TECHNOLOGICAL DETAILS OF SHALE GAS DRILLING

INTRODUCTION

Great Eastern Energy Corporation Ltd ("GEECL") is the first Company to commercially produce CBM gas in India. It is involved in exploration, production and distribution of CBM gas from Raniganj (South) CBM block comprising an area of 210 Sq.km.

Our block has an estimated CBM gas-in-place of 2.62 Trillion cubic feet ("TCF"). In addition, Shale gas resource gas-in-place is estimated at 6.63 TCF in our existing block, taking the total a staggering to 9.25 TCF.

Inspired by the example of USA, where shale gas ushered in an energy revolution, India hopes shale gas can reduce the country's dependence on imports of oil and gas. India's natural gas demand is projected to double by 2030, which underlines the importance of exploration of unconventional hydrocarbons like Shale Gas. India's technically recoverable shale gas resources have been estimated at 63 TCF as per EIA.

Raniganj is the first sedimentary basin in India where shale gas exploration and production tests have been conducted by ONGC in 2011. A well was drilled up to a depth of 1700 m and has shown encouraging results *(LNG World News, 2011; Mendhe et al., 2015a; Varma et al., 2015b)*.

A thick sequence of Ironstone shale is also present in GEECL's allocated area of 210 Sq. Km below the Raniganj formation, which could be an attractive play upon exploration.

GEECL is uniquely placed to explore and produce and monetize the shale resource/reserves in our block. We already have the infrastructure in place, i.e., internal MDPE pipelines connecting the wells to our gas gathering stations, and dedicated steel pipelines for supplying CBM to our customers.

Shale occurrences in Raniganj basin

In Raniganj basin, Gondwana litho-units have thick sections of clastic sediments deposited in elongated erosional intracratonic basins that widened over time (Pareek,

1988) and were deposited from Late Carboniferous to the beginning of the Cretaceous, contains thick shales in Raniganj, Barren Measures, and Barakar Formations. Coal seams are present in Raniganj and Barakar Formations, deposited during the Permian age (Trippi and Tewalt, 2011). There are three perennial rivers - Ajay, Barakar and Damodar - along with their tributaries, channel in northern, eastern and southern parts of the basin, which contributed to sediments accumulation and lithification leading to thick shale beds deposits (Dutt, 2003).The summary of TOC, S1, and S2 values compiled from various published shale gas reports for Raniganj Basin is provided below:

Formation	**TOC**	**S1**	**S2**
	(Wt.%)	(mg/g)	(mg/g)
Raniganj	9.52	0.89	20.4
Barakar	9.85	0.63	10.72
Barren Measures	4.38	0.59	4.7

Raniganj, Barren Measures and Barakar Shale Properties in Raniganj Basin	
Kerogen Type	Type III
Total Organic Carbon (%)	4 -5
Thermal Maturity (%Ro)	0.60 – 1.09
Depth (m)	1,150 – 1,500 m
Gross Thickness (m)	100 – 800 m

Source:

https://doi.org/10.1016/j.coal.2018.01.012
http://dx.doi.org/10.1016/j.petrol.2016.11.008
Marine and Petroleum Geology 59 (2015) 480-490

Exploration and Development

GEECL proposes to adopt a phased approach to further characterize the shale resource. The plan should encompass the characterization of the shale resource while drilling exploration core wells in prospective areas:

- Phase-1: Exploration Core wells to characterize the shale
- Phase-2: Lateral test well drilled from the exploration Core Well to understand the commercial viability

Phase-1 Exploration Core Well

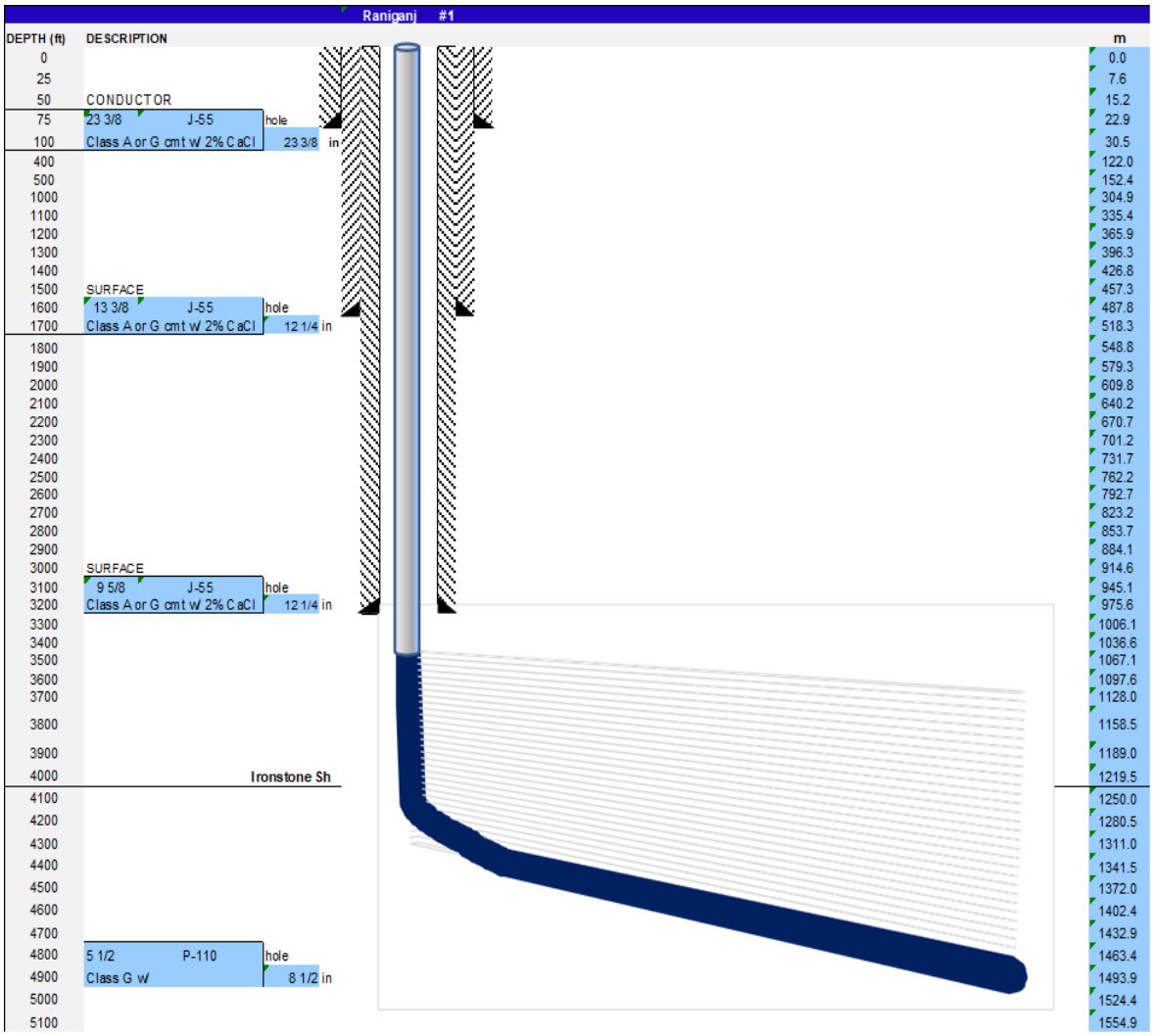
The objective of drilling exploration core wells is to validate the preliminary geotechnical analyses including the stress regime and the presence of natural fractures in the shale reservoir. Data acquisition is the key component in developing a thorough understanding of the reservoir and the evaluation needed to define the production potential. The exploration core wells proposed to be drilled vertically and the size of the cores will be HQ (63.5 mm) and NQ (47.6 mm) sizes. The following data set is proposed to be generated from the cores;

- In-situ Gas Content
- TOC and Rock-Eval Pyrolysis
- Rock Mechanics
- Vitrinite Reflectance
- Kerogen Type
- Porosity
- Permeability
- Mineralogy (XRD)

Phase-2 Lateral Test Well

The objective of drilling out lateral test wells is to validate the optimal well design (deviation, number of stages, etc.), and to demonstrate gas production at rates sufficient to justify a complete field development. Logically, these wells would be drilled at the same location as the exploration well drilled during Phase-1. The wells would deviate with an orientation of 90 degrees to the expected principal stress direction. The lateral portions of these wells should be spaced approximately 300 m apart.

Drilling of the lateral is expected to take approximately two weeks to complete with the built section drilled on 8-10 degree/30 m increments. A 1,000-1,200 HP rig rated to a 150-ton hook load will be deployed to complete the drilling of the lateral. The lateral section is expected to reach approximately 1,200 meters for a total measured depth (MD) of around 2,750 m. The lateral will require 5 ½-in, 17 ppa, P-110 casing or similar grade to withstand the expected hydraulic fracturing pressure of 8,000-10,000 psi at 70 bpm.



Drilling Details:	Air Hammer / bit size	Weight	Grade	Collapse	Burst	Depth		Weight	Orientation
	Casing size (inches)	ppf		(psi)	(psi)	MD (feet)	MD (meters)	(lbs)	Section
Conductor Hole	23 3/8			-	-	75	23	0	V
Conductor Csg	20	106.5	J-55			68	21	7,242	V
Surface Hole	17 1/2	-	-	-	-	1,673	510		
Surface Csg	13 3/8	54.5	J-55	1,130	2,730	1,640	500	89,380	V
Intermediate Hole	12 1/4	-	-		-	3,230	985		
Intermediate Csg	9 5/8	36.0	J-55	1,930	3,200	3,200	976	115,200	V
Lithologic Hole	8 1/2					4,953	1510	-	
	Core w/NQ bbl					4750-4920	1450-1500		
	PB 8 1/2-in hole w/cmt to					3,940	1201	-	V
Production Hole	8 1/2	horizontal lateral				9,010	2747		L
Production Csg	5 1/2	17.0	P-110	7,480	10,640	8,980	2738	152,660	L

Production Potential Test to Shale Horizons

The shale will require several stage stimulations from the toe of the well back to the heel. Pumping rates of about 70 bpm are proposed to extend the fracture within the shale

layers. The extent of coverage of the fracturing wings, along the length of the lateral, will determine the number of stages required to adequately stimulate the productive intervals of the shale.