

EIA/ARI World Shale Gas and Shale Oil Resource Assessment

Prepared For:

U.S. Department of Energy
U.S. Energy Information Administration
EIA 2013 Energy Conference

Prepared By:

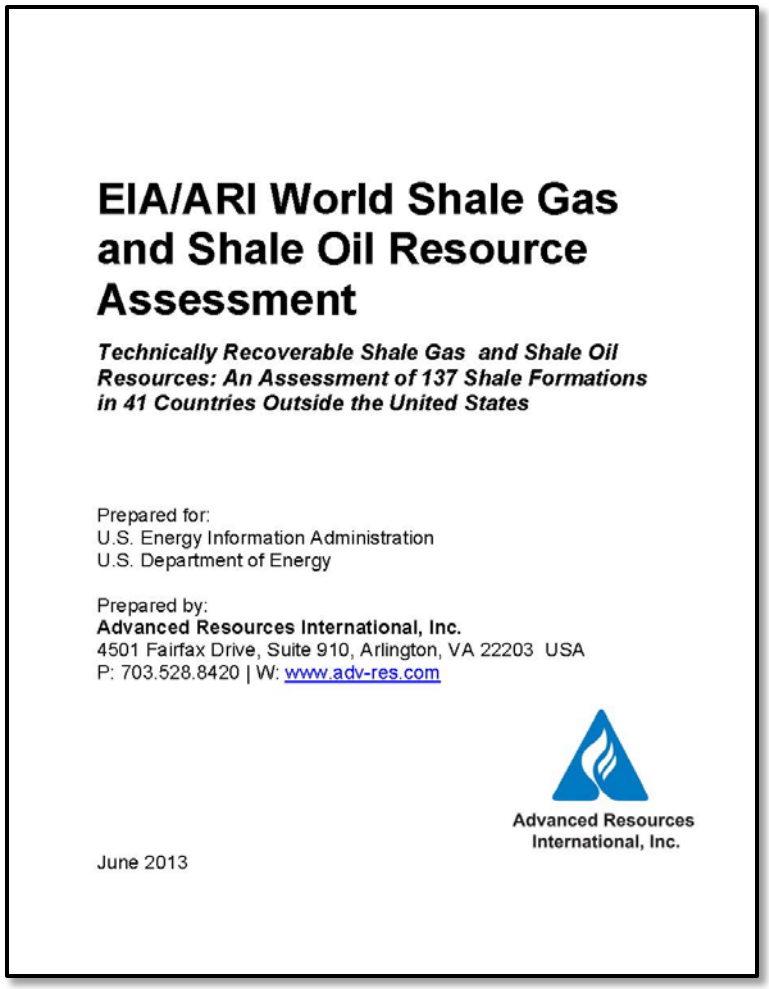
Vello A. Kuuskraa, President
ADVANCED RESOURCES INTERNATIONAL, INC.
Arlington, VA

June 17, 2013 ▪ Washington, DC

Unconventional Resources • Enhanced Recovery • Carbon Sequestration

Advanced Resources International, Inc.

EIA/ARI "World Shale Gas and Shale Oil Resource Assessment"



EIA/ARI World Shale Gas and Shale Oil Resource Assessment

Technically Recoverable Shale Gas and Shale Oil Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States

Prepared for:
U.S. Energy Information Administration
U.S. Department of Energy

Prepared by:
Advanced Resources International, Inc.
4501 Fairfax Drive, Suite 910, Arlington, VA 22203 USA
P: 703.528.8420 | W: www.adv-res.com

Advanced Resources International, Inc.

June 2013

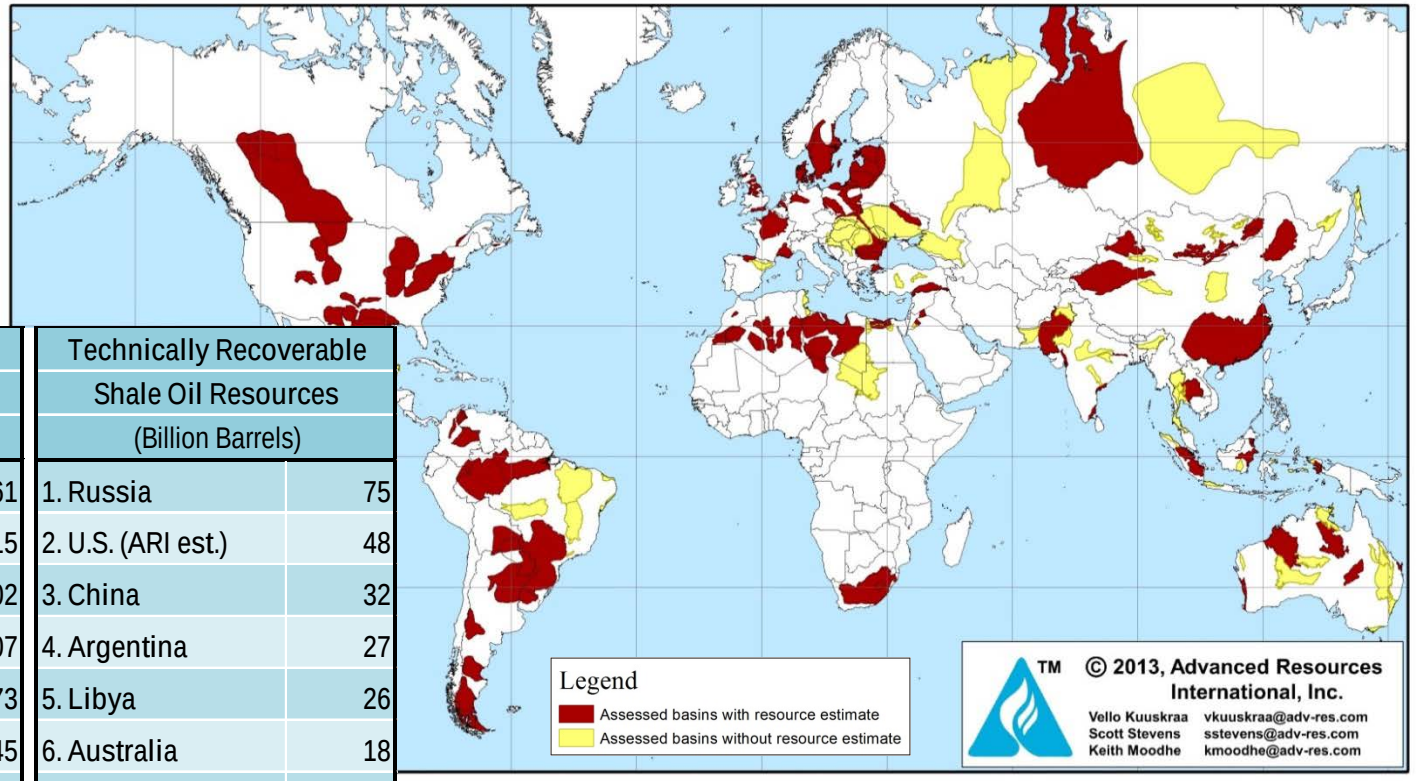
The EIA/ARI "World Shale Gas and Shale Oil Resource Assessment" report represents a major new shale resource assessment :

- 41 distinct countries (42 with U.S.).
- 95 shale basins with 137 shale gas and shale oil formations.
- ~700 page report with 26 Chapters.
- ~200 original maps; prospective areas, reservoir properties, resource quality.

World Shale Gas and Shale Oil Resources

Technically Recoverable Shale Gas Resources (Tcf)	
1. U.S. (ARI est.)	1,161
2. China	1,115
3. Argentina	802
4. Algeria	707
5. Canada	573
6. Mexico	545
7. Australia	437
8. South Africa	390
9. Russia	285
10. Brazil	245
11. Others	1,535
TOTAL	7,795

Technically Recoverable Shale Oil Resources (Billion Barrels)	
1. Russia	75
2. U.S. (ARI est.)	48
3. China	32
4. Argentina	27
5. Libya	26
6. Australia	18
7. Venezuela	13
8. Mexico	13
9. Pakistan	9
10. Canada	9
11. Others	65
TOTAL	335



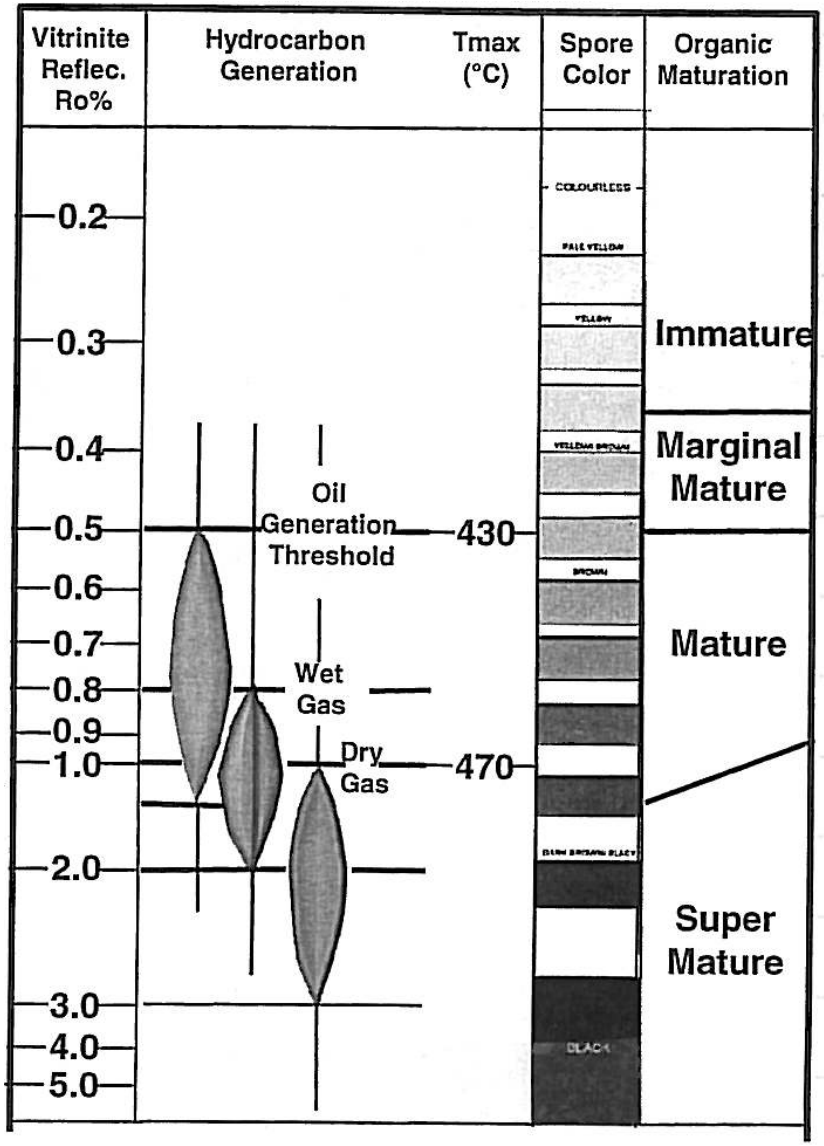
- **Shale Gas.** U.S., China, Argentina, Algeria, Canada and Mexico account for nearly two-thirds of the assessed, technically recoverable shale gas resource.
- **Shale Oil.** Russia, U.S., China, Argentina and Libya account for nearly two-thirds of the assessed, technically recoverable shale oil resource.

Advanced Resources International, Inc.

Our Resource Assessment Methodology

Our shale gas and shale oil resource assessment methodology consisted of four main steps:

1. Conduct geologic and reservoir characterization of major shale basins and formation(s):
    - Minimum TOC (≥2%)
    - Prospective Depth Range (1,000 m to 5,000 m)
    - Thermal Maturity “Windows”
    - Shale Mineralogy
    - Other (Overpressure, Geologic Complexity, Volumetric Data)
2. Define prospective area and risk factors for each shale formation.
3. Estimate risked shale gas and shale oil resource in-place.
4. Calculate risked, technically recoverable shale gas and shale oil resource (TRR).



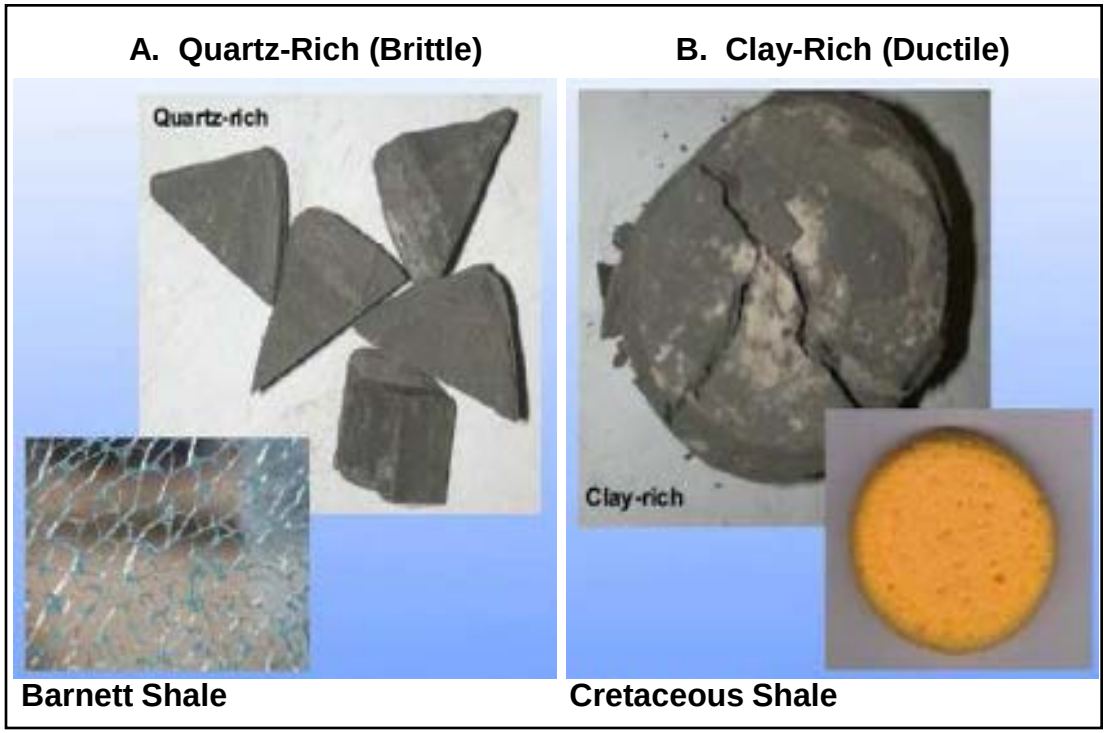
Thermal Maturation Scale

Using Thermal Maturity To Delineate Areas Prospective For Shale Gas and Shale Oil.

- Oil prospective area has vitrinite reflectance (Ro) of 0.7% to 1%.
- Wet gas/condensate prospective area has Ro of 1.0% to 1.3%.
- Dry gas prospective area has Ro greater than 1.3%.
- Higher thermal maturity settings also create nanopores which contribute to additional porosity in the shale matrix.

Importance of Mineralogy on Recoverable Resources

The mineralogy of the shale, particularly its relative quartz, carbonate and clay contents, governs the efficiency of the hydraulic fracture.



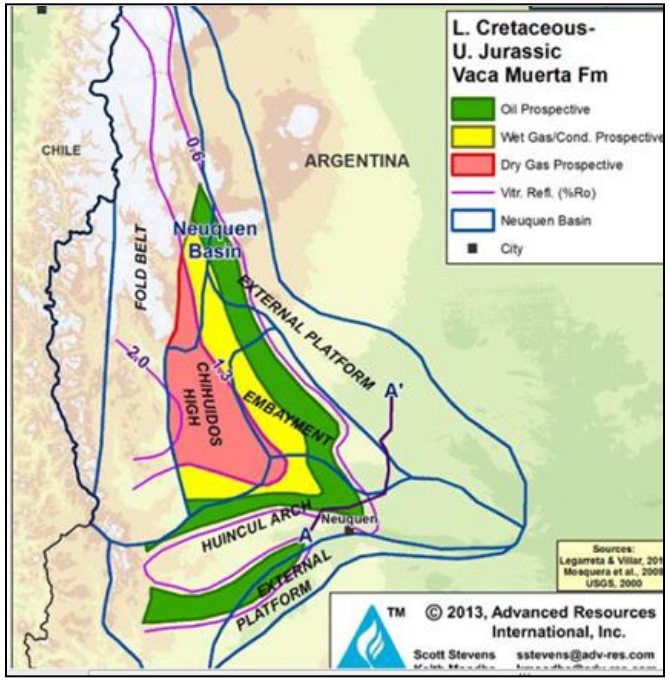
Source: CSUG, 2008

- High clastic content shales are brittle and shatter, providing multiple fractures.
- High clay content shales are plastic and absorb energy, providing planar fractures.
- Recovery factors of 15% to 30% for shale gas and 3% to 7% for shale oil (resource in-place) were assigned based on mineralogy (as well as pressure, TOC and geologic complexity).

Shale Gas Resources of Neuquen Basin, Argentina

One example of 137 shale formations assessed worldwide.

Prospective area of Vaca Muerta Fm: estimated 308 Tcf of dry, wet, associated shale gas resources (TRR).



Basic Data	Basin/Gross Area		Neuquen (66,900 mi^2)		
	Shale Formation		Vaca Muerta		
	Geologic Age		U. Jurassic - L. Cretaceous		
	Depositional Environment		Marine		
Physical Extent	Prospective Area (mi^2)		4,840	3,270	3,550
	Thickness (ft)	Organically Rich	500	500	500
		Net	325	325	325
	Depth (ft)	Interval	3,000 - 9,000	4,500 - 9,000	5,500 - 10,000
		Average	5,000	6,500	8,000
Reservoir Properties	Reservoir Pressure		Highly Overpress.	Highly Overpress.	Highly Overpress.
	Average TOC (wt. %)		5.0%	5.0%	5.0%
	Thermal Maturity (% Ro)		0.85%	1.15%	1.50%
	Clay Content		Low/Medium	Low/Medium	Low/Medium
Resource	Gas Phase		Assoc. Gas	Wet Gas	Dry Gas
	GIP Concentration (Bcf/mi^2)		66.1	185.9	302.9
	Risked GIP (Tcf)		192.0	364.8	645.1
	Risked Recoverable (Tcf)		23.0	91.2	193.5

Advanced Resources International, Inc.

	Risked, Technically Recoverable Shale Gas Resources (Tcf)		Discussion
	April 2011 Report	June 2013 Report	
1. North America			
• Canada	388	573	7 basins vs. 12 basins.
• Mexico	681	545	Better data on areal extent.
2. South America			
• Argentina	774	802	Improved dry and wet gas areal definitions.
• Brazil	226	245	New dedicated chapter.
• Venezuela	11	167	Included associated gas; better data.
3. Europe			
• Poland	187	148	Higher TOC criterion, better data on Ro.
• France	180	137	Better data on SE Basin in France.
• Norway	83	0	Eliminated speculative area for Alum Shale.
• Ukraine	42	128	Added major basin in Ukraine.
• Russia	-	285	New dedicated chapter.
4. Africa			
• Algeria	230	707	1 basin vs. 7 basins.
• Libya	290	122	Higher TOC criterion; moved area to oil.
• South Africa	485	390	Reduced area due to igneous intrusions.
• Egypt	-	100	New dedicated chapter.
5. Asia			
• China	1,225	1,115	Better data; higher TOC criterion.
• India/Pakistan	114	201	Expanded assessment for Pakistan.

Selected Comparison and Discussion of Differences

The chart on the left compares the risked, technically recoverable shale gas resource for 16 major countries: 2011 Report vs. 2013 Report.

International Shale Gas and Shale Oil Revolution

In addition to the U.S., six areas of the world have large, attractive shale gas and shale oil resources:

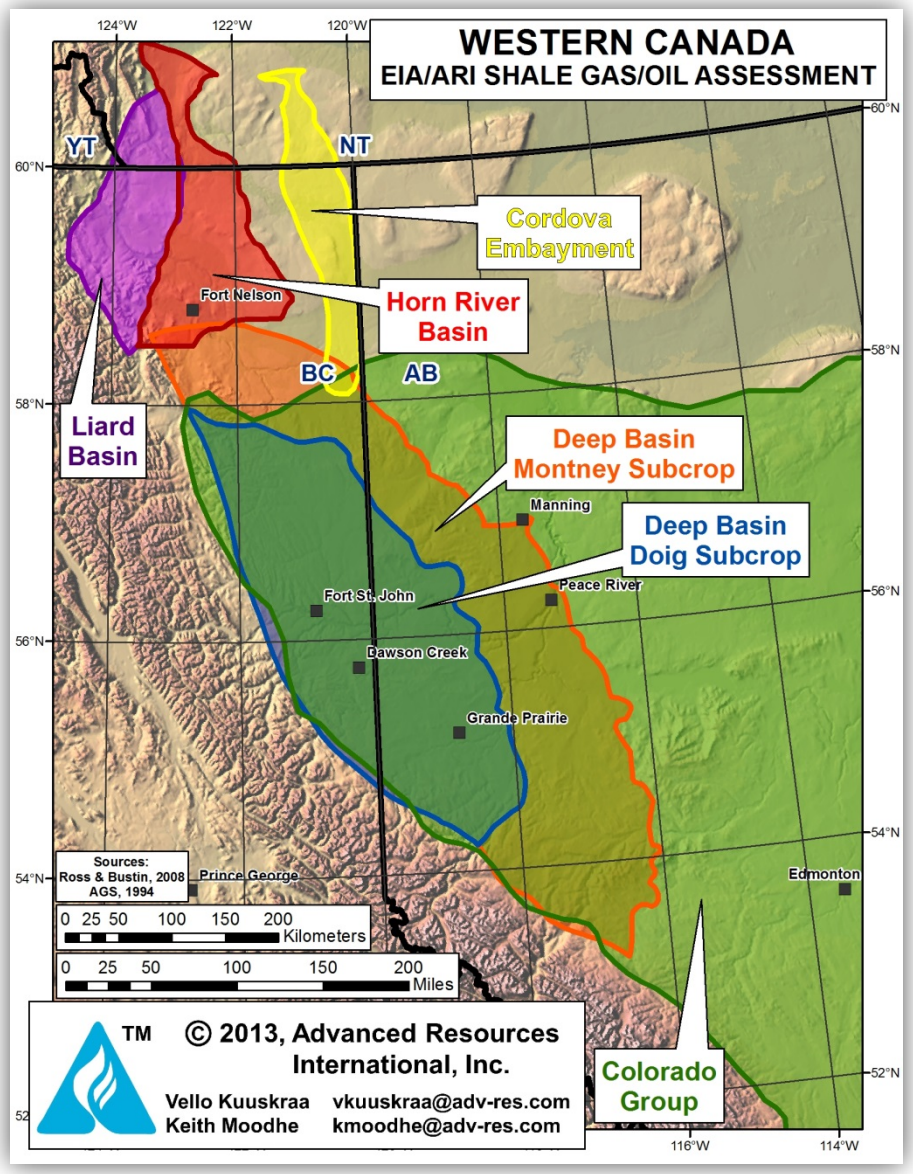
Active Shale Development

- Canada
- Argentina

Active Shale Exploration

- China
- Algeria
- Mexico
- Australia

CANADA



Risked TRR: 573 Tcf and 8.8 Billion barrels

Shale Gas (BC): Devonian marine shales in Horn River, Cordova and Liard basins.

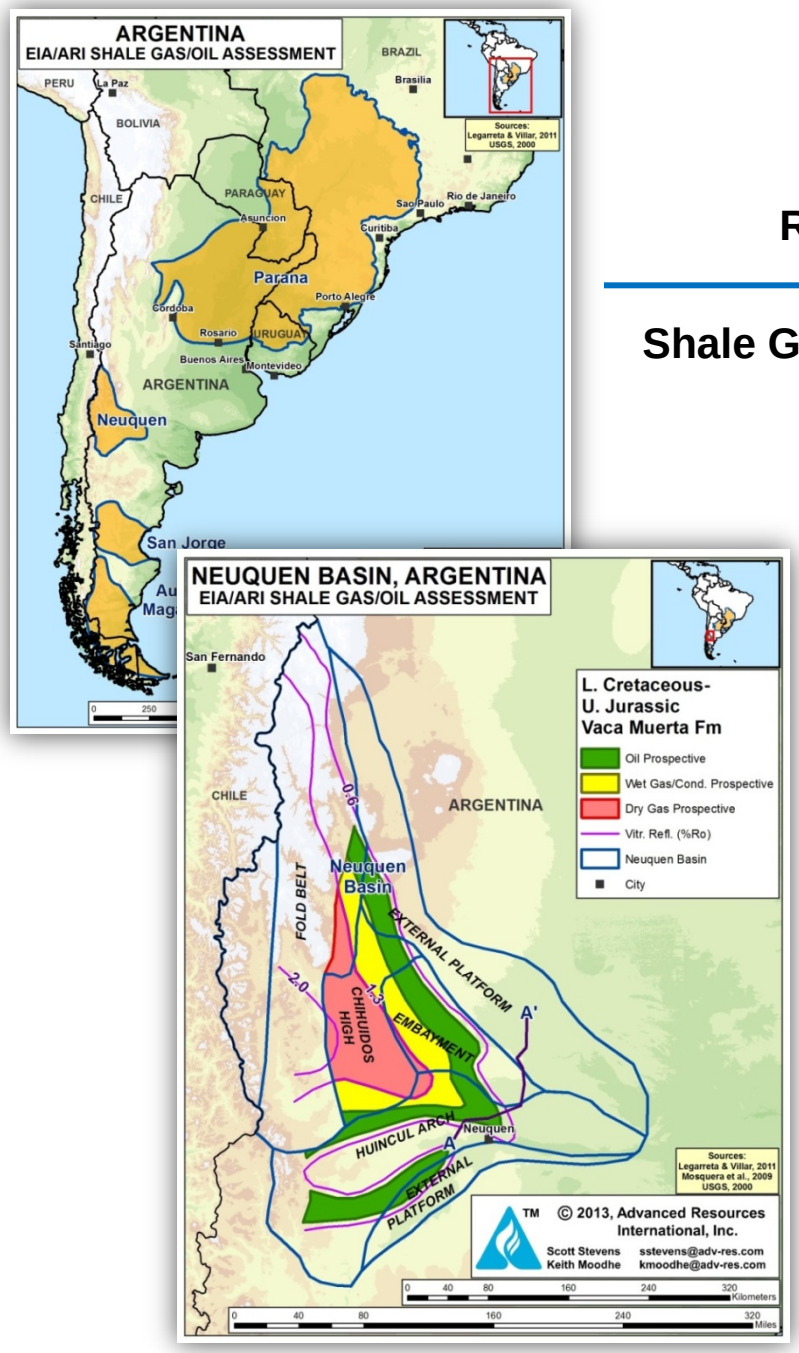
- Favorable geology, high resource concentrations, commercial production (~1 Bcfd)
- Environmental and market challenges
- Apache, EnCana and EOG using long Hz wells, pad drilling

Shale Gas and Shale Oil (Alberta/Sask.)
Devonian through Jurassic marine shales.

- Massive areas, moderate resource concentrations
- Major activity in Canadian Bakken Shale; just starting in Duvernay Shale

Shale Gas Eastern Canada: Ordovician Utica and Mississippian Horton Bluff shales; development on-hold.

Advanced Resources International, Inc.



ARGENTINA

Risked TRR: 802 Tcf and 27.0 Billion barrels

Shale Gas: Jurassic-Cretaceous marine shales in Neuquen Basin.

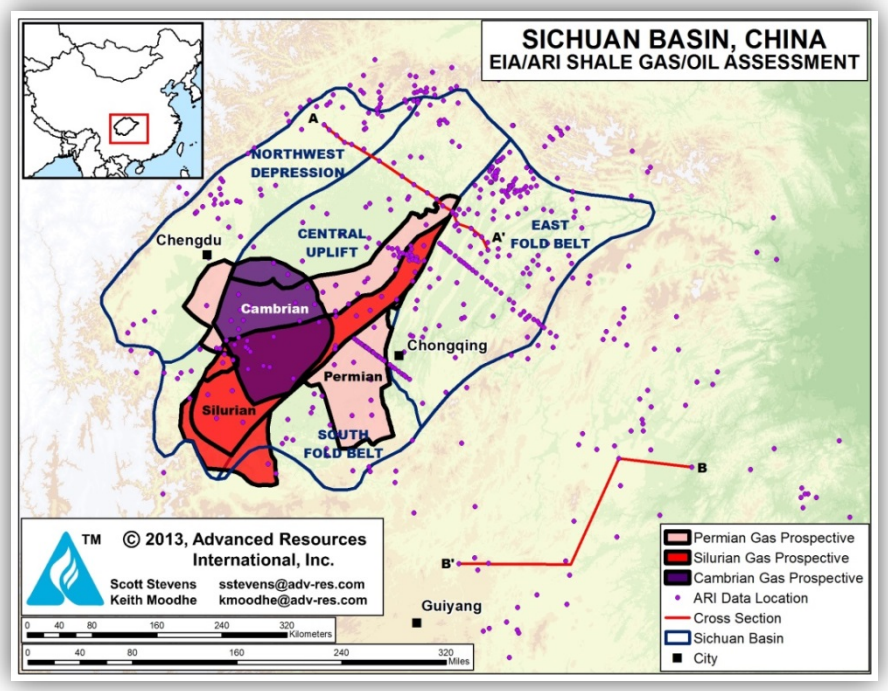
- Geologically perhaps best shale basin outside N. America
- L. Cretaceous non-marine shales in Golfo San Jorge and Austral basins

Shale Oil: High quality, shallower rocks in less thermally mature areas.

Activity: >50 shale gas/oil wells, mostly vertical.

- YPF operating 37 shale wells; Vaca Muerta vertical wells w/5 fracs, IP 180 to 600 bbl/d
- Apache Los Molles 2100' Hz well w/9-stage frac, IP 4.5 MMcfd
- Chevron and CNOC with $1+ Billion programs
- EOG, Exxon and others also active

Advanced Resources International, Inc.



CHINA

Risked TRR: 1115 Tcf and 32.2 Billion barrels

Shale Gas: Paleozoic marine source rocks in Sichuan Basin and southern China.

- Current focus of shale exploration.
- Good rock quality; structurally complex, drilling problems, high stress
- Goal of 6 to 10 Bcfd by 2020.

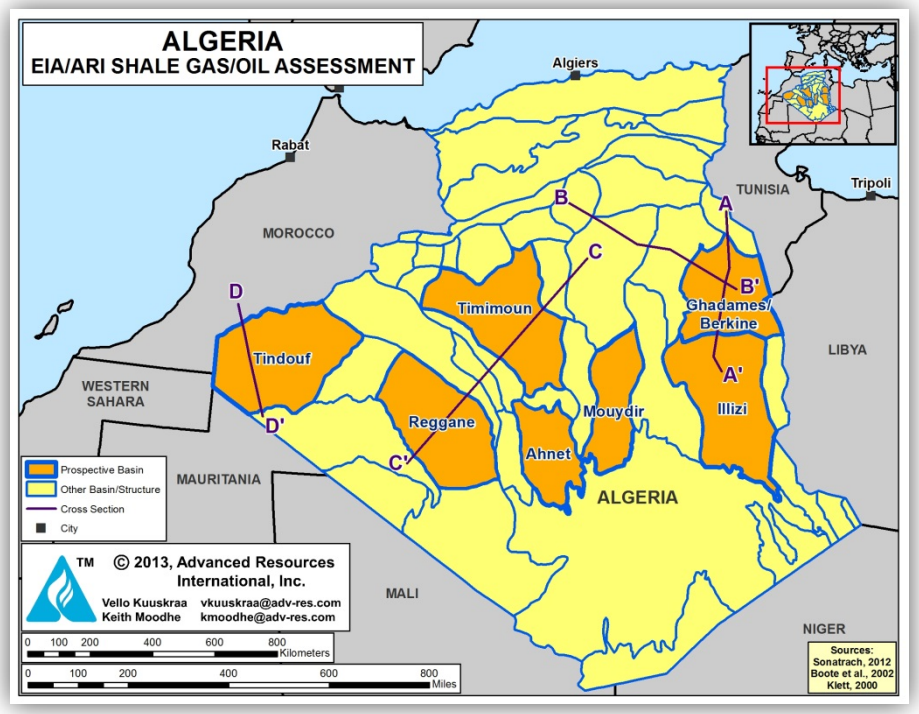
Shale Oil: Mesozoic lacustrine source rocks in Junggar, Tarim, and Songliao basins.

- Some early shale exploration
- Also structurally complex and faulted
- Will clay-rich non-marine shales efficiently fracture?

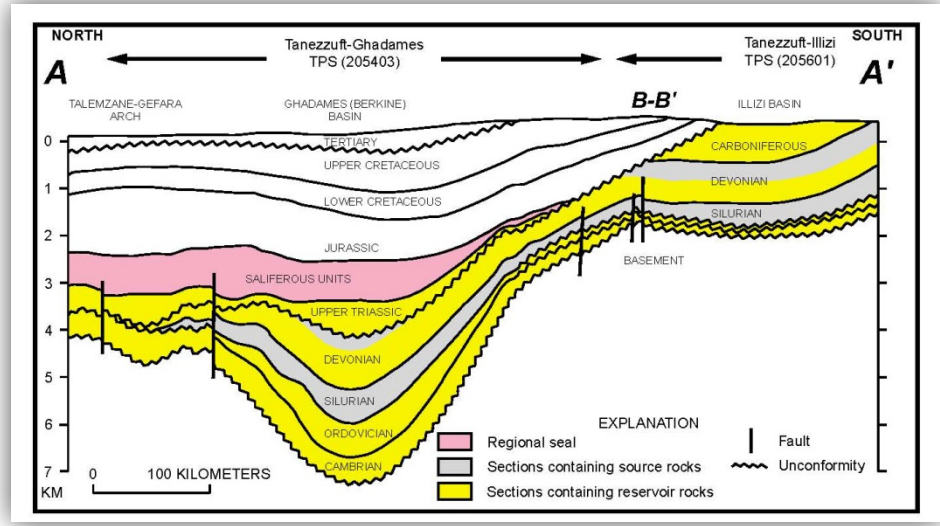
Activity: >100 exploration wells, vertical and horizontal.

- PetroChina, Sinopec, Chinese startups
- Shell, ConocoPhillips, Chevron, others
- Promising but still low gas rates, high costs

Advanced Resources International, Inc.



Cross Section A-A': Ghadames (Berkline) and Illizi Basins



Source: Klett, 2000A.

ALGERIA

Risked TRR: 707 Tcf and 5.7 Billion barrels

Shale Gas and Shale Oil: Silurian Tannezuft and Devonian Frasnian marine "hot shales".

- Seven major basins (Ghadames, Illizi, Timimoun, Ahnet, Mouydir, Reggane, Tindouf)
- Complex, thrusted geology; remote basin settings
- High TOC, overpressured, medium clay

Activity: Comprehensive shale gas and shale oil basin characterization by Sonatrach.

- Private exploration studies by Statoil and Repsol
- Plans by Sonatrach for pilot wells to test shale productivity in target basins
- Proposed hydrocarbon leasing round in 2013

Advanced Resources International, Inc.

MEXICO

Risked TRR: 545 Tcf and 13.1 Billion barrels

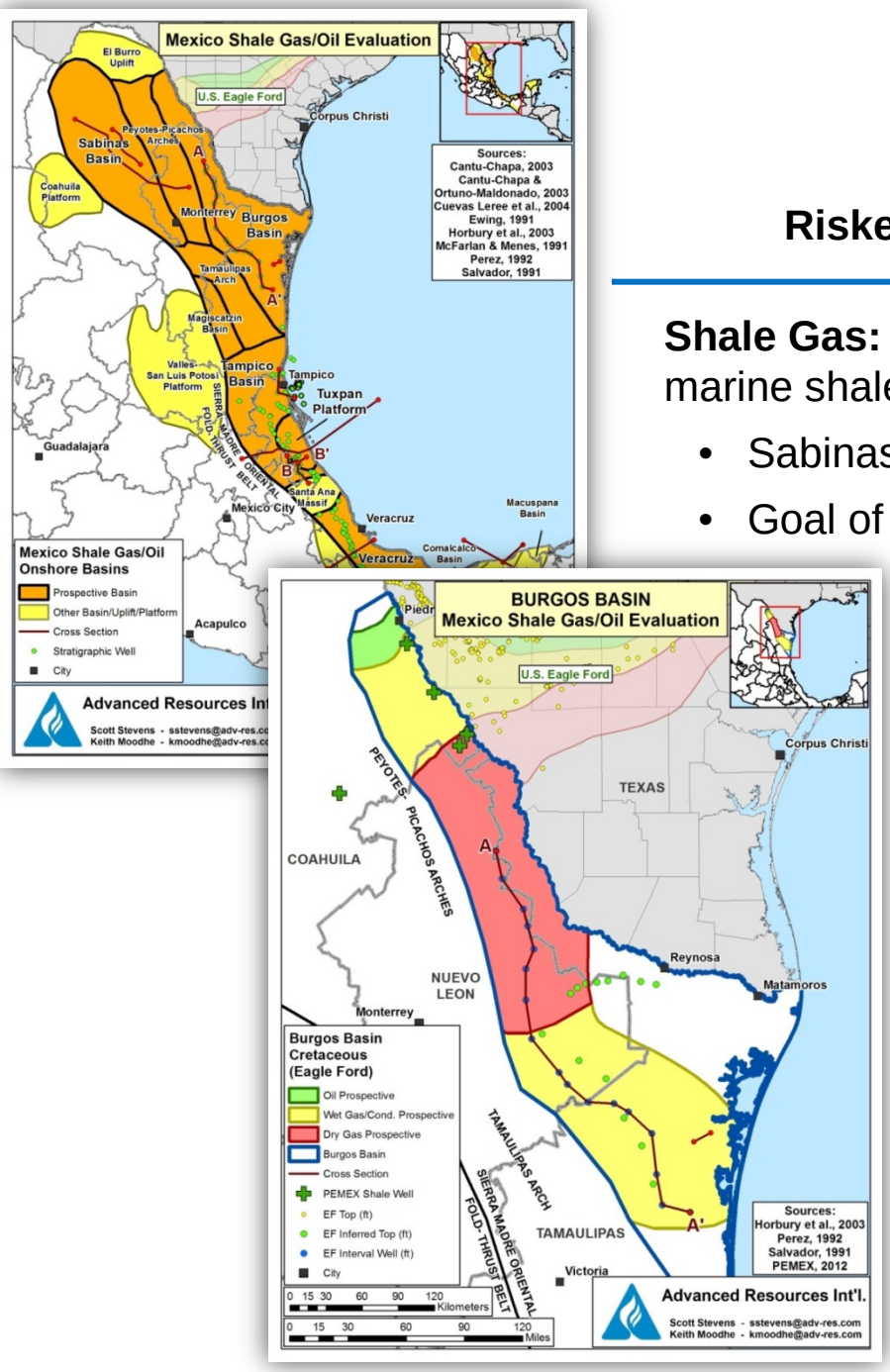
Shale Gas: High quality Eagle Ford and Tithonian (Haynesville) marine shales in Burgos Basin.

- Sabinas Basin faulted; Tuxpan, Tampico, Veracruz less so
- Goal of ~2 Bcfd by 2025

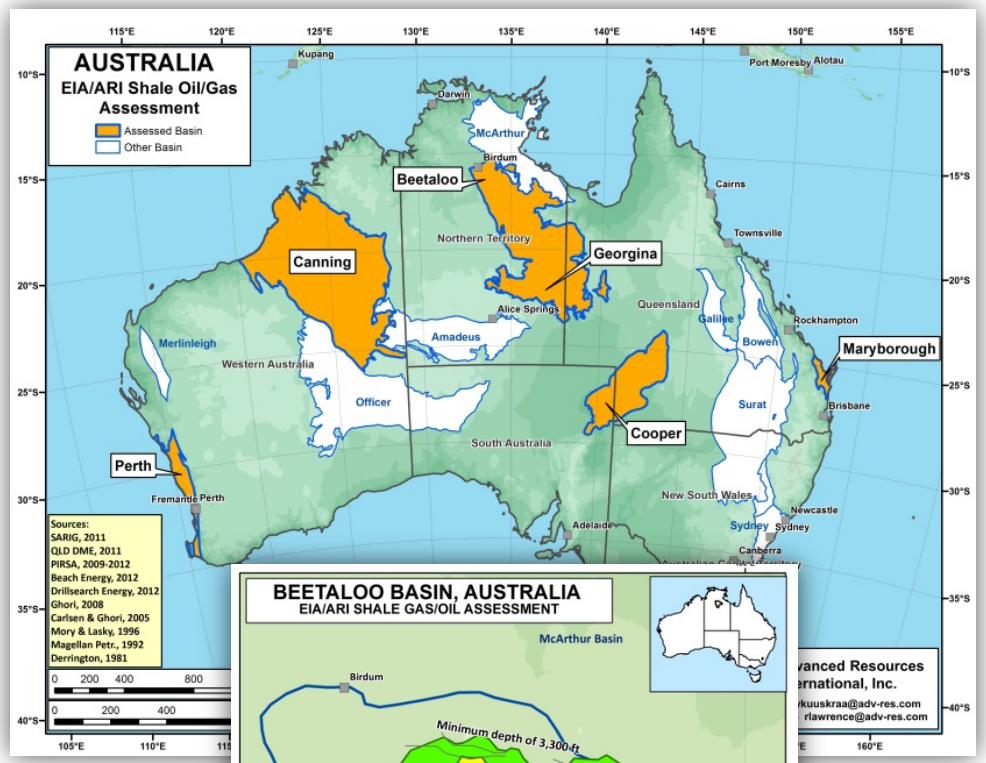
Shale Oil: Same high quality rocks in thermally less mature areas.

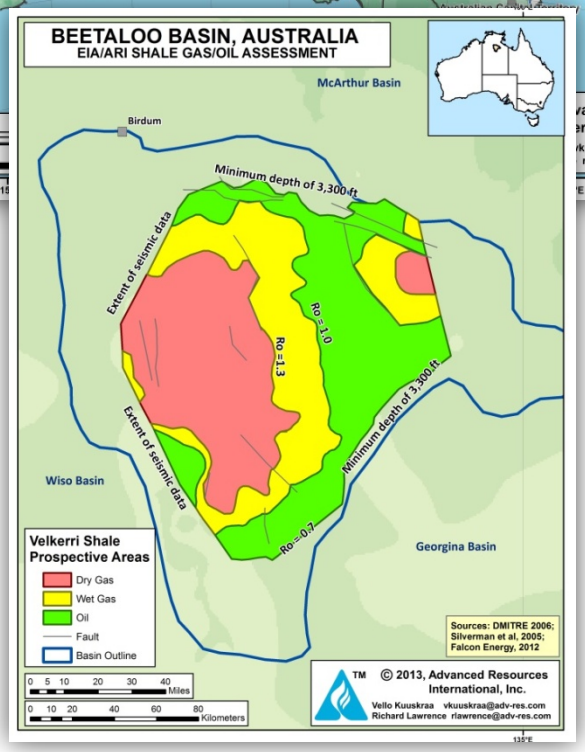
Activity: Pemex drilled 6 Eagle Ford shale wells with modest results.

- Expects commercial production by 2015
- High well costs but modest production: IP 3 MMcfd (steep decline)



Advanced Resources International, Inc.





AUSTRALIA

Risked TRR: 437 Tcf and 17.5 Billion barrels

Shale Gas and Shale Oil: Precambrian-Cretaceous marine and lacustrine shales.

- Six major basins (Cooper, Maryborough, Perth, Canning, Georgina and Beetaloo)
- Canning Basin's Ordovician marine shales most prominent
- Beetaloo and Georgina shale basins remote, leased but lightly explored

Activity: Demonstrated shale gas production in Cooper Basin by Santos and Beach Energy.

- Recent Carynginia Shale well in Perth Basin
- Brue Energy/Mitsubishi and NSE/Conoco-Phillips JVs in Canning Basin
- Petro Frontier/Statoil JV in Georgina Basin
- Falcon/Hess JV in Beetaloo Basin

Advanced Resources International, Inc.

Concluding Thoughts and Next Steps

The June 2013 "World Shale Gas and Shale Oil Resource Assessment" is the second step on a pathway toward a more rigorous understanding of the location and quality of the shale resource - - *"It all starts with the rocks."*

- Understanding finding, development and other costs.
- Defining policy/regulatory and environmental barriers.
- Identifying opportunities for transferring North America shale E&P technology to other countries.
- Assessing remaining major regions and countries (Middle East, Central Africa, Kazakhstan, etc.)

Office Locations
Washington, DC
4501 Fairfax Drive, Suite 910
Arlington, VA 22203
Phone: (703) 528-8420
Fax: (703) 528-0439

Houston, Texas
11490 Westheimer, Suite 520
Houston, TX 77042
Phone: (281) 558-6569
Fax: (281) 558-9202

Advanced Resources International, Inc.