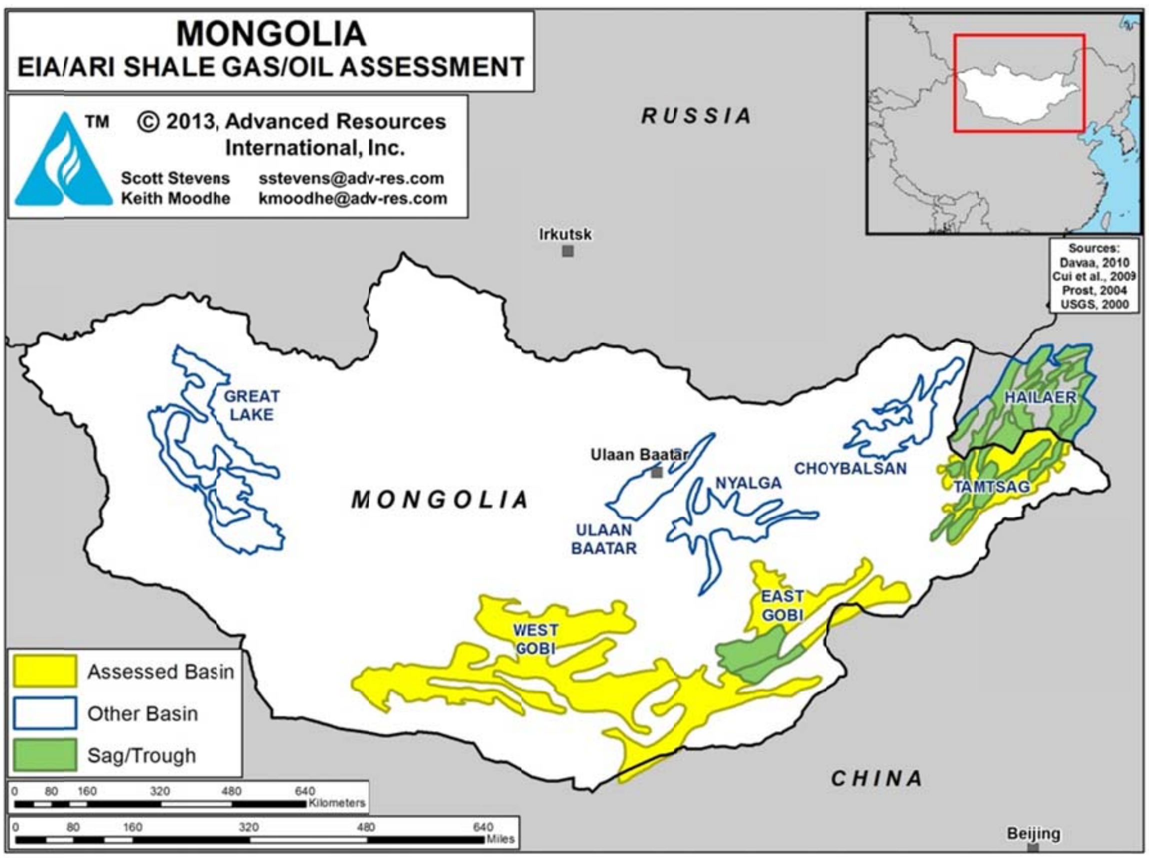
XXI. MONGOLIA

SUMMARY

Mongolia has limited but locally significant shale gas and oil potential located in the eastern and southeastern portions of the country, Figure XXI-1. The narrow and elongated Tamtsag and East Gobi rift basins - - which resemble the oil-productive basins of northeast China -- contain lacustrine mudstone and coaly source rocks within the Lower Cretaceous Tsagaantsav and equivalent formations.

Figure XXI-1. Sedimentary Basins of Mongolia



Source: ARI, 2013

Risked, technically recoverable resources are estimated at 4 Tcf of shale gas and 3.4 billion barrels of shale oil out of 55 Tcf and 85 billion barrels of risked shale gas and shale oil in-place, Tables XXI-1 and XXI-2.

Table XXI-1. Shale Gas Resources and Geologic Properties of Mongolia.

			East Gobi ($24,560\ mi^2$)	Tamtsag ($6,730\ mi^2$)
Basic Data	Basin/Gross Area		East Gobi ($24,560\ mi^2$)	Tamtsag ($6,730\ mi^2$)
	Shale Formation		Tsagaantsav	Tsagaantsav
	Geologic Age		L. Cretaceous	L. Cretaceous
	Depositional Environment		Lacustrine	Lacustrine
Physical Extent	Prospective Area (mi^2)		4,690	5,440
	Thickness (ft)	Organically Rich	600	500
		Net	300	250
	Depth (ft)	Interval	6,000 - 10,000	5,000 - 9,000
		Average	8,000	7,000
Reservoir Properties	Reservoir Pressure		Normal	Normal
	Average TOC (wt. %)		4.0%	3.0%
	Thermal Maturity (% Ro)		0.80%	0.80%
	Clay Content		Medium	Medium
Resource	Gas Phase		Assoc. Gas	Assoc. Gas
	GIP Concentration (Bcf/mi^2)		31.3	23.6
	Risked GIP (Tcf)		29.3	25.7
	Risked Recoverable (Tcf)		2.3	2.1

Table XXI-2. Shale Oil Resources and Geologic Properties of Mongolia.

			East Gobi ($24,560\ mi^2$)	Tamtsag ($6,730\ mi^2$)
Basic Data	Basin/Gross Area		East Gobi ($24,560\ mi^2$)	Tamtsag ($6,730\ mi^2$)
	Shale Formation		Tsagaantsav	Tsagaantsav
	Geologic Age		L. Cretaceous	L. Cretaceous
	Depositional Environment		Lacustrine	Lacustrine
Physical Extent	Prospective Area (mi^2)		4,690	5,440
	Thickness (ft)	Organically Rich	600	500
		Net	300	250
	Depth (ft)	Interval	6,000 - 10,000	5,000 - 9,000
		Average	8,000	7,000
Reservoir Properties	Reservoir Pressure		Normal	Normal
	Average TOC (wt. %)		4.0%	3.0%
	Thermal Maturity (% Ro)		0.80%	0.80%
	Clay Content		Medium	Medium
Resource	Oil Phase		Oil	Oil
	OIP Concentration ($MMbbl/mi^2$)		45.5	39.3
	Risked OIP (B bbl)		43	43
	Risked Recoverable (B bbl)		1.7	1.7

The organic-rich shales of Mongolia are thermally immature near the surface, locally forming combustible oil shale, but reach oil maturity (maximum R_o of 0.8 to 1.0%) in deeper areas ranging from 7,000 to 8,000 ft. However, these troughs are relatively small and disrupted by extensive faulting.

In addition, northwestern Mongolia has marine-deposited organic-rich shales of Devonian age that more closely resemble North America commercial shale lithology. Sporadic oil seeps have been reported in this remote region but no significant oil fields have been discovered. Data on this Devonian shale deposit are extremely limited. Most other areas in Mongolia are covered by non-prospective basement that lacks sedimentary strata.

Mongolia has an established conventional oil and gas investment regime with relatively low royalty (12.5%) and corporate income tax (25%). Nearly all of the country's sedimentary basins have been leased for conventional petroleum exploration. Regulations governing the development of deep shale oil/gas resources have not yet been promulgated in Mongolia. No shale leasing or exploration drilling activity has occurred, although Petro Matad Ltd. is evaluating the Khoid Ulaan Bulag oil shale deposit.

INTRODUCTION

With a population of about 3 million people, Mongolia has the world's lowest population density – only 1.8 inhabitants per km^2 or about half that of Canada. Mining development is helping to boost Mongolia's GDP by an expected 25% per annum over the coming decade and per-capita GDP is expected to reach $10,000 by 2020, up three-fold from the current level. Oil consumption is rising rapidly as the country develops its considerable mineral and coal deposits, including what soon may be the world's largest copper mine at Oyu Tolgoi.

Most of Mongolia is covered by igneous and metamorphic rocks but there are several relatively shallow and sparsely drilled sedimentary basins, Figure XXI-1. Oil production is small at about 5,000 bbl/day, limited to two oil fields in the East Gobi Basin in southeastern Mongolia near the border with China. Mongolia has no commercial natural gas production nor gas pipeline infrastructure. Petroleum drilling services are available locally in the East Gobi Basin, while additional capability may be sourced out of oil fields in northeast China.

Three of Mongolia's sedimentary basins may have limited shale oil potential, but only two basins could be quantitatively evaluated; geologic data are sparse. The most prospective areas for both conventional and shale oil exploration are the East Gobi and Tamtsag basins. These basins are relatively small and somewhat complex structurally; only the East Gobi Basin has small commercial oil production.

In addition, there is a non-productive and poorly defined Devonian deposit in northwest Mongolia close to the border with Russia that may have conventional and shale oil potential, although public data there are lacking. These include Riphean–Cambrian carbonates which formed on platforms of the Siberian passive margin, predating assembly of the present-day Mongolian basement. Devonian shale also is present here and oil seeps have been noted. Carboniferous–Permian coal and coaly mudstone samples immediately postdate these Paleozoic collisions and represent the beginning of non-marine deposition in central Mongolia. TOC reportedly is low (0.58% to 1.68%) and oil prone (T_{max} of 429 to 441).[1] Moreover, these source rocks are remote, poorly understood, and appear to have little shale oil potential.

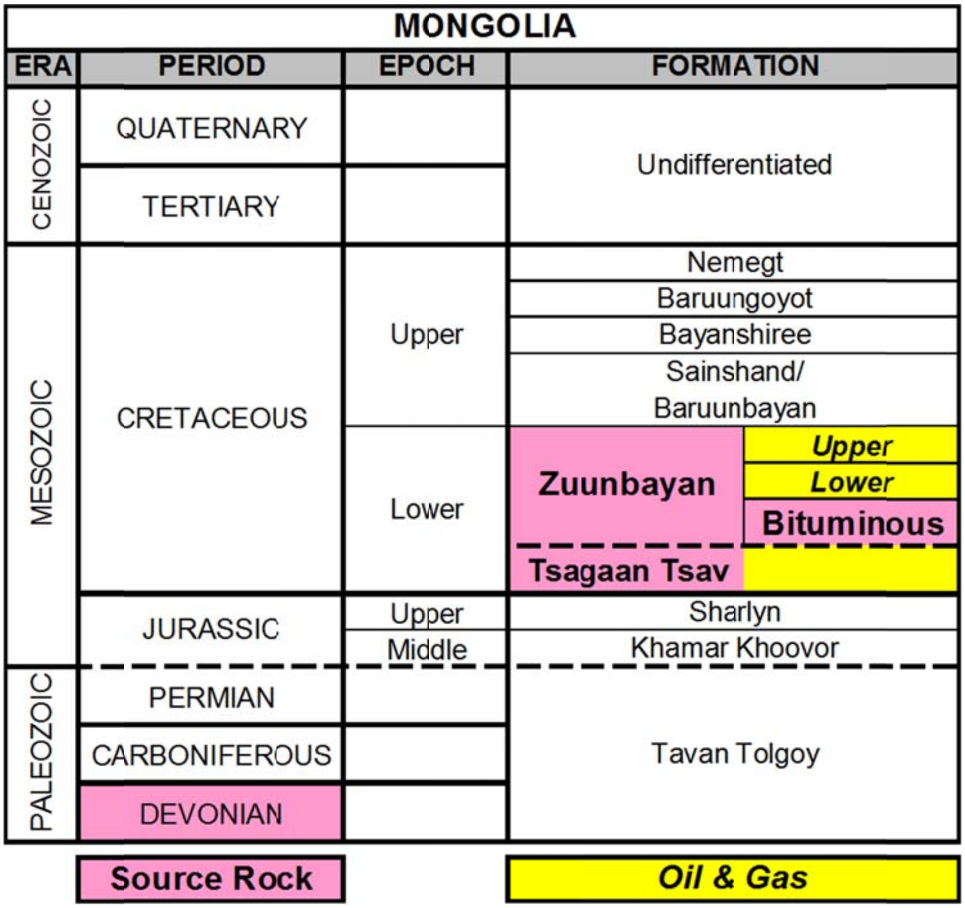
1. EAST GOBI BASIN

1.1 Introduction and Geologic Setting

The 25,000-mi^2 East Gobi Basin is located in southeastern Mongolia close to the border with China, accessible along the main highway between the capitol Ulan Bataar and north-central China. Mongolia's only significant commercial oil-producing region, the basin is along strike with and similar to oil-productive Mesozoic rift basins in northeast China, where much more geologic data are available. The East Gobi Basin shares similar stratigraphy and structural geology with these adjoining basins in northwest China.

The East Gobi Basin comprises a number of discontinuous, fault-bounded rift basins containing Jurassic to Early Cretaceous fluvial to lacustrine sediments, Figure XXI-2. The thick Lower Cretaceous shales that occur in the East Gobi Basin frequently have high TOC but were deposited under lacustrine conditions. Thermal maturity of the shale is immature at shallow depths, becoming oil prone in the deep troughs that sourced the shallow conventional oil fields.

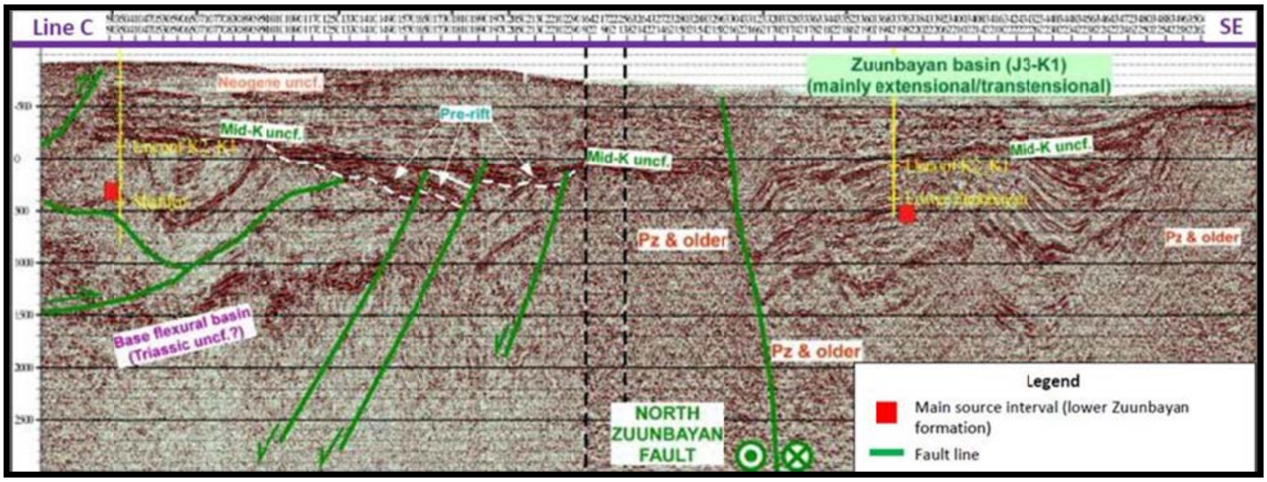
Figure XXI-2. Stratigraphy of Shale Source Rocks and Conventional Reservoirs in Mongolia



Source: ARI, 2013

The East Gobi Basin contains four main sub-basins within a 200- by 400-mi area that is defined broadly by gravity and seismic data.[2] The sub-basins contain discontinuous deep depressions, separated by basement highs that are exposed over much of the region. Deep, fault-bounded troughs with good quality source rock mudstones can occur. However, the deep areas (>6,000 ft) cover only a relatively small area. The largest sub-basins are the Unegt (3,090 mi^2) and Zuunbayan (1,600 mi^2), Figure XXI-3. Uplifted fault blocks occur within these troughs, some forming conventional oil traps.

Figure XXI-3: Seismic Line Across the Zuunbayan and Unegt Sub-basins within the East Gobi Basin Showing their Relatively Small Size and Complex Structure.



Source: Manas Petroleum Corp., 2012

Conventional reservoirs in the East Gobi Basin currently produce about 5,000 bbl/day from two small anticlinal oil fields. The Zuunbayan oil field has produced a total of about 6 million barrels from shallow depths (2,000 to 2,500 ft), while the nearby Tsagaan Els oil field has produced smaller volumes from depths of 4,265 to 4,600 ft. Both fields produce from conventional reservoirs comprising lacustrine siltstones, sandstones and conglomerates within the Tsagaantsav and Zuunbayan formations, which were sourced by the interbedded lacustrine shales. Original oil in place at the two fields totaled an estimated 150 Mmillion barrels. Oil gravity averages 28° API.[3]

Each sub-basin contains up to 13,000 ft of Middle Jurassic to Tertiary sedimentary rock, including thick lacustrine-deposited mudstone. Northeast-trending, mainly normal and strike slip (left-lateral) faults bound the sub-basins. The structural history of the region includes Mid-Jurassic to Early Cretaceous rifting (north-south extension), Early Cretaceous north-south compression and inversion along pre-existing faults, renewed sedimentation and right-lateral displacement along northeast faults during the Mid-Cretaceous, followed by post-Late Cretaceous east-west shortening.

Basement in the East Gobi Basin consists of metamorphosed sandstone and carbonate of the Paleozoic Tavan Tolgoy sequence. The oldest sedimentary unit is the Lower to Mid–Jurassic Khamarkhoovor Formation, a pre-rift sequence consisting of up to 2,500 ft of fluvial sandstones and lacustrine-deltaic shale, including thin coal seams. Although a potential source rock, the Khamarkhoover seldom crops out and remains poorly understood. Unconformably overlying this unit is the Sharlyn Formation, containing up to 600 ft of fluvial sandstone and conglomerate with minor lacustrine shale.

Overlying the Sharlyn Fm are the primary shale targets in the East Gobi Basin, the Lower Cretaceous Tsagaantsav and Zuunbayan formations. The Tsagaantsav Fm, a late synrift sequence 1,000 to 2,300 ft thick that locally can contain thick oil shale, is mainly an organic-rich shale section interbedded with dark gray sandstones and conglomerates, siltstones, bright-red tuffs, and basalt. The unit grades upward from alluvial fan to lacustrine facies, becoming a lithic sandstone reservoir at the Tsagaan Els and Zuunbayan oil fields.

A 125-m thick core section in the Tsagsaantsav Fm was described as consisting of finely laminated mudstone and micrite, dolomitic breccia, and calcareous siltstone. These fine-grained units are interbedded with grainstone and thin, normally graded sandstone beds interpreted as distal lacustrine turbidites. Anoxic, stratified lake-bottom conditions are indicated by micro-lamination, biogenic pyrite, high TOC, and carbonate precipitation. TOC ranges from 1.5% to 15% for shale, mainly oil-prone Types I and II kerogen. S1 and S2 values are above 0.5 and 10, respectively, indicating good quality source rocks. Thermal maturity is immature to middle oil window. Oil quality is waxy with 20-35% paraffin and high pour point. Oil typing indicates a lacustrine algal source.[4]

The other potential shale target is the Lower Cretaceous Zuunbayan Formation, which consists of up to 3,200 ft of sands and minor interbedded shales and tuffs deposited during Hauterivian to Albian time under non-marine to paralic environments. However, the Zuunbayan is coaly, probably clay-rich, and likely less brittle, thus not a very prospective target for shale oil development.

Deep portions (6,000 to 10,000 ft) of the Unegt, Zuunbayan, and other sub-basins in the East Gobi Basin may be oil prone and offer potential shale oil targets. Burial history modeling suggests that peak oil generation occurred during the Cretaceous (90 to 100 Ma), continuing at a lower rate to the present day. However, the East Gobi Basin is structurally complex, with numerous closely spaced faults that may limit its potential for shale oil development.

1.2 Reservoir Properties (Prospective Area)

Within the 4,690-mi^2 high-graded prospective area of the Unegt and Zuunbayan troughs in the East Gobi Basin, the Lower Cretaceous Tsagaantsav Formation contains an estimated 300 ft (net) of organic-rich lacustrine shale at an average depth of 8,000 ft. TOC averages an estimated 4.0% and is oil-prone (R_o averaging 0.8%). Porosity may be significant (6%) given the silty lithology. The reservoir pressure gradient is normal.

1.3 Resource Assessment

The Tsagaantsav Formation contains an estimated 29 Tcf of risked shale gas in-place and 43 billion barrels of risked shale oil in-place, of which 2.3 Tcf of associated shale gas and 1.7 billion barrels of shale oil may be technically recoverable (both risked), Table XXI-1. The closest international analog appears to be the oil-prone window of the REM lacustrine shales in the shallow western Cooper Basin, although these have not yet been proven commercially productive.

1.4 Exploration Activity

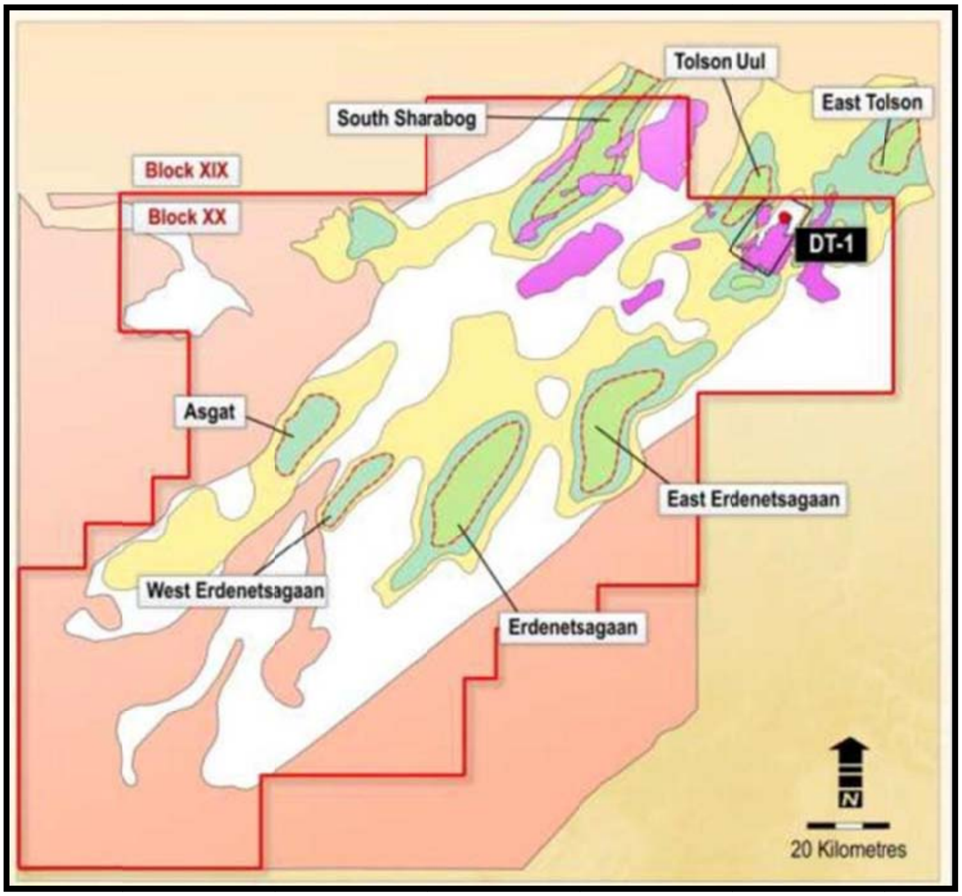
No shale oil or shale gas exploration or leasing has occurred in the East Gobi Basin. Calgary-based Manas Petroleum Corp. is conducting petroleum exploration for conventional targets in this basin but has not discussed its shale potential.[5] London-based Petro Matad Limited is evaluating Khoid Ulaan Bulag oil shale deposit in Block IV for potential mining. This deposit reportedly has similar mineralogy to the Green River Formation in Wyoming, USA, containing carbonate, quartz, and feldspar mineralogy. Extended Fischer Analysis yielded one liter of 29° API oil from a 10-kg sample.[6]

2 TAMTSAG BASIN

2.1 Introduction and Geologic Setting

Although geologically similar to the East Gobi Basin, the 6,700-mi^2 Tamtsag Basin in extreme eastern Mongolia has no commercial oil and gas production. The basin comprises a number of isolated, fault-bounded troughs that trend WSW-ENE along an extent of about 80 by 300 km, Figure XXI-4. Just as in the East Gobi Basin, potential source rocks are the Lower Cretaceous Tsagaantsav and Zuunbayan formations, with TOC averaging about 3%.

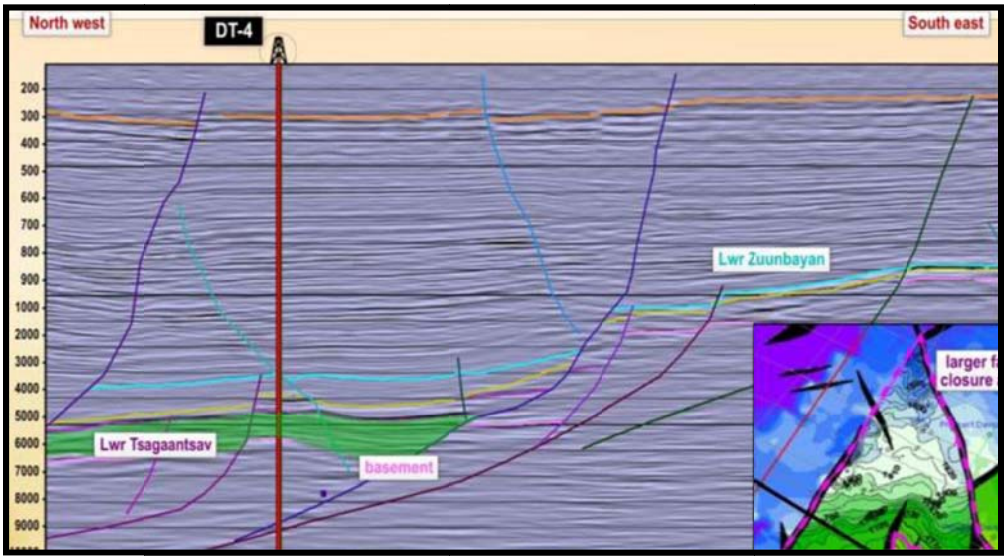
Figure XXI-4. Western Tamtsag Basin Showing Small Isolated Structural Troughs where Source Rock Shales are Buried to Over 5,000 ft and May Reach Oil-window Thermal Maturity.



Source: Petro Matad Ltd., 2012

Internally the Tamtsag Basin comprises a number of uplifted fault blocks and down-faulted grabens created by rifting and Mid-Cretaceous basin inversion, Figure XXI-5.[7] Late Cretaceous transpression formed structural traps in conventional targets, notably tilted fault blocks and anticlines. Structural complexity is most pronounced in the southwest, decreasing towards the northeast. The basement consists of Devonian to Permian metamorphic and intrusive rocks.[8]

Figure XXI-5. Seismic line in the Tsamtsag Basin Showing Source Rocks Buried to a Depth of about 6,000 ft.



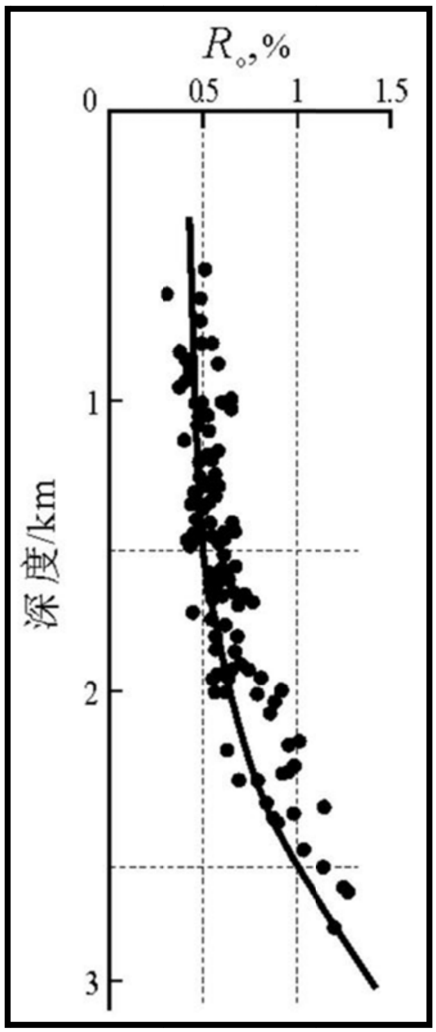
Source: Petro Matad, 2010

The Tamtsag Basin contains up to 13,000 ft of Mid-Jurassic to Tertiary non-marine and volcanic sedimentary rocks. Grain texture fines upward from coarse continental rift-fill and fluvio-deltaic conglomerates and sandstone in the lower section transitioning into lacustrine mudstones and shales. The basal Upper Jurassic consists mainly of volcanic deposits (basaltic to andesitic) with minor interbedded sediments. The overlying Lower Cretaceous deposits consist of fluvio-deltaic conglomerates and sandstones that fine upward into deepwater lacustrine shales. Younger Cenozoic conglomerates, sandstones, and mudstones cover much of the basin, concealing the Mesozoic units.[9]

The Tamtsag Basin is on trend with the Hailaer Basin of northeastern China, a stratigraphically and genetically similar Mesozoic rift basin. Although the Hailaer Basin has not experienced shale exploration, it is oil producing and thus has much better data control. Similar to the Tamtsag, the Hailaer Basin actually comprises over 20 individual fault-bounded sub-basins. Coal deposits and carbonaceous mudstones within the upper portion of the Lower Cretaceous Nantun Formation are considered the major petroleum source rocks in the Hailaer Basin. The Hailaer Basin oil fields produce with high water cut and have locally elevated CO_2 levels.

The Nantun Formation was deposited within fan delta front, pro-fan delta, marsh and lacustrine environments. Organic carbon content of the organic-rich mudstone within this unit ranges from 0.23% to 16.67%, averaging 2.56%. The mudstone becomes oil-prone (R_o above 0.7%) below a depth of about 6,500 ft, Figure XXI-6,[10] while T_{max} averages 447°C with most samples above 435°C, indicating oil-prone kerogen.[11] Limited conventional oil production occurs in the Hailaer Basin, evidently due to poor reservoir conditions and high water saturation. In addition, the Lower Cretaceous conventional sandstone reservoirs can contain elevated CO_2 levels of up to 90%, which has been isotopically linked with granite intrusions emplaced during the Yanshan Orogeny.[12]

Figure XXI-6. Vitrinite Reflectance Increases to About 0.8% Ro at a Depth of 2.5 Km in the Wuerxun Trough of China's Hailaer Basin, Adjacent to the Tamtsag Basin in Mongolia.



Source: Liu et al., 2009

2.2 Reservoir Properties

Within the 5,440-mi^2 high-graded prospective area that is distributed amongst numerous small troughs within the Tamtsag Basin, the Lower Cretaceous Tsagaantsav Formation contains an estimated 250 feet (net) of organic-rich lacustrine shale at an average depth of 7,000 feet. TOC averages an estimated 3.0% and is oil-prone (R_o averaging 0.8%). Porosity may be significant (6%) given the silty lithology.

2.3 Resource Assessment

The Tsagaantsav Formation contains an estimated 26 Tcf of shale gas and 43 billion barrels of shale oil in-place, of which 2.1 Tcf of associated gas and 1.7 billion barrels of shale oil may be technically recoverable (both risked), Table XXI-1. The closest international analog appears to be the oil-prone window of the REM lacustrine shales in the shallow western Cooper Basin, although these have not yet been proven commercially productive.

2.4 Exploration Activity

No shale oil or shale gas exploration or leasing has occurred in the Tamtsag Basin, nor does the basin produce oil or gas from conventional reservoirs. PetroChina is currently conducting exploration drilling for conventional reservoirs in this basin.

REFERENCES

1 Petroleum Authority of Mongolia, personal communication, July 2011.

2 Prost, G.L., 2004. "Tectonics and Hydrocarbon Systems of the East Gobi Basin, Mongolia." American Association of Petroleum Geologists, Bulletin, vol., 88, p. 483-513.

3 Pentilla, W.C., 1994. "The Recoverable Oil and Gas Resources of Mongolia." Journal of Petroleum Geology, vol. 17, p. 89-98.

4 Johnson, C.L., Greene, T.J., Zinniker, D.A., Moldowan, J.M., Hendrix, M.S., and Carroll, A.R., 2003. "Geochemical Characteristics and Correlation of Oil and Nonmarine Source Rocks from Mongolia." American Association of Petroleum Geologists, Bulletin, vol., 87, p. 817-846.

5 Manas Petroleum Corp., Corporate Presentation, September, 2012, 29 p.

6 Petro Matad Limited, Interim Results for the Six Months Ended 30 June, 2012, 10 p.

7 Petro Matad Limited, Corporate Presentation, November 2010.

8 Henk, A., Davaa, B., Geerdts, P., Vogler, M., and Wemmer, K., 2007. "Structure and Evolution of the Tamtsag Basin / NE Mongolia." Geophysical Research Abstracts, vol. 9, p. 2415.

9 Geerdtz, P., Vogler, M., Davaa, B., and Henk, A., 2006. "Evolution of the Tamtsag Basin / NE-Mongolia — part I: Basin Fill." Poster, TSK 11 Goettingen,

Advanced Resources International, Inc.

10 Liu, X.Y., Deng, H.W., Di, Y.X., Gao, X.P., Wang, J.K., and Long, G.Q., 2009. "High Quality Source Rocks of Nantun Formation in Wuerxun Depression, Hailaer Basin." Petroleum Geology and Testing, vol. 31, p. 68-73 (in Chinese).

11 Wang, J.G., Chen, G.P., and Wang, T.Q., 2010. "The Geochemical Characteristics of Coal Measure Strata and Coal-Derived Hydrocarbon in Huhehu Sag, Hailaer Basin, China." American Association of Petroleum Geologists, Search and Discovery Article #10266.

12 Gao, Y.Q., Liu, L., and Hua, W.X., 2009. "Petrology and Isotopic Geochemistry of Dawsonite-Bearing Sandstones in Hailaer Basin, Northeastern China." Applied Geochemistry, vol. 24, p. 1724-1738.

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