

# Assessment of Potential Shale Gas and Shale Oil Resources of the Norte Basin, Uruguay, 2011

Using a performance-based geological assessment methodology, the U.S. Geological Survey estimated mean volumes of 13.4 trillion cubic feet of potential technically recoverable shale gas and 0.5 billion barrels of technically recoverable shale oil resources in the Norte Basin of Uruguay.

## Introduction

The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of State, is assessing the potential for unconventional oil and gas resources (shale gas, shale oil, tight gas, and coalbed gas) in priority geologic provinces worldwide. The authors summarize the geologic model and results of an assessment of potential shale gas and shale oil resources of the Norte Basin, Uruguay. The Norte Basin of Uruguay is the southern extension of the Paraná Basin of Brazil (fig. 1), and is largely covered by volcanic rocks. The main geologic structures in the basin are interpreted to be northwest-southeast trending grabens and horsts, which, if present, control the distribution of Devonian-age shale and oil and gas resources in the basin.

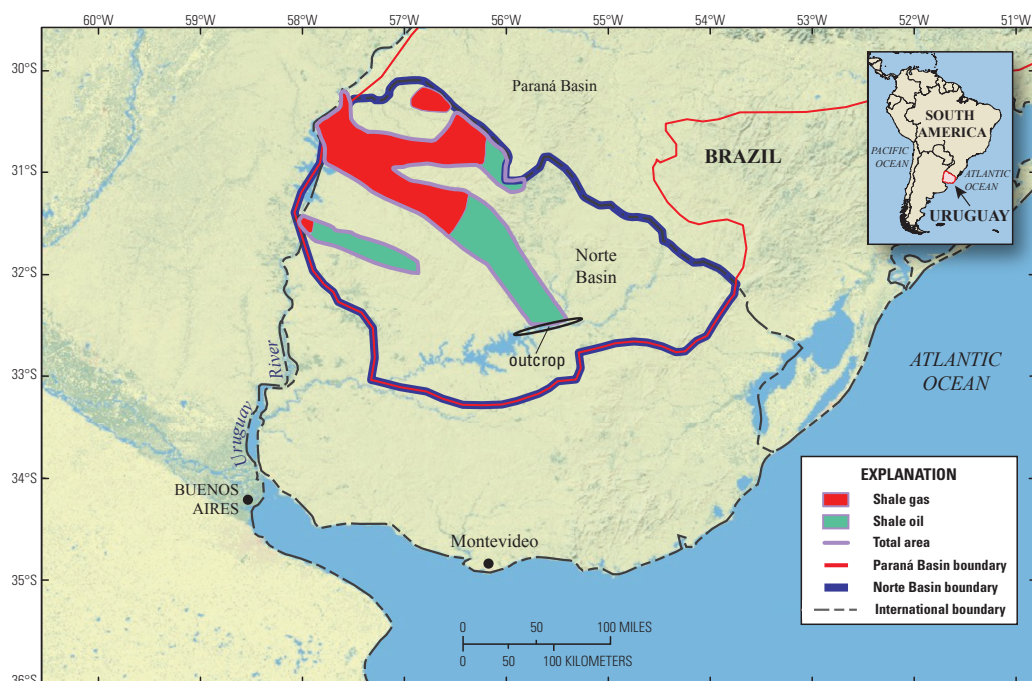
## Devonian Shale System in the Norte Basin

The Devonian Cordobes Formation is interpreted to be the principal petroleum source rock in the Norte Basin and possible reservoir for shale gas and shale oil accumulations. The geologic

attributes of the Cordobes Formation relevant to the assessment are inferred from outcrops along the southern margin of the Norte Basin (Conti and Morales, 2009; ANCAP, written commun., 2011). Thickness of the Cordobes ranges up to 160 meters (m), including as much as 60 m of organic-rich shale. Total organic carbon concentration ranges from 0.7 to 3.6 weight percent. The organic matter is predominantly Type II marine kerogen, with a contribution from Type III kerogen. Thermal maturity at outcrop averages 0.6 percent vitrinite reflectance, suggesting thermal maturity corresponding to the onset of oil generation. Basin modeling suggests that thermal maturity necessary for oil-to-dry gas transition in the Devonian is at a depth of about 3,200 m (ANCAP, written commun., 2011), which was used as the boundary between potential shale oil and shale gas accumulations in the assessment (fig. 1). Given what is known of the thermal maturity, this boundary is uncertain.

## Geologic Model for Assessment

The geologic model used in the assessment of the Norte Basin assumes oil and gas to have been generated in organic-rich shales of the Devonian Cordobes Formation and to occupy matrix porosity and organic porosity in the same shales. The thermal window for gas was modeled to begin at about the 3,200-m depth, with oil as the main petroleum phase at shallower depths. Devonian shales most likely are present beneath the volcanic cover in northwest-southeast trending grabens that have been imaged with geophysical methods. The presence of Devonian organic-rich shale in the grabens, the potential matrix storage of oil or gas, and the thermal windows for oil in relation to gas are subject to significant geologic uncertainty. Shale gas and shale oil accumulations in the United States were used as geologic and engineering analogs in the assessment. Analog data from U.S. accumulations included estimated ultimate recoveries (EUR) from shale gas and shale oil wells, mean drainage areas of wells (cell sizes), and ranges of well success ratios. Key assessment input data are listed in table 1.



**Figure 1.** Locations of the Norte Basin in Uruguay and the areas of the Devonian Cordobes Formation Shale Gas Assessment Unit (red) and Devonian Cordobes Formation Shale Oil Assessment Unit (green) that were assessed in this study.

**Table 1.** Key assessment input data for shale gas and shale oil assessment units in the Norte Basin.

[EUR (estimated ultimate recovery per well), cell size, and success ratios are from U.S. shale gas and shale oil analogs. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; AU, assessment unit; %, percent. Minimum, median, and maximum values represent the variation about the mean values, and do not reflect the total variation in these parameters. Areas of AUs are from maps produced by ANCAP, Montevideo, Uruguay.]

Assessment input data	Devonian Cordobes Shale Gas AU				Devonian Cordobes Shale Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	271,400	2,714,000	4,071,000	2,352,133	213,200	2,132,000	3,198,000	1,847,700
Average drainage area of wells (acres)	120	150	180	150	100	175	400	225
Average EUR (MMBO, oil; BCFG, gas)	0.2	0.8	2.5	0.89	0.02	0.06	0.25	0.07
Success ratios (%)	75	90	95	87	75	90	95	87

## Resource Summary

The USGS assessed potential technically recoverable shale gas and shale oil resources in the Norte Basin of Uruguay, resulting in total estimated mean resources of 13,361 billion cubic feet of gas (BCFG), 508 million barrels of oil (MMBO), and 499 million barrels of natural gas liquids (MMBNGL) (table 2). Of these totals, the estimated mean resource volumes are (1) Devonian Cordobes Formation Shale Gas AU, 11,328 BCFG (range from 0 to 24,042 BCFG), and 453 MMBNGL (range from 0 to 1,002 MMBNGL); and (2) for the Devonian Cordobes Formation Shale Oil AU, 508 MMBO (range from 155 to 1,081 MMBO), and 2,033 BCFG associated gas (range from 574 to 4,521 BCFG), and 46 MMBNGL (range from 12 to 106 MMBNGL). The ranges of resource estimates, particularly those for shale gas (0 to 24,042 BCFG), reflect the considerable geologic uncertainty in these assessment units.

## For Further Information

Supporting geologic studies of total petroleum systems and assessment units, and reports on the methodology used in the Norte Basin assessment, are in progress. Assessment results are available at the USGS Energy website: <http://energy.usgs.gov>

## Norte Basin Assessment Team

Christopher J. Schenk, Mark A. Kirschbaum, Ronald R. Charpentier, Troy Cook, Timothy R. Klett, Donald L. Gautier, Richard M. Pollastro, Jean N. Weaver, and Michael Brownfield.

## Acknowledgments

We thank the staff of ANCAP, Montevideo, Uruguay (Hector de Santa Ana Alvarez, Matias Soto Nunez, Josefina Marmisolle Radesca, and Juan Tomasini), for sharing their data and for educating us on the petroleum geology of the Norte Basin prior to the USGS assessment.

## References

Conti, Bruno, and Morales, Ethel, 2009, Geologia y criterios exploratorios de la lutitas gasíferas; potencial en el Uruguay: Recursos Minerales Energeticos del Uruguay; petróleo, gas, hidratos de gas, lutitas bituminosas, carbon, uranio, y almacenamiento de gases: ANCAP Exploracion and Produccion, Resumenes de los Trabajos Presentados en la Taller realizado en ANCAP, Setiembre 1-2, 2009.

**Table 2.** Assessment results for potential shale gas and shale oil resources in the Devonian Cordobes Formation, Norte Basin, Uruguay.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas fields, all liquids are included as NGL (natural gas liquids). Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. AU, assessment unit. AU probability is the chance of at least one accumulation of minimum size within the AU. TPS, total petroleum system. Gray shading indicates not applicable]

Total petroleum systems (TPS) and assessment units (AU)	AU probability	Field type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
<b>Paleozoic Composite TPS</b>														
Devonian Cordobes Formation Shale Gas AU	0.95	<i>Gas</i>					0	10,306	24,042	11,328	0	402	1,002	453
Devonian Cordobes Formation Shale Oil AU	1.0	<i>Oil</i>	155	444	1,081	508	574	1,740	4,521	2,033	12	38	106	46
<b>Total unconventional resources</b>			<b>155</b>	<b>444</b>	<b>1,081</b>	<b>508</b>	<b>574</b>	<b>12,046</b>	<b>28,563</b>	<b>13,361</b>	<b>12</b>	<b>440</b>	<b>1,108</b>	<b>499</b>