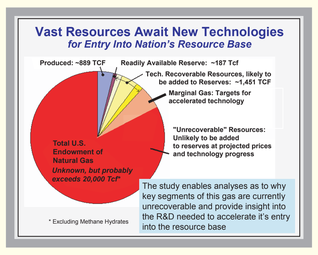
Assessing Subeconomic Natural Gas Resources in the Anadarko and Uinta Basins

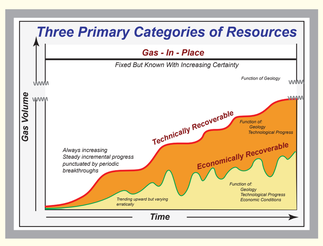
K.K. Rose*, A.S.B. Douds**, J.A. Pancake**, H.R. Pratt III**, R.M. Boswell*; DOE*, EG&G**

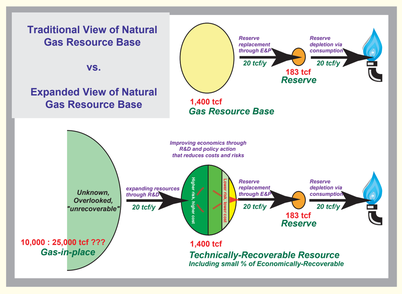
Project Background

Key Points

- Resource assessments conducted at NETL support the DOE's natural gas R&D program planning with a focus on:
  - Resources that are key program targets
  - Regional & deep gas accumulations
  - Producing geo-spatially disaggregated databases
- The disaggregated databases generated for each assessment are used to analyze the potential of different technologies under a variety of future scenarios.

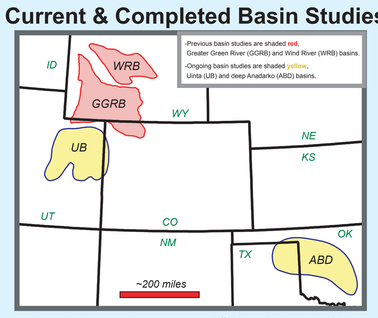






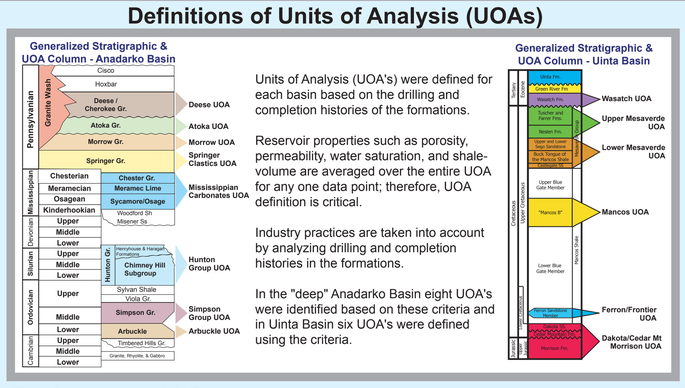
Project Methodology

Current & Completed Basin Studies



This gas-in-place resource assessment effort is continuing currently in the Anadarko Basin of Oklahoma and Texas and the Uinta Basin of Utah.

Definitions of Units of Analysis (UOAs)



Units of Analysis (UOA's) were defined for each basin based on the drilling and completion histories of the formations.

Reservoir properties such as porosity, permeability, water saturation, and shale-volume are averaged over the entire UOA for any one data point; therefore, UOA definition is critical.

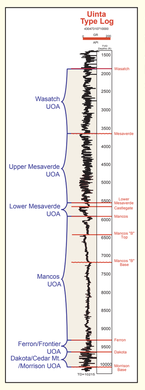
Industry practices are taken into account by analyzing drilling and completion histories in the formations.

In the "deep" Anadarko Basin eight UOA's were identified based on these criteria and in Uinta Basin six UOA's were defined using the criteria.

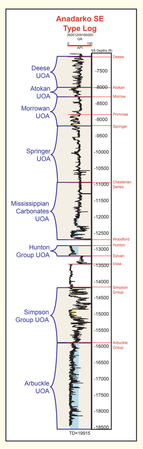
Explanation of UOA parameters

Once the UOA's were defined based on the the drilling/completion history in the basin, UOA extents were defined through correlation of well logs throughout the basins. In the "deep" Anadarko Basin UOA boundaries were typically delineated by structural features, erosional boundaries, and the 10,000' MD structure contour for each.

UOA's in the Uinta Basin were separated into shallow and deep zones based on stratigraphic depth and density of data. The deep portion of the UOA's generally contain significantly fewer well penetrations.

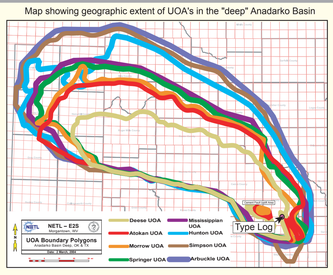


Type logs were generated in the Uinta basin and SE "deep" Anadarko basin to show the lithologic and stratigraphic distribution of the UOA's.

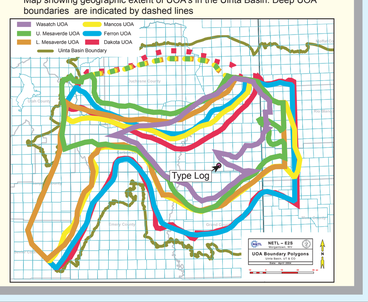


Packages highlighted with yellow are dominately clastics, packages highlighted with blue are dominately carbonates.
Uinta UOAs are primarily clastics.

Map showing geographic extent of UOA's in the "deep" Anadarko Basin



Map showing geographic extent of UOA's in the Uinta Basin. Deep UOA boundaries are indicated by dashed lines

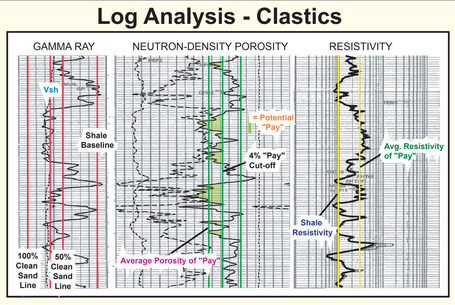


Project Workflow

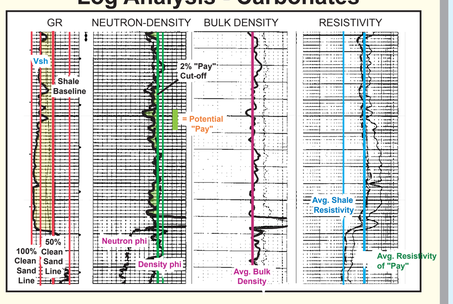
Data Collection	Obtain best quality, evenly-distributed well log data; objective of 1 well per township
UOA Definition	Subdivide stratigraphic section into units of analysis that are to be modeled as separate drilling targets
Correlation	Establish the three-dimensional geometry of each UOA
Mapping	Establish the distribution of resource-bearing sandstone facies to improve extrapolation of parameters to areas of poor data control
Log Analysis	Estimate UOA-average values of porosity, drilling depth, resistivity, shale volume, and potential pay thickness for each well log suite
Engineering Analysis	Estimate pressure and temperature gradients and water resistivity at township or quarter-township scale
Permeability Analysis	Estimate expected matrix permeability and likely natural fracture overprint through reference to field studies and the density of interpreted surfaces and basement features
Gridding	Distribute scattered well data to regular grid filling UOA area. Add control wells to provide interpreted values in areas of poor data
Dataset Preparation	Compile fully-defaulted and formatted database for model input. Remove all areas of significant historical production
Technology Modeling	Conduct GSAM analyses to determine gas-in-place, and the impact of technology/cost scenarios on economically- and technically-recoverable volumes

The project workflow, diagrammed above, shows the basic model followed for each resource assessment in order to determine GIP.

Log Analysis - Clastics



Log Analysis - Carbonates



After correlation of the well logs, log analysis is performed in order to collect reservoir properties for the UOAs and determine the variation within the basin of those properties. The properties collected during log analysis include:

(1) Drilling depth
(2) Net thickness (shale-volume < 50%)**
(3) Average shale resisitivity
(4) "Potential pay" thickness

**Note: This property was not used to calculate GIP. These values are mapped to create the Isochore/Isolith maps indicating sandstone distribution throughout the basins.

Generally, the following parameters were used by the geologist when determining "potential pay" of clastics:
- water saturation < 70%
- porosity > 4%
- shale-volume < 75%
- minimum bed thickness cutoff = 4ft

The following properties are collected over the "potential pay" interval:
(5) Average shale-volume
(6) Average porosity
(7) Average resisitivity

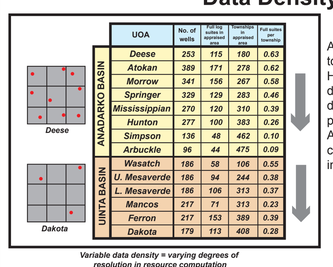
Parameters 1 & 3-7 are entered into either the Simandoux or Archie equations to calculate water saturation. Water saturations >70% are considered wet for this analysis.

Generally, the following parameters were used by the geologist when determining "potential pay" of carbonates:
- water saturation < 70%
- density porosity > 2%
- shale-volume < 50%
- minimum bed thickness cutoff = 4ft

The following properties are collected over the "potential pay" interval:
- Average shale-volume
- Average bulk density, compensated density, and neutron porosities
- Average resisitivity

These parameters are entered into the Archie equation to calculate water saturation. Water saturations >70% are considered wet for this analysis.

Data Density



	UOA	No. of wells	Full log suites per township	Complete log suites per township	Full suites per township
ANADARKO BASIN	Deese	253	115	180	0.63
	Atokan	389	171	278	0.62
	Morrow	341	156	267	0.58
	Springer	329	129	283	0.46
	Mississippian	270	120	310	0.39
	Hunton	277	100	383	0.26
	Simpson	136	48	462	0.10
	Arbuckle	96	44	475	0.09
UINTA BASIN	Wasatch	186	58	106	0.55
	U. Mesaverde	186	94	244	0.38
	L. Mesaverde	186	106	313	0.37
	Mancos	217	71	313	0.23
	Ferron	217	153	389	0.39
	Dakota	179	113	408	0.28

Deese
Dakota

Variable data density = varying degrees of resolution in resource computation

A target data density of one well per township was sought for each UOA. However, in most UOA's data density decreased with increased drilling depth, because the number of well penetrations decreased with depth. As such, resolution in those resource calculations decreased with increasing depth.

Data Sources

Below is a list of references for data used in the assessments

Well Logs: *A2D, MJ Systems, In-house Microfiche*

Well Data (location & production): *IHS Energy, Texas RRC*

Core Data: *Oklahoma Geological Survey, IHS Energy*

Rw Data: *USGS Produced Rw Database, SPE Survey of Rw Data in Oklahoma,1988*

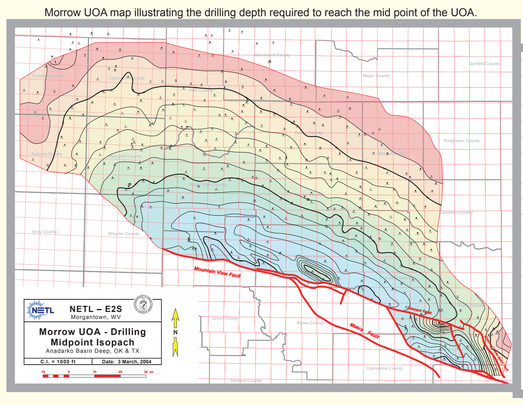
Temperature Data: *- P.K. Cheung, 1975, Thesis " The Geothermal Gradient in Sedimentary Rocks in Oklahoma", OSU*
- BHT data collected from log headers
- IHS Energy

Pressure Data: *- Oklahoma State Univ. "Pressure Data on the Anadarko Basin", OSU website*
- IHS Energy

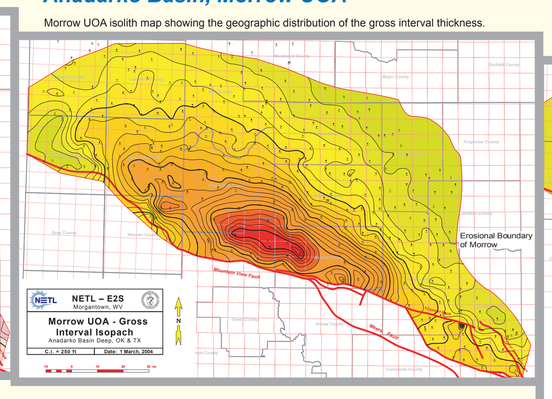
Example Maps for the Anadarko and Uinta Basins

Anadarko Basin, Morrow UOA

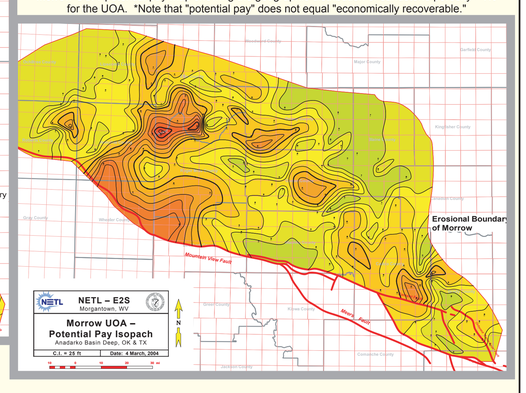
Morrow UOA map illustrating the drilling depth required to reach the mid point of the UOA.



Morrow UOA isolith map showing the geographic distribution of the gross interval thickness.

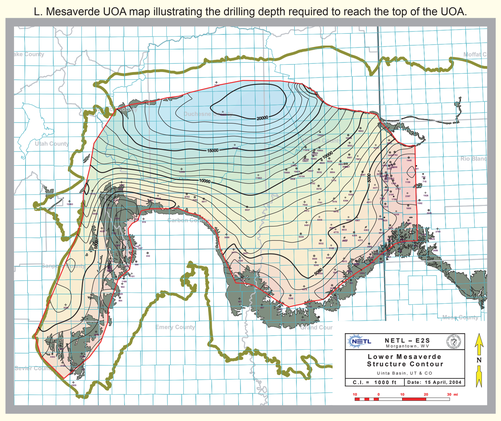


Morrow UOA potential pay map showing the geographic distribution of sandstone porosity >4% for the UOA. *Note that "potential pay" does not equal "economically recoverable."

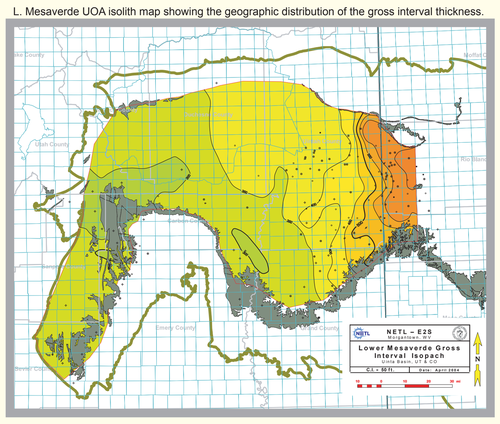


Uinta Basin, Lower Mesaverde UOA

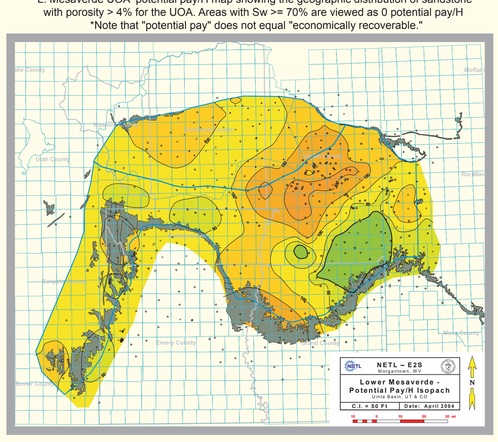
L. Mesaverde UOA map illustrating the drilling depth required to reach the top of the UOA.



L. Mesaverde UOA isolith map showing the geographic distribution of the gross interval thickness.

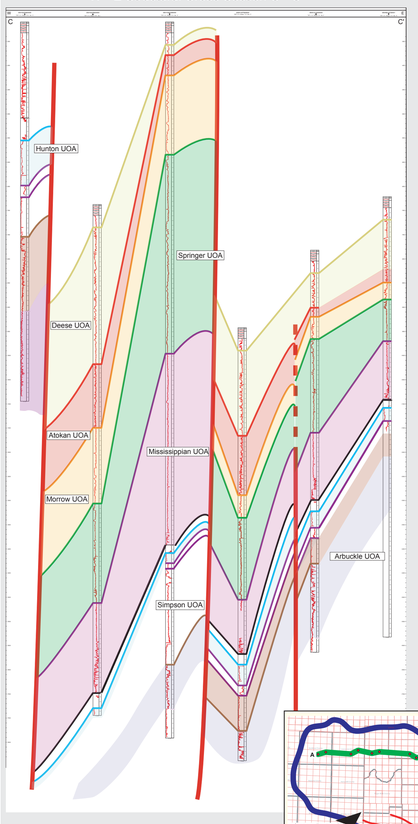


L. Mesaverde UOA potential pay/H map showing the geographic distribution of sandstone with porosity > 4% for the UOA. Areas with Sw >= 70% are viewed as 0 potential pay/H
*Note that "potential pay" does not equal "economically recoverable."

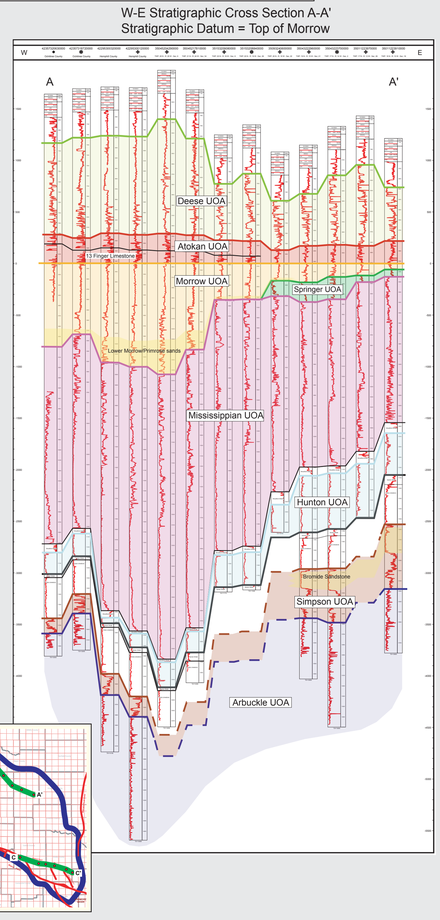


Anadarko Basin Cross Sections

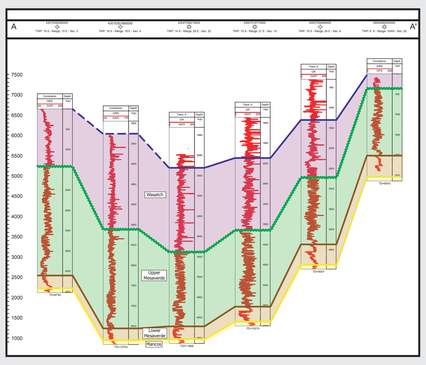
W - E Structural Cross Section C - C'

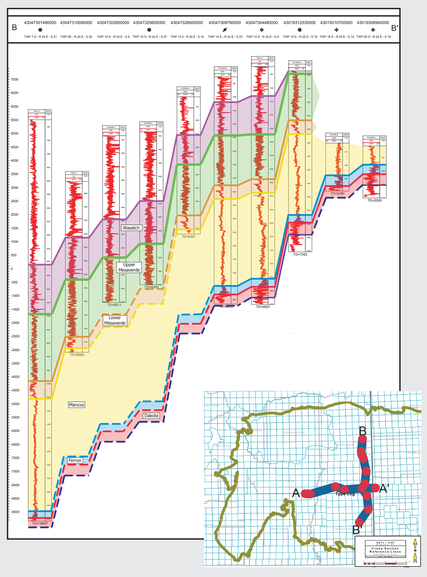


W-E Stratigraphic Cross Section A-A'
Stratigraphic Datum = Top of Morrow



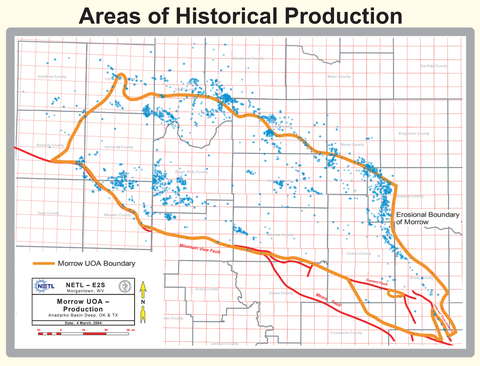
Uinta Basin Cross Sections



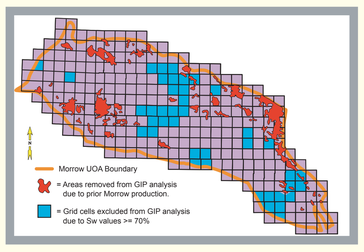


Dataset Preparation

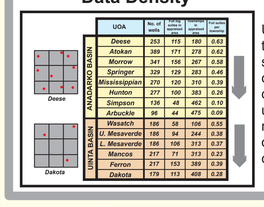
Areas of Historical Production



After values for potential pay thickness have been determined for every grid cell, areas of significant historical production or grid cells that are interpreted as wet due to interpolation of log analysis values, will be extracted from the data set. This will result in a database that reflects the remaining Gas-in-Place potential for all UOAs studied in the basins.



Data Density

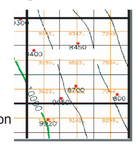


	UOA	No. of wells	Full log suites per township	Complete log suites per township	Full suites per township
ANADARKO BASIN	Deese	253	115	180	0.63
	Atokan	389	171	278	0.62
	Morrow	341	156	267	0.58
	Springer	329	129	283	0.46
	Mississippian	270	120	310	0.39
	Hunton	277	100	383	0.26
	Simpson	136	48	462	0.10
	Arbuckle	96	44	475	0.09
UINTA BASIN	Wasatch	186	58	106	0.55
	U. Mesaverde	186	94	244	0.38
	L. Mesaverde	186	106	313	0.37
	Mancos	217	71	313	0.23
	Ferron	217	153	389	0.39
	Dakota	179	113	408	0.28

Deese
Dakota

Gridding

UOAs will be gridded at the township level. Grid spacing is designed to correlate with the data density. Gridding the unevenly spaced data results in an even distribution of points with a value in the center of the cell.



Gridding unevenly spaced data points results in an even distribution of the mapped variable.

Example: computer interpolates drilling depth from well data for nine 2,560-acre cells per township

Grid cell size is based on the data density for the play

Identical gridding for remaining volumetric parameters (thickness, porosity, Sw, pressure)

USGS' Technically Recoverable Gas Assessments for the Anadarko Basin.

Anadarko Basin - USGS 1995	
Play	Tech. Rec. (BCF)
Deep Structural Gas*	947
Uppermost Arbuckle	46
Internally Sourced Arbuckle	68
Wichita Mtn Uplift	370
Simpson Gas	22
Viola Gas	20
Hunton Stratigraphic-Unconformity Gas	173
Deep Stratigraphic Gas**	2595
U. Mississippian Gas	218
L. Mississippian Gas	228
Springer Stratigraphic Gas	219
Morrow Sandstone Gas	1174
Atokan Sandstone Stratigraphic Gas	124
L. Desmoinesian Stratigraphic Gas	20
U. Desmoinesian Stratigraphic Gas	2389
L. Missourian Stratigraphic Gas	48
U. Missourian Stratigraphic Gas	177
L. Virgilian Sandstone Gas	24
U. Virgilian Sandstone Gas	228
Permian Carbonate Stratigraphic Gas	66
Washes	13
Total	9169

* "Deep Structural Gas" is defined in the USGS' 1995 reportas gas within the basement through Hunton formations at depths of 13,000 to 40,000'

** "Deep Stratigraphic Gas" is defined in the USGS' 1995 report as gas within all strata from the top of the Hunton to the top of the Prue sandstone (Desmoinesian) that are deeper than 13,000'

Previous Assessments

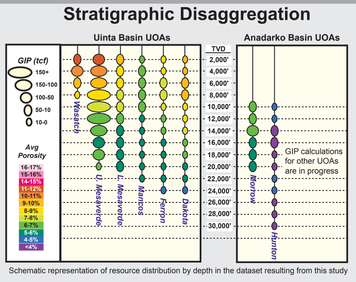
In the past decade the USGS National Assessment quantified Technically Recoverable resources for most major US basins, including the Anadarko and Uinta Basins. In basins where Gas-in-Place assessments have been completed data indicates that only 2% of the existing GIP is technically recoverable. The remaining 98% represents one of the nation's largest untapped natural gas resources.

Expanded access to this gas will require the development of advanced technologies specifically tailored to unlock this segment of the resource. In order to identify the most promising R&D opportunities, NETL uses sopthisticated computer models of the national natural gas E&P system. To increase the reliability of the results, this study produces model databases which capture the geologic variety of resource occurrences.

Gas Assessments for the Uinta Basin.

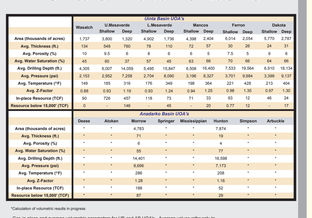
Uinta Basin - USGS 2002	
Play	Tech. Rec. (BCF)
Ferron/Wasatch Plateau Deep(>6000ft) AU	59.10
Ferron/Wasatch Plateau Coal Bed Gas AU	1452.21
Mesaverde Continuous AU	7391.36
Mesaverde Transitional AU	1492.97
Mesaverde Coal Bed Gas AU	367.77
Mancos/Mowry Uinta Basin Continuous AU	3110.69
Total	13874.10
Uinta Basin - Scotia Group/DOE 1995	
Play	Gas-in-Place (Tcf)
Wasatch Gas-Saturated	39.7
Wasatch Gas-Water Transitional	20.2
Mesaverde Gas-Saturated Deep Synclinal > 15000 ft	47.8
Mesaverde Gas-Saturated Rc > 1.1 & < 15000 ft	200.7
Mesaverde Gas-Water Transitional Rc-0.75< 1	87.1
Total	395.5

Stratigraphic Disaggregation



Schematic representation of resource distribution by depth in the dataset resulting from this study

Volumetric Results - Uinta & Anadarko Basins



Uinta Basin UOA's	Wasatch	U.Mesaverde Shallow	U.Mesaverde Deep	L.Mesaverde Shallow	L.Mesaverde Deep	Mancos Shallow	Mancos Deep	Ferron Shallow	Ferron Deep	Dakota Shallow	Dakota Deep
Area (thousands of acres)	1,737	3,800	1,320	4,902	1,736	4,388	2,404	6,014	2,054	5,770	2,797
Avg. Thickness (ft.)	134	134	548	780	72	57	30	36	24	31	
Avg. Porosity (%)	10	9.5	6	9	6	6	5	7.5	5	9	6
Avg. Water Saturation (%)	45	60	37	57	45	63	66	70	66	54	65
Avg. Drilling Depth (ft.)	4,305	6,007	14,059	5,495	15,847	6,508	16,400	7,533	19,564	6,910	18,104
Avg. Pressure (psi)	2,155	2,852	7,258	2,754	8,090	3,196	8,307	3,701	9,984	3,398	9,127
Avg. Temperature (°F)	149	185	316	176	349	198	364	221	428	213	404
Avg. Z-Factor	0.88	0.93	1.18	0.93	1.24	0.94	1.25	0.98	1.35	0.97	1.30
In-place Resource (TCF)	90	726	457	118	73	71	33	63	12	46	24
Resource below 15,000' (TCF)	0		146		45	20	0.77	12		17	

Anadarko Basin UOA's	Deese	Atokan	Morrow	Springer	Mississippian	Hunton	Simpson	Arbuckle
Area (thousands of acres)	*	*	4,763	*	*	7,874	*	*
Avg. Thickness (ft.)	*	*	71	*	*	19	*	*
Avg. Porosity (%)	*	*	8	*	*	4	*	*
Avg. Water Saturation (%)	*	*	55	*	*	77	*	*
Avg. Drilling Depth (ft.)	*	*	14,401	*	*	16,598	*	*
Avg. Pressure (psi)	*	*	8,656	*	*	7,173	*	*
Avg. Temperature (°F)	*	*	286	*	*	258	*	*
Avg. Z-Factor	*	*	1.28	*	*	1.16	*	*
In-place Resource (TCF)	*	*	188	*	*	52	*	*
Resource below 15,000' (TCF)	*	*	87	*	*	28	*	*

*Calculation of volumetric results in progress

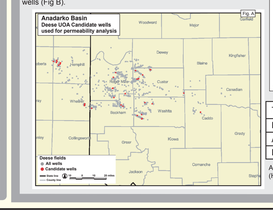
Gas-in-place and average volumetric parameters for UB and AB UOA's. Average values refer only to the potential pay in each grid cell. For example, 7% porosity means that the average porosity of the zones identified as potential pay over all grid cells is 7%. Total values are the aggregate values for all grid cells.

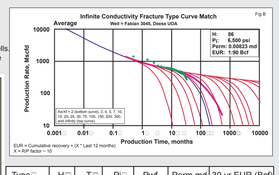
The results can be characterized by the amount of resource contained at specific drilling depths. The stratigraphic and geographic disaggregation of the resource gives a more accurate picture of how the resource is distributed among the UOAs of the basin.

Permeability Analysis

G. Koperna, G. Bank, T. Graham, ARI

ARI was tasked with deriving bulk permeability estimates for each UOA.
Methodology:
1) Identify producing fields for each UOA.
2) Identify low, average, and high productivity wells using estimated 30-year EUR by field/area (Fig A).
3) Analyze logs to calculate H for perf'ed zones in suitable candidate wells.
4) Type curve match production history to determine permeability for the wells (Fig B).





Type	H	T	Pi	Pwf	Perm md	30 yr EUR (Bcf)
High	75	204	7220	1000	0.082	6.67
Average	55	199	6667	1000	0.0277	1.68
Low	52	207	6825	1000	0.009	0.43

Above table shows the averaged values for the 10 wells in each category (High, Average, Low) for the Deese UOA.

The bulk permeability results provided by ARI will be used in conjunction with structural complexity mapping to determine permeability for each UOA. Structural complexity will be determined through analysis of existing structural features, and surface and subsurface lineament data from each basin.

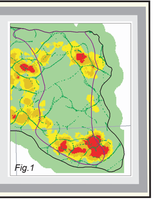


Fig. 1. Example of a structural complexity map from the Greater Green River Basin.

Conclusions

- DOE's National Energy Technology Laboratory is modeling the recoverability of major untapped resources in an effort to identify the most promising R&D opportunities.
- Through log based analyses, NETL's resource assessment of the "deep" Anadarko Basin seeks to produce a detailed, disaggregated dataset of the basin's tight, deep, and unconventional formations.
- This dataset will assist DOE modelers in the identification of future technologies that can unlock GIP resources and help shift them to a technically or economically recoverable status.
- Previous model datasets have been upgraded through new studies of the Gas-in-Place in the GGRB and WRB that capture the full natural variety in key parameters
- Basins currently under investigation: Anadarko Basin, TX & OK, Uinta Basin UT

Information Transfer...

August 2002, COGA presentation of GGRB &WRB Assessments Denver, CO

GGRB & WRB Assessments published in Gas TIPS, Summer 2002

Presentation of the Anadarko Assessment at the "Unconventional Energy Resources in the Southern Midcontinent" OGS workshop, March 2004

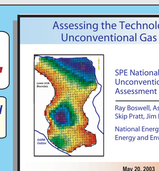
OKLAHOMA GEOLOGICAL SURVEY
A State Agency for Research and Public Service
Charles J. Mankin, Director

Abstract accepted for presentation of the Anadarko & Uinta assessments at the 2004 national AAPG convention

GGRB & WRB assessments presented at the 2003 national AAPG convention
A·A·P·G
American Association of Petroleum Geologists
An International Geological Organization
www.aapg.org

Abstract accepted for presentation of the Uinta Assessment at the August 2004 RMAG-COGA-RMR AAPG joint meeting, Denver, CO

Assessing the Technology Needs of Unconventional Gas Resources



SPE National Capital Section
Unconventional Gas Resources Assessment Symposium

Ray Boswell, Ashley Douds, Kelly Rose, Skip Pratt, Jim Pancake, and Jim Dean

National Energy Technology Laboratory
Energy and Environmental Solutions

May 20, 2003

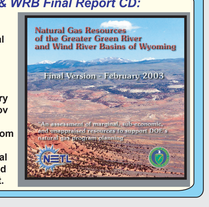
SPE Presentation, May 2003

GGRB & WRB Final Report CD:

Over 400 cd's distributed at the 2003 AAPG National Convention

Numerous CD's distributed via NETL's online library at: www.netl.doe.gov

Various requests from independents and majors for the digital data files associated with the final report.



The maps, cross sections, and other data generated in this study will be available in a CD format in the fall of 2004.

For more information regarding the National Energy Technology Laboratory visit the website at:

www.netl.doe.gov

Disclaimer:

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed ro implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference therein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, or any agency thereof. The views and opinions of authors expressed therein do not necessarily state or reflect those of the Unites States Government or any agency thereof.