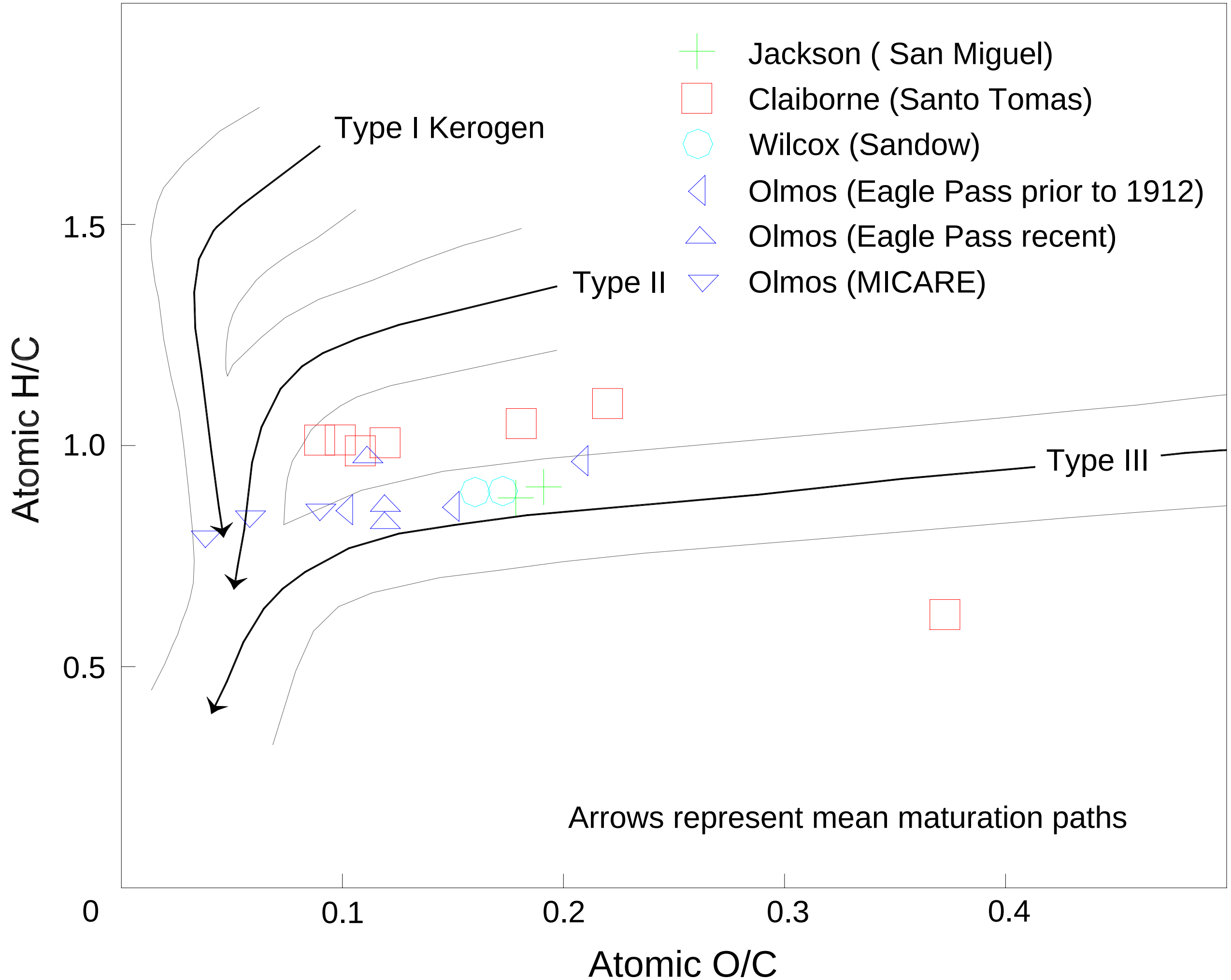
- Keys to Understanding Occurrence of Gaseous Hydrocarbons in Coal
- Essential Data for CBM/CMM Resource Assessment
- Hypothetical Resource Estimate for a Mongolia Coal Deposit
- Approaches to Drainage at Open Cast Mines
- CBM Production in the Raton Basin — A South Gobi Analogy?
- Opportunities for Emissions Reductions

Keys to Understanding Occurrence of Gaseous Hydrocarbons in Coal

Coal Rank and Hydrocarbon Generation



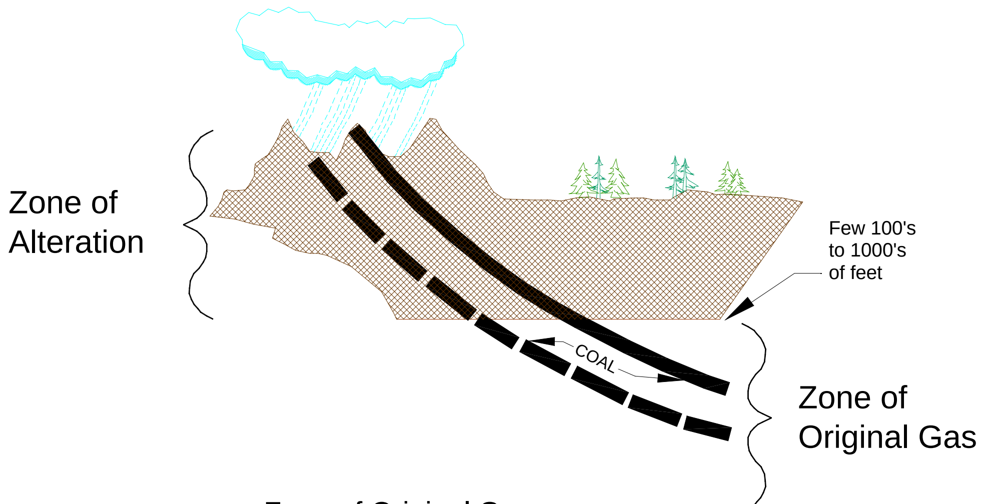
Van Krevelen-type Diagram for Coal Deposits Occurring in South Texas and Northern Mexico



Model of Methane Occurrence and Enrichment in Coal

Zone of Alteration

- Dry gas with isotopically light methane
- Gas composition controlled by (1) mixing of biogenic methane and/or (2) oxidation of heavy gases
- Located in margins and shallow central parts of basins.

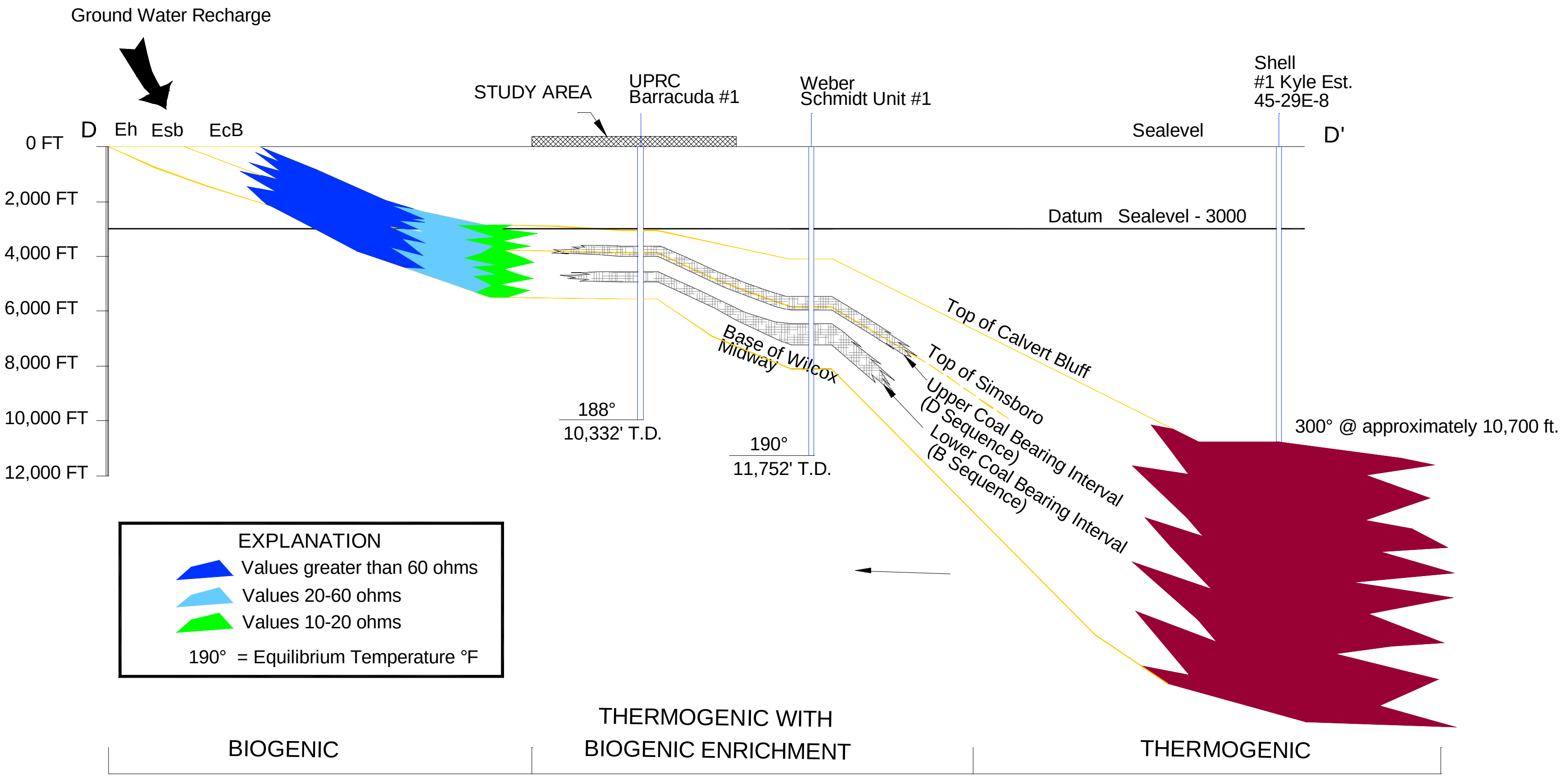


Zone of Original Gas

- Wetter gas with isotopically heavier methane
- Gas composition controlled by rank and composition of associated coal
- Located in deep and central parts of basins

After Rice, 1993

Model for Methane Generation in Upper Texas Gulf Coast



Comparison of CBM Producing Basins in USA to Coal Basins in Mongolia

	San Juan	Raton	Powder River	Tavan-tolgoi	Nariin-sukhait	Nuurstk-hotgor
Coal Rank	hvBb-mvb	hvBb-mvb	subB	hvBb-mvB	hvBb	hvBb-c
Gas Content m^3/tonne	3-14	6-14	<3	?	?	?
Max. Coal Thk.	8-14m	<3.5m	30-50m	1-73m	1-54m	1-38m
Cum. Coal Thk.	13-20m	13-22m	75-105m	?	?	?
Sorption Time	>52 days	>8 days	>7 days	?	?	?
Depth of Completion	~800m	~650m	~150m	?	?	?

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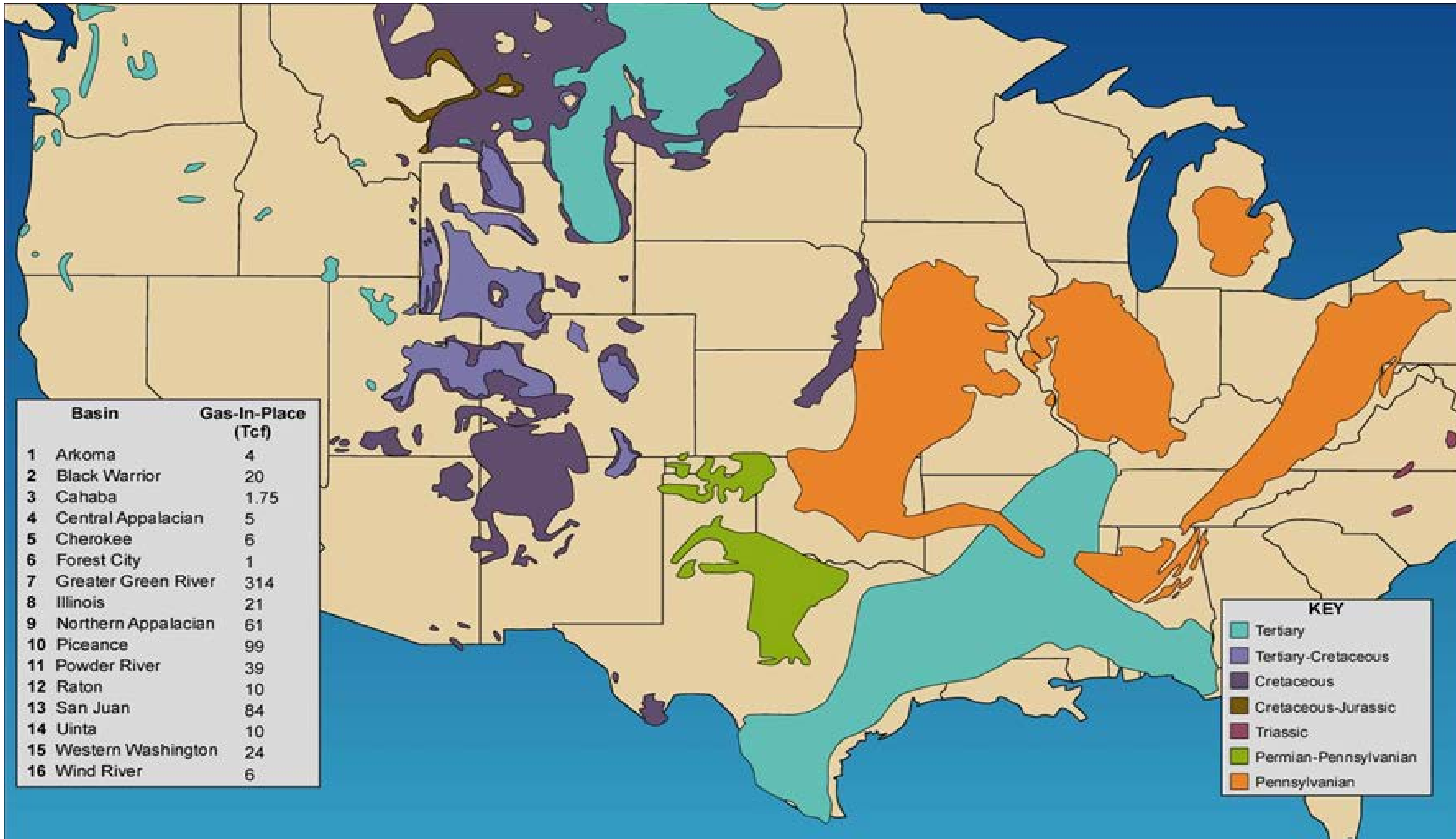
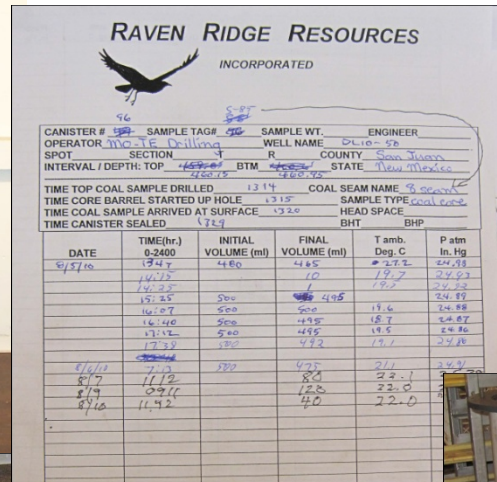
Distribution of CBM and CMM Resources in USA



Mongolia Coal Basins

Essential Data for CBM/CMM Resource Assessment

Desorption Testing



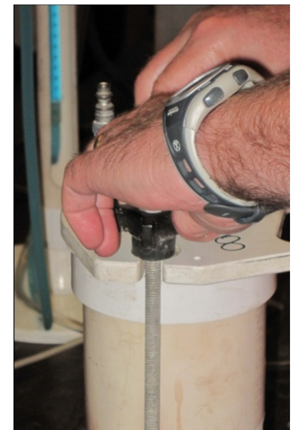
RAVEN RIDGE RESOURCES

INCORPORATED

CANISTER # 96 SAMPLE TAG# S-85 SAMPLE WT. ENGINEER
OPERATOR Mo-TE Drilling WELL NAME DL10-58
SPOT SECTION T R COUNTY San Juan
INTERVAL / DEPTH: TOP 460.15 BTM 460.95 STATE New Mexico

TIME TOP COAL SAMPLE DRILLED 1314 COAL SEAM NAME 8 seam
TIME CORE BARREL STARTED UP HOLE 1315 SAMPLE TYPE coal core
TIME COAL SAMPLE ARRIVED AT SURFACE 1320 HEAD SPACE
TIME CANISTER SEALED 1329 BHT BHP

DATE	TIME(hr.) 0-2400	INITIAL VOLUME (ml)	FINAL VOLUME (ml)	T amb. Deg. C	P atm In. Hg
8/5/10	1347	480	465	27.2	24.93
	14:15		10	19.7	24.93
	14:25		1	19.7	24.92
	15:25	500	495		24.89
	16:07	500	500	19.6	24.88
	16:40	500	495	18.7	24.87
	17:12	500	495	19.5	24.86
	17:38	500	492	19.1	24.86
8/6/10	7:13	500	475	21.1	24.91
8/7	1112		80	22.1	[illegible]
8/9	0911		128	22.0	[illegible]
8/10	11:42		40	22.0	



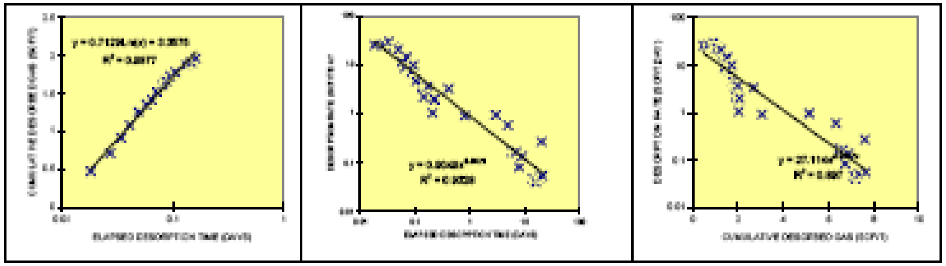
Example Desorption Report

COAL GAS CONTENT	SMITH AND WILLIAMS METHOD (STP)	DECLINE CURVE METHOD (STP)
LOST GAS:	0.8 SCF/T	0.5 SCF/T
VOLUME CORRECTION:	1.105	1.057
RESIDUAL GAS (raw):	11.6 SCF/T	11.6 SCF/T
RESIDUAL GAS (%):	58.3%	59.2%
DESORBED GAS (raw):	8.2 SCF/T	7.9 SCF/T
TOTAL GAS (raw):	19.7 SCF/T	19.4 SCF/T
	0.62 cc/g	0.61 cc/g
RESIDUAL GAS (DAF):	14.0 SCF/T	14.0 SCF/T
DESORBED GAS (DAF):	10.0 SCF/T	9.7 SCF/T
TOTAL GAS (DAF):	24.0 SCF/T	23.7 SCF/T
	0.75 cc/g	0.74 cc/g

RAW MEASURED DATA				
TOTAL RESIDUAL GAS (STP):	525.0 cc			
TOTAL DESORBED GAS:	408.0 cc			
RAW SAMPLE WEIGHT:	1740.0 g			
DAF SAMPLE WEIGHT:	1429.8 g			
RAW SURFACE CONDITIONS:	19.0 CF/T			
	0.59 cc/g			
RAW STP CONDITIONS:	19.7 SCF/T			
	0.62 cc/g			
CANISTER HEAD SPACE:	1080 cc			
TIME COAL SEAM PENETRATED:	8	:	50	17-Sep-08
TIME COAL ARRIVED AT SURFACE:	9	:	04	17-Sep-08
TIME CANISTER SEALED:	9	:	16	17-Sep-08

PROXIMATE ANALYSIS	
% MOISTURE:	5.15
% ASH:	12.68
% VOLATILE:	35.84
% FIXED CARBON:	46.33
TOTAL %:	100.00
HEAT VALUE (BTU/lb):	11532
% SULFUR:	0.85
APP. SPECIFIC GRAVITY:	

Td:	14.00 minutes
Ts:	26.00 minutes
T25%:	207.67 minutes
SURFACE TIME RATIO:	0.46
LOST TIME RATIO:	0.13



T25% = time from seam penetration to the time when 25% of the measured volume has desorbed

Td = time from seam penetration to sample surfacing

Ts = time from seam penetration to container sealing

COMMENTS:

SURFACE TIME RATIO = (Ts - Td)/Ts

LOST TIME RATIO = Ts/T25%

STP = 15 degrees C and 29.92 in. Hg

Adsorption Laboratory

Global Methane Initiative

Example Adsorption Report

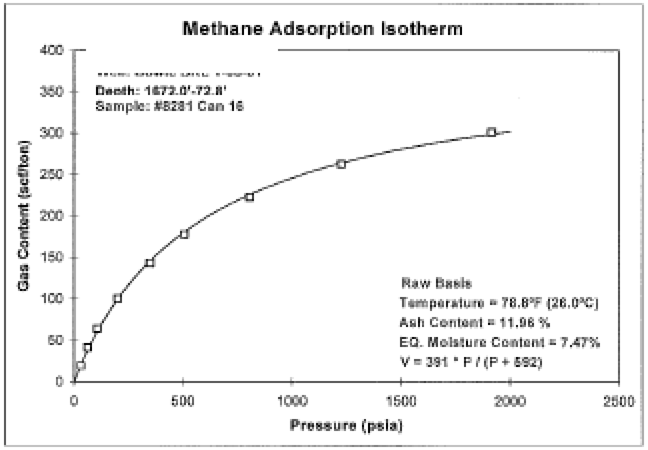
Sample Weight = 104.43 g
Particle Size = < 20 Mesh
Temperature = 78.8°F (26.0°C)
Ash Content = 11.96 %
EQ. Moisture Content = 7.47%

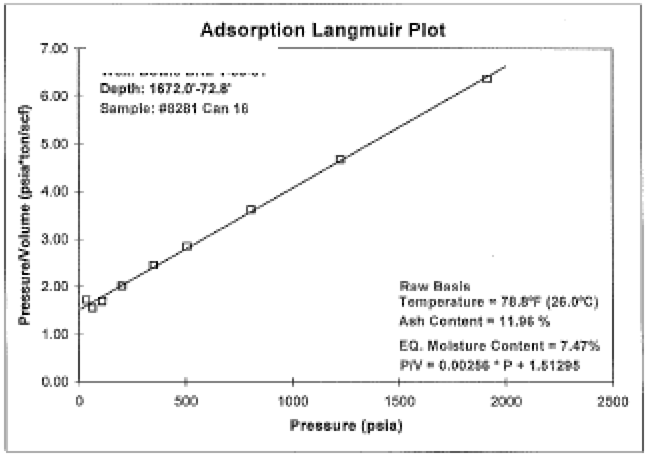
Methane Adsorption

Pressure		Gas Content (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
33	0.23	19.2	0.60
64	0.44	41.1	1.28
108	0.74	63.8	1.99
202	1.39	100.4	3.13
350	2.41	142.9	4.46
507	3.50	177.5	5.54
807	5.56	222.6	6.95
1,226	8.45	262.4	8.19
1,916	13.21	301.0	9.40

Langmuir Coefficients V = 391.1 * P / (P + 591.7)

PL		VL (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
591.7	4.08	391.1	12.2





Data Required for CBM/CMM Resource Evaluation:

Coal Mine Provides:

- Coal resource data:
  - Depth, thickness, lateral extent- tonnes of coal by depth
  - Coal quality data (proximate analysis)-from samples tested

MNEC team provides:

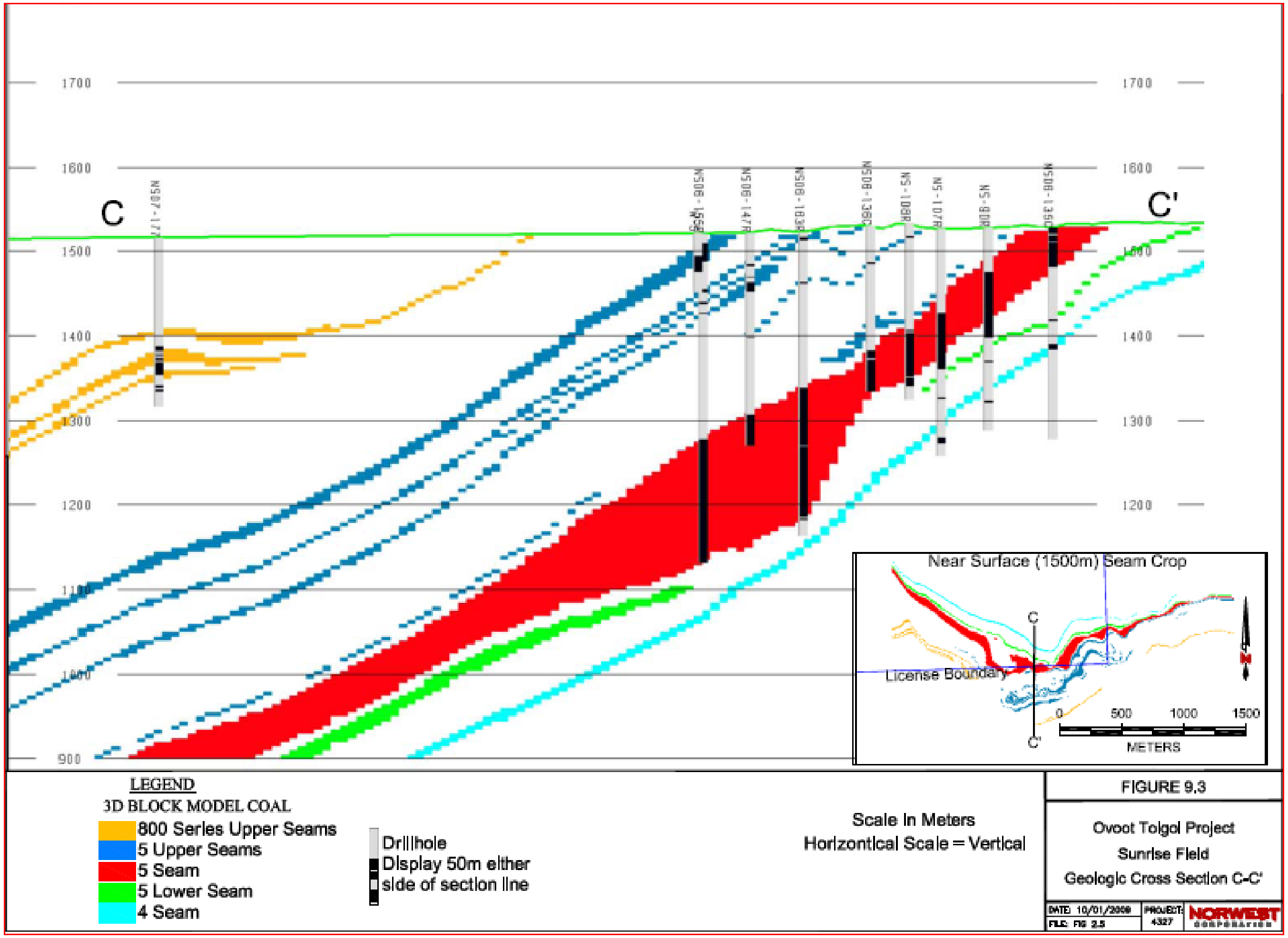
- Desorption test:
  - Gas content of coal sample (m^3/tonne of coal)
  - Field test- takes several days to a few weeks
- Adsorption test
  - Measures Gas Capacity of coal sample
  - Laboratory test- takes a few weeks
- Gas Chromatography
- Determines the gases composition: i.e., CH_4, CO_2, N_2, H_2S

CBM/CMM Resource Assessment Approaches

- Usually a volumetric calculation:
  - multiply mass of coal (tonnes) by gas content (cubic meters of methane per ton of coal) = volume of gas in place
  - Volume of gas is most accurate when based on desorption testing
  - Can use adsorption testing to get estimate by using predicted volume of gas for coal resource at given depth
- Two accepted approaches to calculate estimate:
  - Use low, high, and mid range single values for all parameters; result is a resource estimate ranging from low to high forecasts
  - Stochastic estimate using probability functions developed for each parameter yielding a probabilistic forecast of resources

Hypothetical Resource Estimate for a Mongolia Coal Deposit

Cross-section through Ovoot Tolgoi hvB-hvA Coal Deposit



Thickness of Seams Occurring in Ovoot Tolgoi Deposit

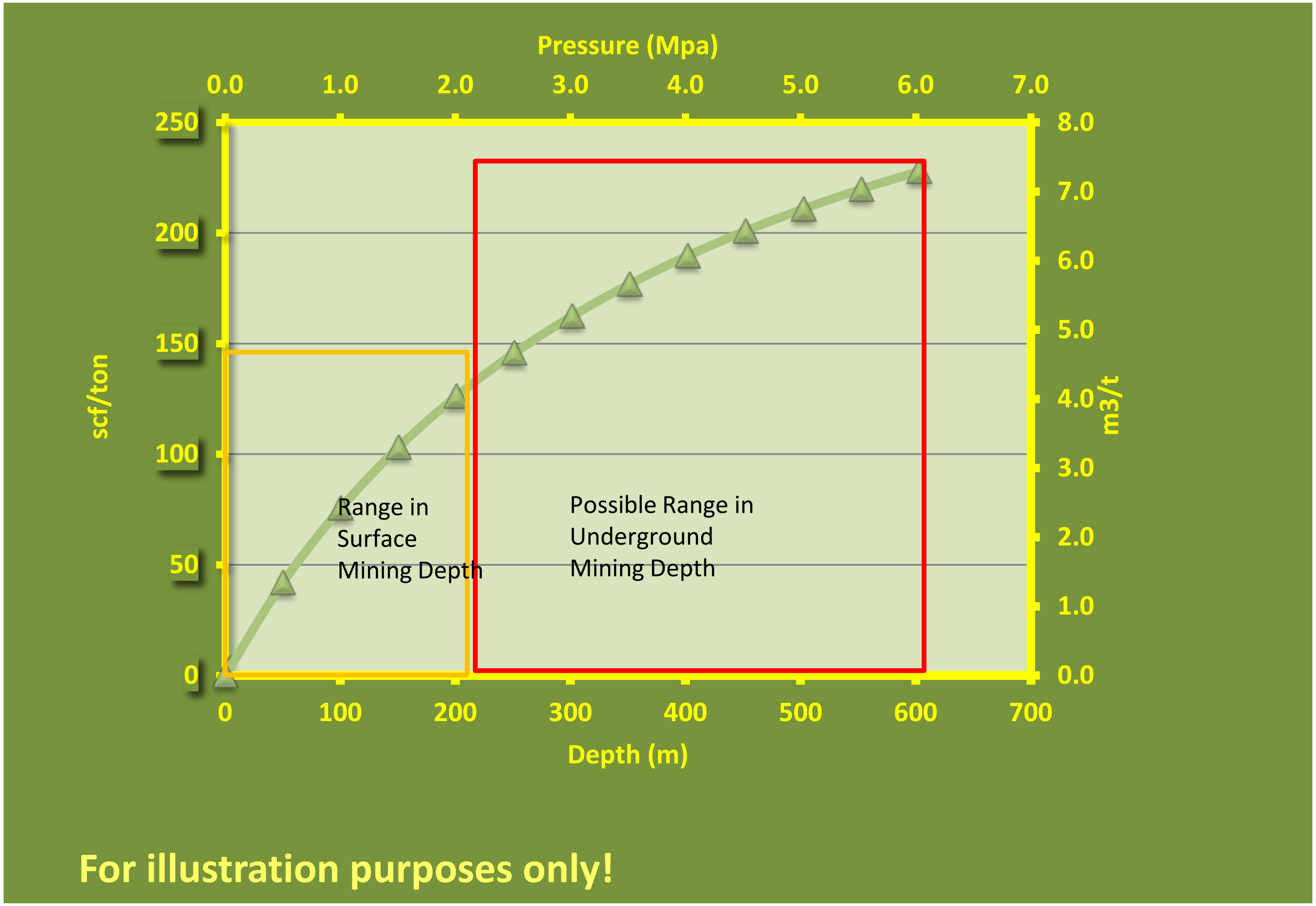
Property	Series	No Seams	Minimum Thickness* (m)	Maximum Thickness* (m)	Mean Thickness* (m)
Sunrise Field	Upper Seams	11	0.6	74	10
	5 Main	1	0.9	157	53
	5 Lower	1	0.6	100	16
	4 Main	1	1.0	30	8
Sunset Field	Upper Seams	60	0.6	31	7
	5 Main & Lower	2	0.6	142	39

In- Place Coal Resources Delineated by 430 Boreholes Drilled from 2006 through 2009

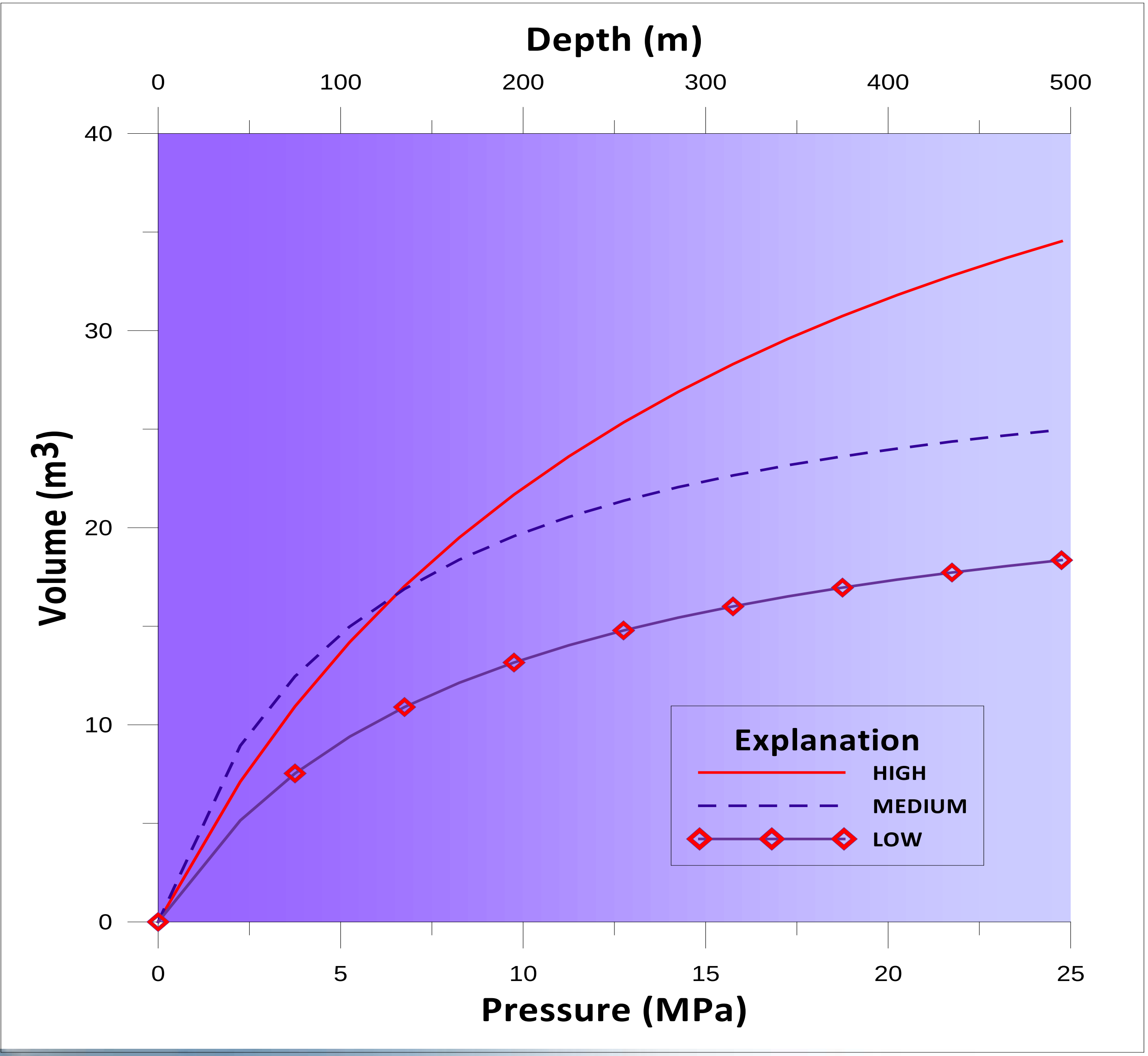
Area	Type	Resource Limits Depth (m)	ASTM Group	In-Place Resources (Million Tonnes)		
				Measured	Indicated	Inferred
Sunrise Field	Surface	Surface to 250m	hvB to hvA	53.8	15.7	4.9
Sunset Field	Surface	Surface to 250m	hvB to hvA	82.1	19.4	8.1
Sub-Total				**135.9**	**35.1**	**13.0**
Sunrise Field	Underground	250m to 600m	hvB to hvA	11.2	5.2	11.2
Sunset Field	Underground	250m to 600m	mhB to hvA	34.6	27.8	9.3
Sub-Total				**45.8**	**33.0**	**20.5**
Total				181.7	68.1	33.5

Resources estimated using cross-section method

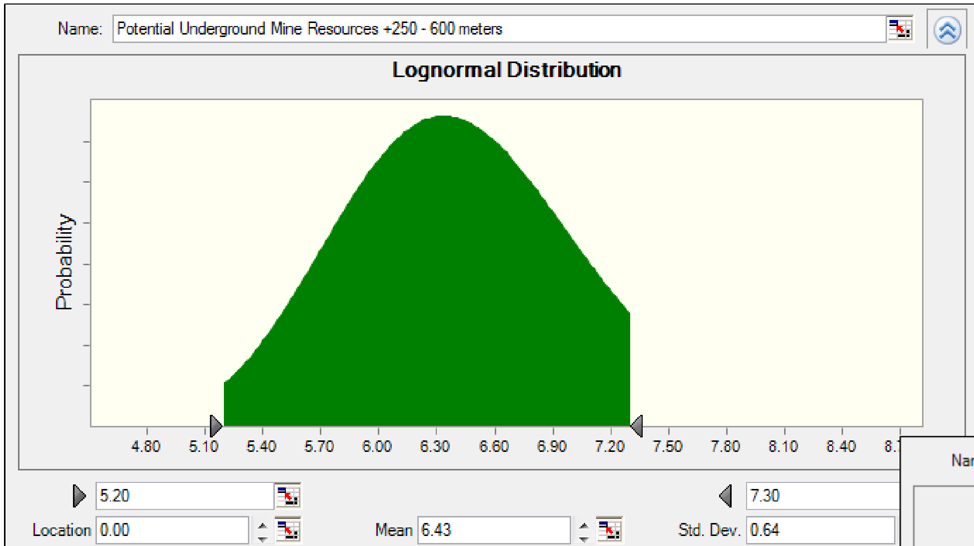
Hypothetical Isotherm for hvB-hvA Coal Rank

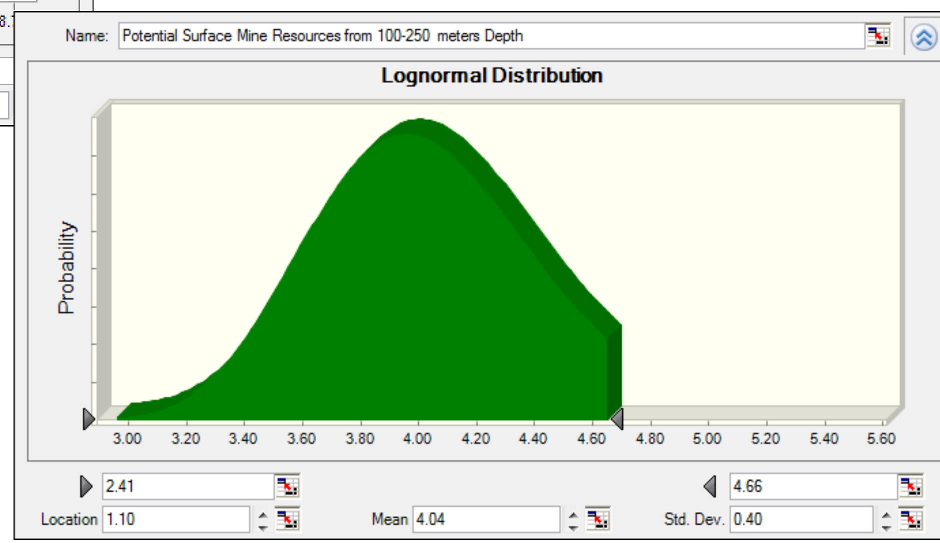


Adsorption Isotherm
High Volatile Bituminous Coal



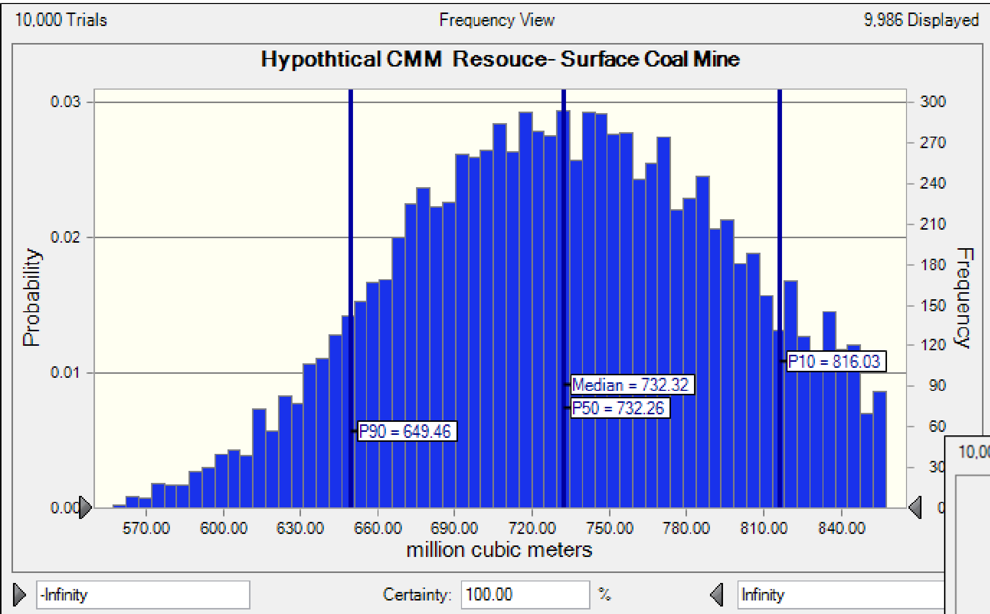
Hypothetical Gas Content Probability Distributions for Ovoot Tolgoi Coal Resources



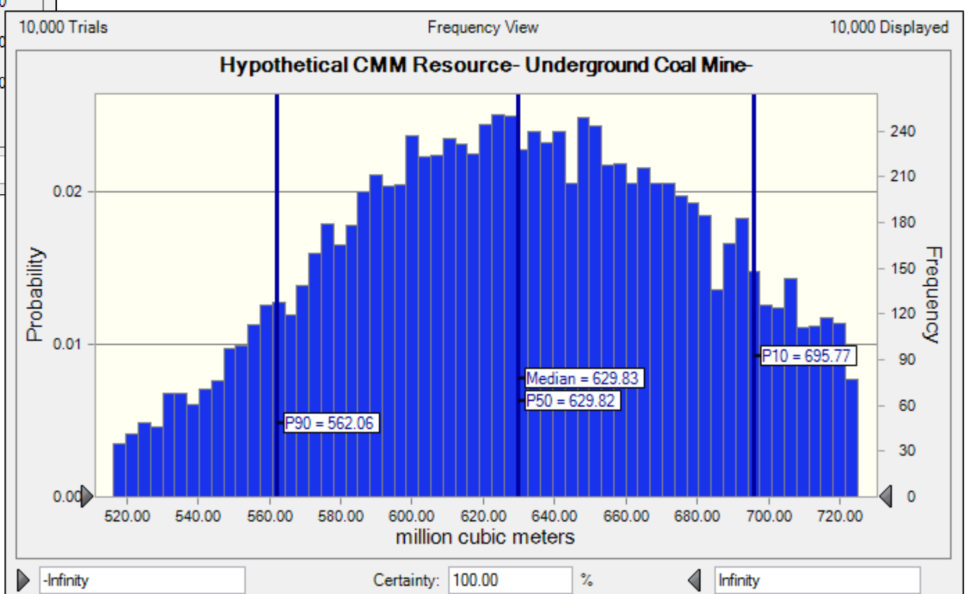


For illustration purposes only!

Hypothetical CMM Resources of Ovoot Tolgoi Coal Deposit



Potential Surface Coal Mine CMM Resource Estimate (million cubic meters)		
P_{90}	P_{50}	P_{10}
649	732	816



Potential Underground Coal Mine CMM Resource Estimate (million cubic meters)		
P_{90}	P_{50}	P_{10}
562	630	696

For illustration purposes only!

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Approaches to Drainage at Open Cast Mines

Vertical in Advance of Mining

- Boreholes are shut-in as mining approaches/evidence of air in produced gas
- Surface equipment and casing is removed prior to mine-through
- Timing – producing as far in advance of mining as possible
- Applicable to strip mines

Figure 1: Pre Mine Drainage

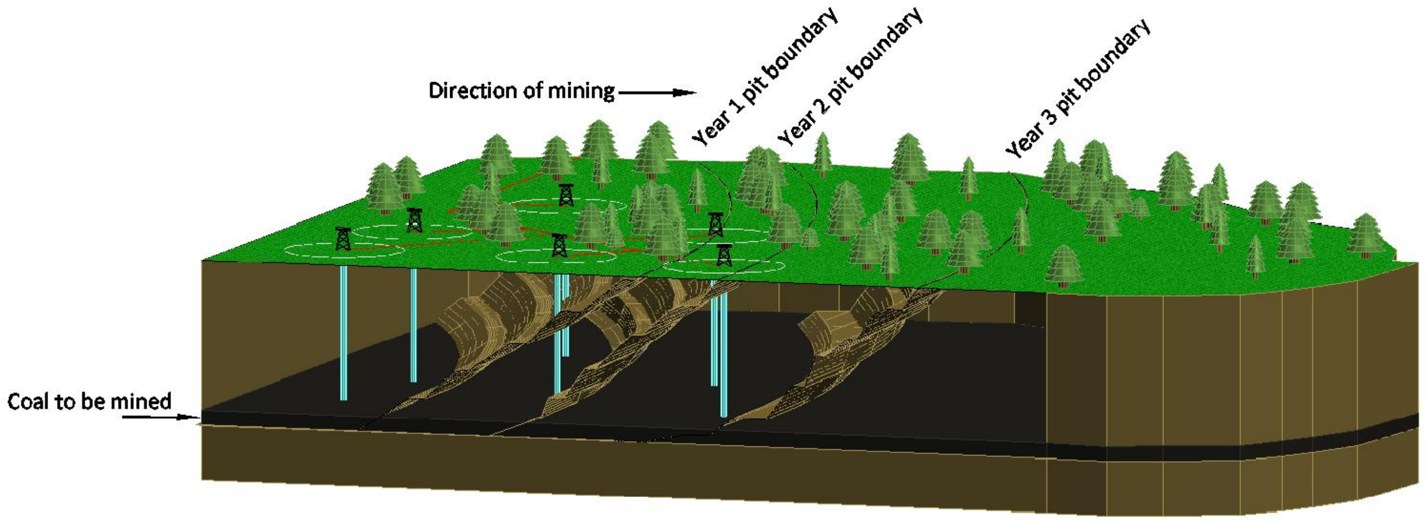
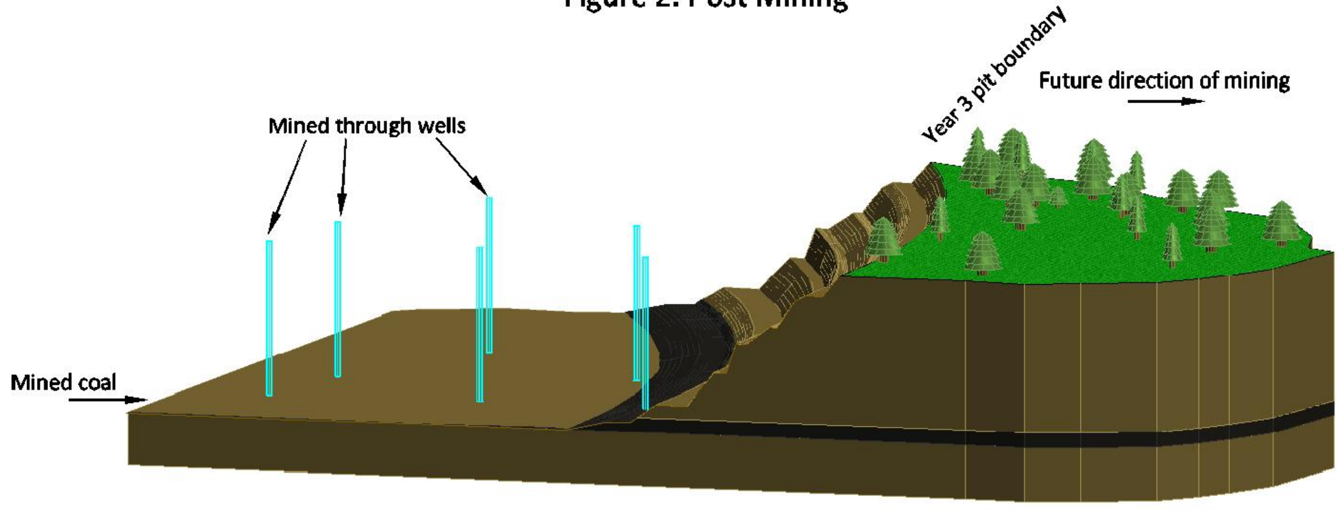


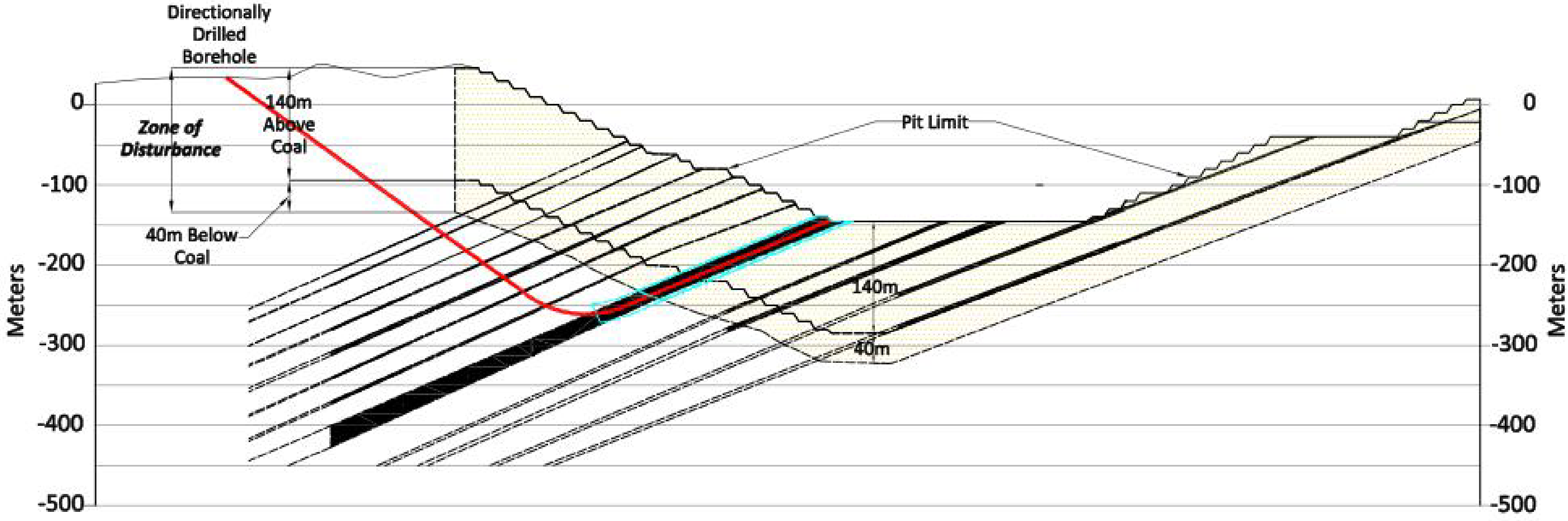
Figure 2: Post Mining



Lateral in Advance of Mining

- Depending on placement, boreholes may continue to produce during mining and post mining
- Applicable to some single seam strip mines and to open pit mines
- May access more coal if sidetracks are employed

Laterally-drilled Borehole



Surface Mine Drainage Considerations

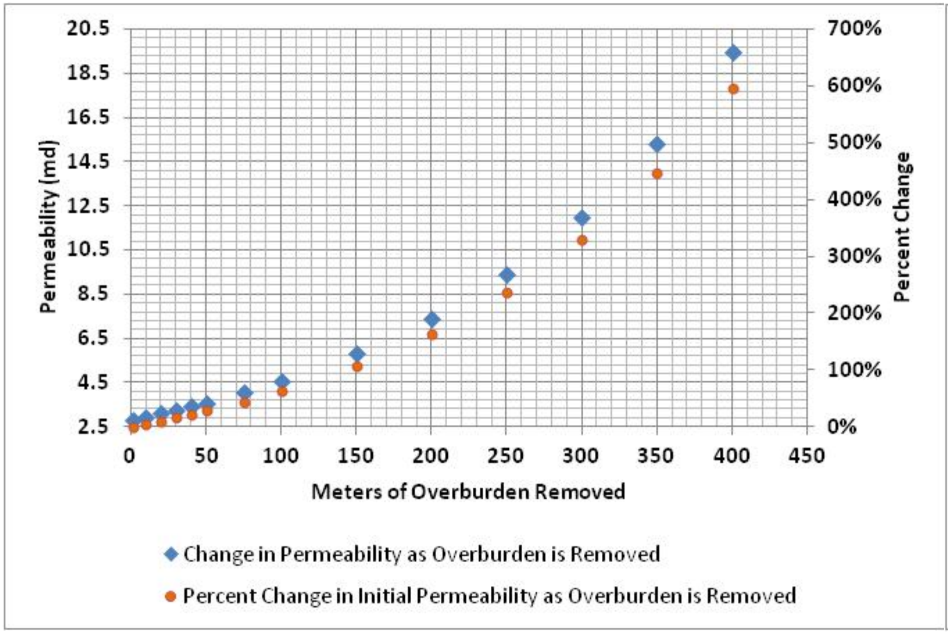
- Coordination of gas drainage project development with mining operations is essential
- Surface logistics
  - Waste piles, storage, space issues
  - Gas transportation
    - Permanent vs. temporary gathering lines

Overburden Removal Increases Permeability

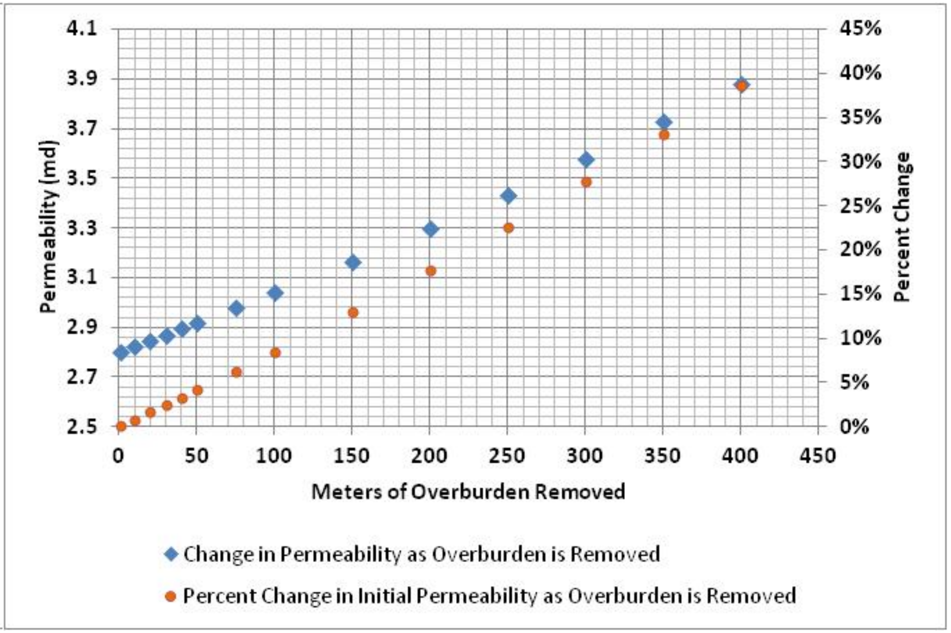
- Permeability increases exponentially with decreasing effective stress
- Effective stress is diminished as overburden is removed during mining
- Permeable pathways occurring in geologic structures such as breached folds or faults are enhanced as overburden is removed.
- Matrix and fracture permeability is enhanced as a function of the stiffness of the rock mass, density of fracturing and thickness of overburden removed.

Impact of Rock Stiffness on Increases in Permeability as Overburden is Removed

Medium-Volatile Bituminous Coal



Sub-bituminous Coal



Fracture compressibility for bituminous coal from *A New Coal-Permeability Model: Internal Swelling Stress and Fracture-Matrix Interaction* by Hui-Hai Liu and Jonny Rutqvist, Transp Porous Med (2020) 82: 157-171.

Fracture compressibility for sub-bitumious coal , high volatile bituminous and equation for relationship between overburden removal and permeability increase from *Improvements in Measuring Sorption-Induced Strain and Permeability in Coal* by E.P. Robertson, SPE 116259, 2008 SPE Eastern Regional/AAPG Eastern Section Joint Meeting held in Pittsburgh, Pennsylvania.

CBM Production in the Raton Basin — A South Gobi Analogy?

Raton Basin Stats

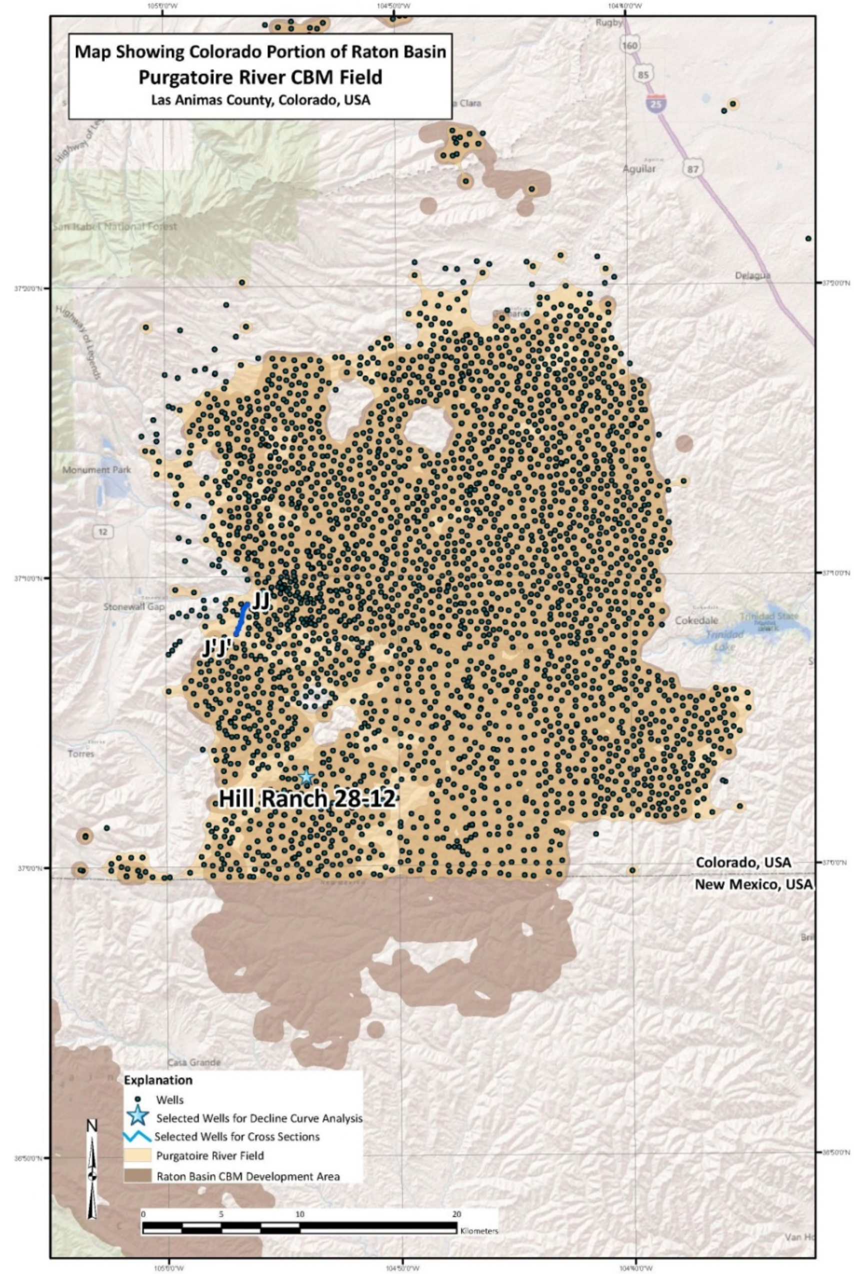
The adjacent map is of wells within the Purgatoire River Basin and includes both conventional gas and CBM wells. The data for New Mexico was not available online.

According to the COGCC production, which is digitally available beginning 1999:

- 1,084,690,019 mcf / 30,714,665,566 m^3 of gas has been produced from both conventional and CBM wells.
- 1,267,849,786 bbls / 151,176,829 m^3 / 151,179,022,629 L

The basin is approximately 50 miles (80 km) east-west, and 90 miles (140 km) north-south.

- 11,200 km^2
- 4,500 $mile^2$



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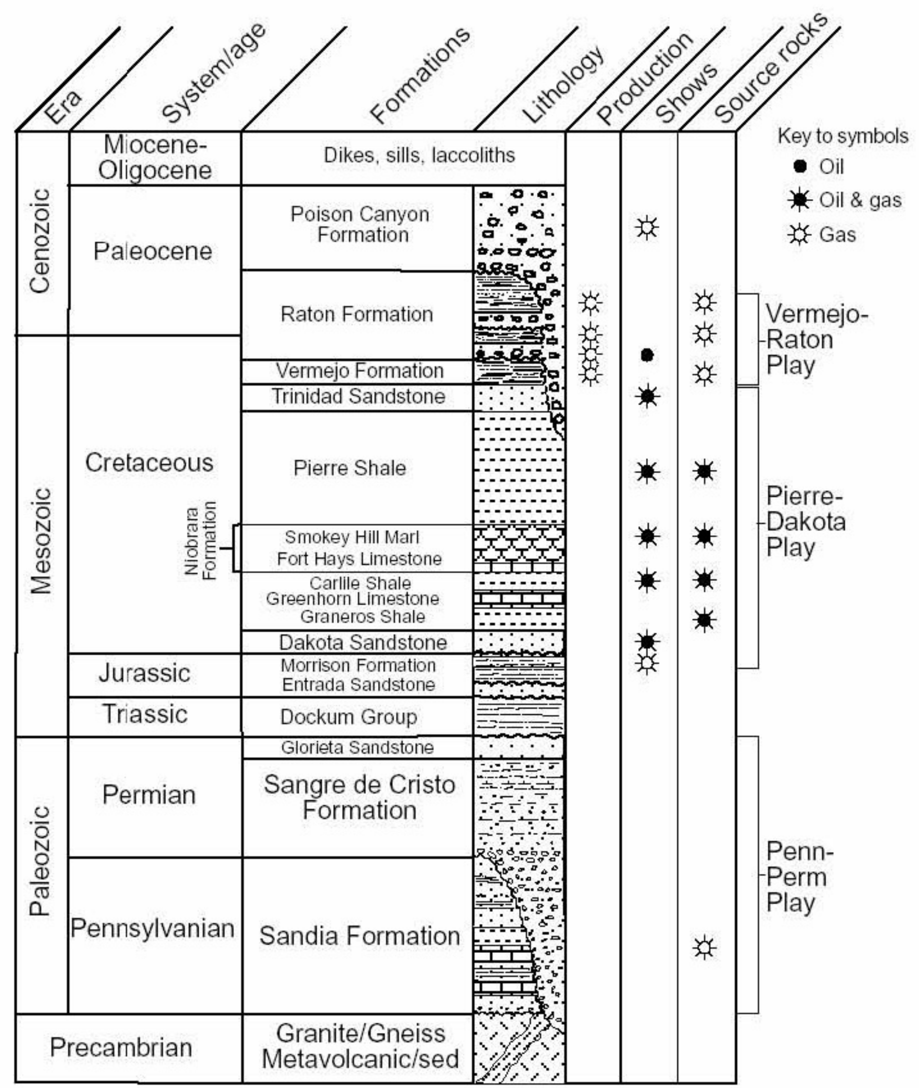
Generalized stratigraphic column for Raton Basin

Source: Dolly, E. D., and Meissner, F. F., 1977, Geology and gas exploration potential, upper Cretaceous and lower Tertiary strata, northern Raton Basin, Colorado, *in* Veal, H. K., ed., Exploration Frontiers of the Central and Southern Rockies: Rocky Mountain Association of Geologists, Field Trip and Conference Guidebook, p. 247-270.



Structural Cross Section

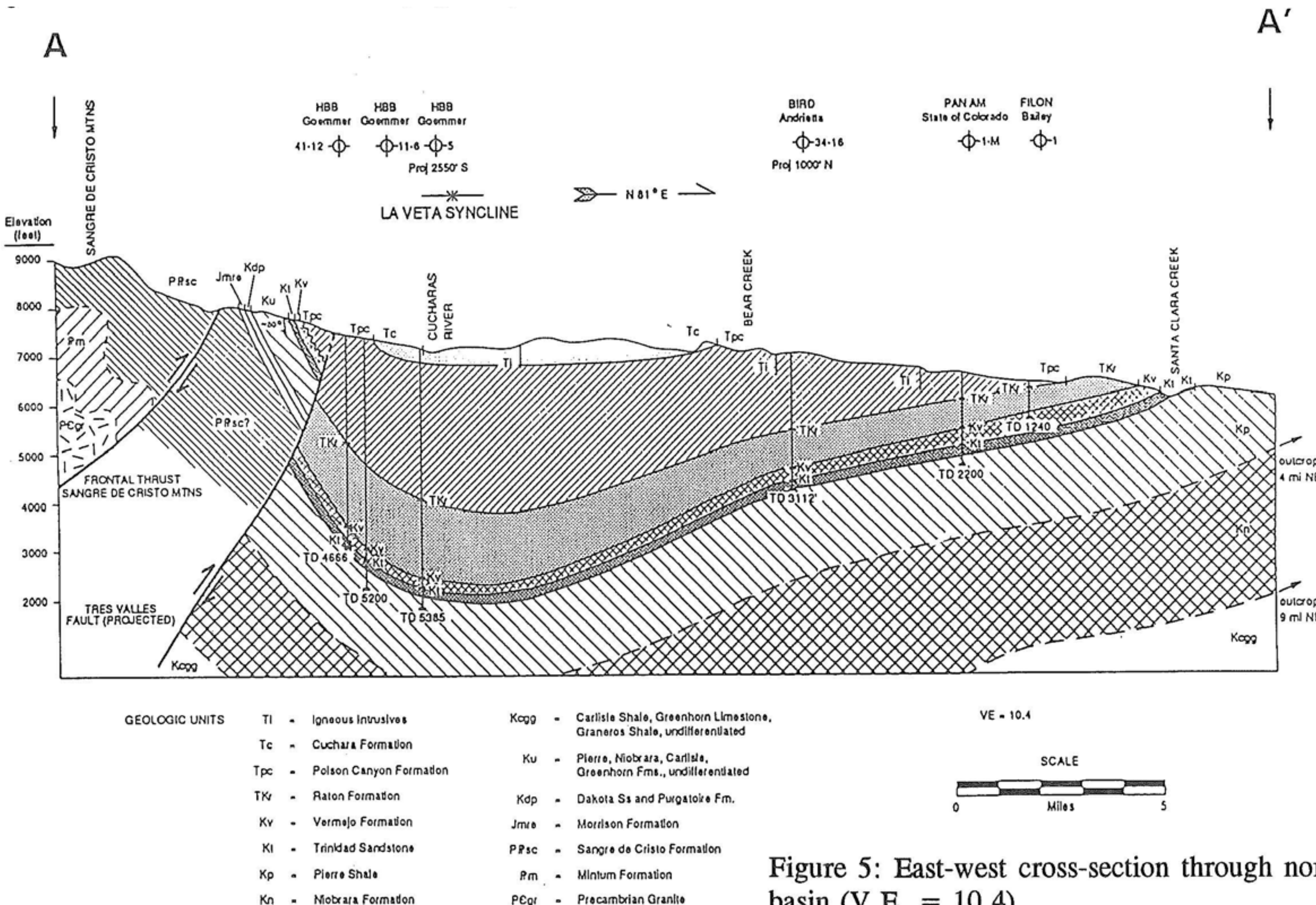
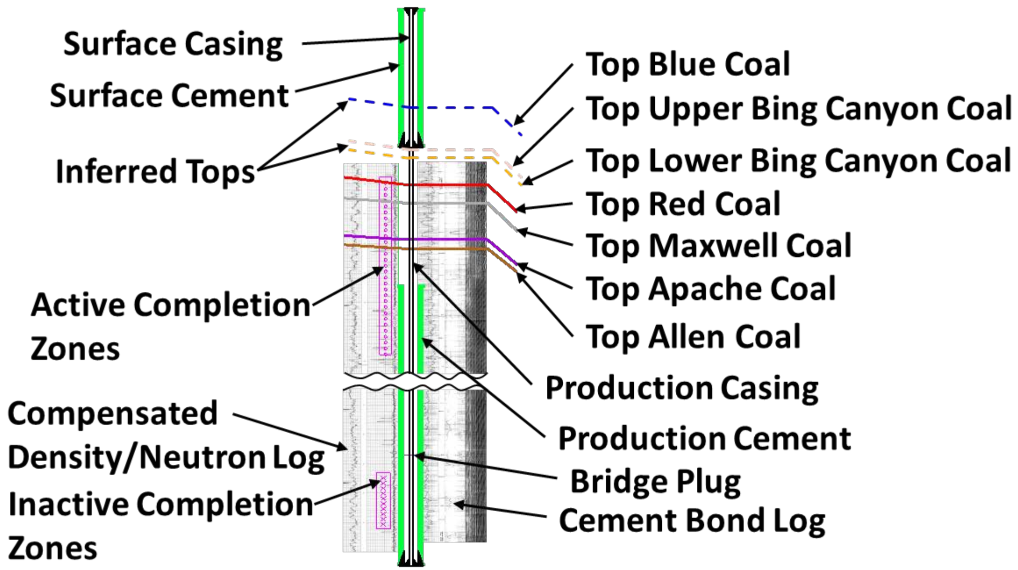
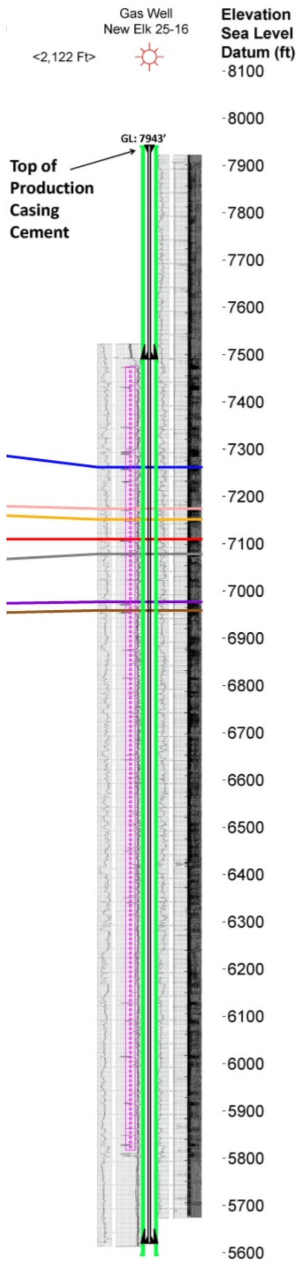


Figure 5: East-west cross-section through northern Raton basin (V.E. = 10.4).

Source: Stevens, S.H., Lombardi, T.E., Kelso, B.S., McBane, R.A., and Oldaker, P.; "Geologic and Hydrologic Controls on Coalbed Methane Resources in the Raton Basin", Proceedings of the 1993 International Coalbed Methane Symposium, Birmingham, Alabama, May 17-21, 1993.

Example Wellbore





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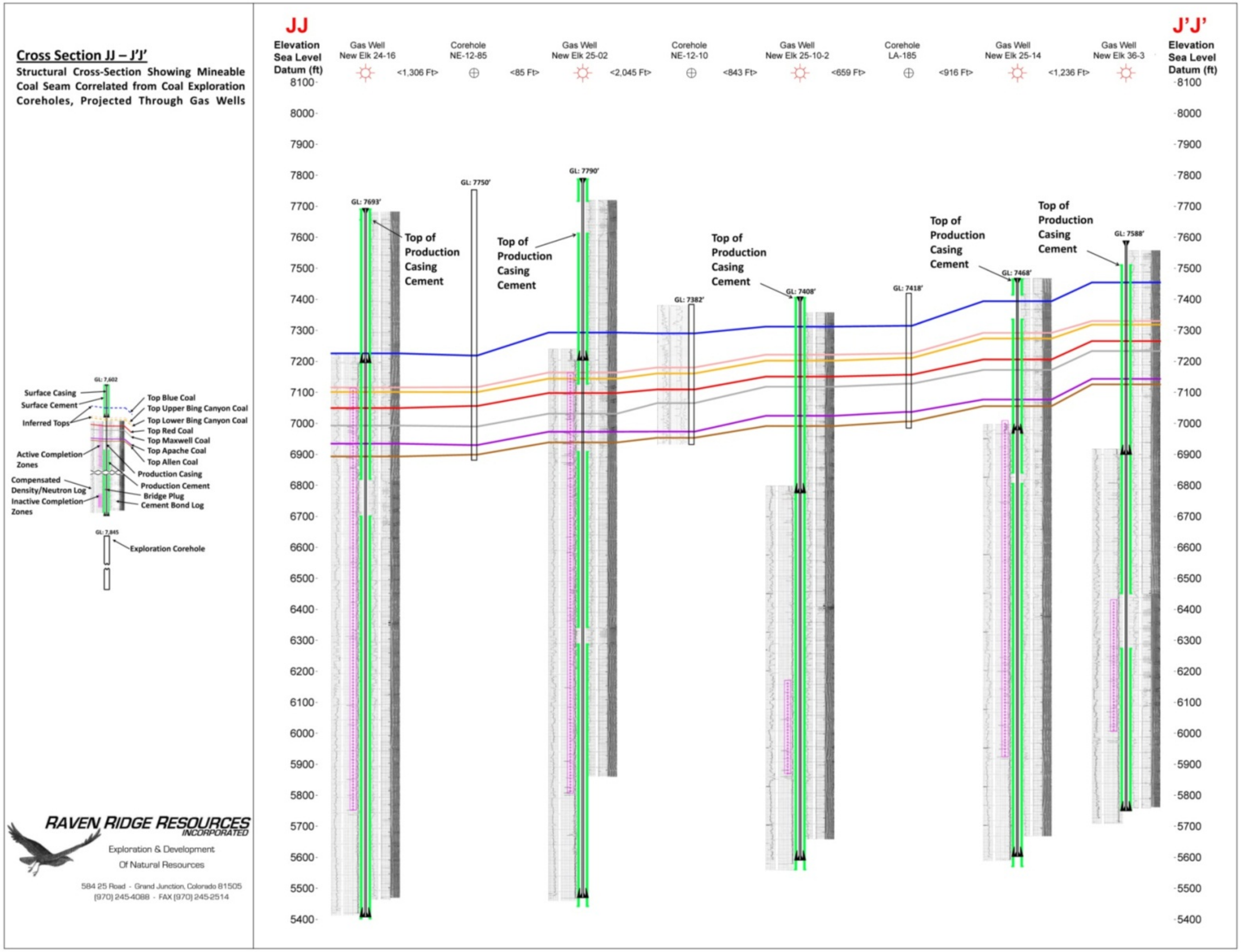
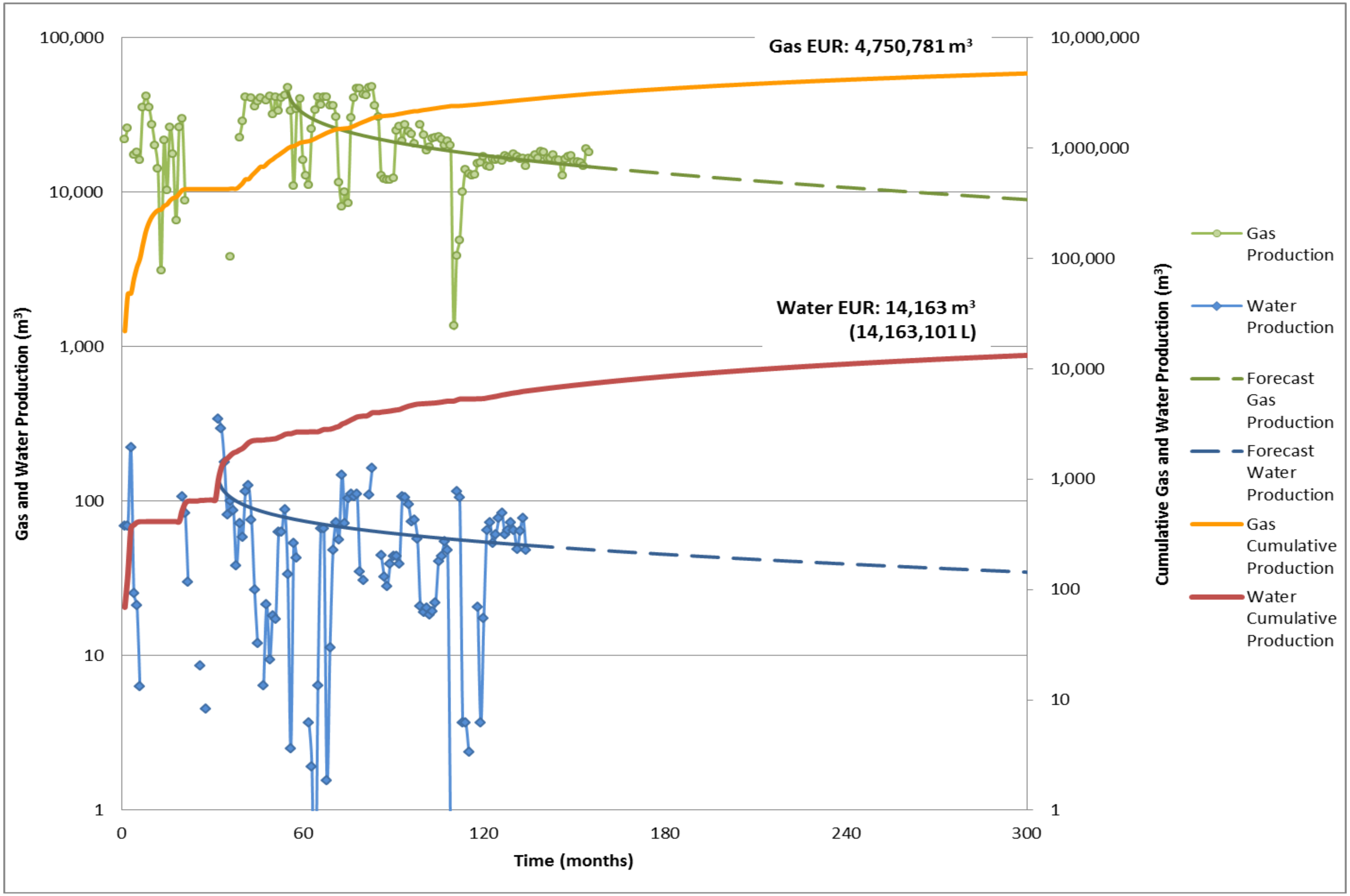
Cross Section Through Mining Property



Hill Ranch 28-12 Gas and Water Production Decline Curves



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Opportunities for Emissions Reductions

Estimated Emission Reductions from Surface Mine Projects

Project	Average Annual Emission Reductions (tCO_2e)	Emission Reductions for Crediting Period (tCO_2e)
Wahana Baratama, Indonesia	207,111	1,449,778
Semirara, Philippines	385,478	2,698,346
North Antelope Rochelle, Wyoming, USA	90,463	904,628

Wahana Baratama Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/9Y4C1SLSOQIMHIZGRXF053RFNRQERO/view.html; Semirara Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/YCCWHT4J05P2A4OSN6LGDGK9RYEBXQ/view.html; NARM PDD: https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/Project_ViewFile.asp?FileID=70&IDKEY=niquwesdfmnk0iei23nnm435oiojnc909dsflk9809adlkmlkf496530

End-Use Options


Pipeline Sales


Power Generation



Direct Use or Flaring


CNG/LNG

Thanks!

Contact Information:

pilcher@ravenridge.com

+1 (970) 245-4088

www.ravenridge.com

mnec8@yahoo.com

+976 11 354365

www.mnec.org.mn

Global Methane Initiative

Approach for a Surface Mine Methane Emissions Inventory in Mongolia

Ms. Charlee A. Boger, Dr. Badarch, &
Mr. B. Ochirsukh

Ulaanbaatar, Mongolia
June 25, 2012

Presentation Outline

- Project Background
- Surface Mines and Emissions
- Development of a Surface Mine Methane Emissions Inventory in Mongolia
- Considerations for the Future

PROJECT BACKGROUND

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USEPA's Coalbed Methane Outreach Program

- Coalbed Methane Outreach Program (CMOP) is a voluntary program whose goal is to reduce methane emissions from coal mining activities
- Working cooperatively with coal companies and related industries, CMOP:
  - Helps to address barriers to using CMM instead of emitting it to the atmosphere
  - Mitigate climate change
  - Improve mine safety and productivity
  - Generate revenues and cost savings

CMOP Activities

- Identify profitable opportunities for CMM recovery
- Identify and help overcome market, regulatory, technical barriers
- Offer technical and analytic support where appropriate
- Conduct direct outreach to coal mines

CMOP's International Activities

- Methane is a well-mixed gas in the atmosphere – Methane emitted from a coal mine anywhere in the world has the same impact on climate change
- U.S. is a world leader in CMM recovery and utilization – Opportunity to showcase, transfer U.S. goods and services internationally
- Long-standing EPA support for international CMM development – Since 1994, provided support for CMM recovery and use in key coal mining countries - China, India, Russia, Ukraine, Mongolia since 2008
- Today, CMOP conducts its international activities under the auspices of the Global Methane Initiative

Global Methane Initiative

U.S. EPA Coalbed Methane Outreach Program

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Global Methane Initiative

- International initiative launched in 2004 (originally as Methane to Markets)
- Focus on five key sectors: coal mining, landfills, natural gas, agriculture, wastewater
- Country profiles, project database, technology database
- Project Expos, workshops and grants

GMI Project Expos

- 2008 Project Expo in Beijing
- 2010 Project Expo in New Delhi
  - Featured two potential projects from Mongolia
  - CMM Project at Kharkhiraa Basin
  - Power Generation and Heating Project at Nalaikh Mine
- 2013 GMI Expo in Vancouver


COAL MINE PROJECT OPPORTUNITY
Nalaikh Mine Power Generation and Heating Project
Tsagaan Shonkor Holding Company
Nalaikh District, Mongolia

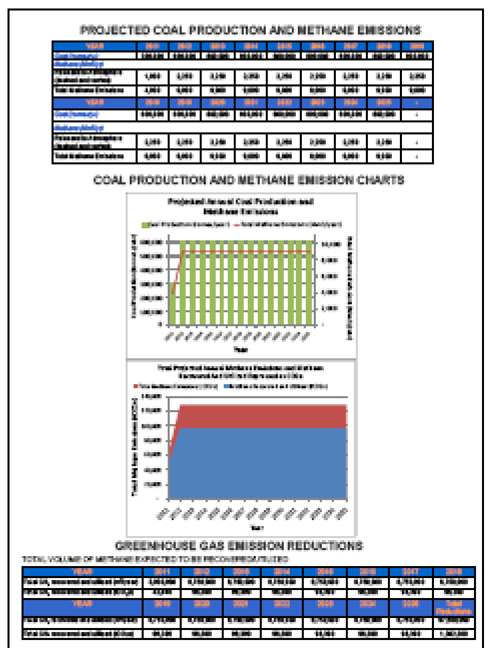
OVERVIEW OF COAL MINE PROJECT OPPORTUNITY:

PROJECT DETAILS

MINE INFORMATION

TYPE OF ASSISTANCE SOUGHT

PROJECT FINANCES


PROJECTED COAL PRODUCTION AND METHANE EMISSIONS

COAL PRODUCTION AND METHANE EMISSION CHARTS

GREENHOUSE GAS EMISSION REDUCTIONS


PROPOSED TECHNOLOGIES

MARKET ANALYSIS / DEMAND ANALYSIS

FOR MORE INFORMATION, CONTACT:

GMI Workshops

- **GMI Workshops in Mongolia**
- September 2008: Coal Mongolia CMM Workshop
- August 2010: Methane to Markets Partnership Mongolia CMM Project Development Workshop
- More workshops to come!

USEPA/GMI Grants

- USEPA has supported 17 grants for projects promoting coal mine methane recovery and utilization under GMI
- Pre-feasibility Study on Methane Recovery & Utilization in Nalaikh Coal Mine – 2008
- **Coal Mine Methane (CMM) Resource Assessment and Emissions Inventory Development in Mongolia**

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U.S. EPA Coalbed Methane OUTREACH PROGRAM

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Project Background

- Mongolian Nature and Environment Consortium was awarded a grant from the United States Environmental Protection Agency to develop a country-wide coal mine methane (CMM) resource estimate and improved CMM/surface mine methane (SMM) emissions inventory

MNEC   Global Methane Initiative   U.S. EPA Coalbed Methane OUTREACH PROGRAM   RAVEN RIDGE RESOURCES INCORPORATED

Project Background cont'd

- Why an inventory?
  - Non-annex I Party, not required
- Identify project opportunities
- Gauge viability of future carbon emission reduction projects post-2012
- Track progress

Project Background cont'd

- Raven Ridge Resources (RRR) is an independent energy consulting and exploration firm founded in 1987.
  - Specializes in assessment and development of conventional and non-conventional energy resources, particularly coal mine and coalbed methane
  - Developed and maintained the CMM emissions inventory in the U.S.
- Hired by MNEC for consultancy services through competitive bidding

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U.S. EPA Coalbed Methane OUTREACH PROGRAM

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SURFACE MINES AND EMISSIONS

Surface Mines in Mongolia

- There are more than 30 surface (or open cast) mines in Mongolia, providing almost 99 percent of coal production
- Estimated fugitive emissions from coal mining totaled 150 Gg CO_2e (150,000 metric tons CO2e/10.5 million cubic meters CH_4) in 2006
- Large surface mine developments on the horizon
- Potential for even more significant surface mine methane (SMM) emissions

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Surface Mine Methane Emissions

- Methane emitted by the **coal excavated** and processed during mining activities
- Methane emitted by the **coal and other gas bearing strata in the overburden and/or underburden** exposed by mining activities
- Methane emitted from the **floor and/or highwall** of the mine
- Methane emitted by the **overburden coal excavated and stored on site in waste piles**

Surface Mine Methane Emissions cont'd

- Methane emissions from excavated coal
  - Gas content
  - Quantity of material excavated
- Methane emissions from over/underburden
  - Gas content and thickness of the adjacent coal seams
  - Permeability of the coals and other strata found in the overburden, interburden and underburden
  - Overburden thickness
  - Amount of disturbance to the mine floor and highwall as a result of mining

Surface Mine Methane Emissions cont'd

- Methane emissions from floor
  - Gas content of the unmined coal beneath the mine floor
  - Proximity of the coal seams to the mine floor
  - Extent of disturbance of the coal and the effect this has on its permeability
  - Amount of coal left in the floor
  - Presence of water

Surface Mine Methane Emissions cont'd

- Methane emissions from highwall
  - Gas content of the unmined coal remaining in the highwall
  - Extent of disturbance of the coal near the highwall and the impact this has on the permeability
  - Presence of water

DEVELOPMENT OF SMM INVENTORY IN MONGOLIA

Project Background

- Mongolia's First National Communication to the UNFCCC (2001)
  - Limited data – coal gas investigations had not yet been conducted.
  - Only data for the Nailakh deposit were available.
- Second National Communication (2010)
  - 2006 inventory data
  - IPCC Tier 1 methodology

IPCC Guidelines

- The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change.
- Developed *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* and *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
- Volume 2> Chapter 4: Fugitive Emissions>Fugitive Emissions from Mining, Processing, Storage, and Transportation of Coal>Coal Mining and Handling

IPCC Guidelines cont'd

- Tier 1: countries choose from a global average range of emission factors and use country-specific activity data (coal production) to calculate total emissions > Highest Uncertainty
- Tier 2: country- or basin-specific emission factors that represent the average values for the coals being mined
- Tier 3: uses direct measurements on a mine-specific basis > Lowest Uncertainty

Inventory Approach for Mongolia

- Not yet feasible to collect mine-specific Tier 3 measurement data for surface mines
- Alternative – collect data on surface mine coal production and use emission factors
- **For countries with significant coal production and multiple coal basins, disaggregation of data and emission factors to the coal basin level will improve accuracy**

Inventory Approach for Mongolia cont'd

- Tier 2 approach is desirable in Mongolia to reduce uncertainty
- With widespread coal deposits of varying rank, it is important to develop *basin-specific emission factors*

Mongolia Coal Basins

Inventory Approach for Mongolia cont'd

- Geologic data collection via questionnaire and consultation
  - Coal characteristics: Rank, quality, permeability
  - Coalbed characteristics: Depth of occurrence, lateral extent of the coalbed, coalbed thickness
  - Other information: Presence of water, extent of disturbance of the coal near the highwall and the impact this has on the permeability, gas content of the unmined coal beneath the mine floor, etc.

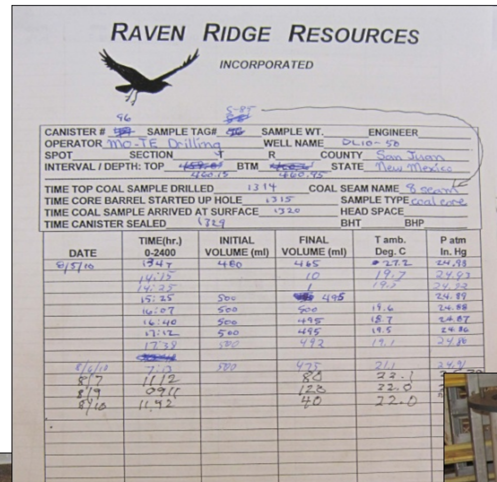
Sample Data from U.S. Mines Compared with Mongolia

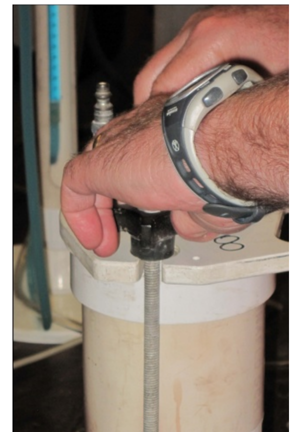
	San Juan	Raton	Powder River	Tavan-tolgoi	Nariin-sukhait	Nuurstk-hotgor
Coal Rank	hvBb-mvb	hvBb-mvb	subB	hvBb-mvB	hvBb	hvBb-c
Gas Content m^3/tonne	3-14	6-14	<3	?	?	?
Max. Coal Thk.	8-14m	<3.5m	30-50m	1-73m	1-54m	1-38m
Cum. Coal Thk.	13-20m	13-22m	75-105m	?	?	?
Sorption Time	>52 days	>8 days	>7 days	?	?	?
Depth of Completion	~800m	~650m	~150m	?	?	?

Inventory Approach for Mongolia cont'd

- Equip Mongolia with gas desorption equipment for gas content analysis
  - Can used in combination with geologic data to calculate gas resources contained within coal strata for methane resource assessment
  - Calculate basin-specific gas content based on coal analysis from select mines

Desorption Testing





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Example Desorption Report

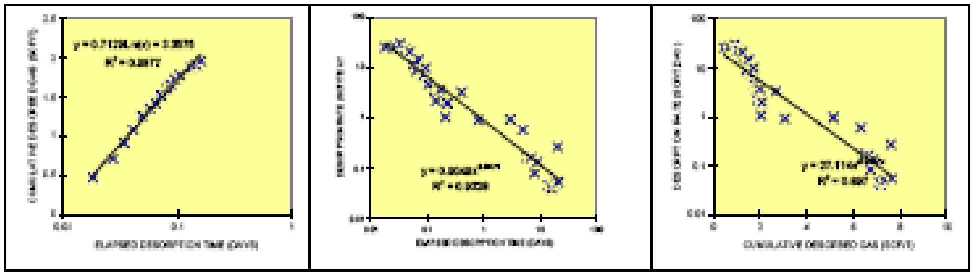
COAL GAS CONTENT	SMITH AND WILLIAMS METHOD (STP)	DECLINE CURVE METHOD (STP)
LOST GAS:	0.8 SCF/T	0.5 SCF/T
VOLUME CORRECTION:	1.105	1.057
RESIDUAL GAS (raw):	11.5 SCF/T	11.5 SCF/T
RESIDUAL GAS (%):	58.3%	59.2%
DESORBED GAS (raw):	8.2 SCF/T	7.9 SCF/T
TOTAL GAS (raw):	19.7 SCF/T	19.4 SCF/T
	0.62 cc/g	0.61 cc/g
RESIDUAL GAS (DAF):	14.0 SCF/T	14.0 SCF/T
DESORBED GAS (DAF):	10.0 SCF/T	9.7 SCF/T
TOTAL GAS (DAF):	24.0 SCF/T	23.7 SCF/T
	0.75 cc/g	0.74 cc/g

RAW MEASURED DATA	
TOTAL RESIDUAL GAS (STP):	625.0 cc
TOTAL DESORBED GAS:	405.0 cc
RAW SAMPLE WEIGHT:	1740.0 g
DAF SAMPLE WEIGHT:	1429.8 g
RAW SURFACE CONDITIONS:	19.0 CF/T
	0.59 cc/g
RAW STP CONDITIONS:	19.7 SCF/T
	0.62 cc/g
CANISTER HEAD SPACE:	1080 cc

TIME COAL SEAM PENETRATED:	8	50	17-Sep-08
TIME COAL ARRIVED AT SURFACE:	9	04	17-Sep-08
TIME CANISTER SEALED:	9	16	17-Sep-08

PROXIMATE ANALYSIS	
% MOISTURE:	5.15
% ASH:	12.68
% VOLATILE:	35.84
% FIXED CARBON:	46.33
TOTAL %:	100.00
HEAT VALUE (BTU/lb):	11532
% SULFUR:	0.85
APP. SPECIFIC GRAVITY:	

Td:	14.00 minutes
Ts:	26.00 minutes
T25%:	207.67 minutes
SURFACE TIME RATIO:	0.46
LOST TIME RATIO:	0.13



T25% = time from seam penetration to the time when 25% of the measured volume has desorbed

Td = time from seam penetration to sample surfacing

Ts = time from seam penetration to container sealing

COMMENTS:

SURFACE TIME RATIO = (Ts - Td)/Ts

LOST TIME RATIO = Ts/T25%

STP = 15 degrees C and 29.92 in. Hg

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Inventory Approach for Mongolia cont'd

- Adsorption isotherm testing samples
  - Taken from the desorbed coal sample at the end of the desorption test (sent to another laboratory)
  - Results are used to determine gas capacity of coal sample, or how much gas the coal can hold at reservoir temperature and pressure
  - Critical information can be interpreted from this test: pressure at which the gas will begin to desorb from the coal, maximum volume of recoverable gas; this data can be used to characterize the coal and estimate the amount of gas that may be present a different pressure (depth).

Example Adsorption Report

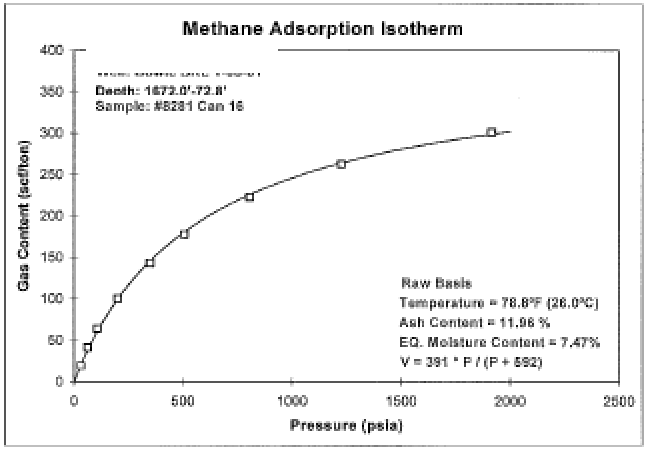
Sample Weight = 104.43 g	Ash Content = 11.96 %
Particle Size = < 20 Mesh	EQ. Moisture Content = 7.47%
Temperature = 78.8°F (26.0°C)	

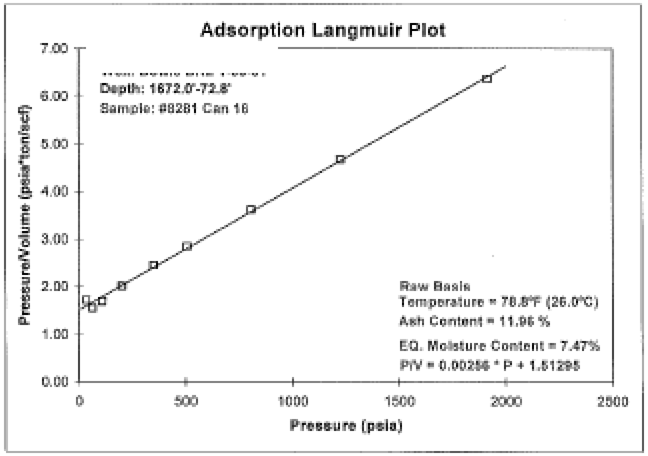
Methane Adsorption

Pressure		Gas Content (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
33	0.23	19.2	0.60
64	0.44	41.1	1.28
108	0.74	63.8	1.99
202	1.39	100.4	3.13
350	2.41	142.9	4.46
507	3.50	177.5	5.54
807	5.56	222.6	6.95
1,226	8.45	262.4	8.19
1,916	13.21	301.0	9.40

Langmuir Coefficients V = 391.1 * P / (P + 591.7)

PL		VL (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
591.7	4.08	391.1	12.2





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Adsorption Laboratory

Inventory Approach for Mongolia cont'd

- Construct a basin-wide gas content map using isotherm and gas content data
- Measured gas content and isotherm data will be used to estimate the gas content of the coals contained in nearby basins

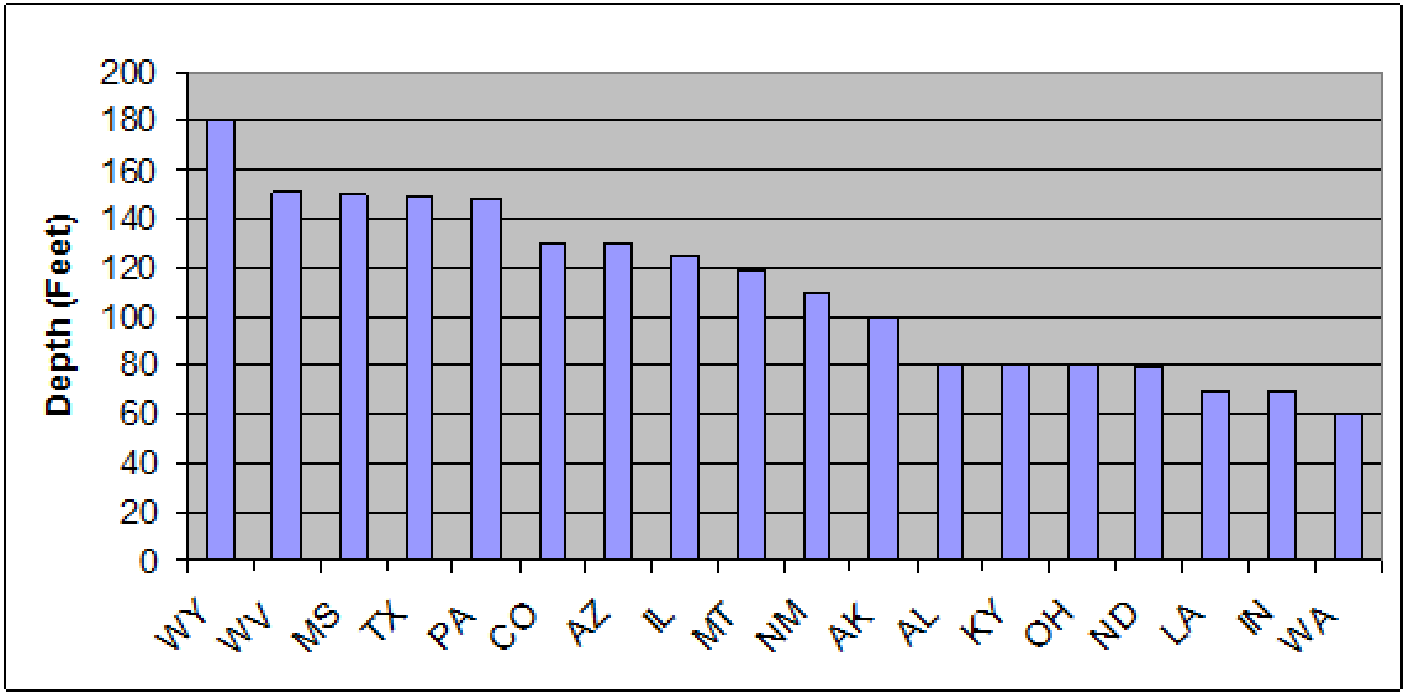
Example U.S. Coal Basin Gas Content Data

Coal Basin	Inventory Code	Major Coal Rank Mined	2003 Revised Gas Content (cf/t)	Recommended New Gas Contents (cf/t)	Comments
Northern App	NAB	Bituminous	59.5	59.5	Data compiled from USBM report
Central App	CAB	Bituminous	24.9	24.9	Data compiled from USBM and MRCP reports
Warrior	WRB	Bituminous	30.7	30.7	Data compiled from USBM report
Illinois	ILB	Bituminous	34.3	34.3	Data compiled from USBM and MRCP reports
S.West/Rockies	WTB	Bituminous			
S.West (NM, AZ, CA)		Bituminous	7.3	7.3	Data compiled from USBM and MRCP reports
Rockies (CO)		Bituminous	33.1	33.1	Data compiled from USBM and MRCP reports
Rockies (UT)		Bituminous	16.0	16.0	Data compiled from USBM and MRCP reports
N.Great Plains	NGP	Lignite	5.6	5.6	North Dakota mines lignite coal
Northern Rockies (MT,WY)	WYM	Sub-bituminous	5.6	20.0	Data compiled from USGS, and private sector
West Interior	WIN				
Forest City, Cherokee		Bituminous	34.3	34.3	Arkansas, Missouri, Kansas, Iowa coals similar to Illinois Basin
Arkoma (OK)		Bituminous	74.5	74.5	Data compiled from USBM and MRCP reports
TX, LA		Sub-bituminous	33.1	11.0	Texas & Louisiana mine borderline sub-bituminous coal
Northwest	NWB	Sub-bituminous	5.6	16.0	Washington, Alaska coals similar to Powder River Basin

Inventory Approach for Mongolia cont'd

- Geologic data will be used to develop country or basin-specific (depending on data) emission factors for active surface mining and post-mining emissions

Example Data: Average Overburden Depth of U.S. Surface Coal Mines



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Basin-specific Emission Factors

- In order to develop accurate emission factors for some basins in Mongolia, analysis will be conducted on:
  - Thickness of the adjacent coal seams
  - Permeability of the coals and other strata found in the overburden, interburden and underburden
  - Overburden thickness
  - The amount of disturbance to the mine floor and highwall as a result of mining coal
- In U.S., current emission factor is 200% to account for gas in over- and underburden, adjacent seams, etc.

SMM Emissions Estimation

- Emissions from surface mines (and post-mining activities) will be calculated by multiplying basin-specific coal production by a basin-specific gas content and then by the basin/country-specific emission factor to determine methane emissions

Annual emissions (m^3) = basin specific gas content (m^3/tonne) x emission factor (%) x coal production (tonnes)

Products

- Once this analysis is complete, and gas contents and emission factors are determined, a set of spreadsheets will be developed that will facilitate completion of an annual inventory.
- Utilizing the latest coal production data available, the MNEC and other interested institutions staff will be trained on use of the spreadsheets to complete inventories in following years.

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CONSIDERATIONS FOR THE FUTURE

Future Considerations

- Some surface mines have indicated plans to eventually move mining to underground operations to reach deeper seams
- Emissions calculations for underground mines may be done directly – Tier 3 data
- Ventilation air volume, methane concentration
- Drainage data from any CMM wells

Future Considerations cont'd

- Methane recovery projects will be subtracted from inventory

United States' CH_4 Emissions from Coal Mining (million m^3)					
Activity	**1990**	**1995**	**2000**	**2005**	**2010**
UG Mining	4,364	3,272	2,761	2,445	3,616
Liberated	4,755	4,129	3,806	3,512	5,002
Recovered & Used	**-391**	**-857**	**-1,044**	**-1,067**	**-1,386**
Surface Mining	843	806	861	931	924
Post-Mining (UG)	542	485	468	450	384
Post-Mining (Surface)	137	131	140	151	150
Total	5,886	4,695	4,230	3,977	5,075

Thanks!

Contact Information:

cboger@ravenridge.com

+1 (970) 245-4088

www.ravenridge.com

mnec8@yahoo.com

976 11 354365

http://www.mnec.org.mn/

Approach for a Methane Emissions Inventory and CMM Resources Assessment in Mongolia

Ulaanbaatar, Mongolia
22 July 2013

CMM Emissions Inventory Methodology

- IPCC Tier 2 Methodology is based on coal production and emission factors
  - With widespread coal deposits of varying rank, it is important to develop *basin-specific emission factors*
- Work is currently underway to develop emission factors for surface mining in Mongolia
  - Based on gas content data from MNEC USEPA grant-funded resource assessment and IPCC 2006 guidelines
  - Range of post-mining (coal transportation and storage) factors are established by IPCC
- Professor Namkhainyam is responsible for emission inventory work (experience with IPCC as working group member)

Emission Factor Methodology

Range of emission factors established by IPCC

- Overburden thickness helps determine use of low, medium, or high CH4 emission factor
- Post-mining emission factors
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories Section 4.1.4

More accurate gas content data and isotherms developed from sampling at key mines during resource assessment and prefeasibility studies

- Nalaikh
- Naryn Sukhait (June 2012)
  - Site of USEPA Prefeasibility Study
- Baganuur (June 2012)
  - Site of USEPA Prefeasibility Study
- Khotgor (2013)
- Work underway to acquire remaining sample at Sharyn Gol
- Gas content extrapolated to other basins

Based on coal rank and other basin characteristics

- Use IPCC emission factors as a guideline
  - Use IPCC average post-mining emission factor unless data indicates otherwise
- Basin-specific emission factors are multiplied by basin coal production to determine surface mining emissions

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Resource Assessment Methodology

Review prior estimations of CBM resources

- Review Nalaikh study report
- Review public reports on coal and CBM resource data
- Consult with participating mines to complete questionnaires and synthesize data
- Work facilitated by both USEPA grant to MNEC and USEPA/RRR prefeasibility studies at Naryn Sukhait and Baganuur

Collect coal samples and complete testing

- Utilizing analogous US basins, determine ideal sampling locations based on coal rank
- Collect coal samples
- Complete desorption testing to determine gas content
- Submit samples for adsorption isotherm and proximate analysis

Calculate CMM Resources

- Use existing data and coal resource calculations with gas content and adsorption isotherm results to calculate CMM resources at Mongolian coal basins
- Develop final report for USEPA and publish to GMI and MNEC websites

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Resource Assessment Reporting

- RRR will supply report on , methodology, results of investigations and resource calculations
- Mongolian researcher, will supply detailed information on each mining site at which data has been collected for desorption and adsorption:
  - Location and topography
  - History of exploration
  - Coal geology
  - Coal quality
  - Coal reserves
  - Status of mining

Coal Sample Sites for Adsorption Isotherms

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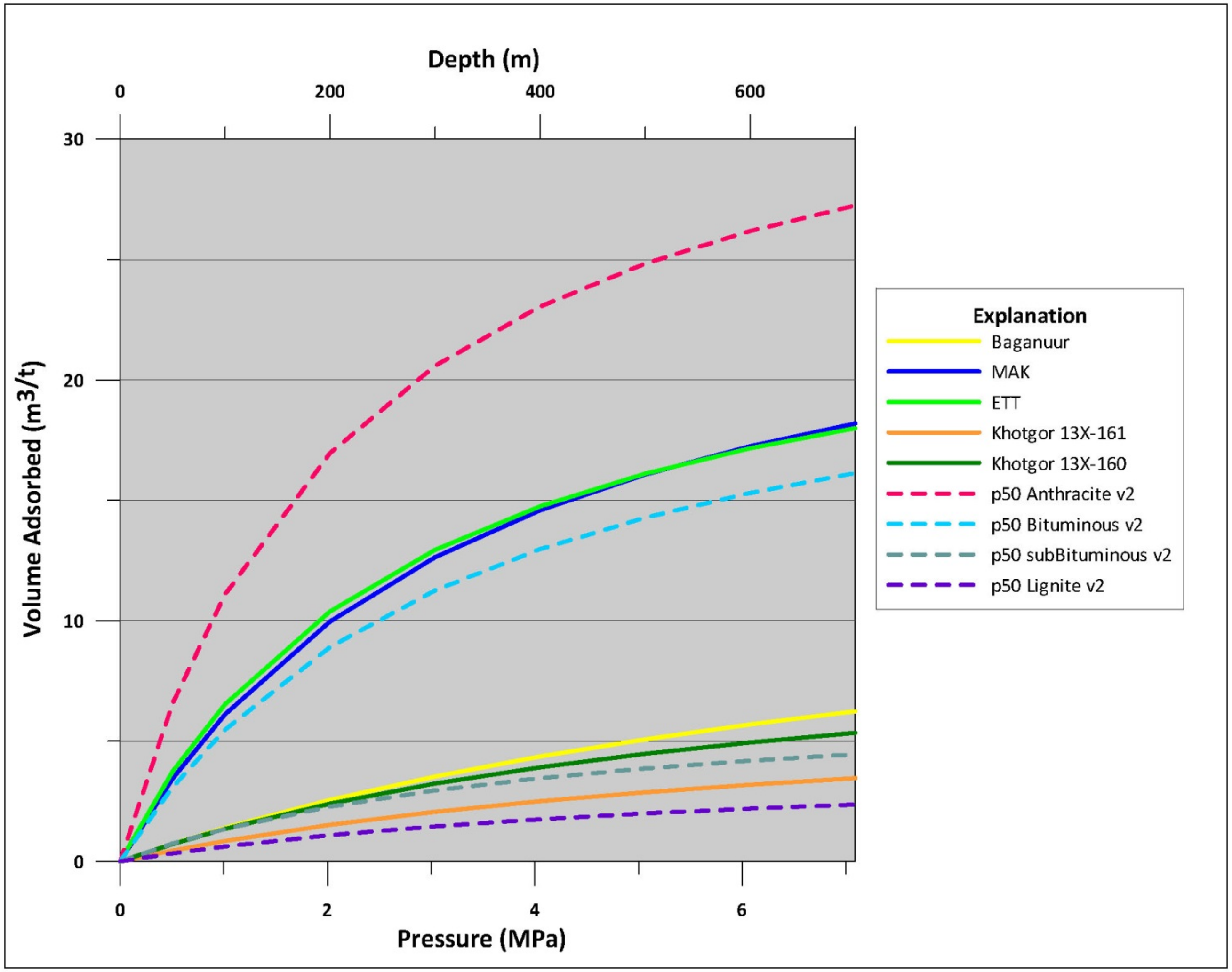
Comparison of Isotherms from Mongolia to U.S. Isotherm Database



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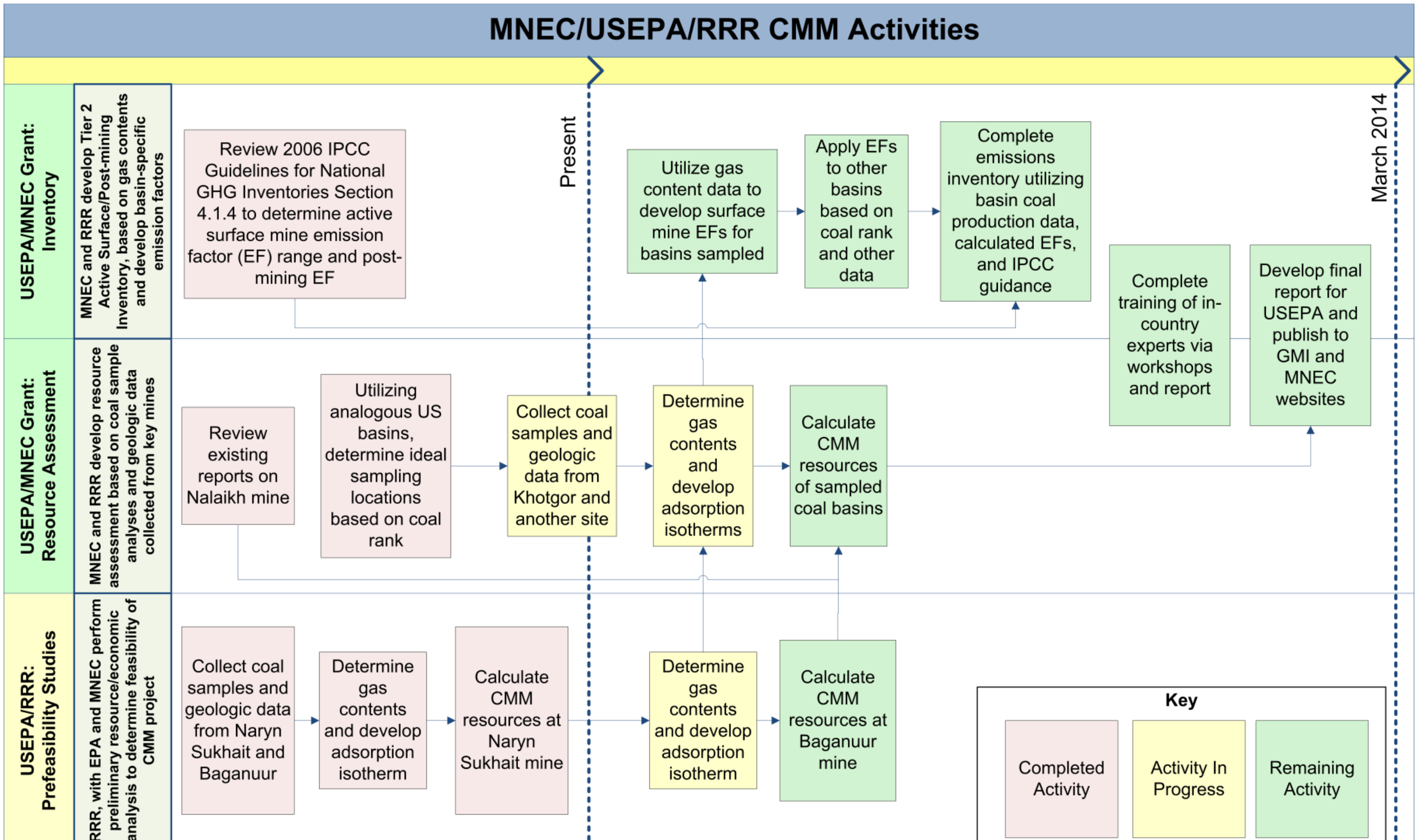
Output from Working Database of Mongolian Coal Characteristics

Coal Deposit	Basin	Depth (m)	Carbon		Volatile Matter		Calorific Value (BTU/lb)		Rank - Low (ASTM)	Rank - High (ASTM)	Coal Reserves (million t)	Gas of CH_4, m^3/t	Reserves of CH_4 (million m^3)
			d.m.m.f. high	d.m.m.f. low	d.m.m.f. high	d.m.m.f. low	mmmf low	mmmf high					
Nuurst khotgor	Kharkhiraa	100	70.4	58.8	23.95	19.48	9,137	14,666	hvAb	hvAb	143.3		
Khar tarvagatai	Kharkhiraa	80	61.0	56.6	31.67	26.54	11,745	13,322	hvBb	hvCb	19.73		
Khushuut	Mongol altai	105	80.9	74.9	17.12	18.08	10,931	14,800	lvb	mvb	88		
Zeegt	Mongol altai	50	71.4	67.4	23.54	20.71	10,955	10,609	mvb	mvb	4.58		
Mogoin gol	Orkhon-Selenge	85	66.8	66.8	25.32	24.89	11,706	12,345	hvCb	hvCb	4.1		
Saikhan-Ovoo	Orkhon-Selenge	250	92.3	55.4	7.39	26.64	14,350	13,844	an	hvBb	28.3		
Uvurchuluut	Uvurkhangai	65	57.5	58.8	34.04	15.29	6,668	8,311	ligA	subC	3.8		
Bayan teeg	Ongyin Gol	110	49.4	49.4	36.18	36.19	11,070	11,072	hvCb	hvCb	29.7		
Tevshiin govi	Nyalga-Choir	325	55.8	55.9	23.53	23.55	7,575	7,579	ligA	ligA	588		
Tavan tolgoi	South–Govi	400	68.4	68.4	27.51	26.51	10,941	11,748	hvCb	hvCb	6400		
Sharyn gol	Orkhon-Selenge	250	56.4	56.4	30.41	30.41	9,115	9,821	subC	subB	61.3		
Nalaikh	Orkhon-Selenge	350	56.0	56.0	33.03	33.04	8,440	8,442	subC	subC	58.85		
Baga nuur	Nyalga-Choir	275	56.5	56.5	26.68	26.69	6,983	7,642	ligA	ligA	511		
Shivee-Ovoo	Nyalga-Choir	350	55.4	55.4	28.96	28.98	5,854	5,855	ligB	ligB	563		
		350	56.6	56.6	32.27	32.29	7,080	7,083	ligA	ligA	563		
Chandgan tal	Nyalga-Choir	100	54.2	54.3	31.10	31.14	6,049	6,867	ligB	ligA	123		
Tal bulag	Sukhbaatar	200	53.8	53.9	31.96	31.99	5,921	5,924	ligB	ligB	81.5		
Aduun chuluun	Choibalsan	60	52.9	53.0	26.79	26.83	5,129	5,132	ligB	ligB	241.26		
Nariin sukhait	South–Govi	150	72.4	62.2	26.39	21.83		19,729	mvb	hvAb	21.84		
Ulaan-Ovoo	Orkhon-Selenge	155	54.6	54.6	36.21	36.21	8,650	8,651	subC	subC	53.98		
Khuut	Dundgovi	100	57.9	57.9	31.81	31.82	8,620	8,623	subC	subC	87.5		
Uvdug khudag	Dundgovi	100	56.2	56.3	32.57	30.85	6,362	6,348	ligA	ligA	159.2		
Aman gol		375									1500		

Table of coal characteristics compiled and edited from data received from Bayarsaikhan and Dr. Namkhainyam.

Overall Approach to and Workflow of MNEC/USEPA/RRR CMM Projects



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