# Study of Cauvery Basin, Damodar Valley Basin for Shale Oil and Gas

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## Abstract

This paper contains a detail study about the two major basins of India in the perspective of shale oil and gas. According to estimates by EIA, India has 96 tcf of recoverable shale gas reserves. However there has been a recent downward revision in the estimates. India's shale gas reserve estimates pale in comparison to global standards, however limited exploration has been carried out so far. The Cambay, Krishna Godavari, Cauvery and the Damodar Valley are the most perspective sedimentary basins for carrying out shale gas activities in the country. Overall, ARI estimates a total of 584 Tcf of risked shale gas in-place for India, The risked, technically recoverable shale gas resource is estimated at 96 Tcf in India. In addition, we estimate risked shale oil in-place for India of 87 billion barrels. The risked, technically recoverable shale oil resource is estimated at 3.8 billion barrels for India. Cauvery, comprised a series of extensively faulted horst and graben structures. As such, the prospective areas for shale gas and oil in these basins are often restricted to a series of isolated basin depressions (subbasins). While the shales in these basins are thick, considerable uncertainty exists on the areal extents of the prospective areas in these basins. To account for this uncertainty, we have applied prospective area risk factors to each basin.

**Keywords: Shale oil, Shale gas, Cauvery Basin, Damodar Valley Basin, Geologic Setting**

## I. CAUVERY BASIN

### *A. Introduction and Geologic Setting:*

The Cauvery Basin covers an onshore area of about 9,100 mi2 on the east coast of India, Figure 1. The basin comprises numerous horsts and grabens, with thick organicrich source rocks in the Lower Cretaceous Andimadam Formation and Sattapadi Shale.

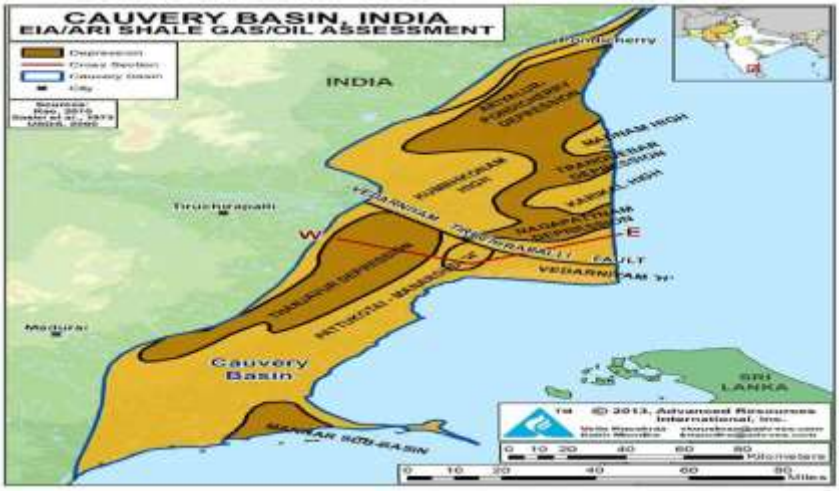


Fig. 1: Cauvery Basin Horsts and Grabens

The gas- and oil-prone shale source rocks in the Cauvery Basin are the Lower Cretaceous Andimadam Formation and the Sattapadi Shale, Figure 2. The shale resource prospective area of the Cauvery Basin is limited to four depressions (troughs) Nagapattnam, Tranquebar, Ariyalur-Pondicherry and Thanjavur and the Mannar Sub-basin. The source rocks are generally shallow marine Type III with some Type II kerogen. The thermally mature source rocks in the shallower Sattapadi Shale and the deeper Andimadam Formation contain thermogenic wet gas and condensate.

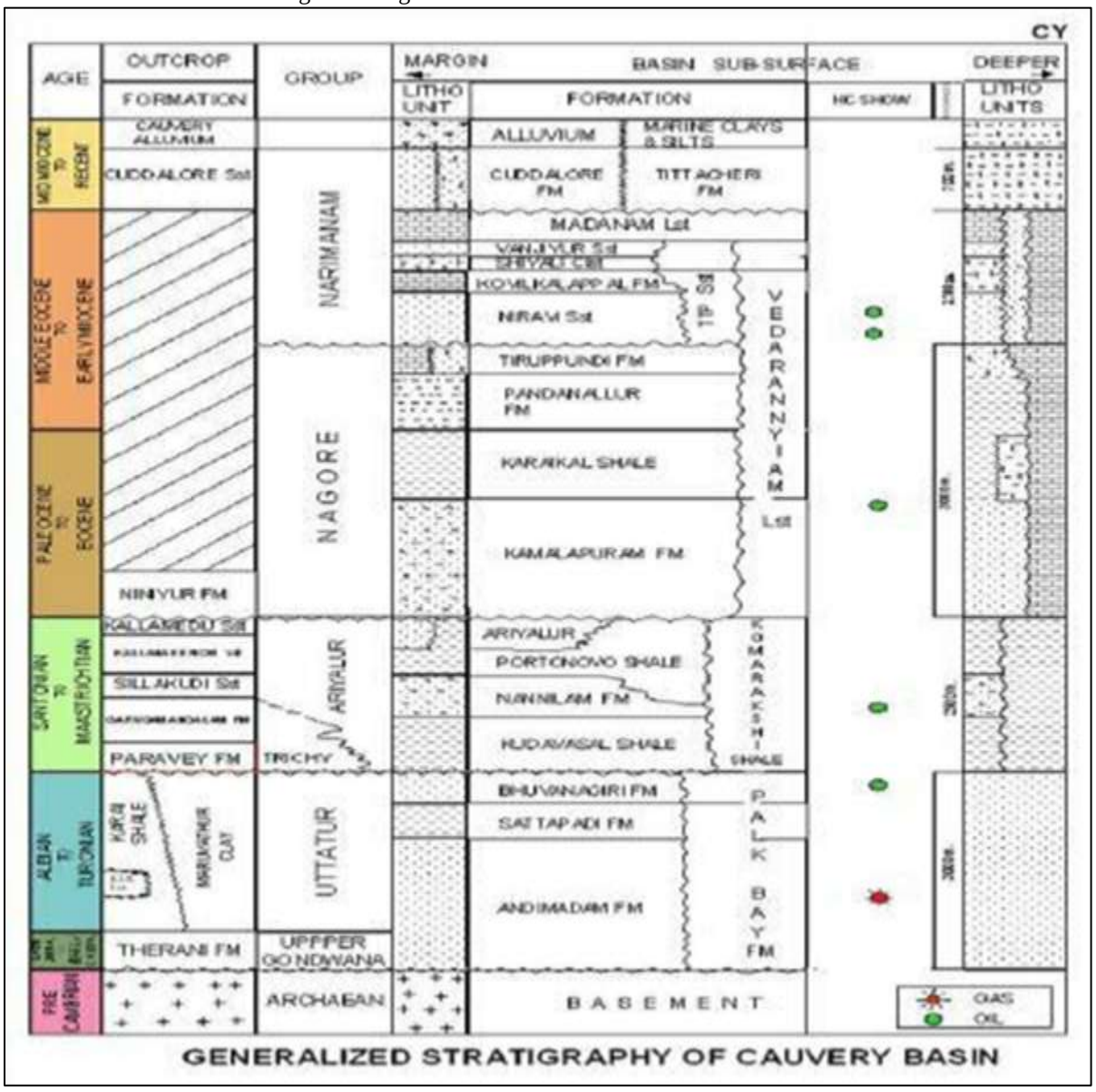


Fig. 2: Generalized Stratigraphy, Cauvery Basin

### *B. Reservoir Properties (Prospective Area):*

We have identified a 1,010-mi$^2$ wet gas and condensate prospective area for the shales in the Cauvery Basin. The thickness of the Lower Cretaceous interval is 3,000 to 5,000 ft, with the Andimadam Formation and the Sattapadi Shale accounting for the bulk of the gross interval, Figure 3. The TOC of the combined Andimadam/Sattapadi Shale is estimated at 2% to 2.5%, averaging 2.3%. The organic shales are distributed irregularly over the Cauvery Basin, Figure 4.

| AGE | | FORMATION | | THICKNESS in m |
|---|---|---|---|---|
| Recent to Mid. Miocene | | Tittacheri Sandstone | | 300-500 |
| Lower Miocene | | Madanam Limestone<br>Vanjiyur Sandstone<br>Shiyali Clay stone | <br><br>CAP | 600-1200 |
| Oligocene | | Kovilkalappal Fm.<br>Niravi Sandstone | <br>PLAY | 500-800 |
| Eocene | | Pandanallur Fm.<br>Karaikal Shale<br>Up.Kamalapuram Fm. | <br>CAP<br>PLAY | 200-400 |
| Paleocene | | Lr.Kamalapuram Fm. | PLAY | 200-800 |
| Creta-ceous | Upper | Porto-Novo Shale<br>Nannilam Fm.<br>Kudavasal Shale | CAP<br>PLAY<br>CAP | 600-1500 |
| | Lower | Bhuvanagiri Fm.<br>Sattapadi Shale<br>Andimadam Fm. | PLAY<br>SOURCE+CAP<br>SOURCE+PLAY | 1000-1500 |
| Archaean | | Basement | PLAY | |

Fig. 3: Formation Thickness, Cauvery Basin

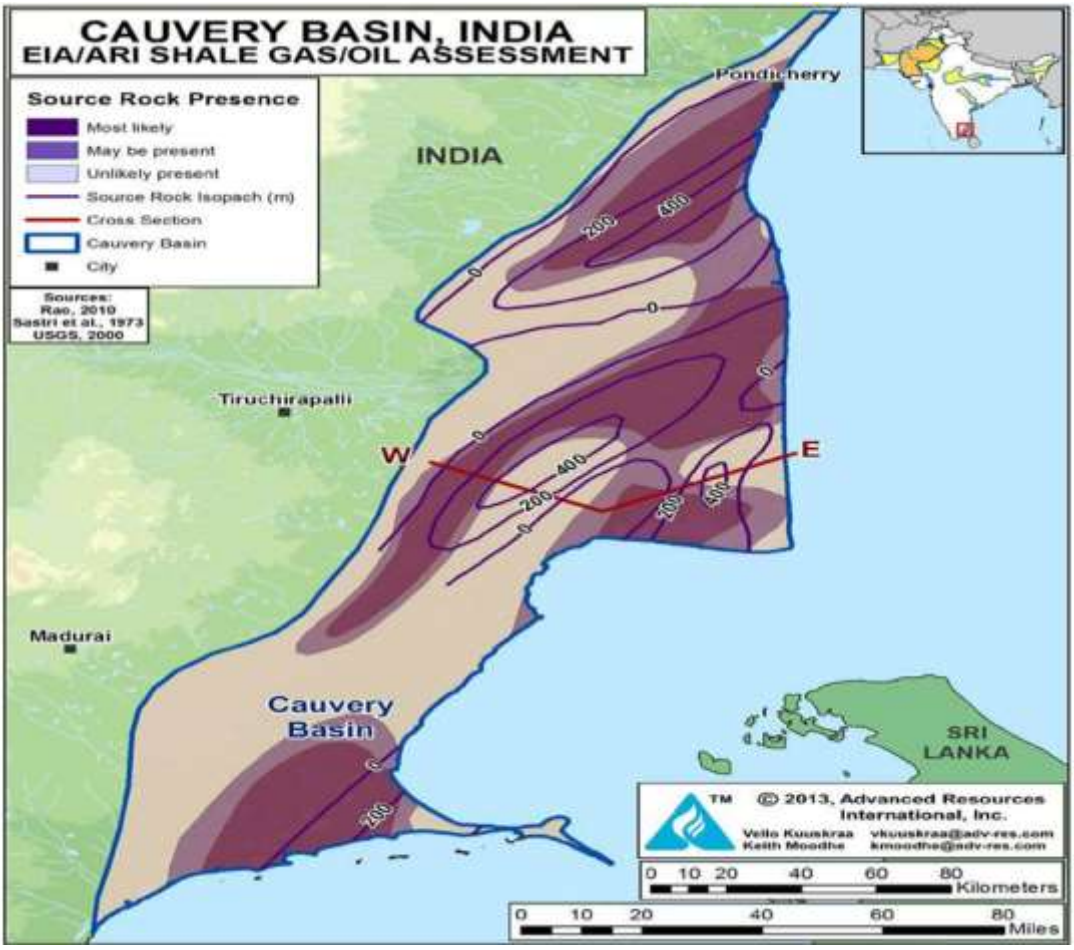


Fig. 4: Shale Isopach and Presence of Organics, Cauvery Basin

The Cauvery Basin contains a series of depressions (sub-basins) that hold potential for shale gas. Two of these Ariyalur-Pondicherry and Thanjavur contain thick, thermally mature shales.

### C. *Ariyalur-Pondicherry Sub-Basin:*

The Ariyalur-Pondicherry Depression (Sub-basin) is in the northern portion of the Cauvery Basin. The Lower Cretaceous Andimadam and Sattapadi Shale encompasses a thick interval at a depth of 7,000 to 13,000 ft, averaging 10,000 ft. Organic-rich gross pay thickness is 1,000 ft with net pay of about 500 ft. The thermal maturity of 1.0% to 1.3% Ro places the shale in the wet gas and condensate window. The onshore prospective area of this sub-basin is estimated at 620 $mi^2$, Figure 5.

### D. *Thanjavur Sub-Basin*

The Thanjavur Depression (Sub-basin), in the centre of the Cauvery Basin, has a thick section of Andimadam and Sattapadi Shale at a depth of 7,000 ft (top of Sattapadi Shale) to 13,000 ft (base of Andimadam Fm), averaging 9,500 ft deep, Figure 6. The organic-rich average net pay thickness is 500 ft. Given limited data, we assume the TOC and thermal maturity for the shale in this sub-basin is the same as in the Ariyalur-Pondicherry Sub-basin. The onshore prospective area with thick organic-rich shale is small, estimated at 390 $mi^2$, Figure 5.

### E. *Resource Assessment*

In the 1,010$mi^2$ prospective area of the Cauvery Basin, the combined Andimadam Formation and Sattapadi Shale have an average wet shale gas resource concentration of 120 Bcf/$mi^2$ and a shale condensate resource concentration of 30 million barrels/$mi^2$. For the combined Andimadam Formation and Sattapadi Shale in the Cauvery Basin, we estimate risked shale gas in-place of 30 Tcf and risked shale oil in-place of 8 billion barrels.
Of this, 5 Tcf of shale gas and 0.2 billion barrels of shale oil are the risked, technically recoverable shale resources.

### F. *Recent Activity*

We are not aware of any shale gas or oil development in the Cauvery Basin.

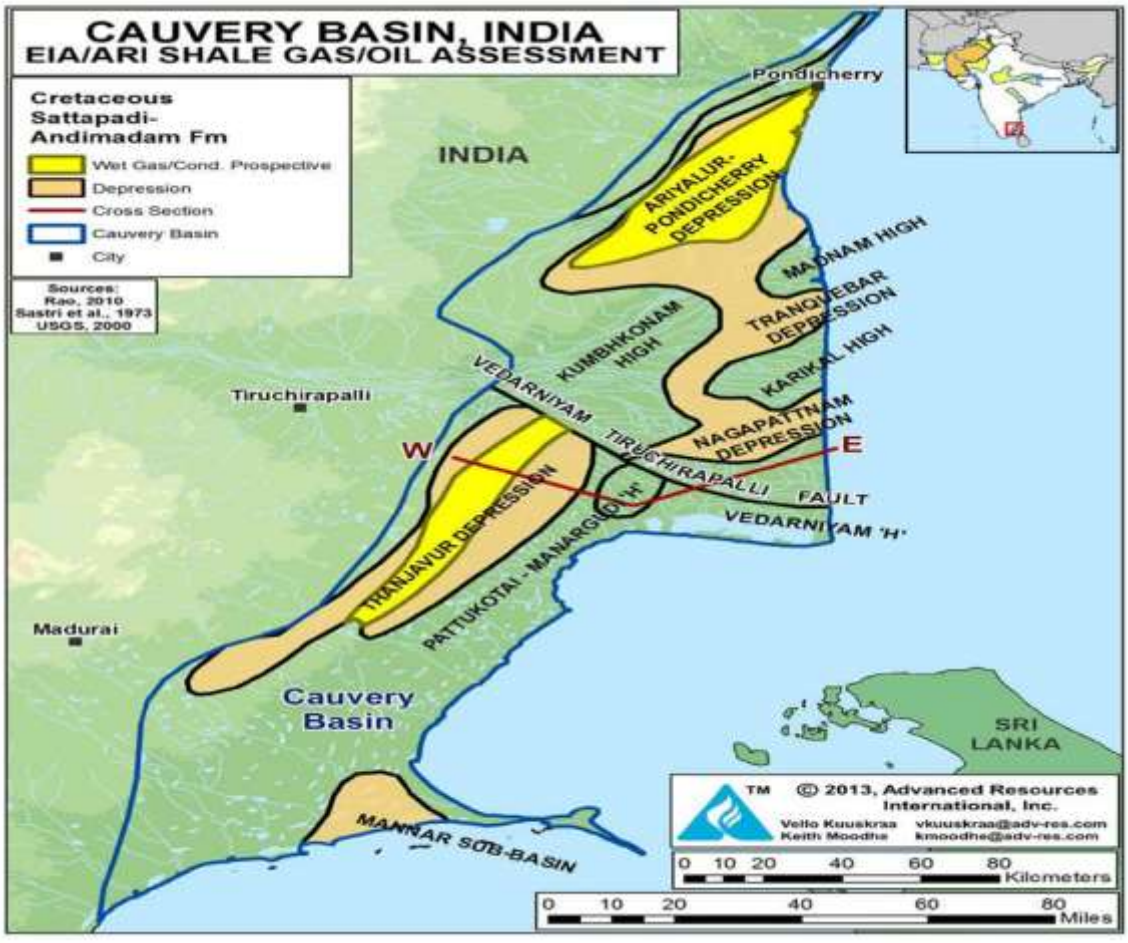


Fig. 5: Prospective Areas for Shale Gas and Shale Oil, Cauvery Basin

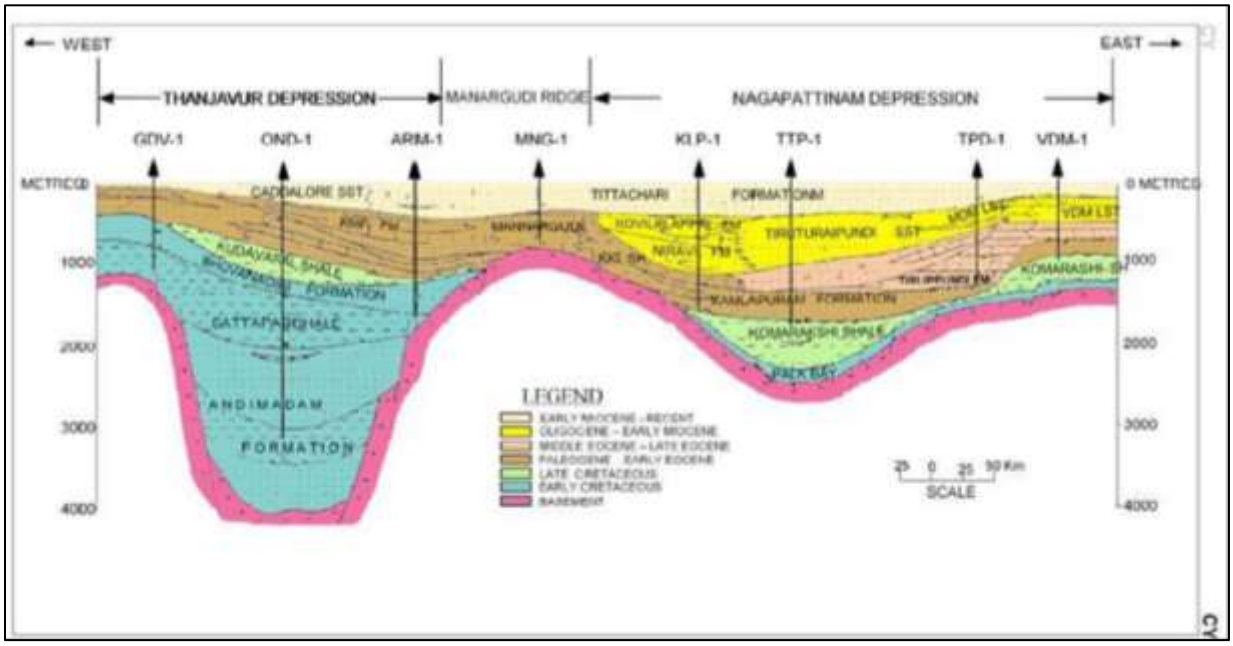


Fig. 6: East to West Cross-Section across Cauvery Basin

## II. DAMODAR VALLEY BASIN, INDIA

### *A. Introduction and Geologic Setting*

The Damodar Valley Basin is part of a group of basins collectively named the "Gondwanas", owing to their similar dispositional environment and Permo Carboniferous through Triassic deposition. The "Gondwanas," comprising the Satpura, Pranhita-Godavari, Son-Mahanadi and Damodar Valley basins, were part of a system of rift channels in the northeast of the Gondwana super continent. Subsequent tectonic activity formed the major structural boundaries of the Gondwana basins, notably the Damodar Valley Basin, Figure 7.

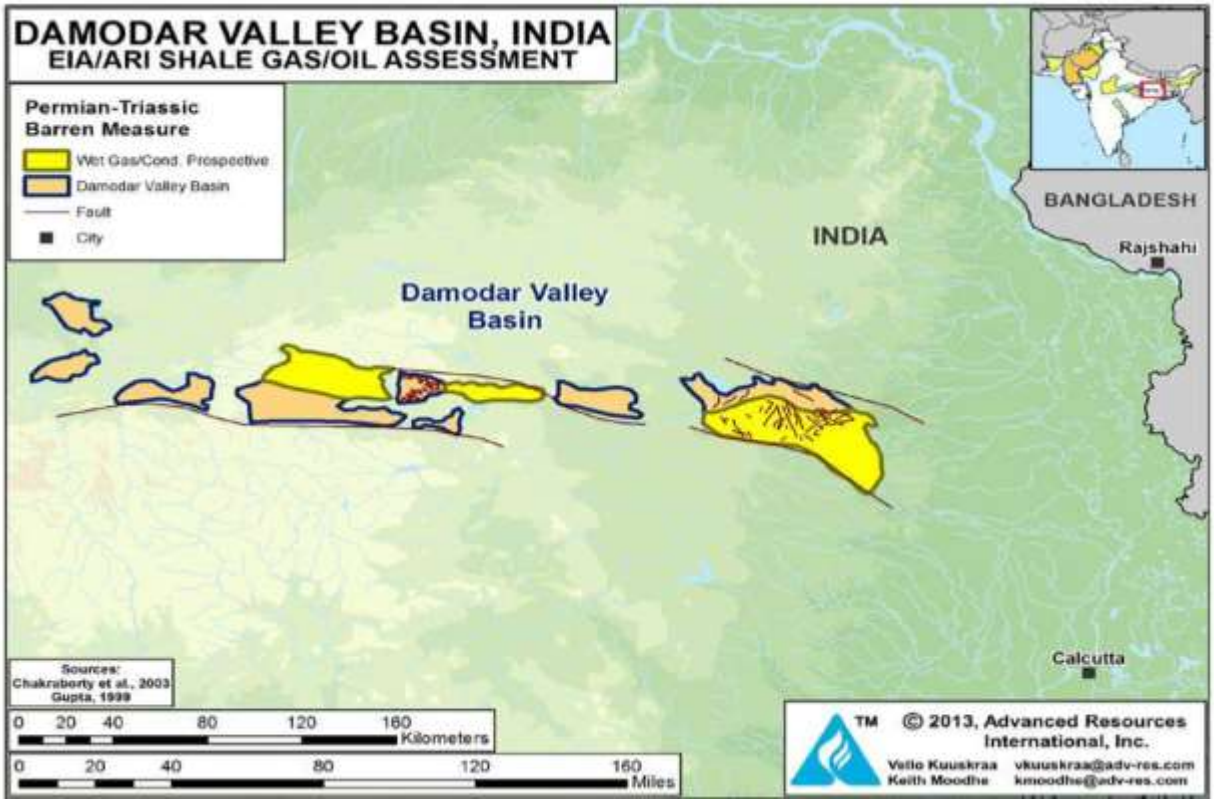


Fig. 7: Damodar Valley Basin and Prospectivity for Shale Gas and Shale Oil

Sedimentation in the Early Permian was primarily glacial-fluvial and lacustrine, resulting in significant deposits of coal. As such, the majority of exploration in the Damodar Valley has focused on the coal resources of the basin, which account for much of India's coal reserves. However, a marine incursion deposited a layer of early Permian Shale, called the Barren Measure Shale in this basin, Figure 8. This shale formation was the target of India's first shale gas exploration well in the eastern portion of the Damodar Valley. Though present in other Gondwana basins, such as the Rewa Basin, in central India, data suggest that the Barren Measure Shale is only thermally mature in the Damodar Valley Basin.

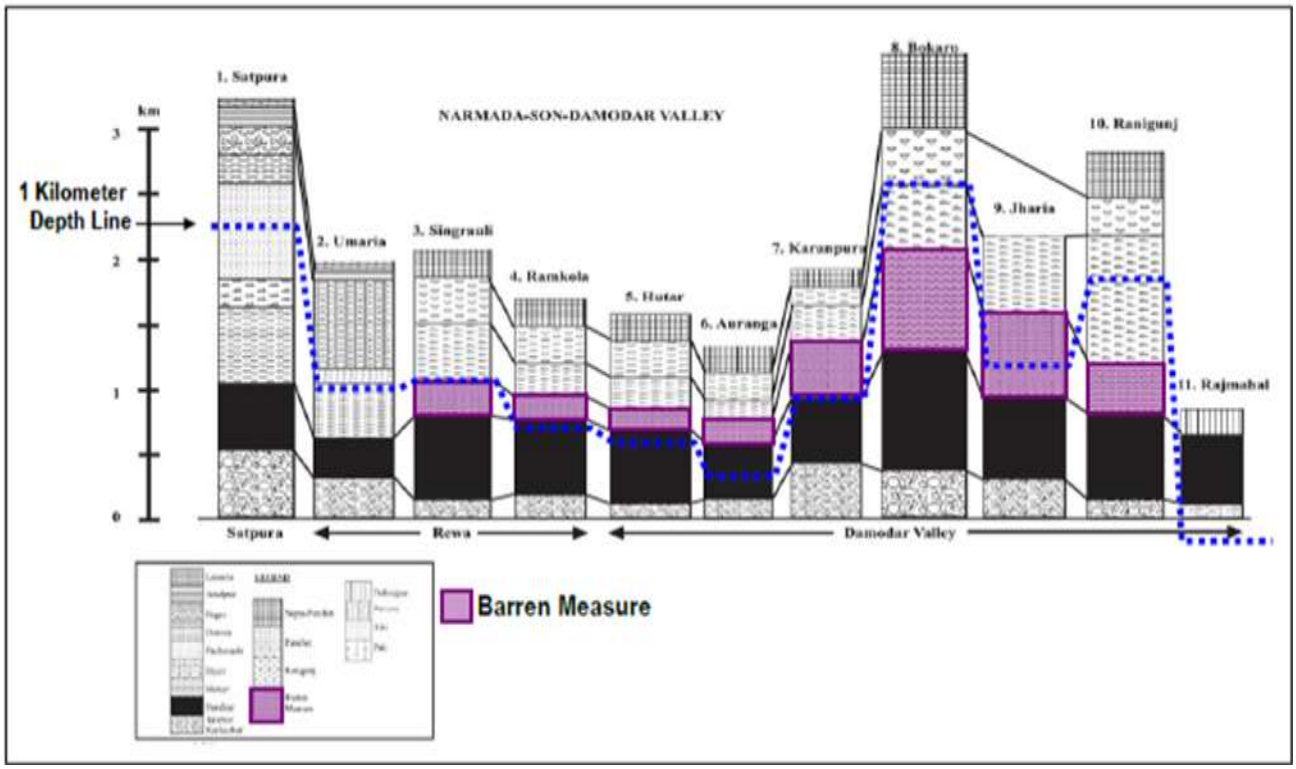


Fig. 8: Regional Stratigraphic Column of the Damodar Valley Basin, India

The Damodar Valley Basin comprises a series of sub-basins (from west to east) the Hutar, Daltonganj, Auranga, Karanpura, Ramgarh, Bokaro, Jharia and Raniganj. Though these sub-basins share a similar geologic history, tectonic events and erosion since the early Triassic have caused extensive variability in the depth and thickness of the Barren Measure Shale in these basins.
Because exploration has focused on the coal deposits within the Damodar Valley Basin, relatively little geologic data is available on the Barren Measure Shale. Thermal maturity data on coals adjoining the Barren Measure Shale suggest that the shale is within the wet gas/condensate (Ro of 1.0% to 1.3%) window, and regional studies have shown favourable TOC, with average values of 3.5%.

Present-day burial depth and lower pressures are the main limitations for the shale gas and condensate prospectively of the Barren Measure Shale in the Damodar Valley Basin. In some sub-basins, regional erosion has removed up to 3 kilometres of overlying sediments.

Based on the regional stratigraphic column, Figure 9, and operator data, the overall 1,080-mi$^2$ prospective area for the Barren Measure Shale in the Damodar Valley is limited to the Bokaro, Karanpura and Raniganj sub-basins.

The prospective areas within the Bokaro (110 mi$^2$) and Raniganj (650 mi$^2$) sub basins are limited by surface outcrops of formations of the Barren Measure Shale to the west and north, respectively. We have estimated a 320-mi$^2$ prospective area for the northern half of the Karanpura Basin, based on statements by Schlumberger and ONGC.

### *B. Reservoir Properties (Prospective Area)*

Absent data on thermal maturity and organic content specific to each of the three sub-basins, we assigned average published reservoir property values to these three sub-basins. TOC is assumed to range between 3% and 6% averaging 3.5%, based on information from INOC and ESSAR. Thermal maturity was estimated from the coal formations surrounding the Barren Measure Shale, indicating values of 1.1% to 1.3% Ro, placing the shale within the wet gas/condensate window. Depth to the Barren Measure Shale averages about 5,000 ft, based on reports from the shale gas well drilled into the Raniganj sub-basin and from regional cross sections, Figure 10. We estimate a weighted average gross interval thickness in the three prospective sub-basins of about 2,000 ft, of which about 1,000 ft is organic-rich and 250 ft is net shale.

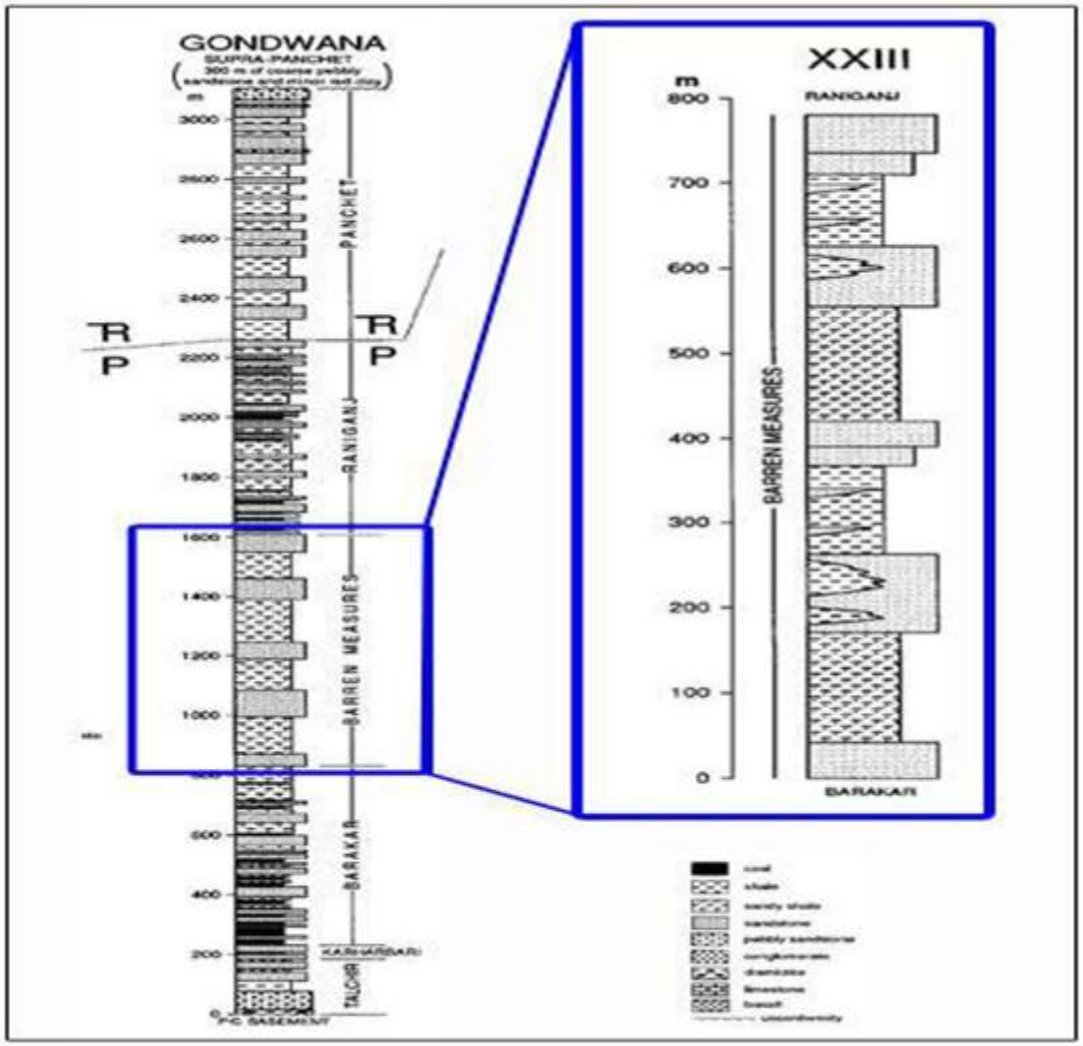


Fig. 9: Generalized Stratigraphic Column of the Gondwana Basin.

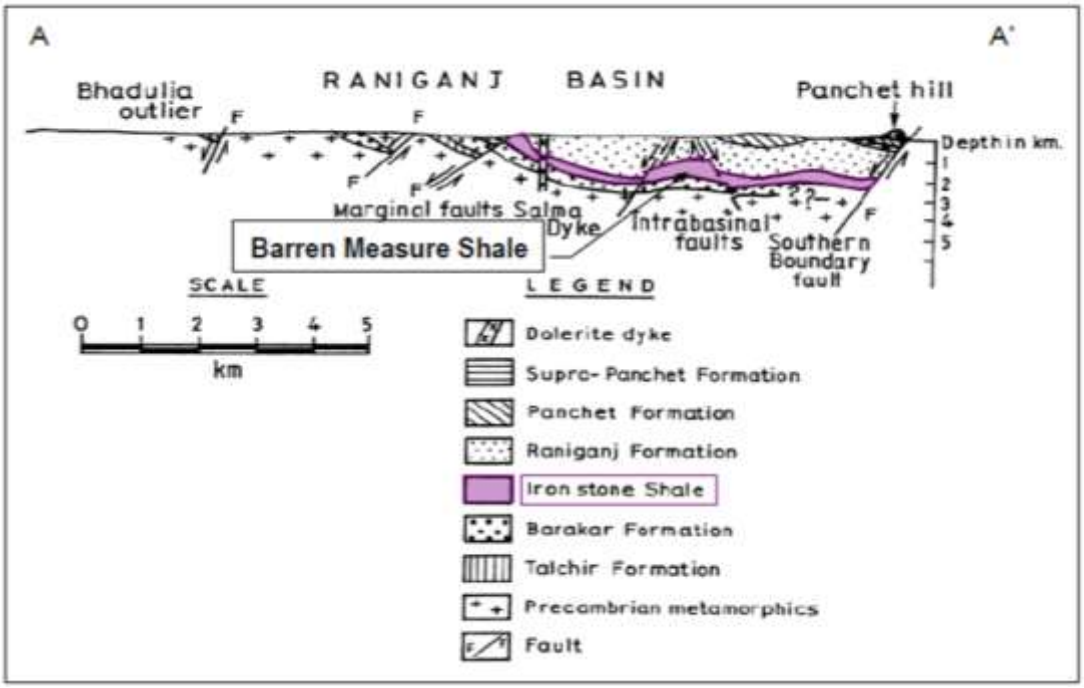


Fig. 10: Raniganj Sub-Basin Cross Section

### C. *Resource Assessment*

Using the geologic characteristics discussed above, we estimate that the Barren Measure Shale in the Damodar Valley Basin has a wet shale gas resource concentration of 63 Bcf/mi$^2$ and a shale condensate resource concentration of 12 million barrels/mi$^2$. Risked shale gas in-place is estimated at 27 Tcf, with the prospect area risk factor recognizing the significant faulting present in the basin. We estimate 5 Tcf of risked shale gas may be technically recoverable from the Barren Measure Shale in the Damodar Valley Basins. In addition, we estimate risked shale oil in-place of 5 billion barrels, with 0.2 billion barrels as the risked, technically recoverable shale oil resource.

### D. *Recent Activity*

Along with the Cambay Basin, the Damodar Valley Basin has been set as a priority basin for shale gas exploration by the Indian government. In late September 2010, Indian National Oil and Gas Company (ONGC) spudded the country's first shale gas well, RNSG-1, in the Raniganj sub-basin of the Damodar Valley. The well was completed mid-January 2011, having reportedly encountered gas flows from the Barren Measure Shale at approximately 5,600 ft. detailed well test and production results are not publicly available. This well was the first of a proposed four-well R&D program in the basin. The plan calls for an additional well to be drilled in the Raniganj sub-basin and for two wells to be drilled in the Karanpura sub-basin.

## III. CONCLUSIONS

If the excavation and production of shale oil in India is continued then we can reduce the importing of oil from the other countries. Thus the Indian economic can be waked from the downstream strategy. Thus by excavating the shale oil from the Indian basin can lead a fore step to the growth of great nation India. The modern technology would surely yield the growth of shale oil from India. By the start of the shale oil production from India we can reduce the importing of fuel from other countries of with high price. So, our modern technologies in hands with ONGC and geological men's we can hope for the production of fuel oil and it will enhance the industrial growth. shale gas has potential but it is not the silver bullet which will resolve India's energy crisis tomorrow. And although we need a policy around shale gas, it needs to be holistic and we should incorporate lessons learned from the experiences of other countries (USA and UK) that are further ahead. Understanding the challenges they faced around water, investment incentives, land, etc. will allow us to create a more robust policy for India which will sustain over the long term. Moreover, everyone following the new developments in the Shale gas industry knows about its importance in the future. Shale gas is definitely an opportunity; if harnessed effectively, can bring about a change in the energy mix of the country. The effects of shale gas can be far reaching and therefore it needs to be given adequate importance. There are some kinks and considerations that need to be worked out before the shale gas takes off economically. The industry and the government need to work together to come up with a shale gas exploration policy that not only encourages foreign investment but also encourages domestic economic growth.

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