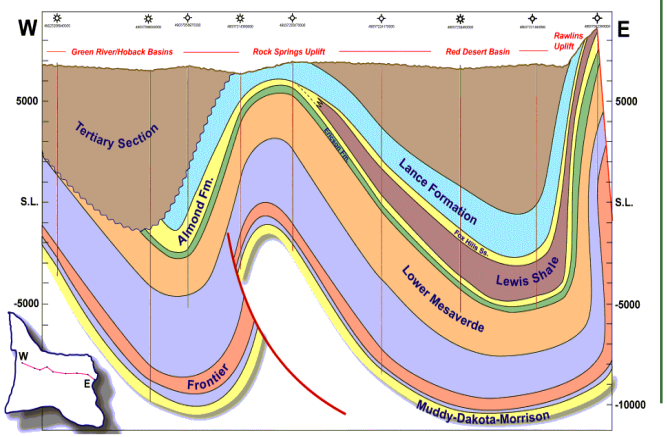
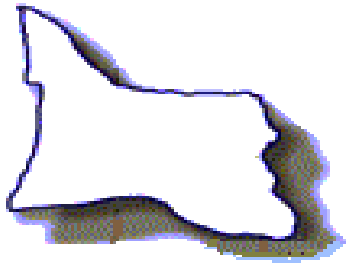
Energy and Environmental Solutions



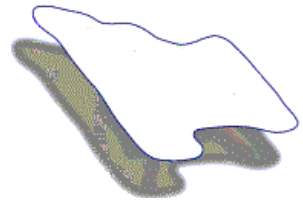
Assessing Technology Needs of Sub-economic Gas Resources

Phase I: Greater Green River and Wind River basins

Ray Boswell, Ashley Douds, Skip Pratt, Kelly Rose, Kathy Bruner, Jim Pancake-EG&G Services
Vello Kuuskraa, Randy Billingsley, Greg Bank-Advanced Resources International



Presentation in Brief



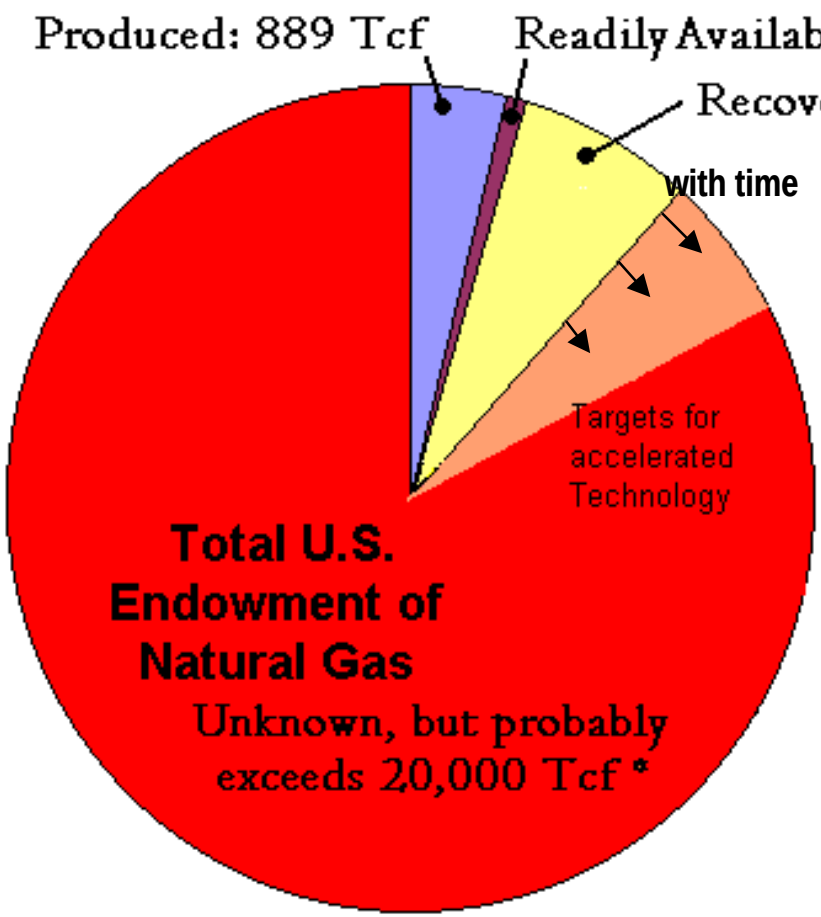
WHAT? **Studies in the Greater Green and Wind River basins as part of a new program of detailed characterizations of marginal and sub-economic resources**

HOW? **Log-based, gas-in-place approach focusing on detailed geographic and vertical dissaggragation of the resource**

WHY? **Primarily - to allow NETL to model the role of technology in expanding the nation's recoverable resource base**

Also - to add new information on natural gas resources and, where applicable, resources on federal lands

Vast Resources Await New Technologies
for Entry Into Nation's Resource Base



* Excluding Methane Hydrate

Demand is growing, private R&Dis declining, and technical challenges are increasing...

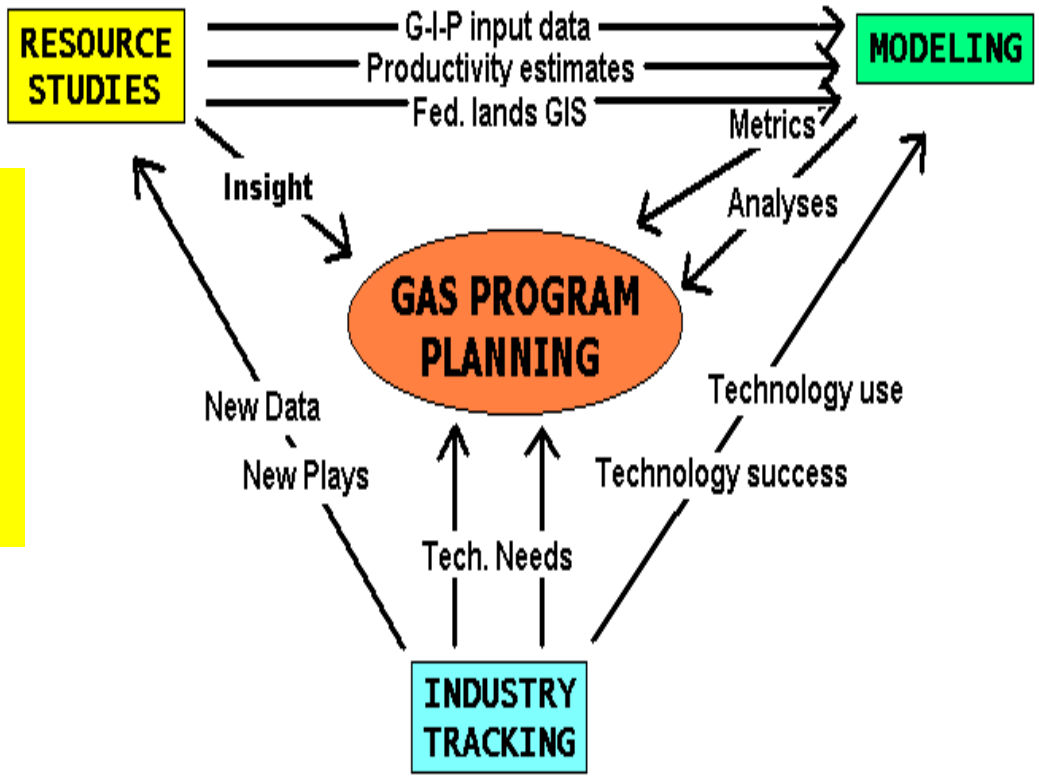
What is the nature of this resource?

What are the key barriers to expanded, accelerated recovery?

What are the most effective R&D approaches?

E²S Support to NETL Natural Gas E&P Program

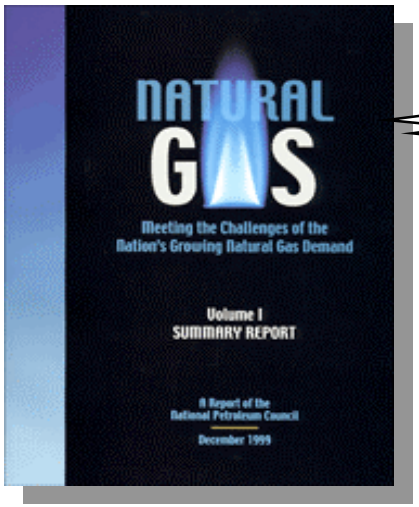
Providing detailed characterizations of emerging resources that are the targets of the program



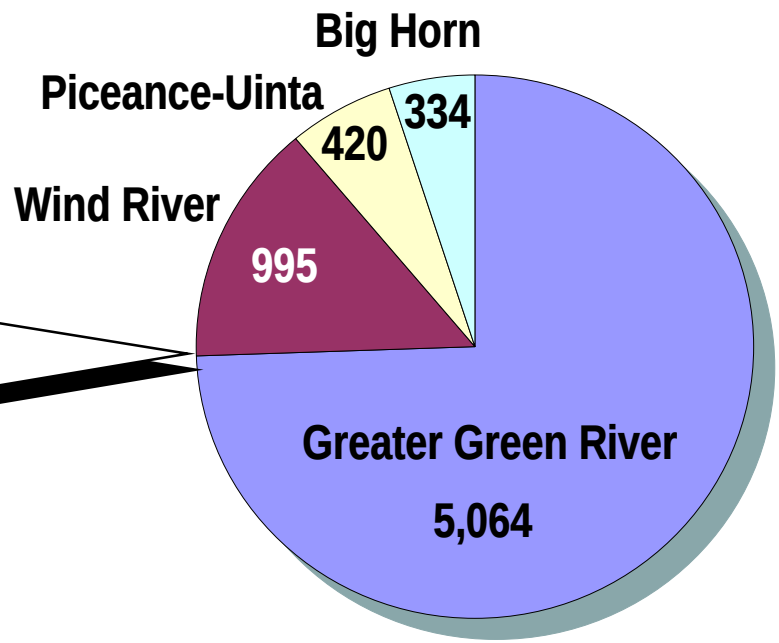
Conducting analytical studies of the relative potential of alternative R&D approaches

Tracking the use and effectiveness of advanced technologies

What to Study First?



NPC's 1999 REPORT RECOMMENDED SPECIFIC ATTENTION BE GIVEN TO ROCKY MOUNTAIN RESOURCE, TECHNOLOGY, AND POLICY ISSUES



A SERIES ('87-'99) OF USGS/DOE GAS-IN-PLACE RESOURCE ASSESSMENTS IDENTIFIED THE GGRB AND WRB AS HOLDING THE BULK OF THE ROCKY MTN. RESOURCE

98% of GIP Considered Not Recoverable

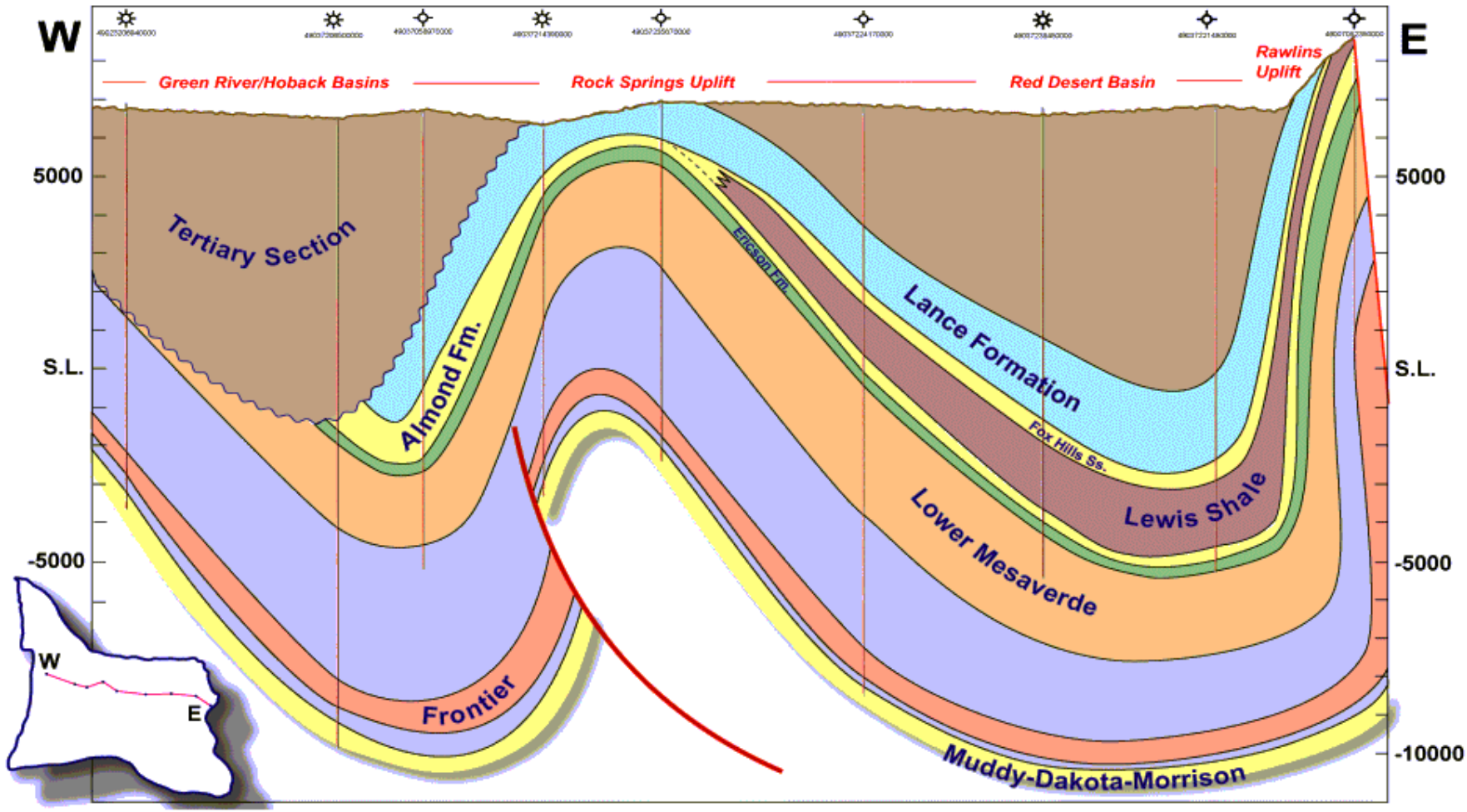
USGS Assessments of Resources in GGRB and WRB

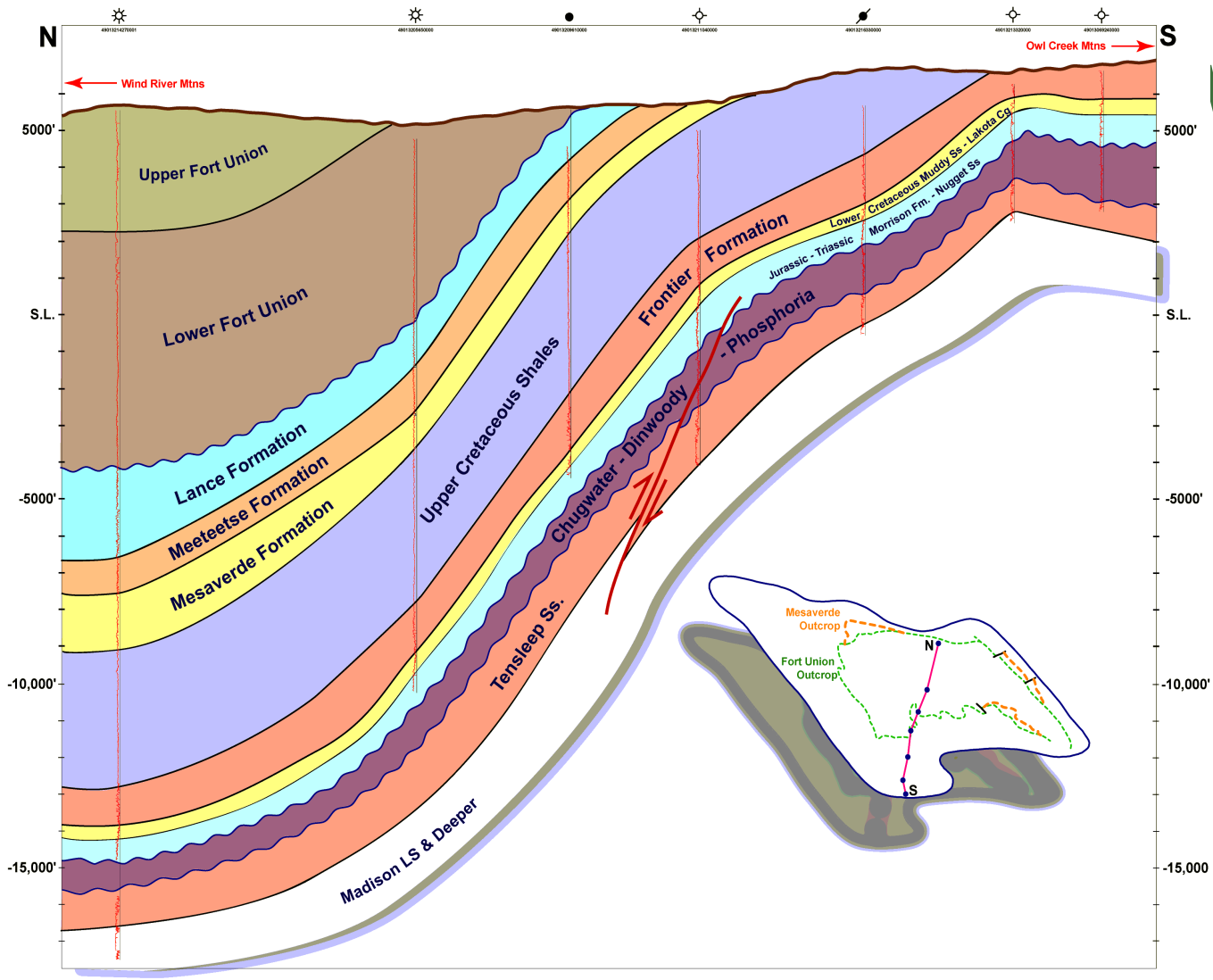
Greater Green River Basin			Wind River Basin		
Play	**GIP ('89)**	**Tech. Rec. ('95)**	**Play**	**GIP ('96)**	**Tech. Rec. ('95)**
Ft. Union	96	1	Ft. Union	101	Not Assessed
Fox Hills/Lance	707	10	Lance	365	Not Assessed
Lewis	610	19	Meeteetsee	124	Not Assessed
Mesaverde	3,347	52	Mesaverde	193	Not Assessed
Frontier-Cloverly	307	37	Frontier	151	Not Assessed
TOTAL	**5,063**	**119**	**TOTAL**	**995**	**Not Assessed**

Values in trillion cubic feet of gas

Greater Green River Basin

West-East Structural Cross Section (VE=26x)

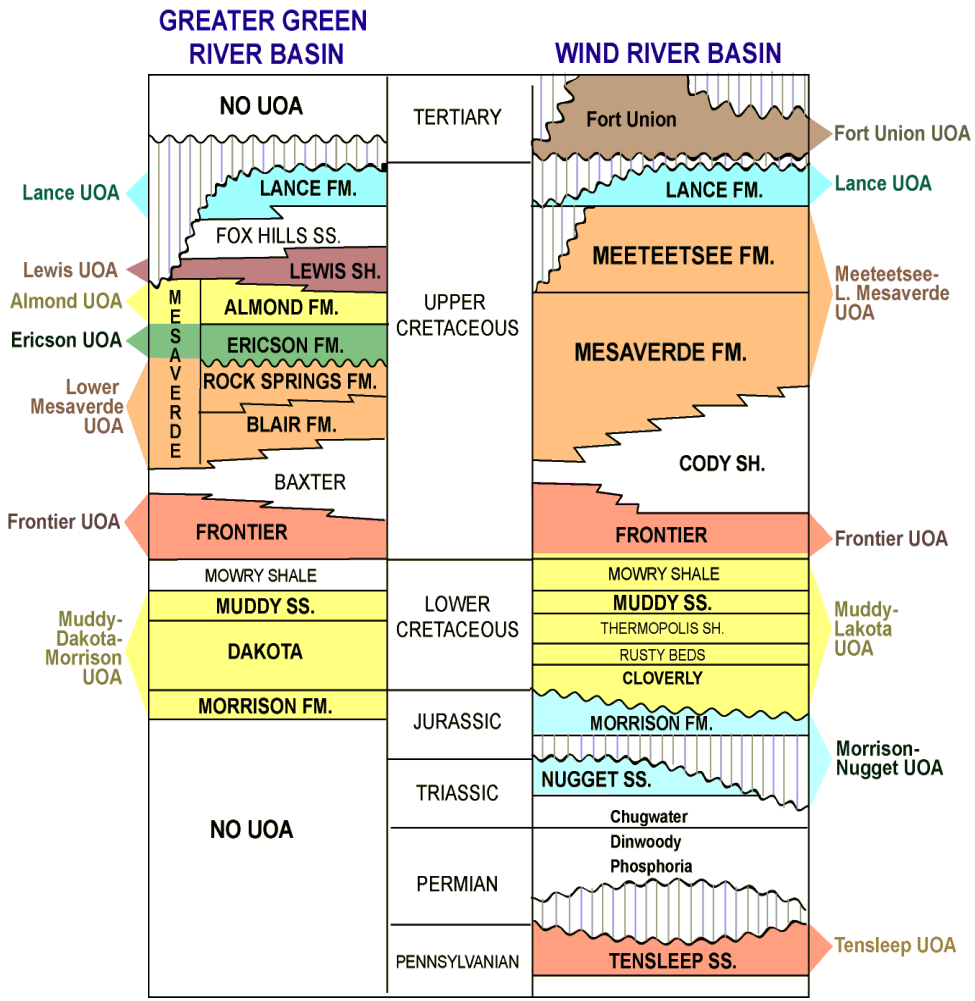




Wind River Basin

North-South Structural Cross-section (VE=15x)

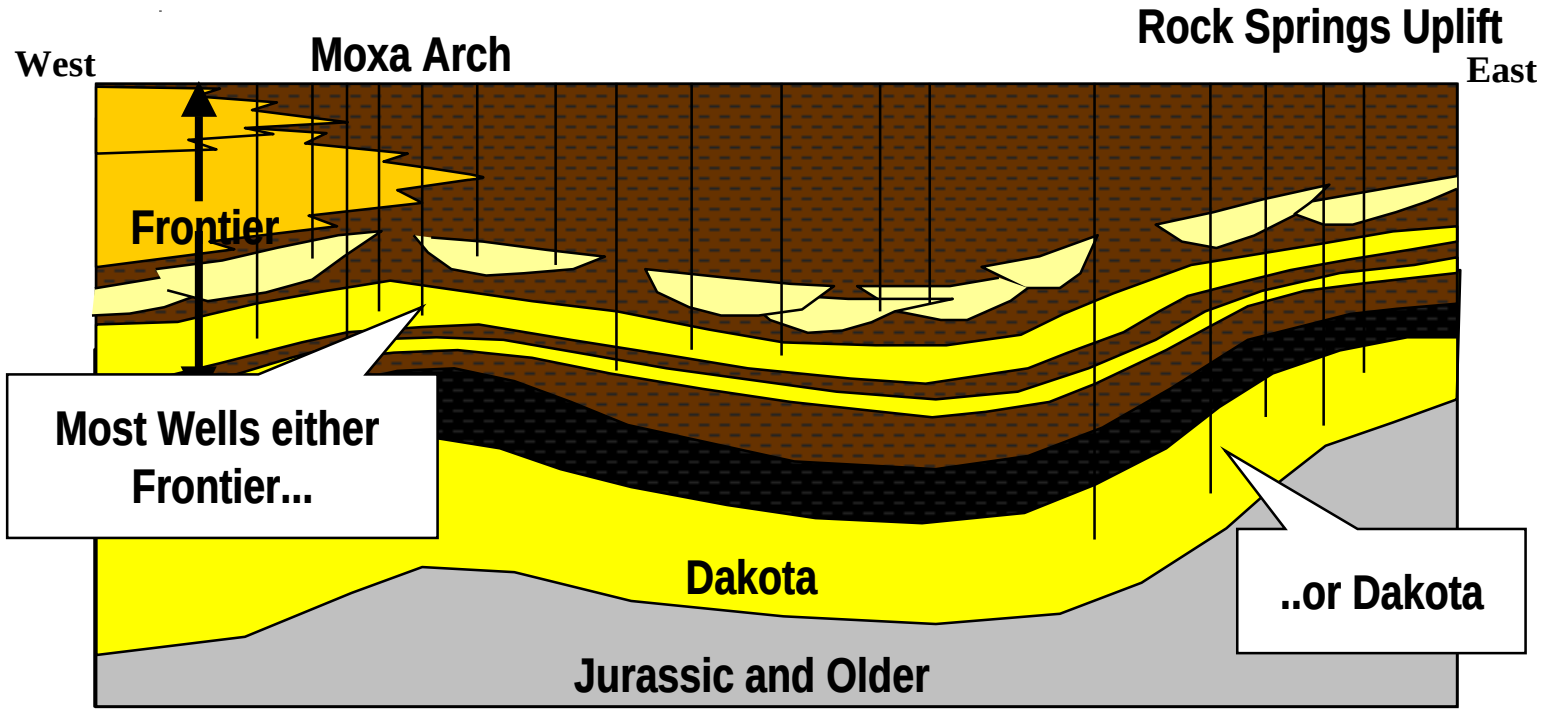
The Units of Analysis (UOAs)



- **Similar to Plays**
- **Encompass vast majority of target resource**
- **Deeper units lack data required for this methodology**
- **Partition resource into units consistent with our goal of modeling industry behavior: UOAs represent resources to be targeted by a single well**

Determining UOA; Frontier-Dakota; GGRB

5-township survey of completion practice

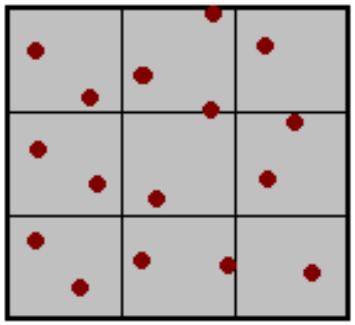


- Single Completions = 68%
- Dual Completions = 19%
- Recompletions = 16%

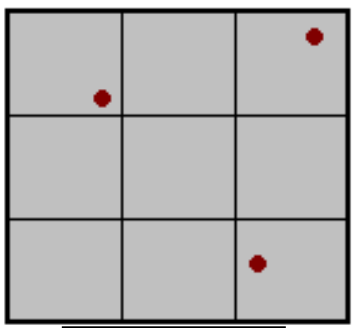
Total exceeds 100% as values are township averages

Data Density

The search for complete well log suites

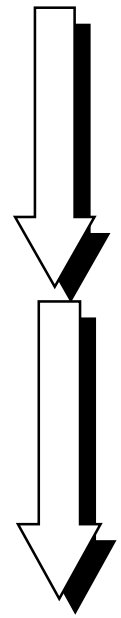


LEWIS



FRONTIER

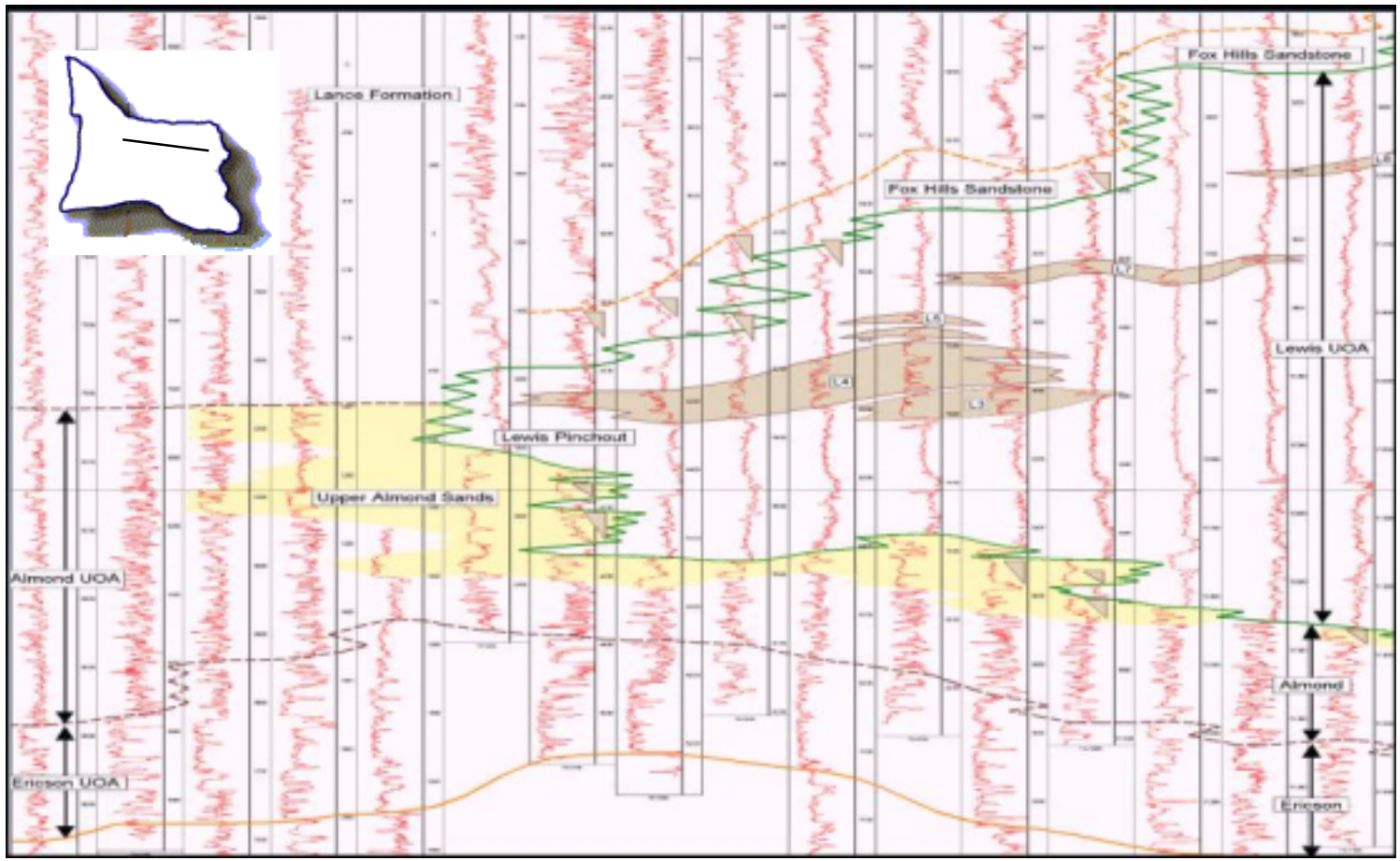
	UOA	No. of Wells	Full Log Suites in Appraised Area	Townships in Appraised Area	Full Suites per Township
GGRB	LEWIS	399	297	168.9	1.76
	ALMOND	369	293	264.7	1.11
	ERICSON	301	242	337.8	0.72
	L. MESAVERDE	153	136	352.7	0.39
	FRONTIER	266	158	488.7	0.32
	MUDDY-MORRISON	192	131	466.6	0.28
WRB	FORT UNION	75	44	47.9	0.92
	LANCE	63	28	58.8	0.48
	MEET.-MESAVERDE	60	27	67.1	0.40
	FRONTIER	136	19	56.2	0.34
	MUDDY-LAKOTA	123	16	56.6	0.28
	NUGGET	95	8	55.0	0.15
	TENSLEEP	82	4	24.8	0.06



Variable data density = varying degrees of resolution in resource computation

West-East Stratigraphic Cross-Section

Lewis, Almond, Ericson UOAs; GGRB

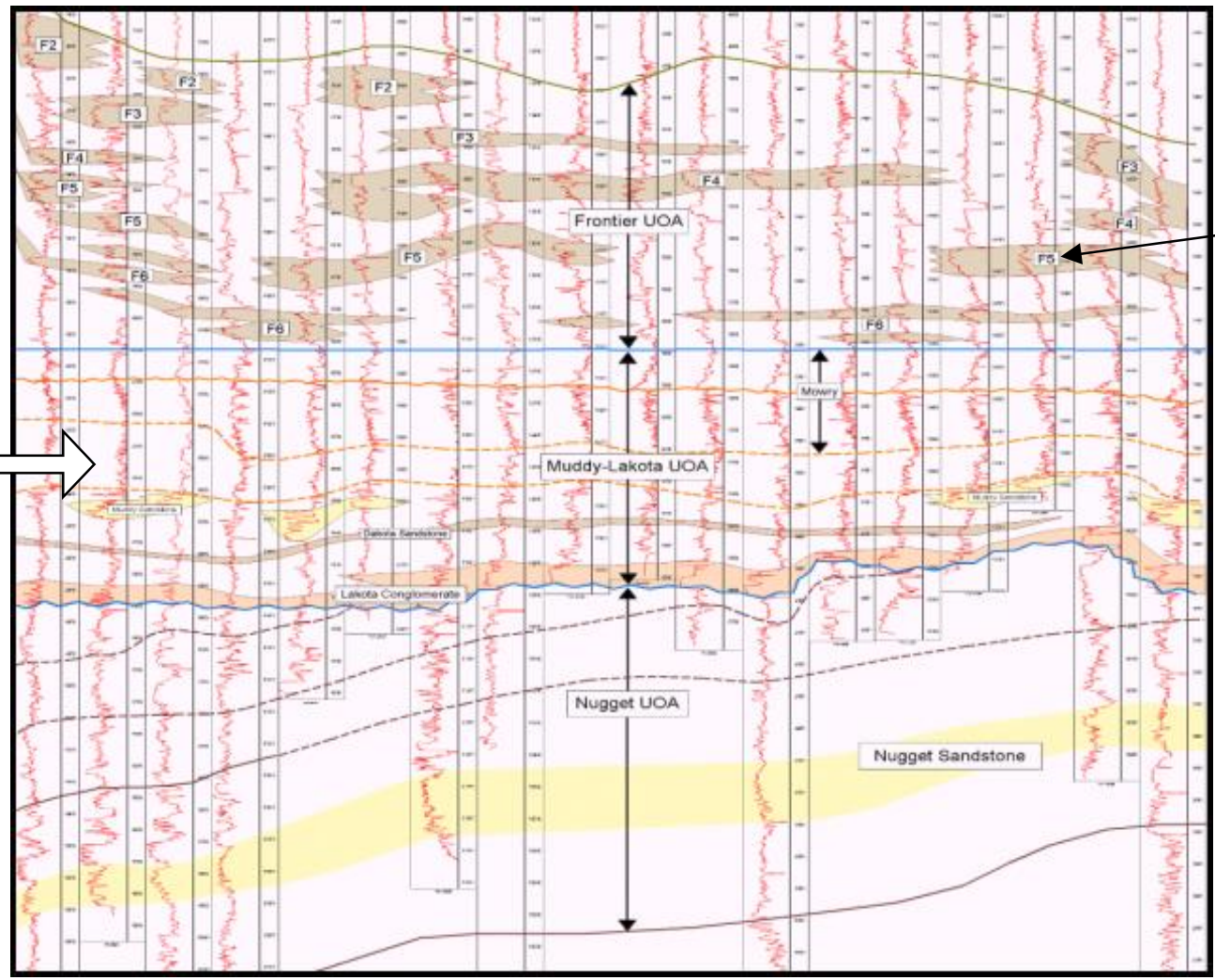


West-East Stratigraphic Cross Section

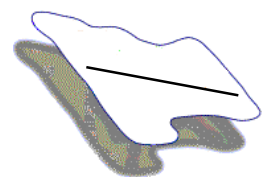
Frontier, Muddy-Lakota, Nugget UOAs; Wind River basin

Sandstone Isolith Maps for UOAs

Drilling depth to UOA midpoint

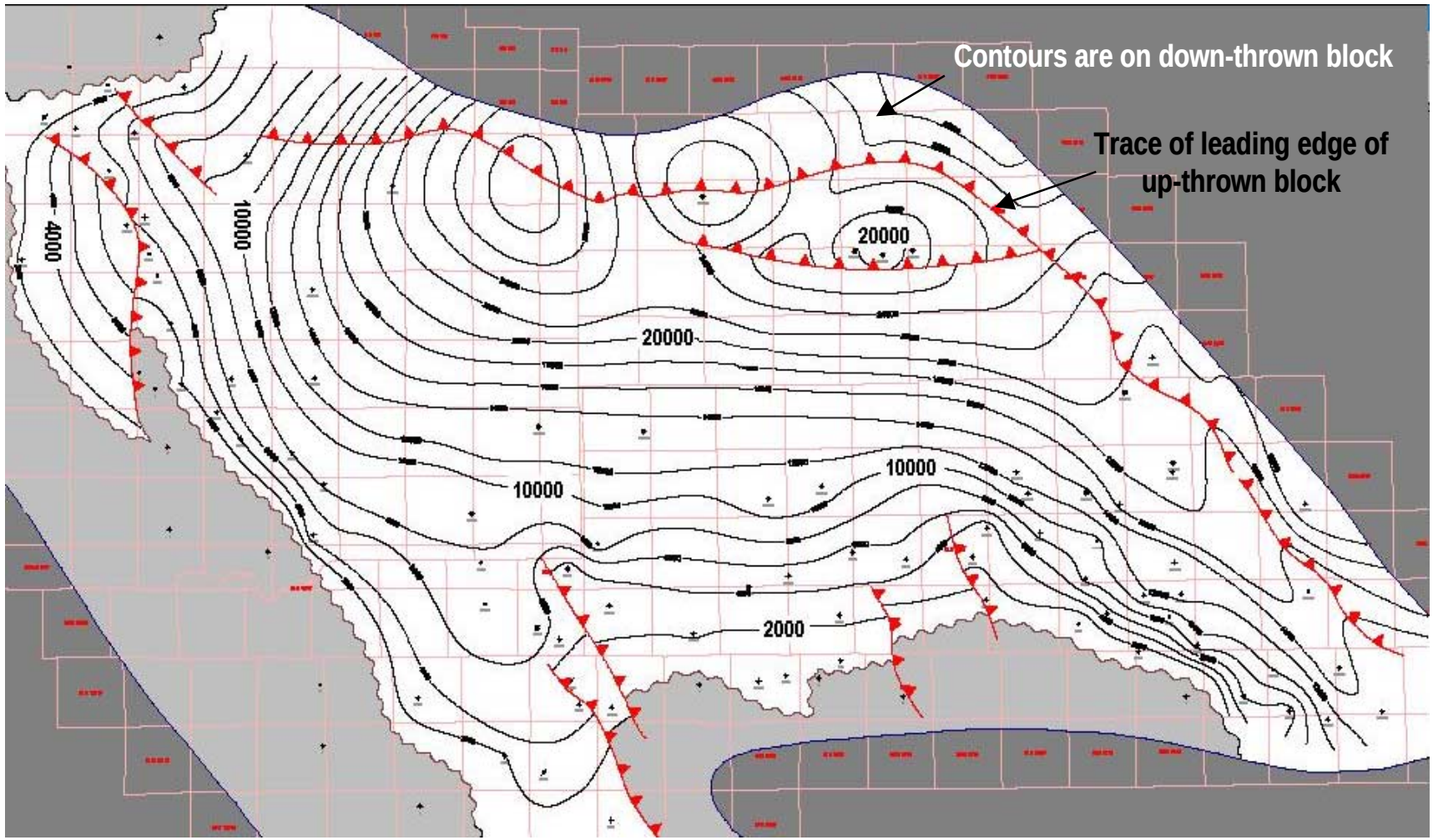


Isopach maps on individual sandstones (Lewis, Almond, Frontier, Muddy-Dakota UOAs)



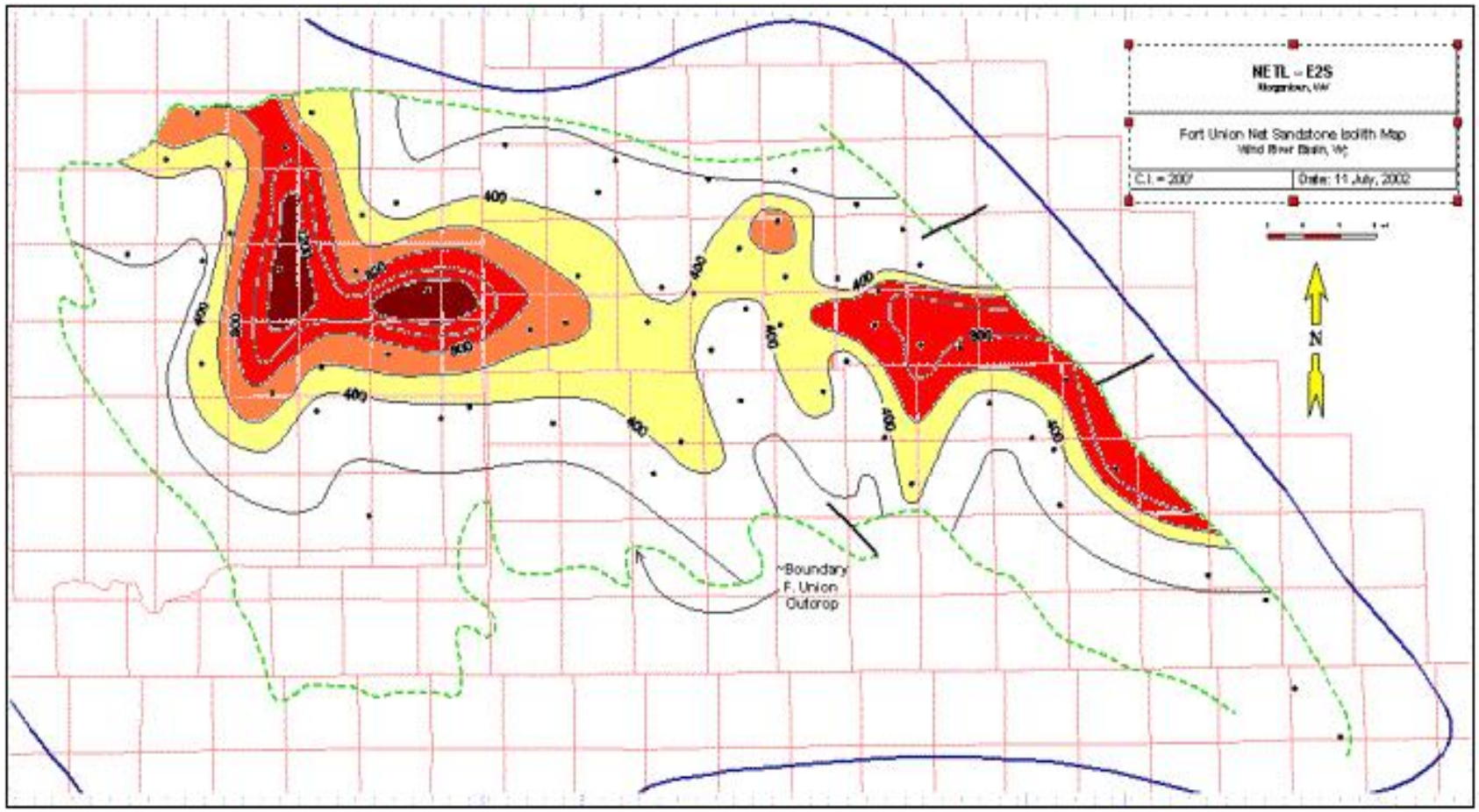
Drilling Depth to UOA Mid-point

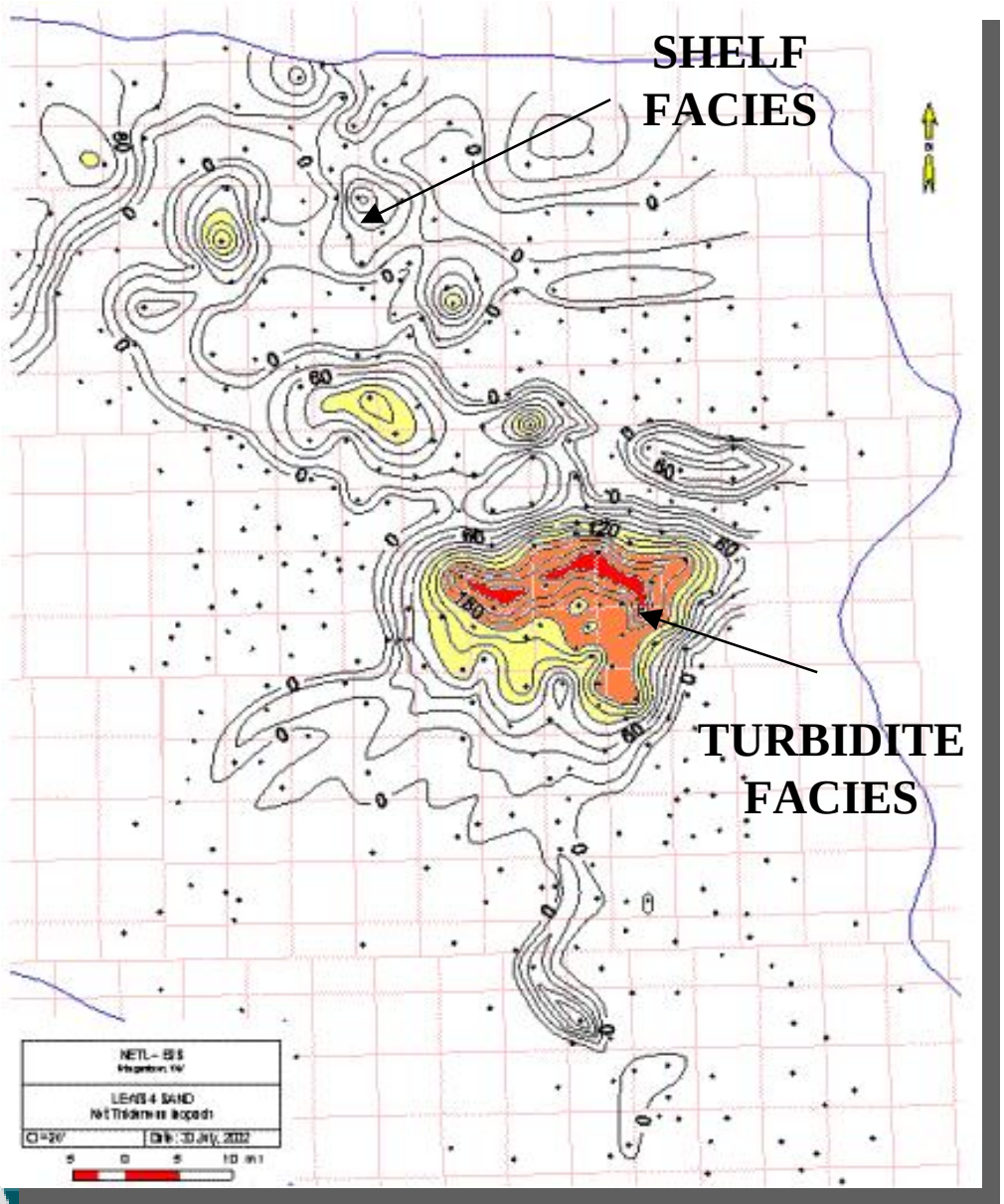
Frontier UOA, Wind River Basin



Net Sandstone Isolith

Fort Union UOA: Wind River Basin



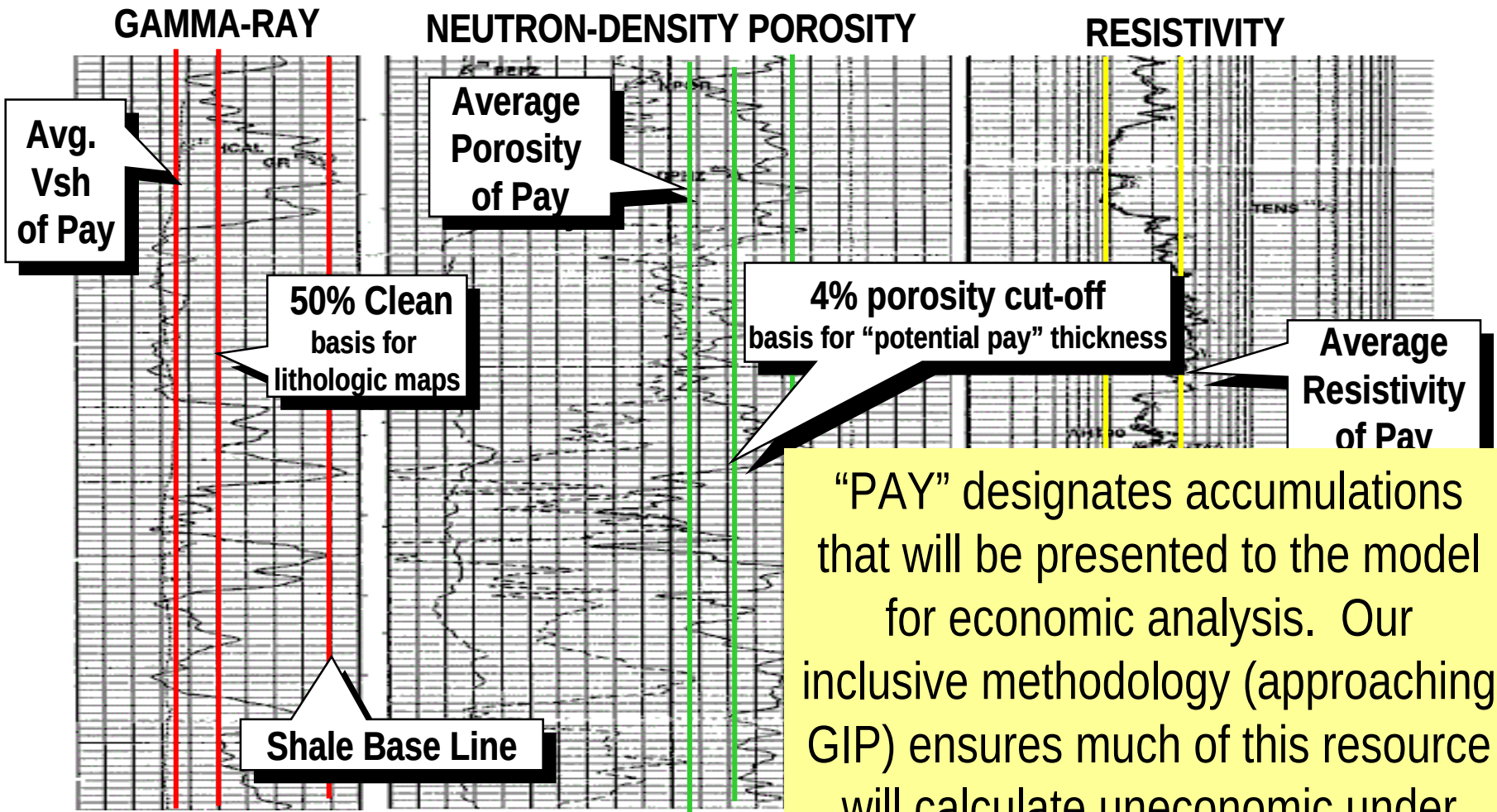


Sandstone Isopach Map

Lewis "4" sand: Eastern Greater Green River Basin

Well Log Analysis

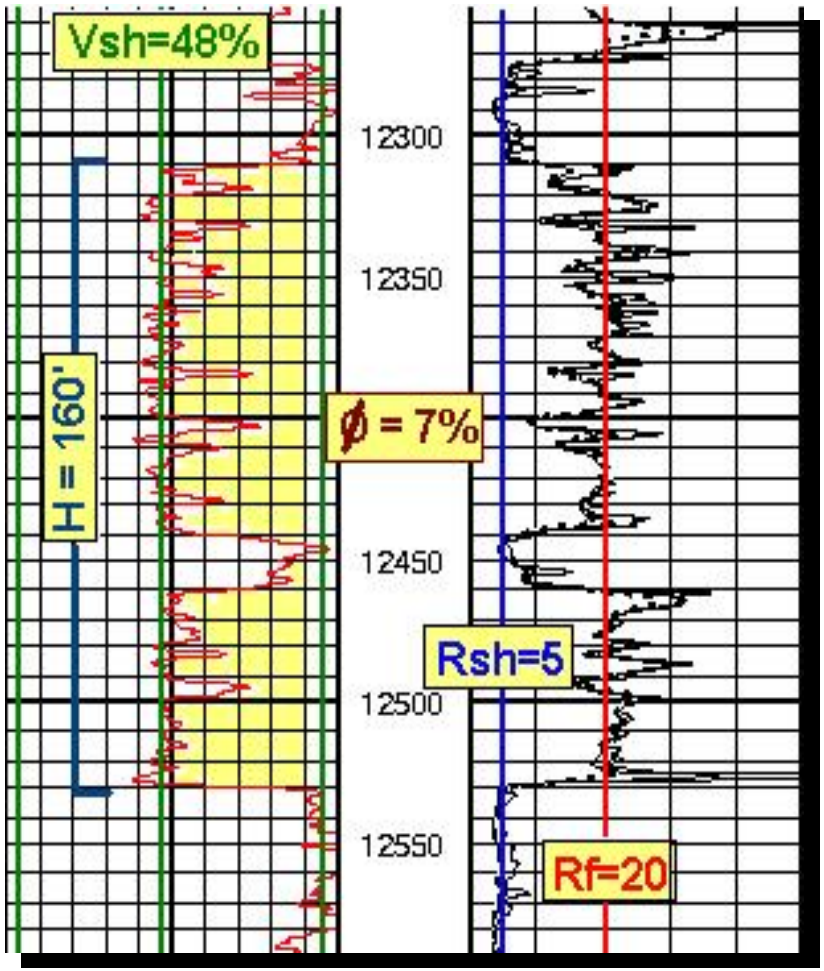
Example from Frontier Fm. Wind River Basin



"PAY" designates accumulations that will be presented to the model for economic analysis. Our inclusive methodology (approaching GIP) ensures much of this resource will calculate uneconomic under most technology scenarios

Uncertainty in Rw = ?Sw = ?GIP

Example from Lewis UOA, Eastern GGRB



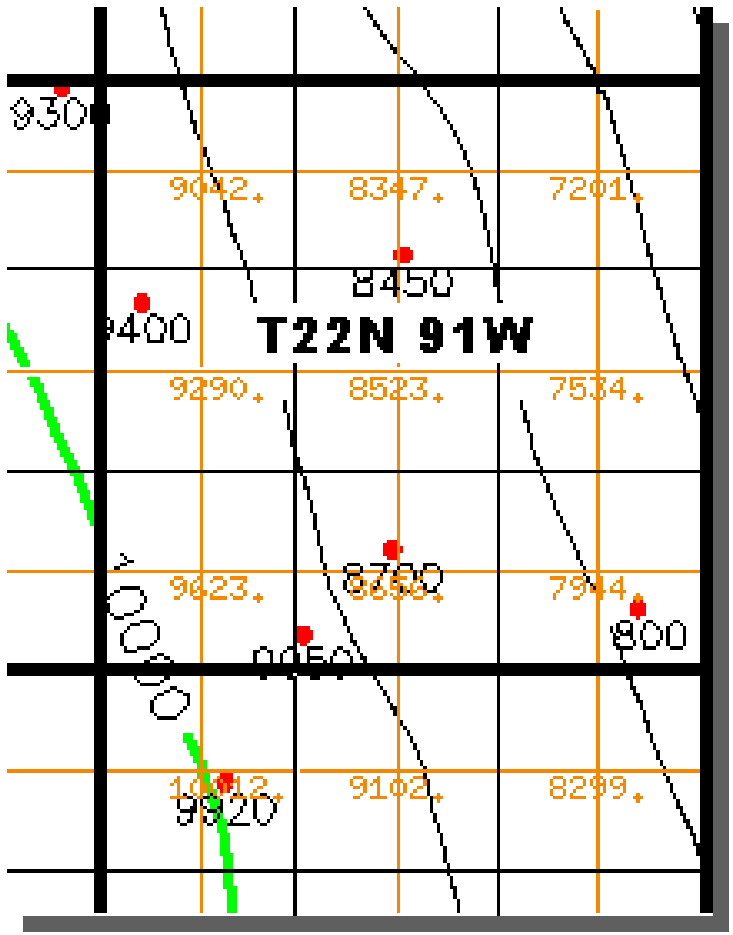
- **Rw assigned from best available data - but generally is poorly known**

- **High Shale Volume**
- **Low Porosity**
- **Moderate Resistivity**

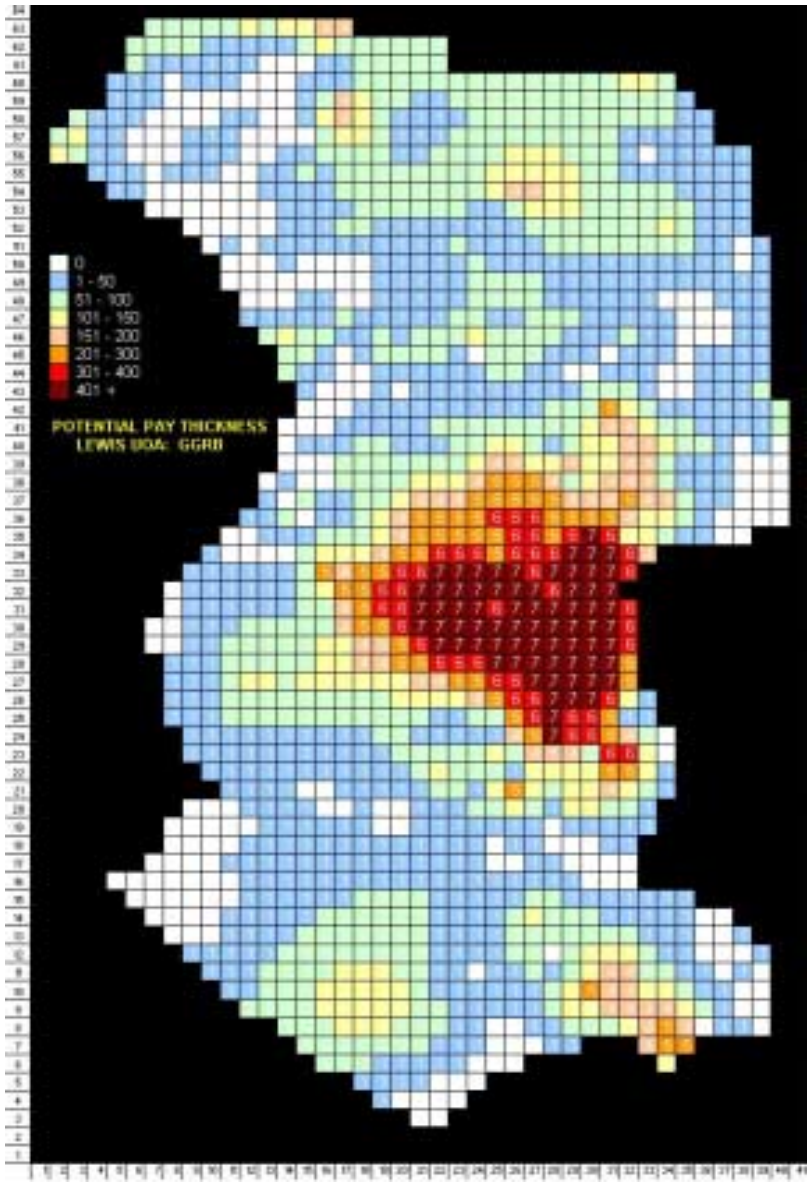
Rw = 0.005	**Sw = 18%**
Rw = 0.05	**Sw = 37%**
Rw = 0.5	**Sw = 49%**

Gridding

Translating Well Data to Cell Data



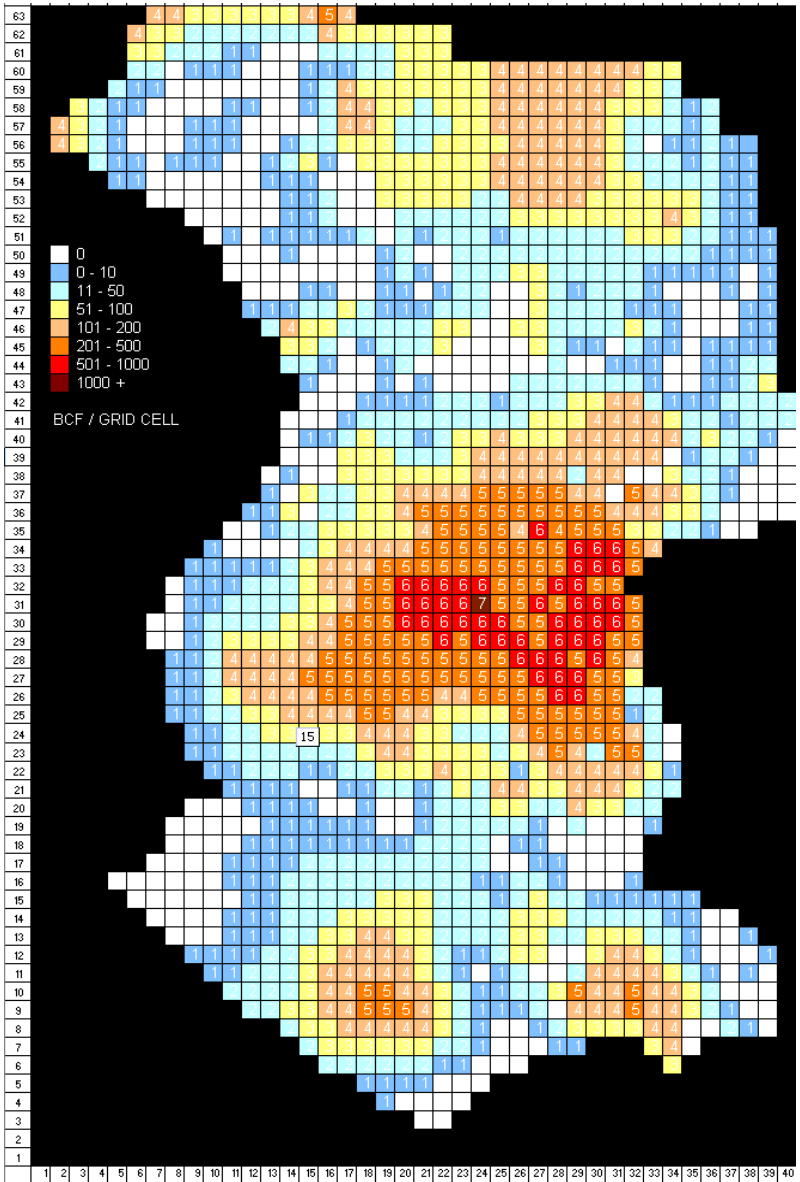
- **Example; computer interpolates drilling depth from well data for nine 2,560-acre cells per Township**
- **Grid Cell size is based on the data density for the play**
- **Identical gridding for remaining volumetric parameters (Thickness, Porosity, Sw, Pressure)**



Potential Pay Thickness Per Cell

Lewis UOA; GGRB

- **Values for 3,477 grid cells with average drilling depth > 5,000’**
- **Dark red = area with >400’ potential pay**



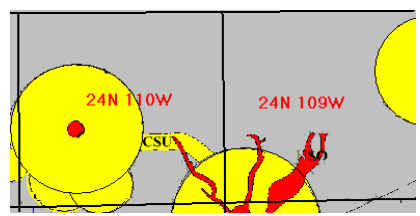
Gas-in-Place Per Cell

Lewis UOA : GGRB

- ***Achieves a detailed geographic representation of resource parameters***

- **White = areas of historical production or no sand**

WILL ALLOW FOR DIRECT COMPARISON TO LAND ACCESS INFORMATION



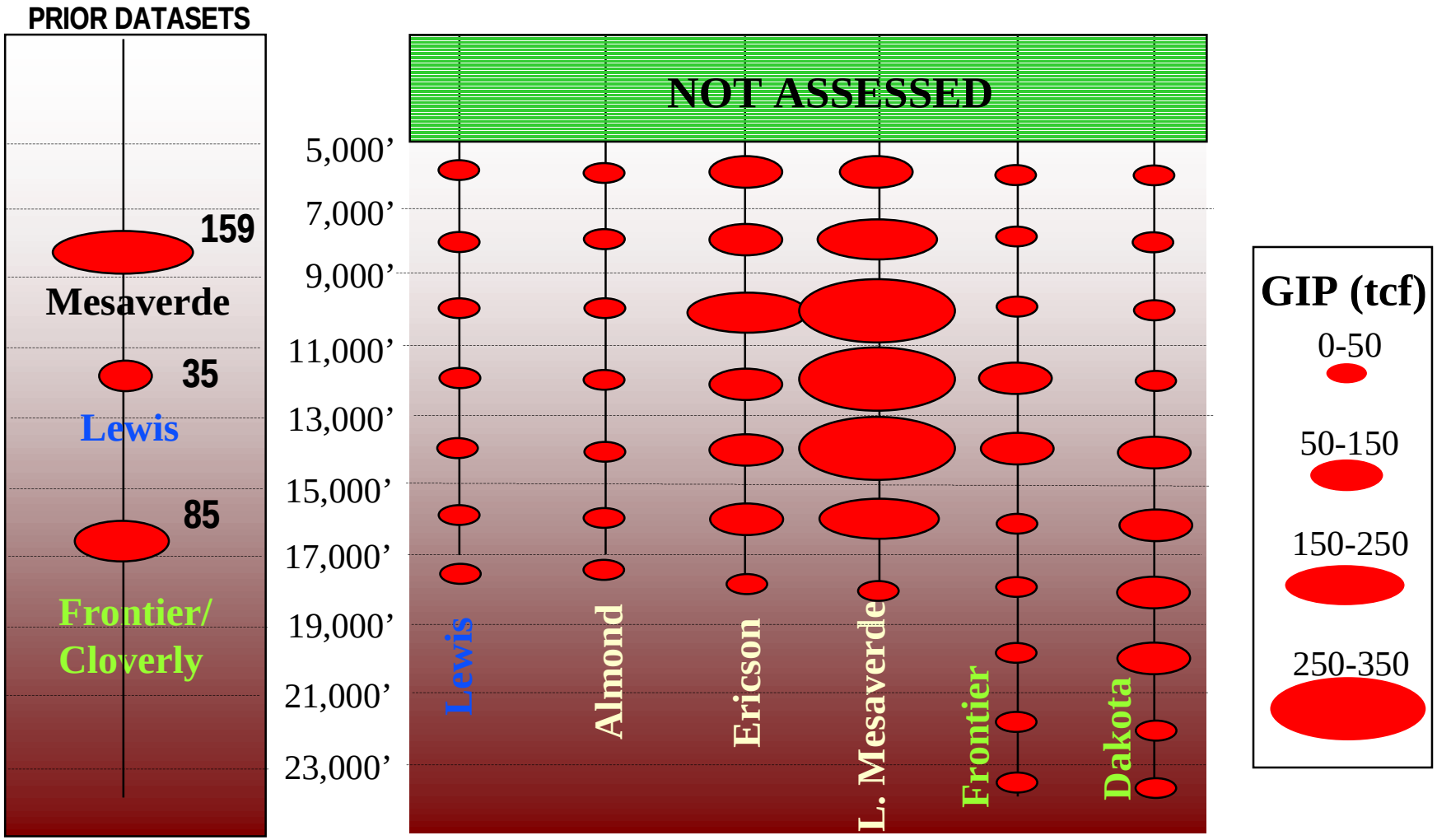
Summary Volumetric Results: GGRB UOAs

3,013 Tcf gas-in-place: 711 tcfg below 15,000'

	LEWIS	ALMOND	ERICSON	L. MSVD	FRONTIER	DAKOTA
Total Area (Acres)	3,891,200	6,097,920	7,782,400	8,125,440	11,258,880	10,749,440
Avg. Thickness (ft.)	100	44	173	369	47	52
Avg. Porosity (%)	7%	9%	9%	8%	8%	8%
Avg. Water Sat. (%)	56%	60%	47%	53%	43%	40%
Avg. Depth (ft.)	10,211	9,615	10,663	10,767	15,472	15,670
Avg. Pressure (psi)	5,428	5,075	5,488	5,559	10,186	10,415
Avg. Temperature (oF)	223	214	226	223	255	257
Avg. Z-Factor	1.05	1.03	1.06	1.06	1.39	1.4
Total Resource (tcf)	132	87	528	1,481	368	417
Deep Resource (tcf below 15,000')	10	3	60	214	198	226

Vertical Resource Dissaggragation

Greater Green River Basin



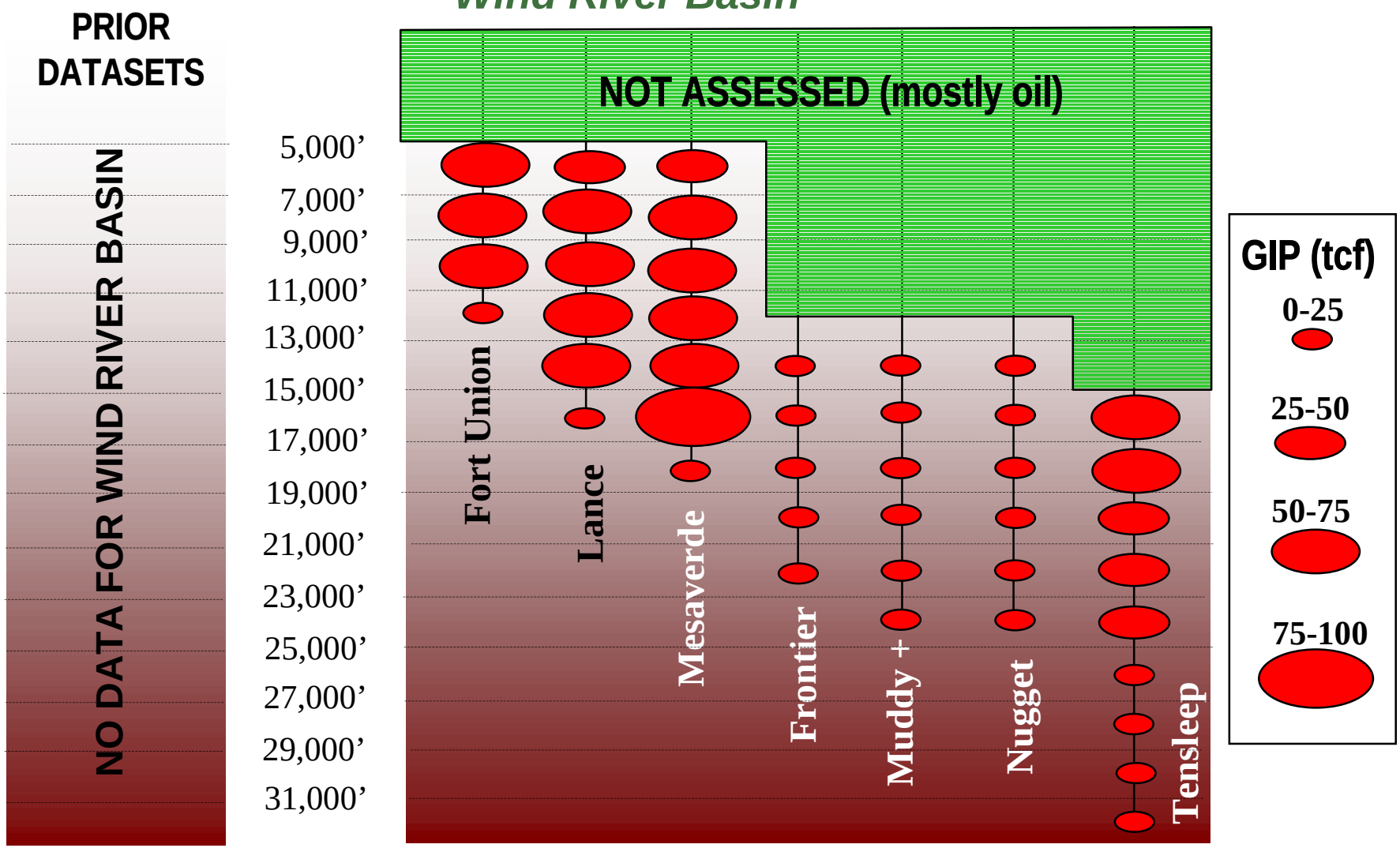
Summary Volumetric Results: WRB UOAs

1,322 Tcf gas-in place; 533 tcfg below 15,000'

	FORT UNION	LANCE	MEET/MSVD	FRONTIER	MUDDY +	NUGGET	TENSLEEP
Total Area (Acres)	1,103,360	1,354,240	1,546,240	1,525,760	1,672,960	1,681,920	1,246,720
Avg. Thickness (ft.)	441	512	461	91	34	76	285
Avg. Porosity (%)	10%	9%	8%	6%	6%	5%	6%
Avg. Water Sat. (%)	57%	51%	43%	46%	45%	47%	22%
Avg. Depth (ft.)	8,110	10,117	11,991	18,191	18,423	19,485	20,458
Avg. Pressure (psi)	3,627	5,104	6,933	12,420	12,559	13,444	14,184
Avg. Temperature (oF)	189	222	252	351	355	372	387
Avg. Z-Factor	0.94	1.03	1.16	1.52	1.52	1.57	1.61
Total Resource (tcf)	180	322	374	74	30	76	276
Deep Resource (tcf below 15,000')	0	2	109	62	23	61	276

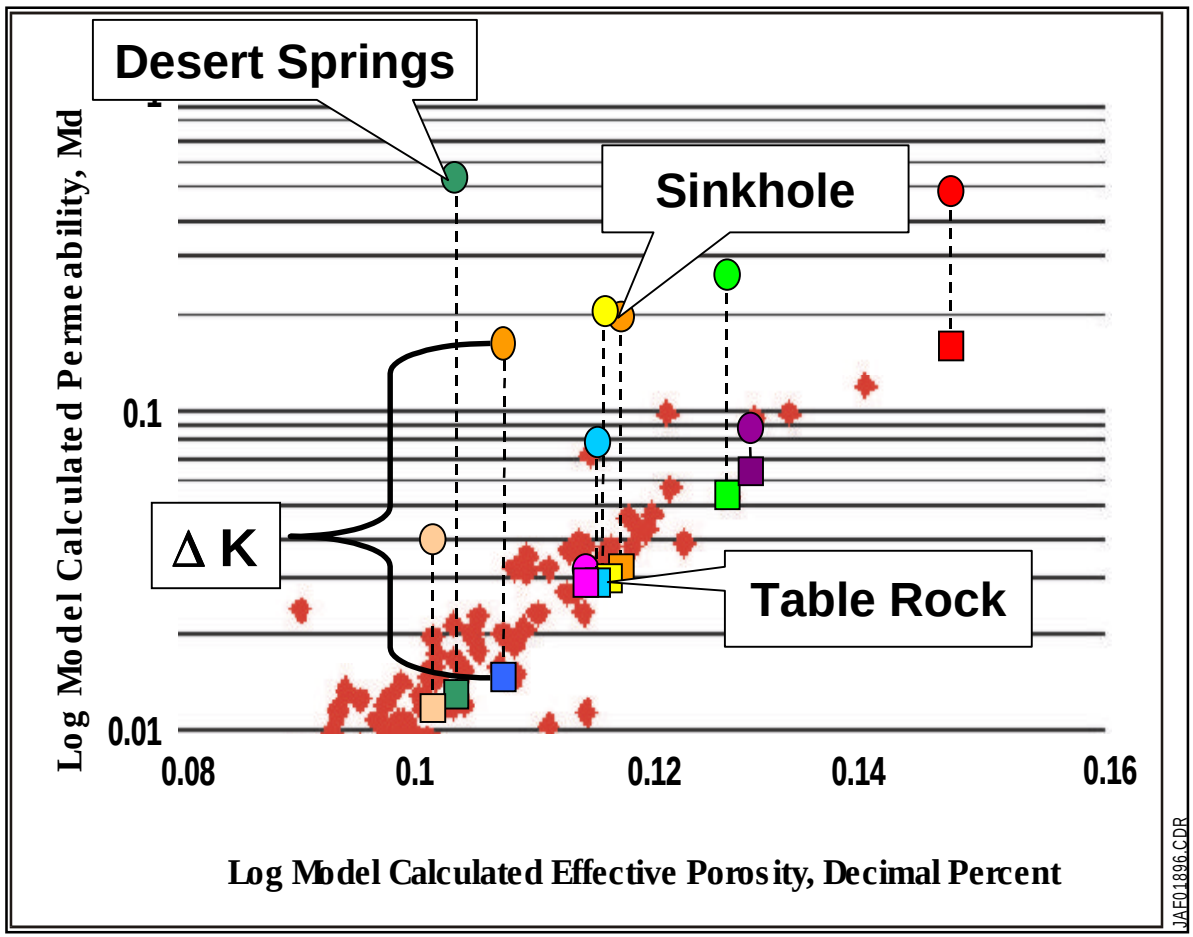
Vertical Resource Dissaggragation

Wind River Basin



Estimation of Permeability

Total Reservoir Permeability vs. Matrix Permeability

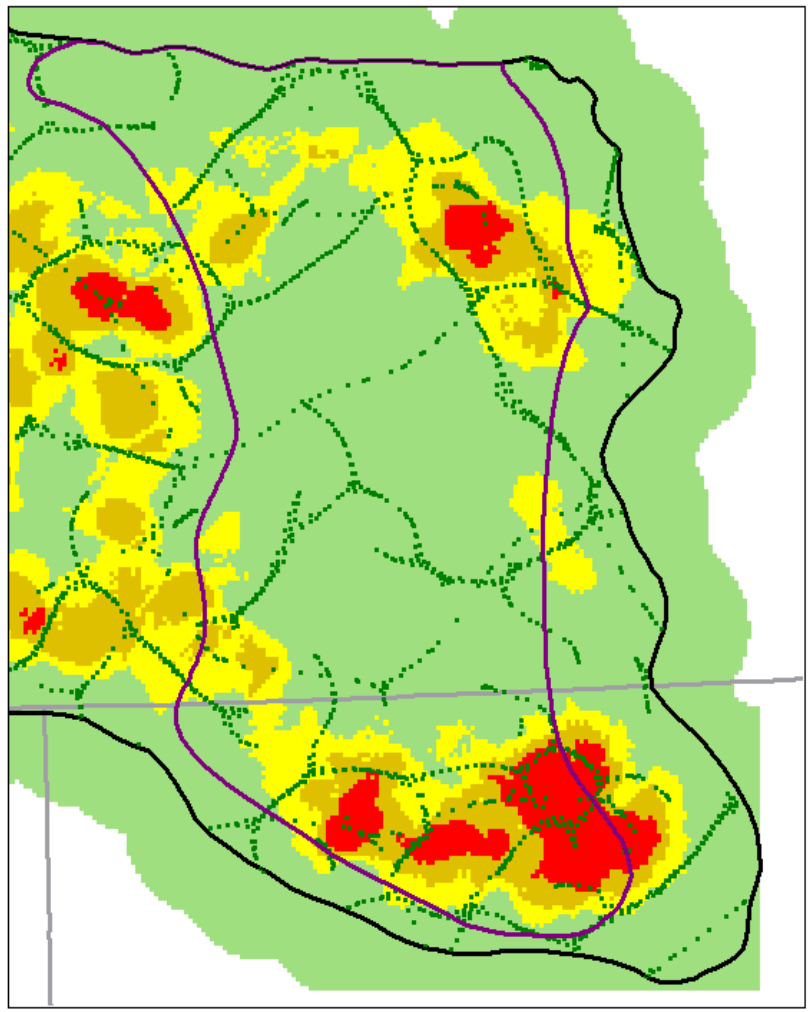


- Matrix Perm estimated through porosity-perm. Relationships
- Estimated Bulk Perm compared to expected matrix perm - the difference (Δ K) is attributed to natural fracture overprint
- How to estimate fracture overprint?

Estimating Fracture Overprint

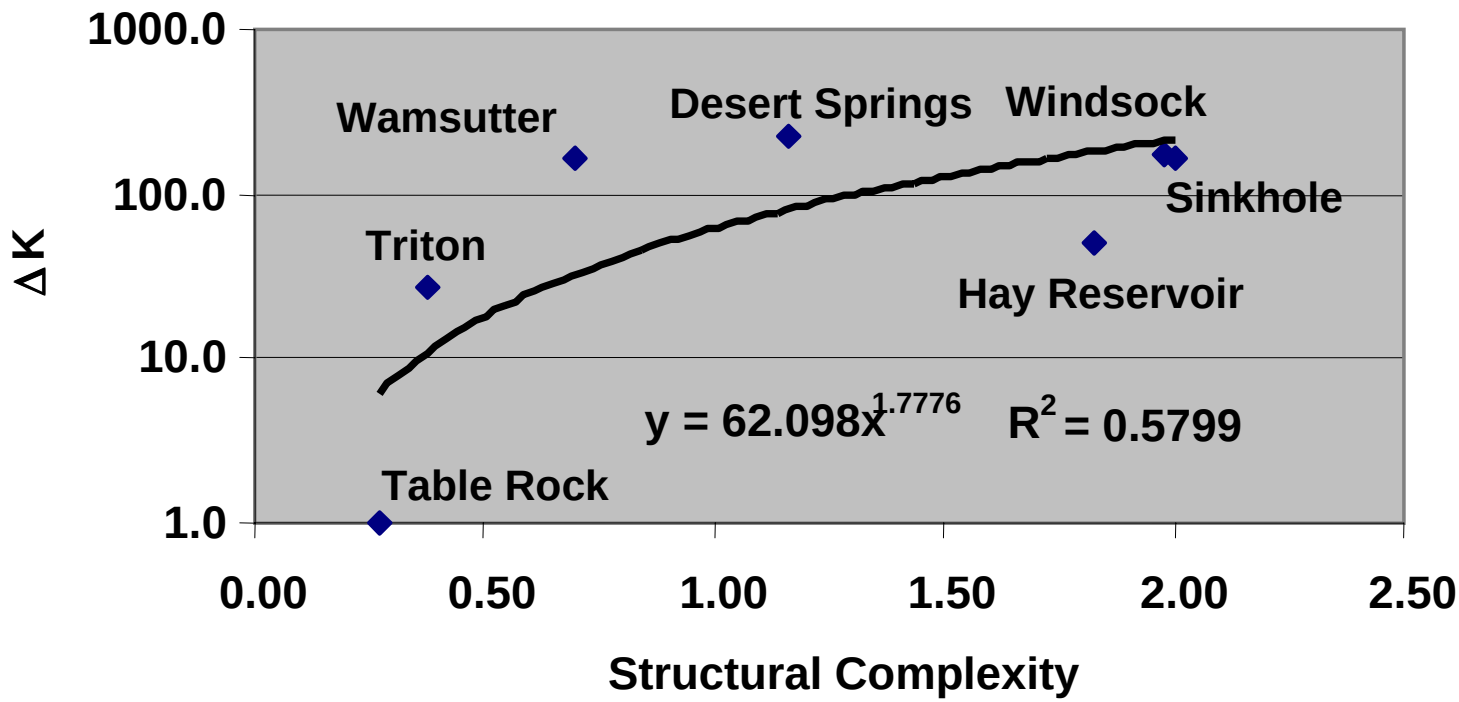
Predicting Structural Complexity

- **Estimate Structural complexity by Township or 1/4 Twn. through reference to aeromagnetic and gravity data**
- **Correlate incremental permeability in Type fields to Structural Complexity**
- **Estimate Fracture perm overprint**



Testing the Permeability Methodology

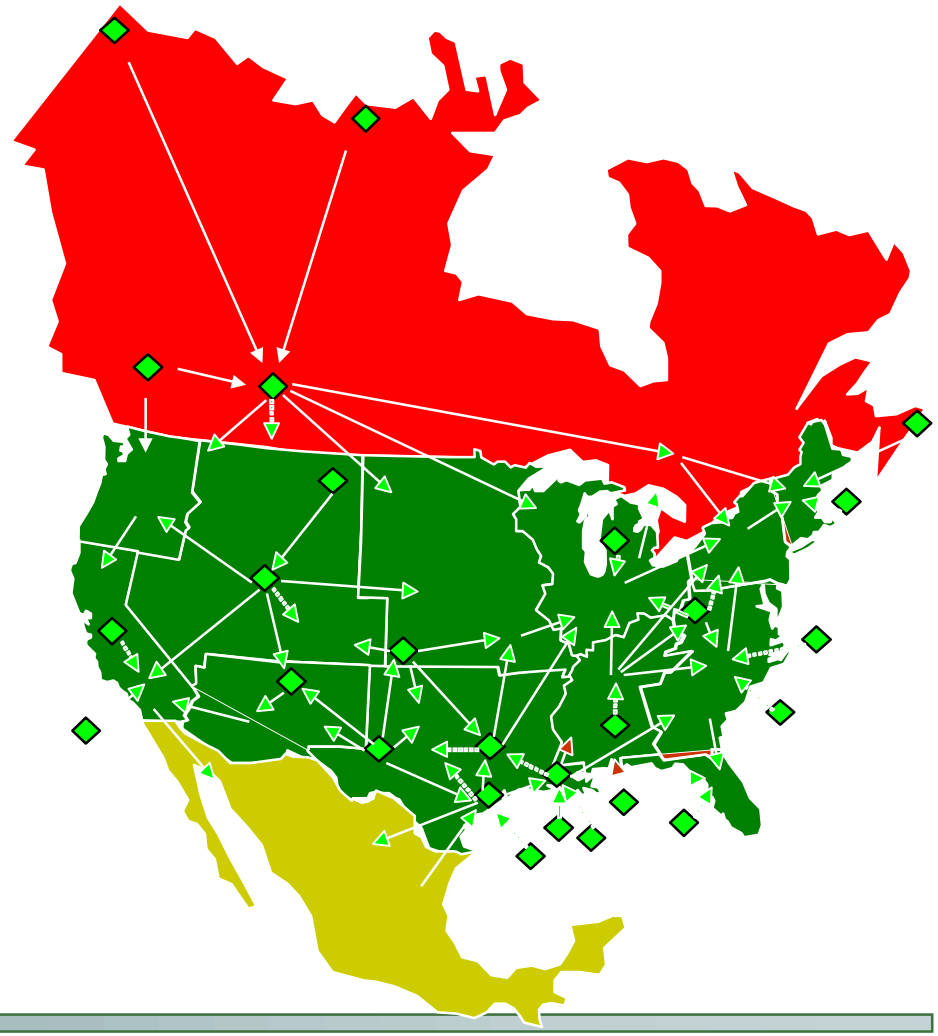
58% R-squared: Lewis UOA - GGRB



Gas Systems Analysis Model

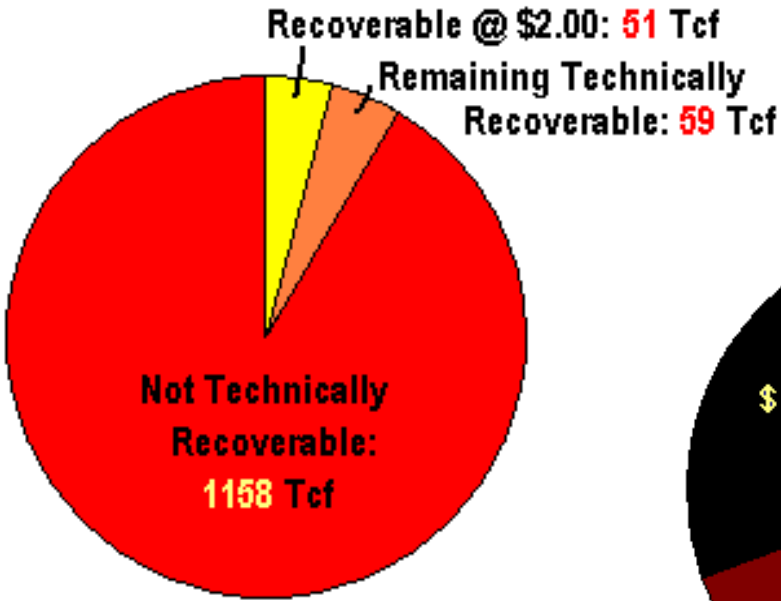
The Nation's leading tool for estimating the impact of technology/policy on North American gas supply and prices

- **A national model designed to analyze the impact of future technology/cost on total use production and use.**
- **Estimates unique response for each of 15,000 reservoirs.**
- **Integrates supply, demand, and infrastructure characterizations.**
- **Has supported numerous analyses for the federal and private sectors.**



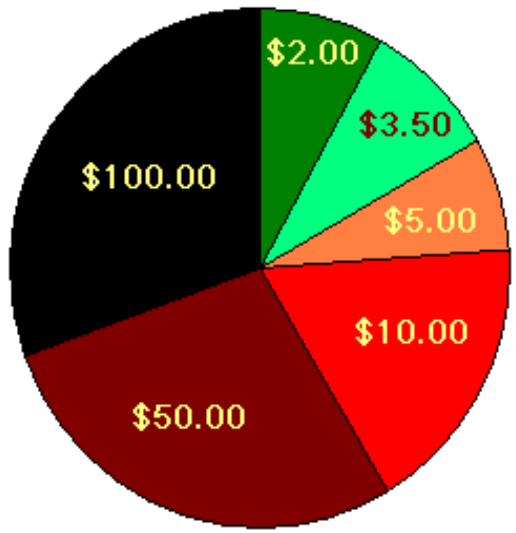
Impact of Technology on Resource Economics

Lower Mesaverde UOA: GGRB

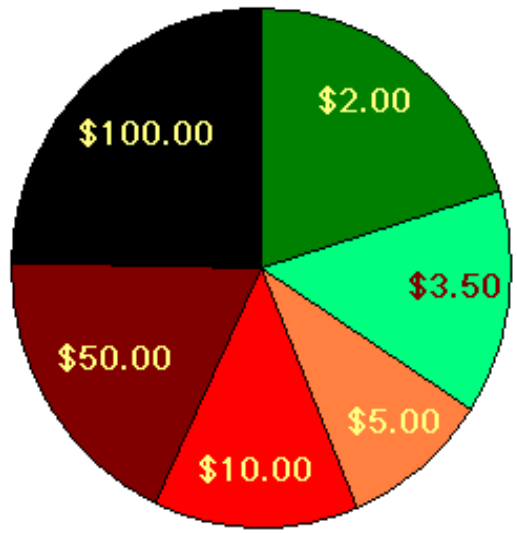


Recoverability of GIP by Volume

Economics of the Technically-Recoverable by Acreage



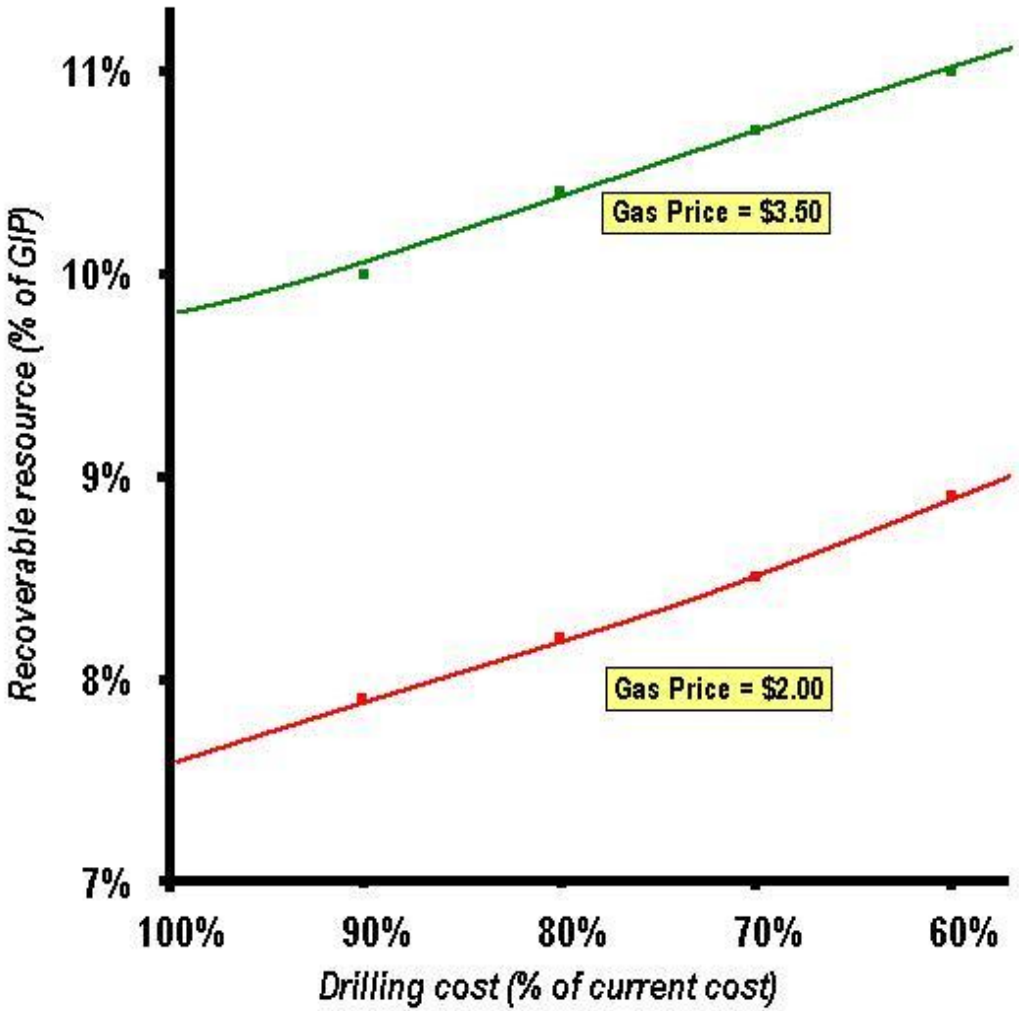
2002 Technology



2020 Technology

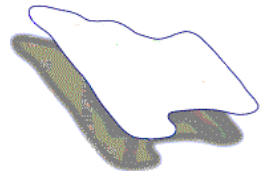
Modeling the Impact of Specific Technologies

Drilling Cost Reduction v. Recoverable Resource



In LOWER MESAVERDE; each 10% reduction in drilling costs increases economically-recoverable by 0.3% (4 Tcf)

Summary



- NETL has completed detailed characterizations of the gas resources of the Greater Green River and Wind River basins.

- A preview of products and results is available on CD in the meeting room and is described in the current ***GasTIPS***.

- **NEXT STEPS**
  - **finalize GGRB-WRB reports and post to web**
  - **conduct analytical studies of the impact of technology**
  - **initiate resource studies for the ANADARKO and UINTA basins**
  - **compare GGRB resource data to detailed land access information to provide new insight into the impact of federal land policy**