A Multiple Model Technique for Evaluating the Potential Hydrocarbon Volumes and Risk of an Exploration Prospect*

By
Chris Swarbrick[1], Robert Kimmel[2], Steve Jenkins[3], Peter Leiggi[4], and P.M. (Mitch) Harris[4]

Search and Discovery Article #40291 (2008)
Posted July 21, 2008

*Adapted from oral presentation at the 2006 AAPG International Conference and Exhibition, Perth, Australia, November 5-8, 2006

[1]Chevron Australia Pty Ltd, Perth, Australia.
[2]Chevron International Exploration & Production Bellaire, TX, (ksro@chevron.com)
[3]Chevron Corporation, San Ramon, CA (sdje@chevron.com)
[4]Chevron Energy Technology Company, San Ramon, California, USA (Mitch.Harris@chevron.com) .

Abstract

The potential hydrocarbon volumes and geologic risk of an exploration prospect are usually assessed by constructing a single geological model describing the likely structure, reservoir, seal and hydrocarbon charge. However, a single model often does not adequately capture the wide range of alternate geological models which could exist within the constraints of available data. Though the probability of these other models occurring may be relatively small, their impact on the probabilistic distribution of potential hydrocarbon-in-place volumes may be large.

To assess potential hydrocarbons volumes and geologic risk of a Paleozoic carbonate buildup in the southern PreCaspian Basin, Kazakhstan, suites of possible reservoir and possible seal models were developed in an attempt to adequately describe the full spectrum of potential reservoir and seal scenarios which could exist within the data constraints. A workflow was then followed comprising a) estimation of the probabilities for each reservoir-seal combination, b) calculation of volumes for each combination, and c) generation of a cumulative probability curve relating resource volumes to their probability of occurrence. Model probabilities were used to calculate the appropriate geologic risks for reservoir and seal failure.

We found the multiple model technique is very effective in capturing, evaluating, and ranking a wide range of geologic concepts and divergent expert opinions. The technique has the additional advantage that the calculated risk incorporates all possible outcomes, not just the risk associated with a single geologic model. We believe the multiple model technique can be applied to other prospects which have a wide range of geologic outcomes for two or more key play elements.

A Multiple Model Technique for Evaluating the Potential Hydrocarbon Volumes and Risk of an Exploration Prospect

Chris Swarbrick[1], Rob Kimmel[2], Steve Jenkins[3],
Peter Leiggi[4] & Paul (Mitch) Harris[4]

[1] Chevron Australia Pty Ltd, Perth, Australia;
[2] Chevron Thailand Exploration & Production Ltd, Bangkok, Thailand;
[3] Gulf Oil Company, Luanda, Angola;
4 Chevron Energy Technology Company, San Ramon, California, USA.

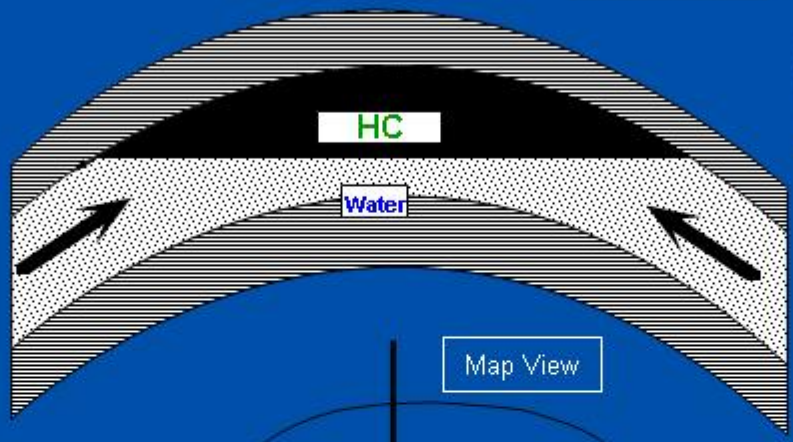
Single Model Approach to Prospect Evaluation

Seal ?

POS_{seal}

Reservoir ?

$POS_{reservoir}$



Structure ?

$POS_{structure}$

Hydrocarbon Charge ?

Source ?

Migration Pathway ?

POS_{charge}

- Prospective HC volumes calculated from a range of prospect parameters
- Geologic Probability of Success (GPOS) =

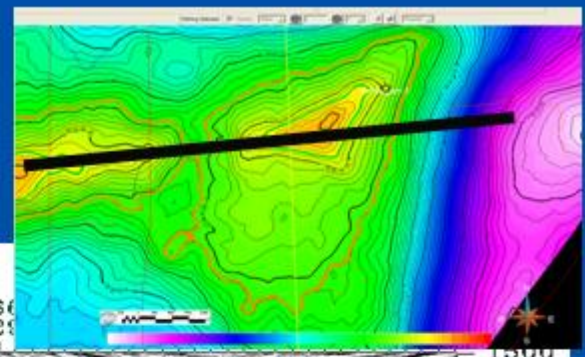
$$POS_{seal} \times POS_{reservoir} \times POS_{structure} \times POS_{charge}$$

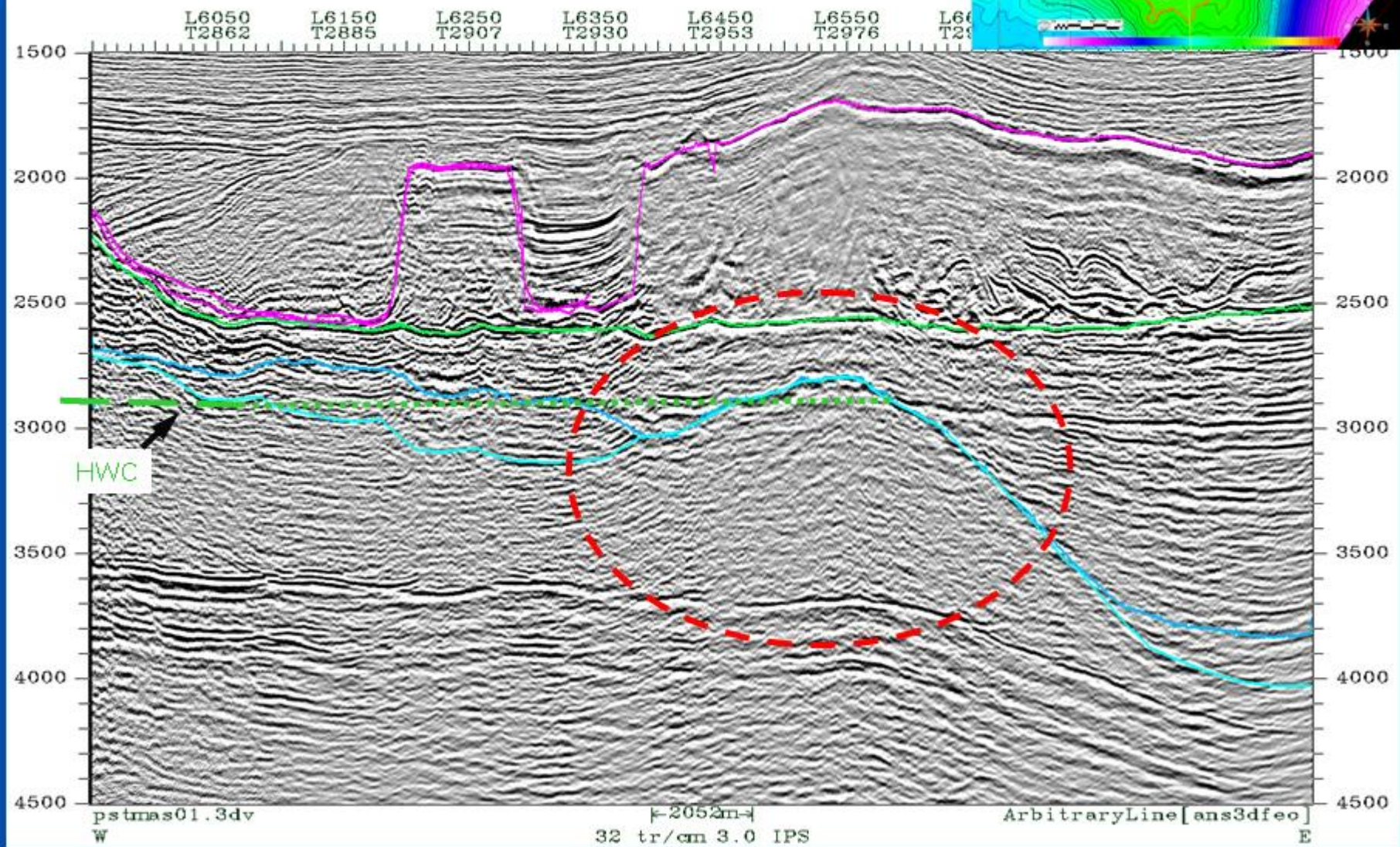
Shortcomings of the Single Model Approach

- Usually based on a pre-conceived notion of the prospect in a success case;
- Often the available data is not adequate to confirm and/or define a single prospect model;
- Geologists often want to incorporate data from multiple, but mutually exclusive, analogues;
- Success case HC volumes are unrelated to assessed geologic risk.

The Prospect

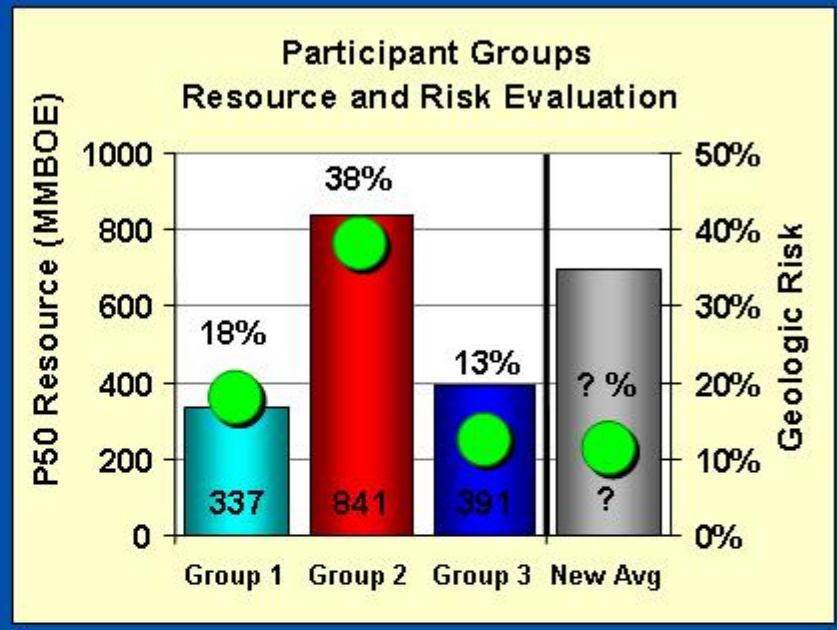
Producing Field





Why use a Multiple Model Approach?

- Prospect evaluation had reached the "Drill/No Drill" decision point;
- Differences of opinion regarding potential resource size & geologic risk;
- Alignment needed on
  - Seals and potential column heights
  - Reservoir parameters and their spatial distribution



Range of Seal Models

- Potential HWC is controlled by saddle stratigraphy

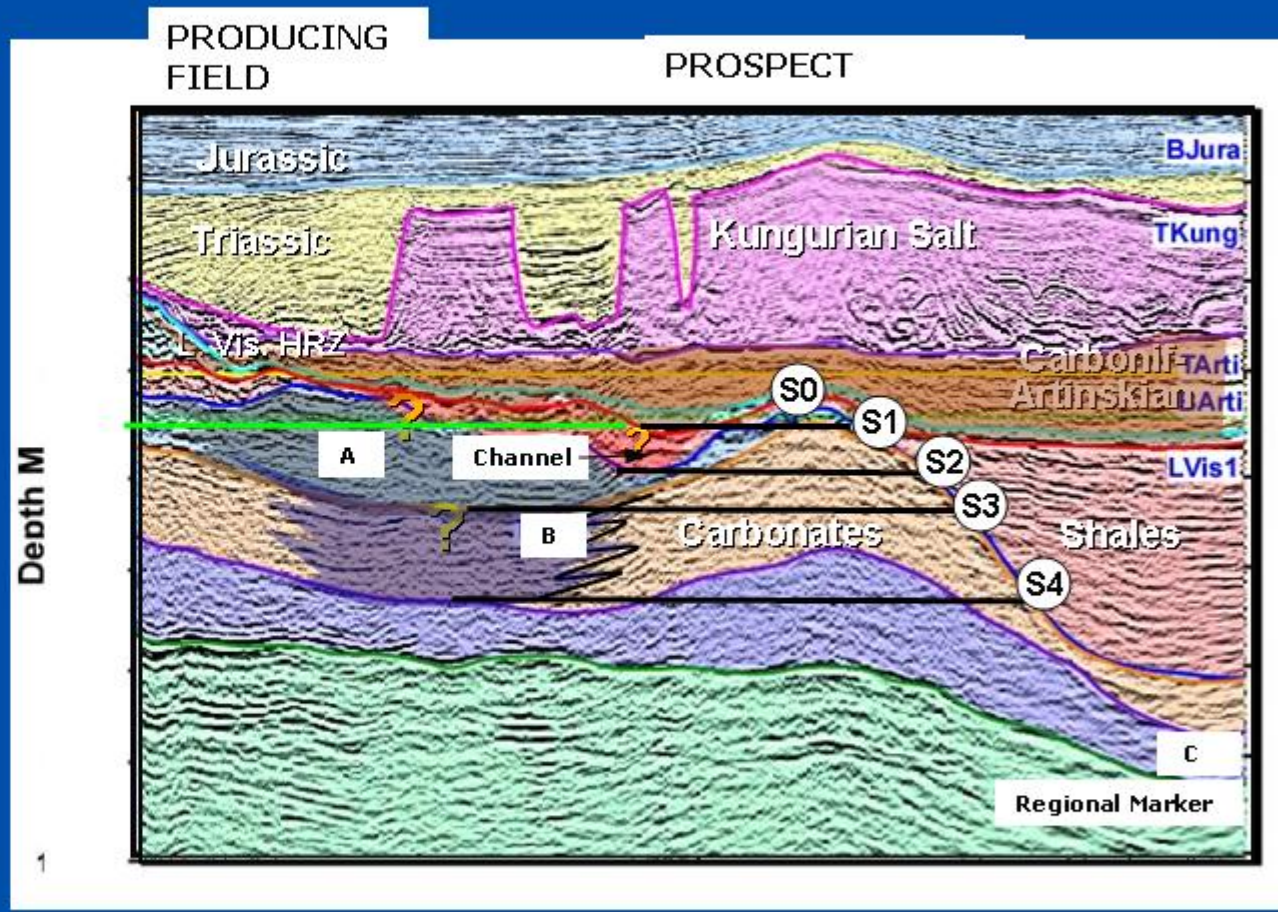
S0 – No top seal

S1 – Common HWC with field

S2 – Channel fill is a lateral seal.

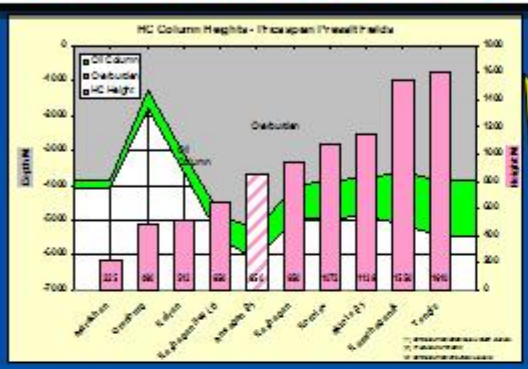
S3 – Sequence A is a lateral seal.

S4 – Lateral stratigraphic seal within Sequence B

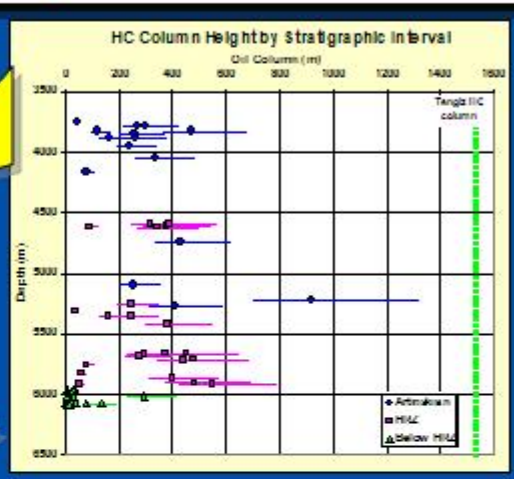


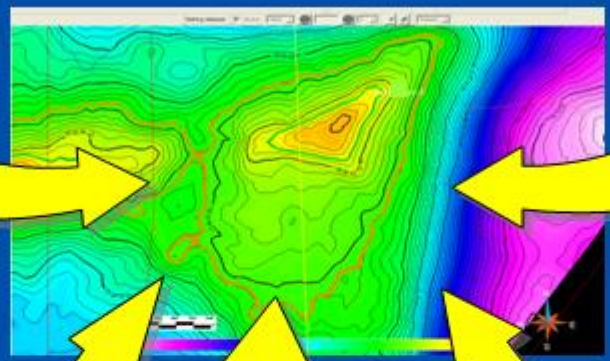
Probability Ranking of Seal Models Incorporating Local & Regional Field Data & Analogs

Column Height Data

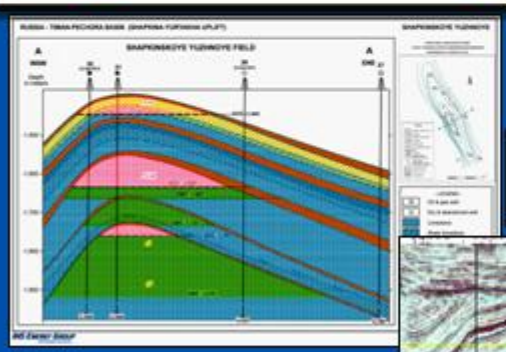


Cap Pressure Data

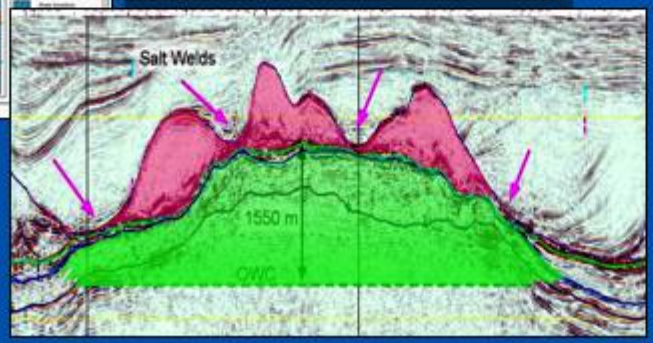




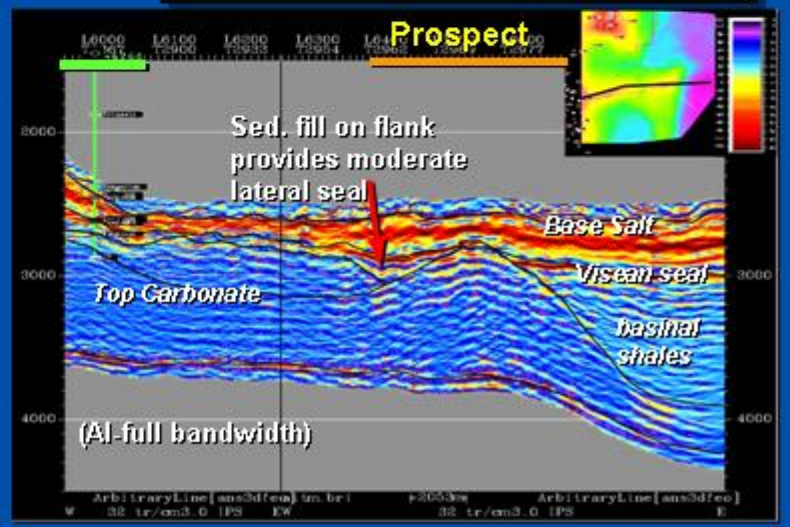
Regional Analogs



Field Analogs

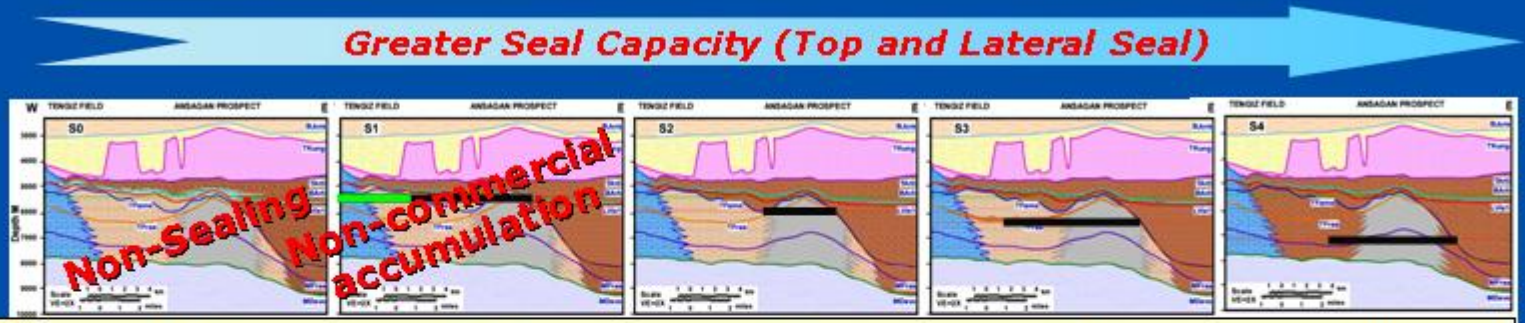


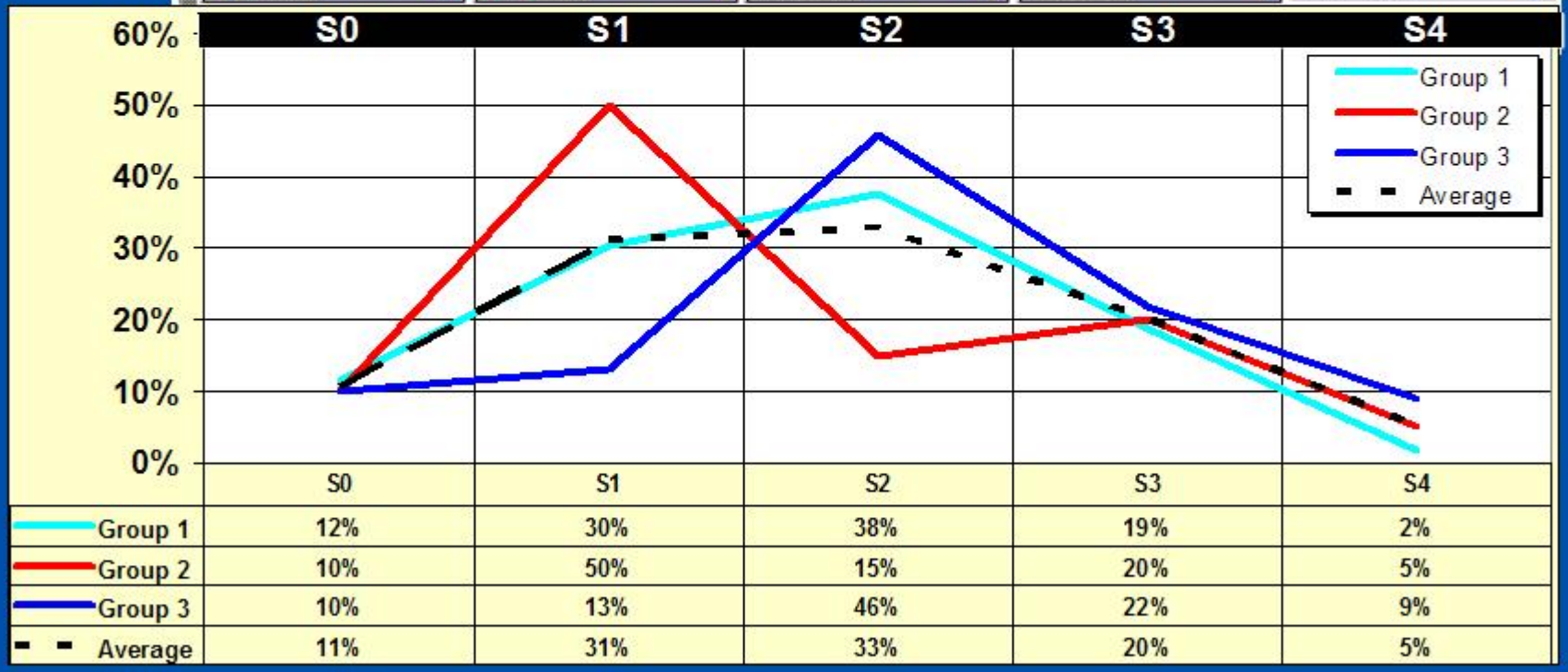
Seismic Attributes



Seal Model Probabilities by Group

- Experts from each participant group assigned probabilities





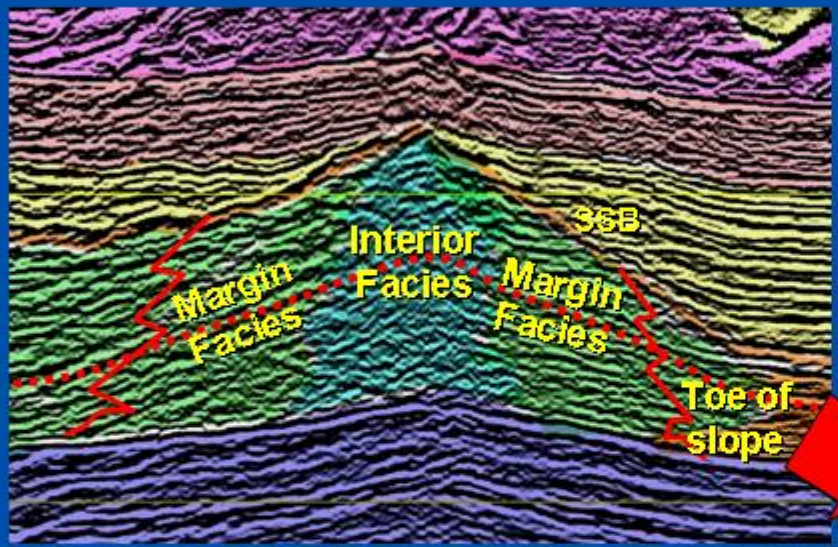
	S0	S1	S2	S3	S4
Group 1	12%	30%	38%	19%	2%
Group 2	10%	50%	15%	20%	5%
Group 3	10%	13%	46%	22%	9%
Average	11%	31%	33%	20%	5%

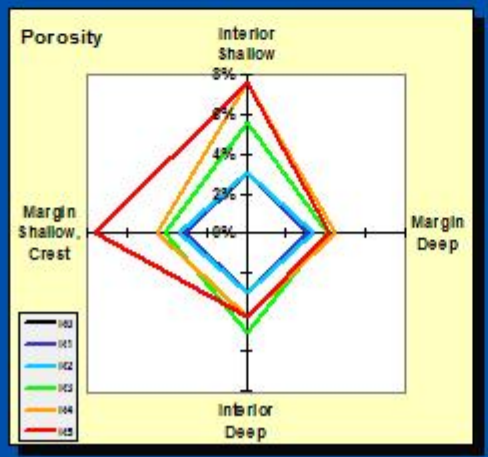
81% Chance of Seal Success; 58% if S1 is considered non-commercial

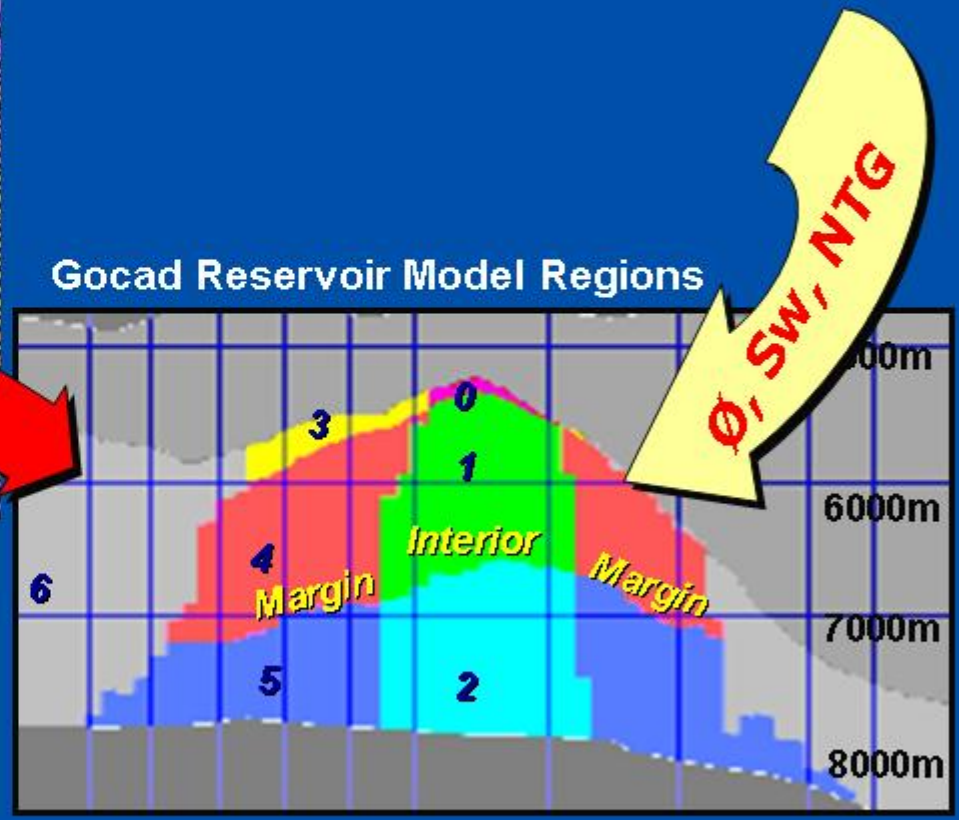
Tank Model for Reservoir Scenarios

- Model regions populated with reservoir properties:

  Ø, Sw, NTG from analog fields:







Range of Reservoir Properties

- Selected regions of nearby fields were used to capture the likely range of depositional facies, diagenesis, porosity & permeability.

R0 - Non-reservoir

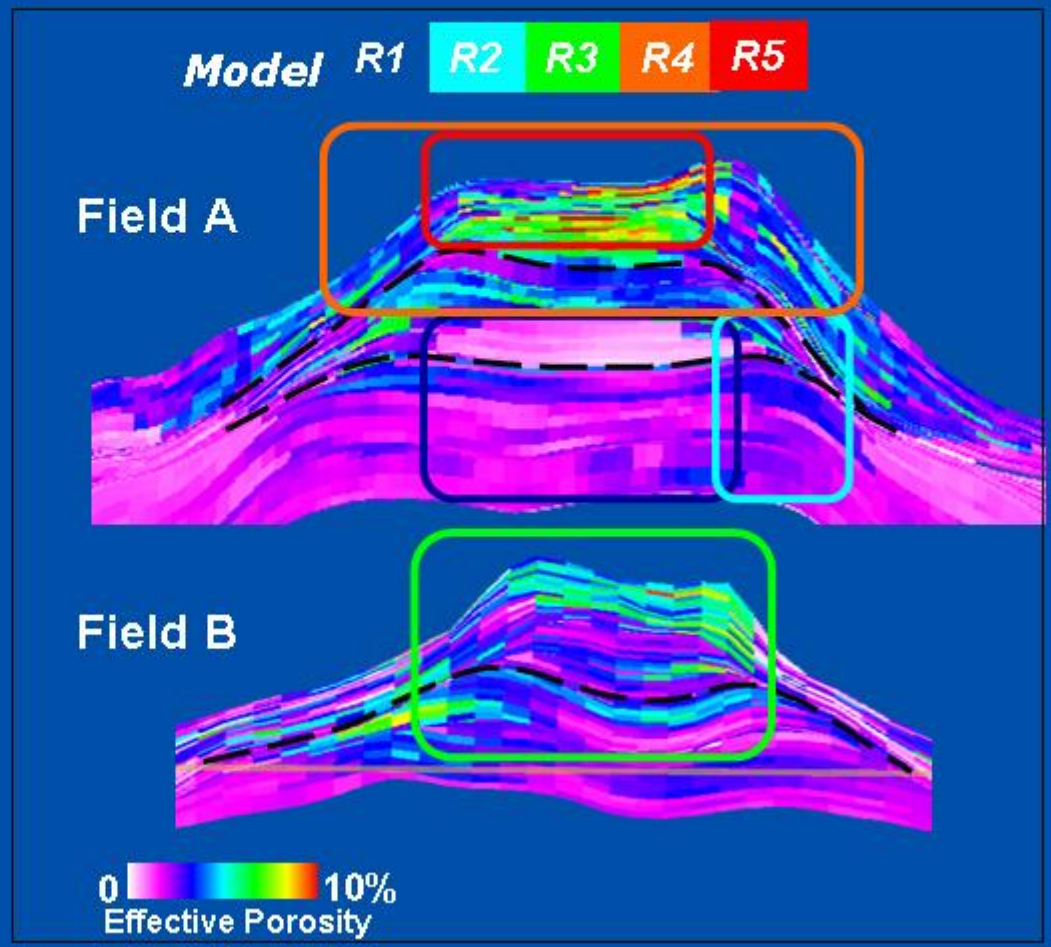
R1 - Tight platform grainstone/packstones; sub-commercial well rates.

R2 – R1 with zones of enhanced diagenetic porosity typical of rim and upper slopes.

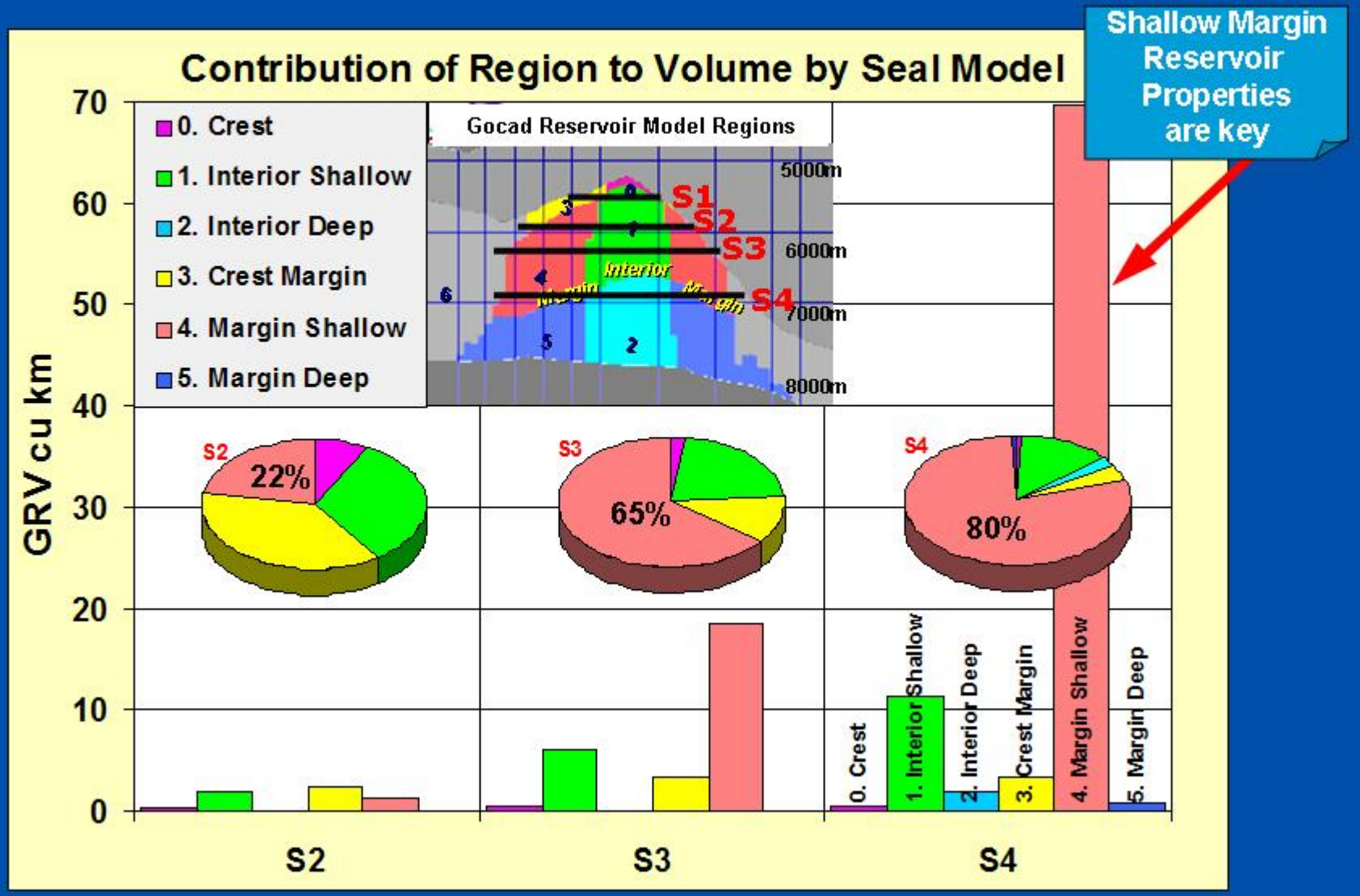
R3 – Thicker, more widespread zones of enhanced porosity typical of platform and upper slopes in Field B.

R4 - Good platform interior porosity and enhanced margin porosity

R5 - Highest porosity; primary porosity in upper platform interior of Field A

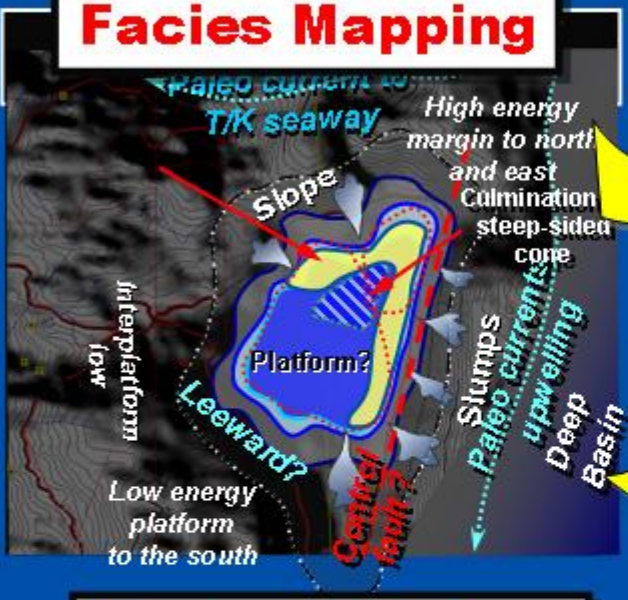


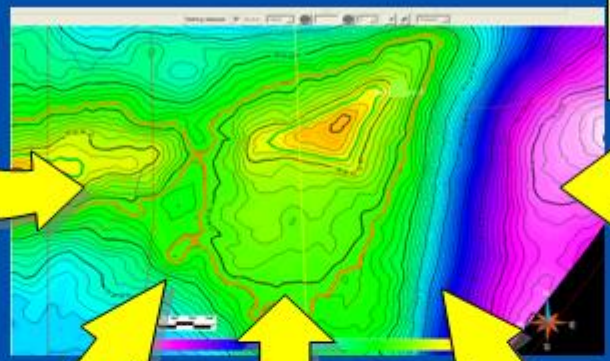
Impact of Regions on Volumetrics



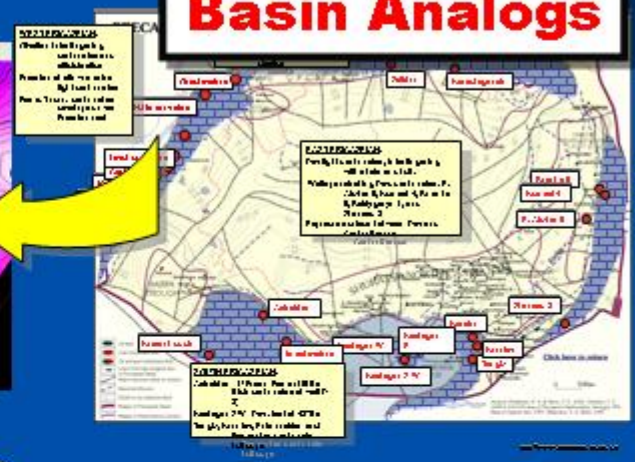
Probability Ranking of Reservoir Models Incorporating Local, Regional & Analog Data

Facies Mapping

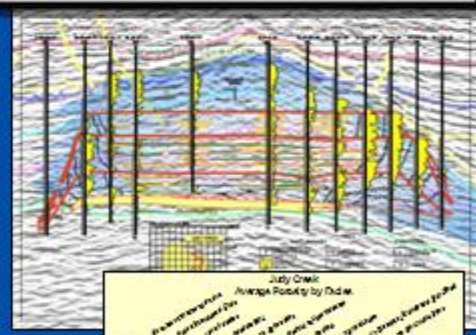


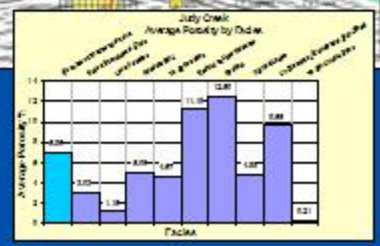


Basin Analogs



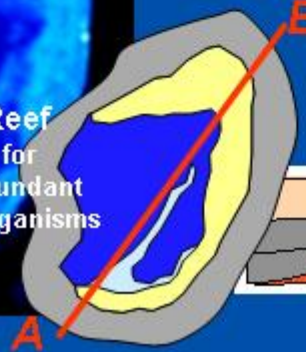
Global Analogs



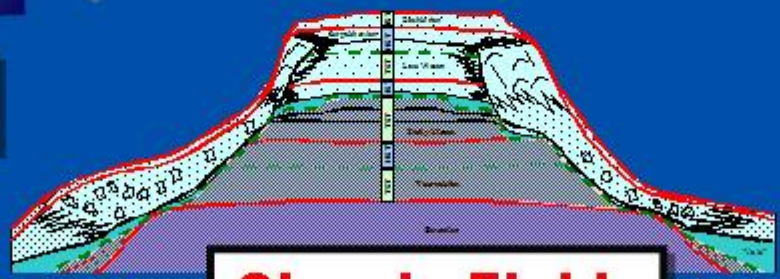


Modern Analogs

Great Barrier Reef
A modern analog for Frasnian, with abundant frame-building organisms

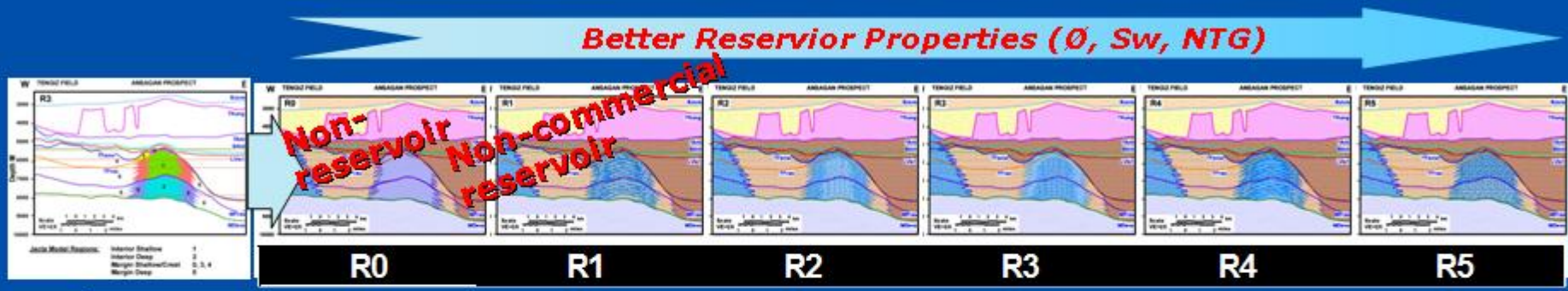


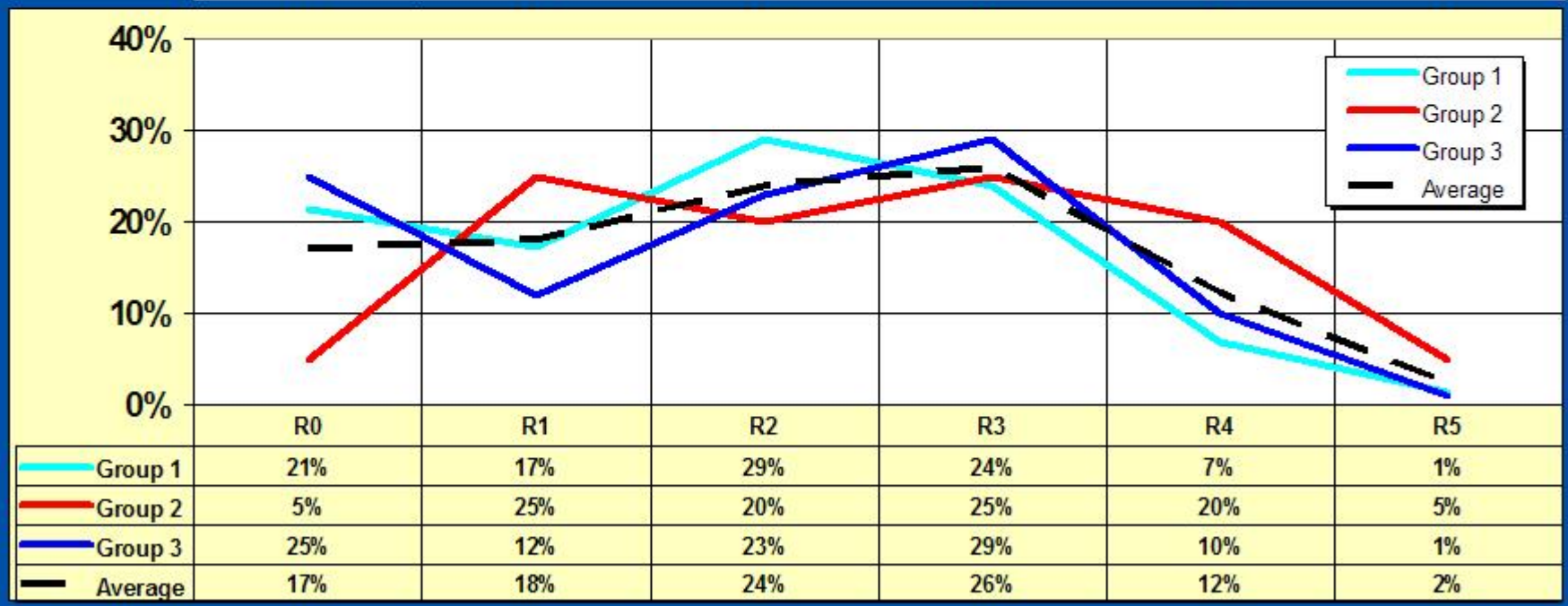
Classic Fields



Reservoir Model Probabilities by Group

- Experts from each participant group assigned probabilities

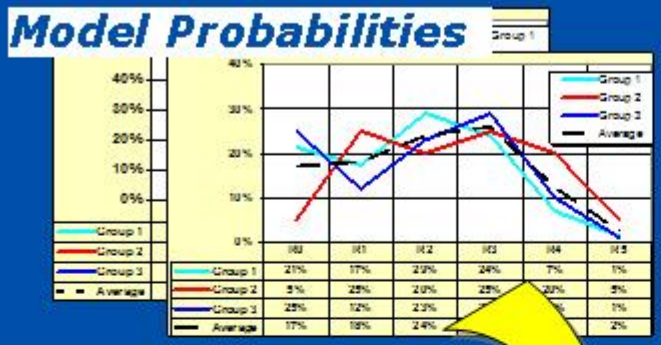




	R0	R1	R2	R3	R4	R5
Group 1	21%	17%	29%	24%	7%	1%
Group 2	5%	25%	20%	25%	20%	5%
Group 3	25%	12%	23%	29%	10%	1%
Average	17%	18%	24%	26%	12%	2%

83% Chance of Reservoir Success; 65% if R1 is considered sub-commercial

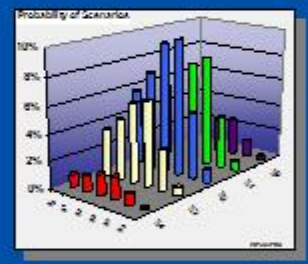
Calculation of Scenario Probabilities & Volumes



- Model probabilities cross-multiplied yield scenario probabilities and volumes
- Most probable scenario is R3S2

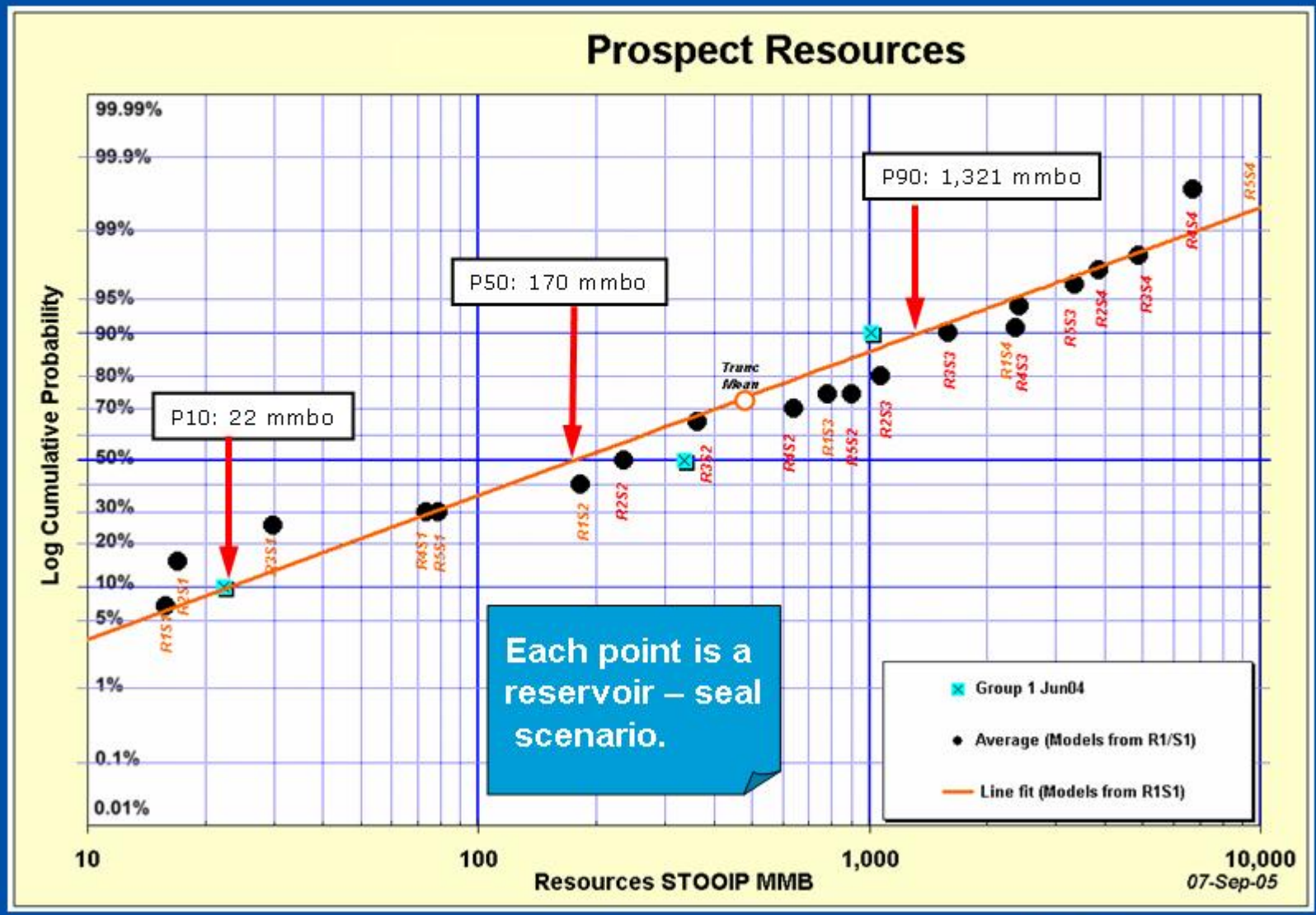
Reservoir Model	Seal Model S1	S2	S3	S4
R1	R1S1	R1S2	R1S3	R1S4
R2	R2S1	R2S2	R2S3	R2S4
R3	R3S1	R3S2	R3S3	R3S4
R4	R4S1	R4S2	R4S3	R4S4
R5	R5S1	R5S2	R5S3	R5S4

Case	POO	MMBO
R5S4	0.18%	11,540.0
R4S4	0.66%	6,730.0
R3S4	1.86%	4,890.0
R5S3	0.66%	3,863.0
R2S4	1.72%	3,340.0
[illegible]	3.32%	2,409.0
[illegible]	1.30%	2,370.0
R3S3	6.99%	1,587.0
R2S3	6.46%	1,066.0
R5S2	1.09%	904.0
R1S3	4.87%	780.0
R4S2	5.48%	[illegible]
R3S2	11.95%	[illegible]
R2S2	10.66%	235.0
R1S2	8.05%	183.0
R5S1	1.03%	79.0
R4S1	5.20%	73.5
R3S1	10.96%	29.9
R2S1	10.12%	17.0
R1S1	7.64%	15.9

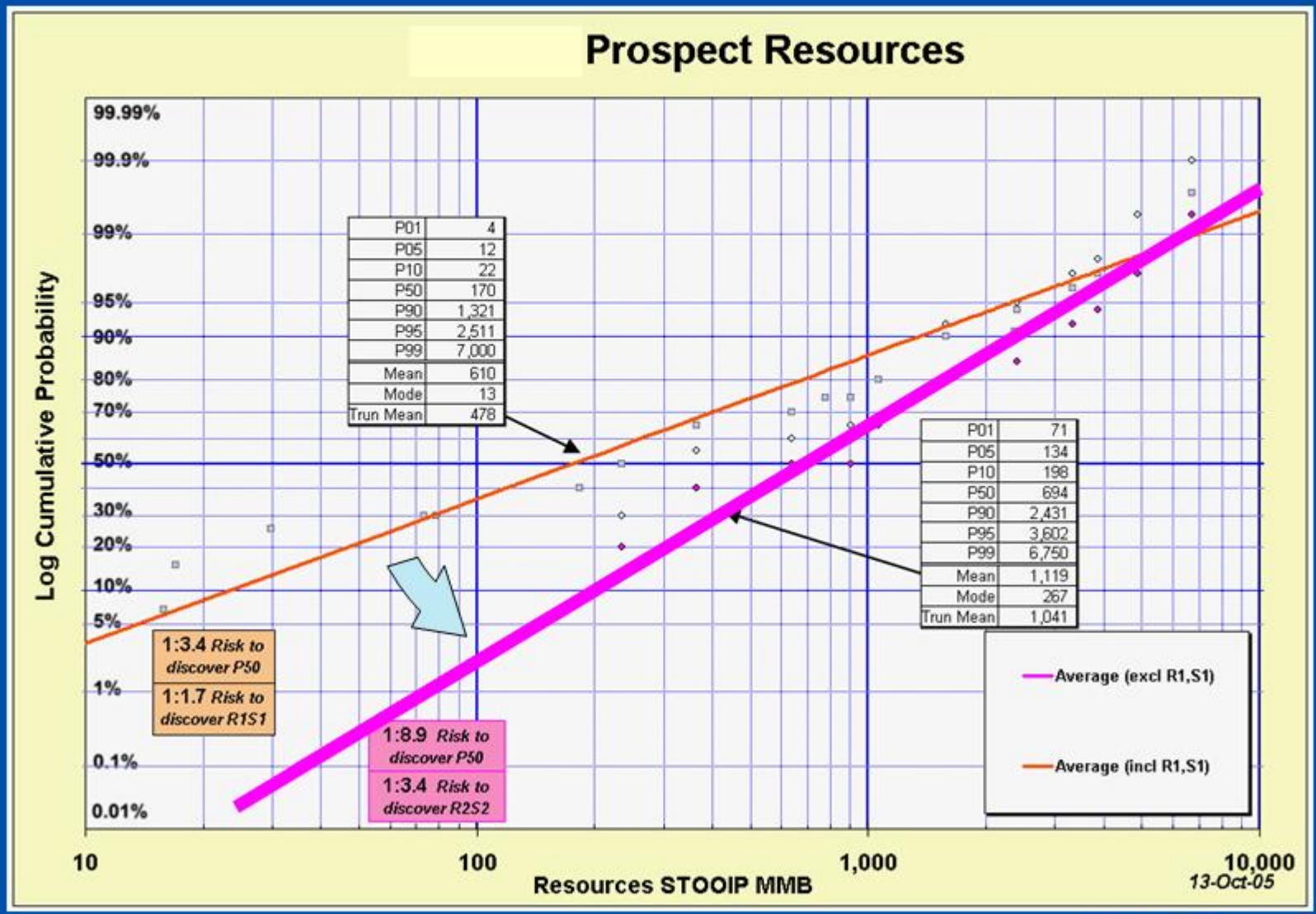


Scenario Volumetrics

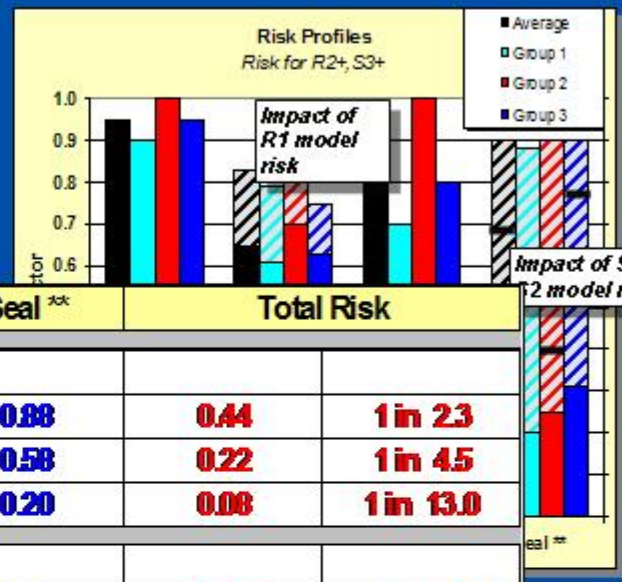
Plotted on a Cumulative Probability Distribution plot



Distribution with Sub-Commercial Reservoir-Seal Scenarios Excluded



Prospect Risk Profile

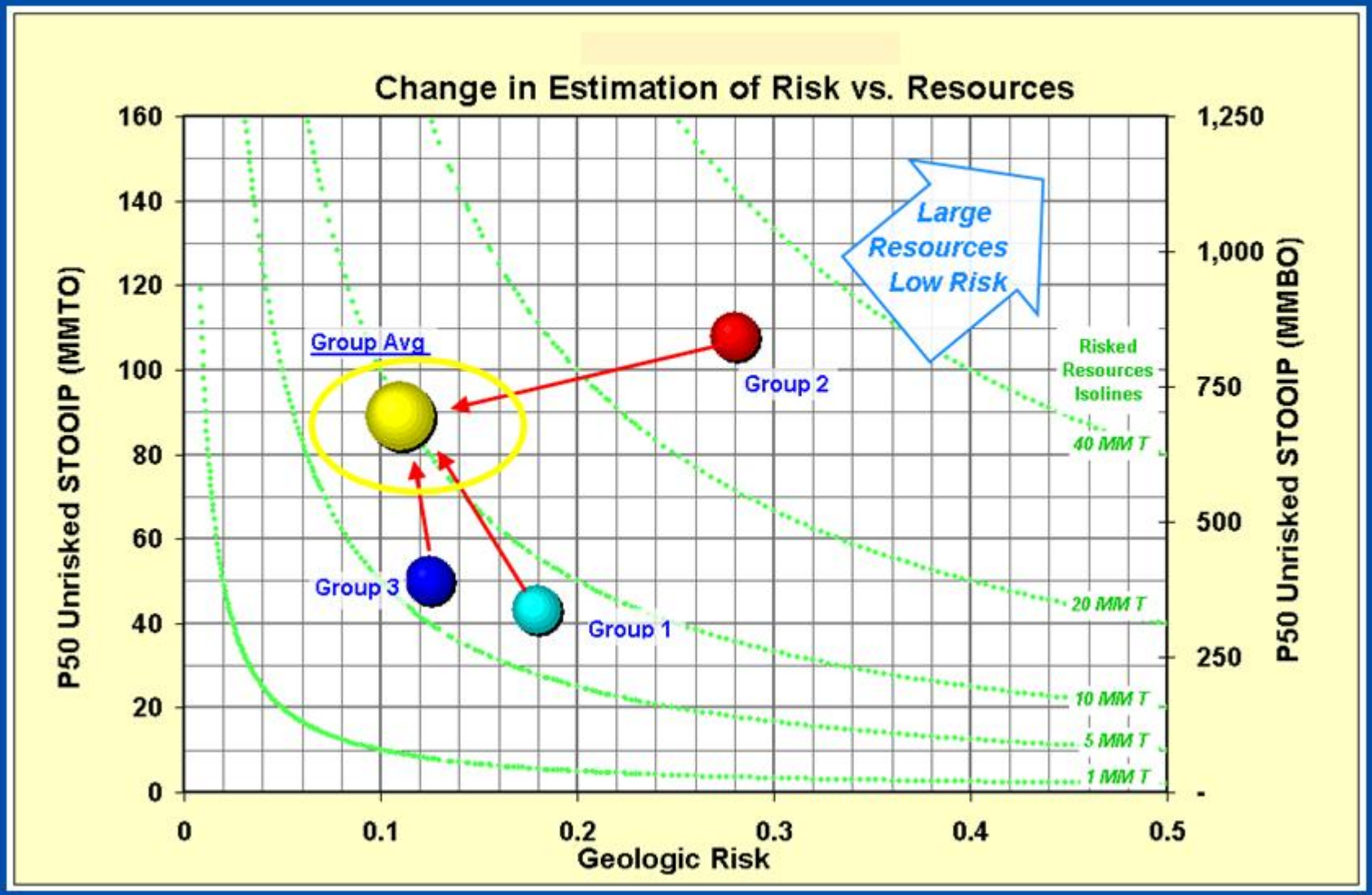


Geological Discovery (P50~R2S2)
Reservoir Risk: 65%
Seal Risk: 58%
Total Risk: 29% (1:3.4)

Commercial Discovery (P50~R2S3)
Reservoir Risk: 65%
Seal Risk: 25%
Total Risk: 11% (1:9)

			Trap	Seal **	Total Risk	
G						
			0.70	0.88	0.44	1 in 2.3
			0.70	0.58	0.22	1 in 4.5
			0.70	0.20	0.08	1 in 13.0
G						
			1.00	0.90	0.86	1 in 1.2
			1.00	0.40	0.28	1 in 3.6
			1.00	0.25	0.18	1 in 5.7
G						
			0.90	0.90	0.51	1 in 1.9
			0.90	0.77	0.37	1 in 2.7
		0.63	0.45	0.31	0.08	1 in 12.0
Average						
Risk for R1S1	0.95	0.83	0.83	0.90	0.60	1 in 1.7
Risk for R2S2	0.95	0.65	0.83	0.58	0.29	1 in 3.4
Risk for R2S3 (P50)	0.95	0.65	0.72	0.25	0.11	1 in 8.9

Method facilitated Group Alignment



Multiple Model Method: Process Summary

1. Build a suite of conceptual geological models which captures a full range of potential outcomes;
2. Analyze supporting and refuting evidence for each model using available local & regional data, and analog field information;
3. Quantitatively characterize each model with parameters;
4. Collect expert input on probabilities of occurrence for each model;
5. Combine models into a range of scenarios;
6. Calculate hydrocarbon volumes for each scenario;
7. Plot cumulative probability/volume pairs on distribution graph;
8. Identify scenarios which are commercial "failure" cases;
9. Use probabilities to determine risk factors
10. Check for reasonableness

Conclusions

- Use of multiple conceptual models recognizes the uncertainty common in geological interpretations;
- Probability-weighting of volumetric outcomes provides a representative resource distribution curve which incorporates intermediate success cases;
- Model probabilities can be used to estimate geologic risks;
- Geologic risking is based on a range of possible outcomes, not just the chance of success for a single model;
- The Multiple Model approach can help achieve alignment among groups with diverse interpretations.

Acknowledgments

- **Co-authors**

  Rob Kimmel and Steve Jenkins
  – Chevron International Exploration & Production

  Peter Leiggi and Paul (Mitch) Harris
  – Chevron Energy Technology Co., San Ramon, USA

- **Permission to present at this Conference:**

  Chevron International Exploration and Production Co.,

- **Many Others**

The End