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[AV]Why Bother? (With Play Based Exploration): The Five Reasons Why Play Based Exploration Worthwhile in a Modern Busy Understaffed and Overworked Exploration Company Environment*

Ian Longley[1] and Jeff Brown[2]

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[1]GIS-PAX Pty Ltd, Perth, WA, Australia (ian.longley@iinet.net.au)
[2]Rose & Associates, Houston, TX, United States

Abstract

Exploration and new business teams use play mapping because it provides "focus" via the use of a spatial tool over which opportunities can be layered to quickly rank and rate the flood of opportunities that teams typically have to filter in any active exploration area. At a functionality level, the available tools diverge and many just provide qualitative or relative goodness maps. This is still useful but without numeric estimates, it is always difficult to estimate the value or ranking of any opportunity and thus get corporate endorsement. The simplest play tool is a crayon on tracing paper but this is hard to update as new data becomes available and it is also easy to lose. The best play tools are consequently software packages that integrate dynamic well data into the maps in a way that helps geologists build and make the maps and provides a way of evergreening the evaluation with an audit trail and an archive mechanism that ensures that valuable corporate knowledge captured and retained. The second function more advanced tools can deliver is the integration of postulated prospects from a calibrated analog database into the evaluation. The third function advanced play tools can do is calculate the estimated yet to find volumes and values for each evaluated play incorporating both identified and postulated/unidentified prospects. The forth function advanced tools can provide is the ability to predict pre-drill what the impact of drilling one prospect will be on the evaluation of adjacent prospects. This derisking "success volume" calculation of volumes and values associated with each target means geologists can numerically justify wells that were always intuitively sensible but were never supported by the previously simplistic non-spatial economic evaluations. The fifth function that more advanced tools can deliver is to assist companies exploring in proven play areas where the play elements are all proven. In these areas information relating to types of traps that have been drilled and

which work and why some may have failed can be compared these data to the trap types of undrilled features thus providing a methodology for the systematic search for new traps. In summary the play tools that are quantitative and can deal with the dynamic changing environments of data, interpretations, prospects and trap types provide exploration and new business teams with tools for making their jobs easier and ultimately delivering superior results.

Selected Reference

Milton, N.J., and G.T. Bertram, 1992, Trap styles; a new classification based on sealing surfaces: AAPG Bulletin, v. 76, p. 983-999.

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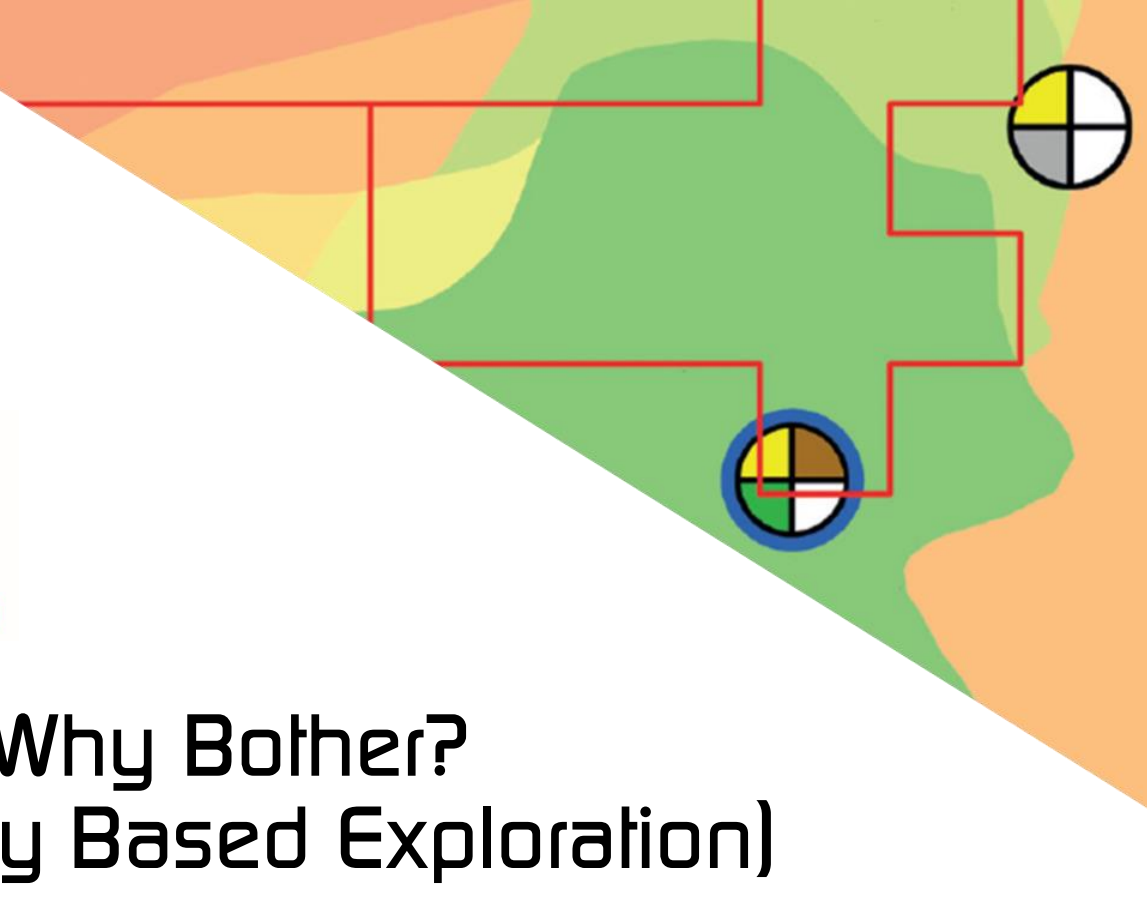
PLAYER PLAYHOUSE PLAYPEN



Why Bother?
(with Play Based Exploration)

The five reasons why Play Based Exploration worthwhile in a modern busy understaffed and overworked exploration company environment.

Ian Longley (GIS-pax)

Jeff Brown (Rose & Associates)

Rose & Associates

Oil & Gas Exploration Risk Assessment

Why Bother? The five reasons why Play Based Exploration worthwhile in a modern busy understaffed and overworked exploration company environment.

Jeff Brown (Rose & Associates) and Ian Longley (GIS-Pax Pty Ltd)

As technicians, we frequently debate the nuances of play mapping techniques and the relative merits of the many tools available that are designed to facilitate the process, and forget why we actually use play maps in front-line exploration. The first and primary function of play mapping (of any flavor) is that it provides "focus". More specifically it provides a spatial tool with which opportunities can be layered to quickly rank and rate the flood of opportunities that exploration teams typically have to filter in any active exploration area, or when choosing entry opportunities.

The simplest play tool is a crayon on tracing paper or polygons in PowerPoint but these are hard to update as new data become available, and paper maps are easy to lose. The best play tools are consequently software packages that integrate well data into the maps in a way that helps geologists build and make the maps and this provides a way of 'evergreening' the evaluation with an audit trail and an archive mechanism that ensures that valuable corporate knowledge captured and retained. At a functionality level though the available tools diverge in subtle ways and many just provide qualitative or 'relative goodness' maps that show where play elements are most favorable. This is still useful but without numeric estimates it is always difficult to estimate the value or ranking of any opportunity and thus get corporate endorsement.

The second function advanced play tools provide is the ability to calculate the estimated yet to find volumes (and associated value) for each evaluated play, incorporating both identified and postulated/unidentified prospects. The latter requires the quantitative chance mapping to emulate the risking mathematics done for prospects consequently the tool must be capable of dealing with different risking structures.

The third function advanced tools can provide beyond is the ability to predict, pre-drill, the impact/influence of successfully drilling one prospect will be on remaining adjacent prospects, which is profoundly important in unproven potions of plays. This derisking "success volume" calculation of volumes and values associated with each target means that prospects that were evaluated in isolation as sub-economic can sometimes be elevated positions in the drilling portfolio. This calculation can only be done by splitting play and prospect chance estimates into polygons of equal chance value; hence, grid/raster methodologies simply cannot provide this important insight.

The fourth function that more advanced tools can deliver is to assist companies exploring in proven play areas is the ability to integrate well results (key well analysis), both in terms of data analysis and in simply displaying why each wildcat succeeded or failed in map sense When properly documented, analysis can be related to types of traps, providing a better understanding of critical risks by trap type, better prediction of future success rates, and a basis for systematically looking for new material discoveries in old basins.

Lastly, more advanced tools recognize that many key exploration decisions happen early in the exploration phase of a basin or play, when prospects have not been defined and 2D/3D charge models have not been built. In these areas, the prediction of prospect sizes and frequency/density from a calibrated analog database is key, as is the simple integration of source and charge models (typically 1D modelling or seismic isochron work) into the analysis.

In summary there are many play tools and techniques but the ones that are quantitative and can deal with the dynamic changing environments of data, interpretations, prospects and trap types provide exploration teams with a tool that should provide inputs for better exploration decisions and, ultimately, deliver superior results.

Abstract from AAPG ICE Conference Melbourne, Australia, 2015

Presentation Material from this presentation is also on AAPG Search & Discovery

What Is Player?

- Player is an extension in ArcGIS that provides the tools to do conventional and unconventional Play Mapping and Play Assessments with the data saved into an industry standard database structure
  - It now has 8+ years of development with 30+ global E&P companies using the software – it is the benchmark for Play Analysis tools – nothing else comes close (see www.gis-pax.com for more info)
    - It is not a prospect evaluation or volumetrics tool..
    - The Player Suite is applicable to both unconventional and conventional exploration types
  - Player is particularly well suited to evaluated large complex basins with multiple play levels and lots of fields but it can be just as easily applied to frontier unproven basins with limited data and no discoveries. In either setting it has a well defined workflow and is designed to make using ArcGIS easier – it is a working geologist product not a specialist tool.
  - Player in an unconventional setting provides the tools to qualitatively or quantitatively evaluate established single or stacked plays using your company defined workflows– every unconventional play is different! These workflows then become the corporate knowledge libraries for unconventional plays and these can be used to evaluate by analogy more frontier areas or unproven plays.
- Its in ESRI ArcGIS because "the platform matters!"
  - It's the software that deals with spatial objects the best
    - Objects are spatially "aware"
    - There are no grids or edges
    - It's a proper GIS and deals with projections properly and easily
  - Its an open development platform with 30 million licenses
    - Means its robust and can deal with large complex datasets
    - It uses the clever functions developed in Arc Objects that have been developed over the last 20+ years
  - It's the industry platform- every regional team in every large company we have seen uses it. Period.
  - It can sit on local flat files or on Oracle or SQL databases
  - We could not do what we do on any other platform…

First of All..

- Let me point out that this talk is focussed on conventional oil and gas plays not unconventional ones.. we (at GIS-pax and Rose) have solutions for the latter but this is not covered nor discussed in this presentation

- Secondly let me give credit to Jeff Brown from Rose & Associates for both his contribution to this pack and to my learning over the last few years..
  - Many of the concepts and ideas here are from him and I would recommend anyone thinking about a Play Based Exploration focus engage Rose and him in both your planning and training plans..

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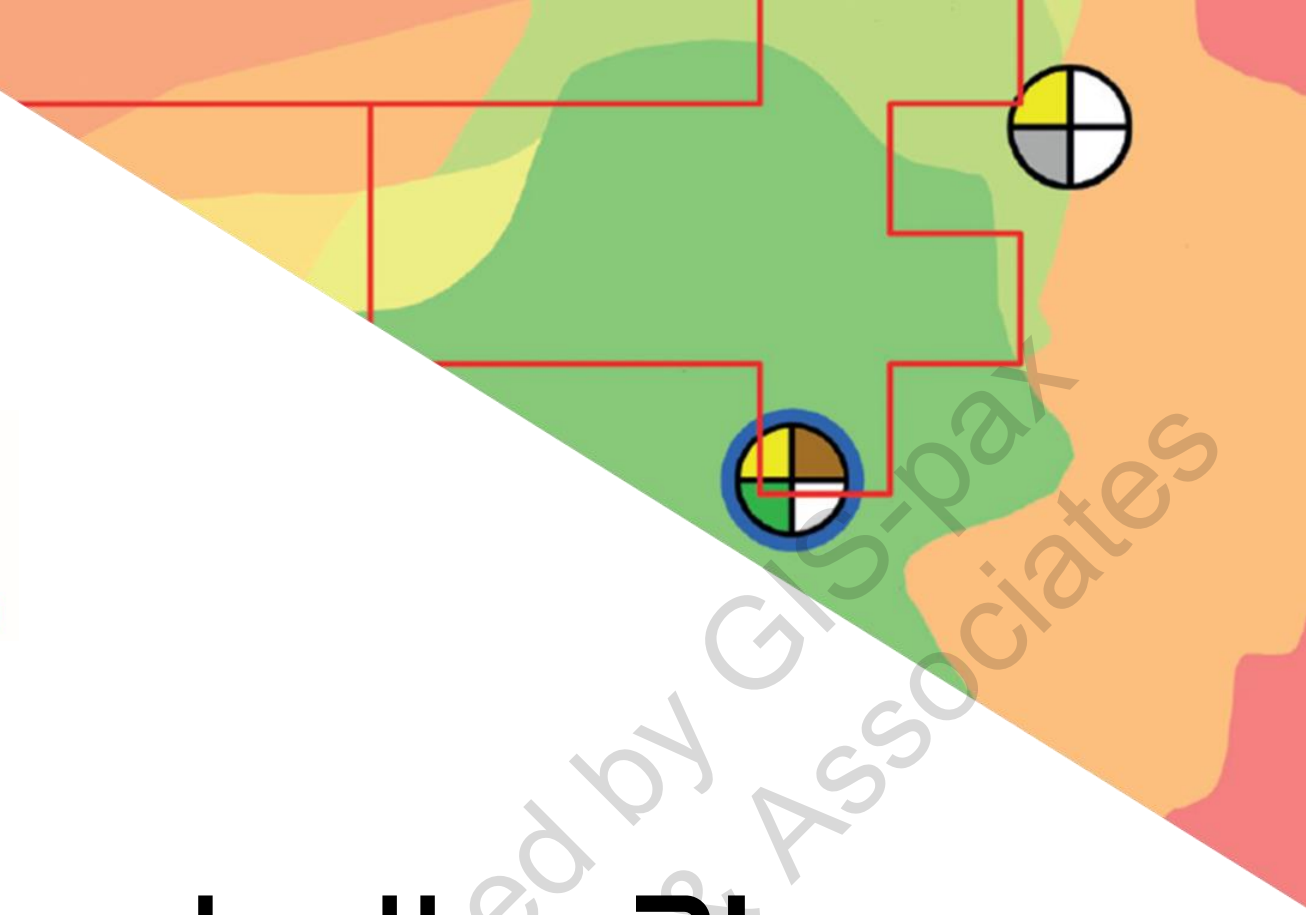
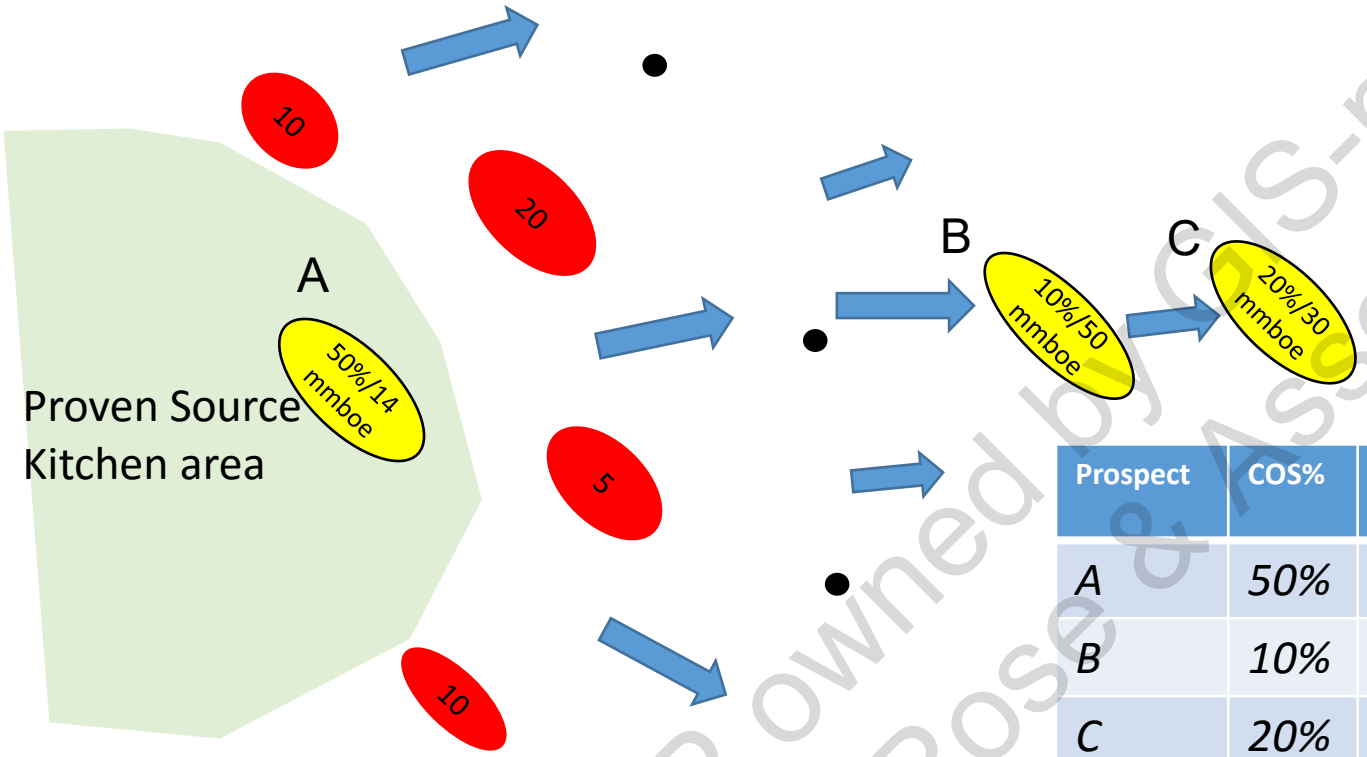
PLAYER PLAYHOUSE PLAYPEN



So why bother?!
A simple example

Example of Why PBE



Prospect	COS%	Vol mmboe	Product
A	*50%*	*14*	*7*
B	*10%*	*50*	*5*
C	*20%*	*30*	*6*

- 3 prospects – which one would you drill?
- All prosects and discoveries in the same play/reservoir interval
- Risks and volumes all peer reviewed by same team and process

Legend

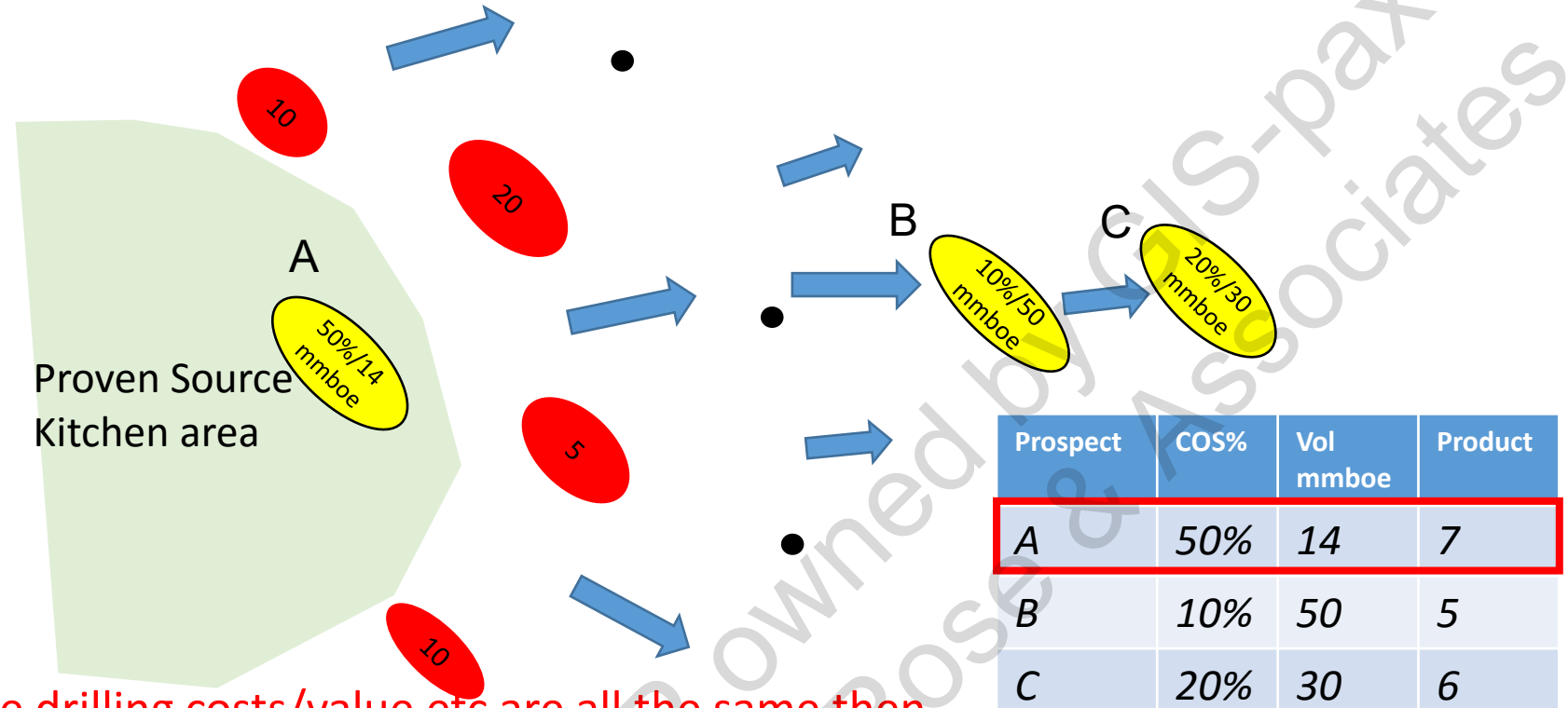
HC Field mmboe

Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

Example of Why PBE



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Legend

HC Field mmboe

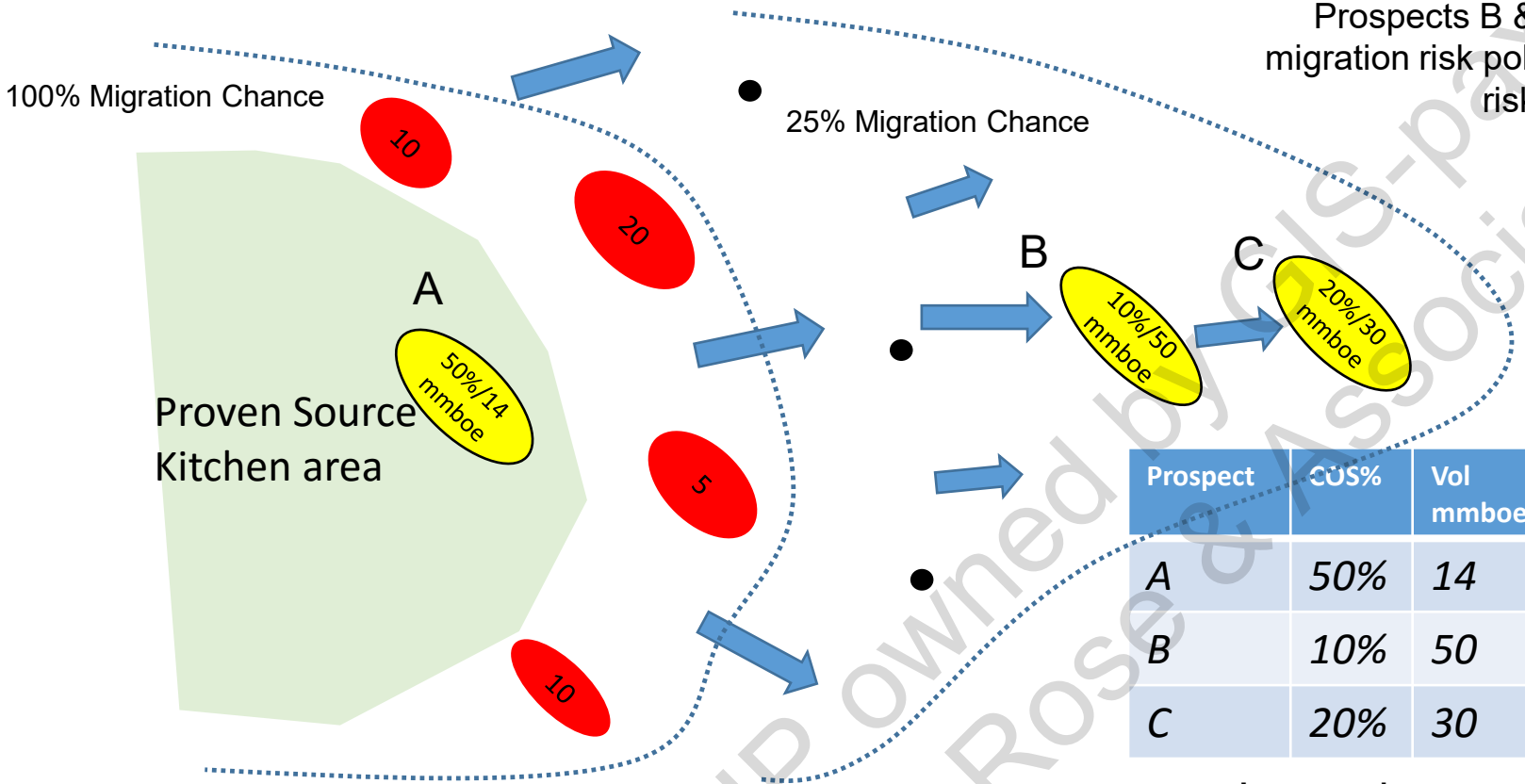
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

- If the drilling costs/value etc are all the same then **every** E&P company on the planet would drill Prospect A because it has the highest risk volume result.
- This one is close to the discoveries as well so everyone feels happy about this kind of easy decision!
  - Do you agree?!!

Example of Why PBE



Prospect	COS%	Vol mmboe	Product
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B	*10%*	*50*	*5*
C	*20%*	*30*	*6*

- So now lets add some migration risks
- We have 3 dry wells between the kitchen and Prospect B & C so the migration risk is in this case put at 25%..
  - Clearly in the real work we need to know why these wells failed to understand this risk..

Legend

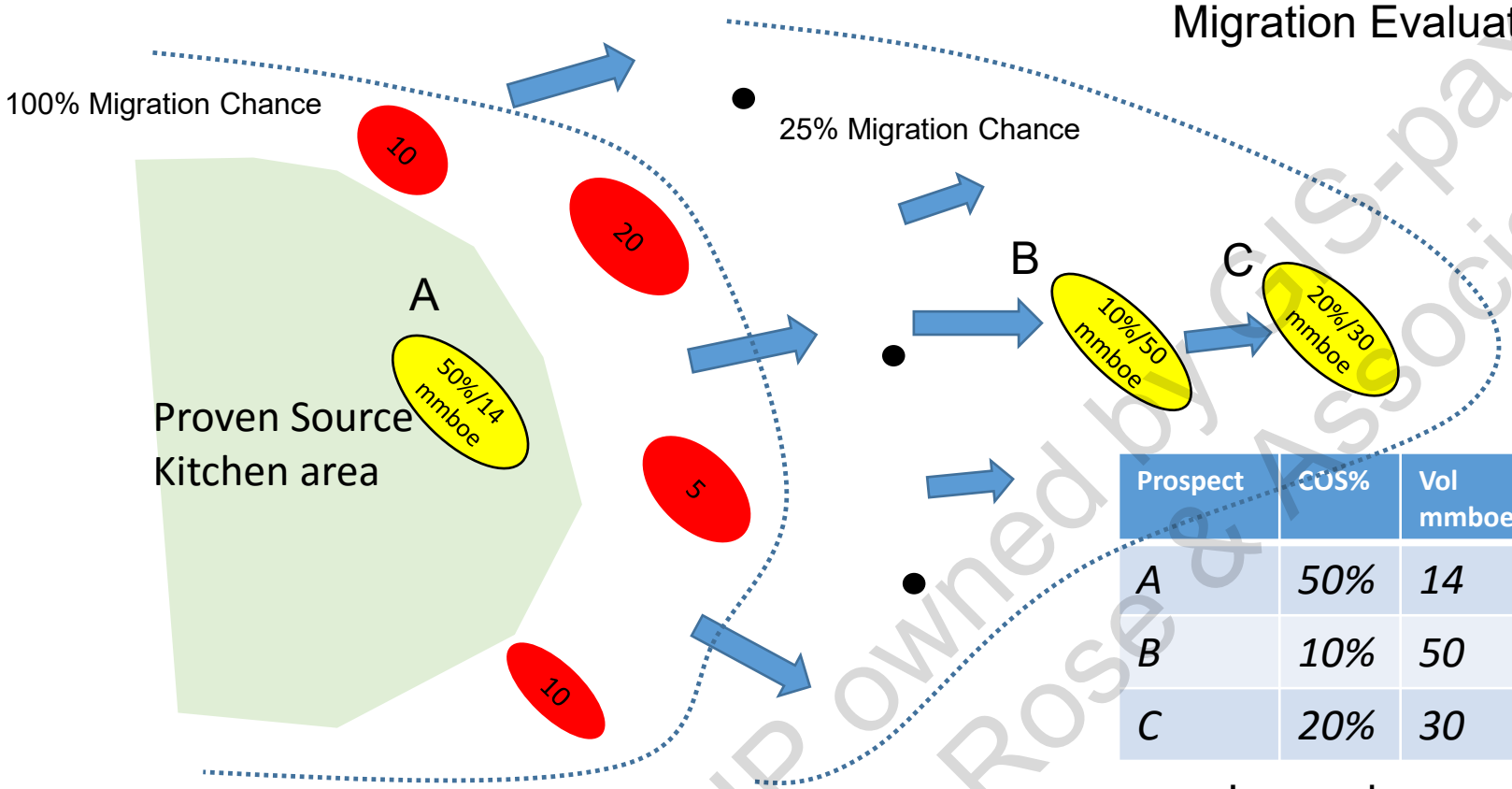
HC Field mmboe

Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

Example of Why PBE



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Legend

HC Field mmboe

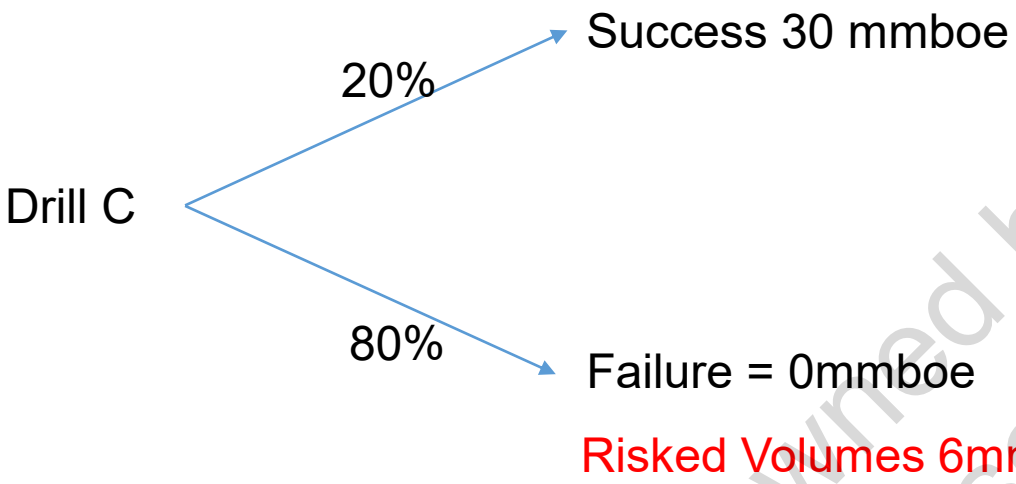
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

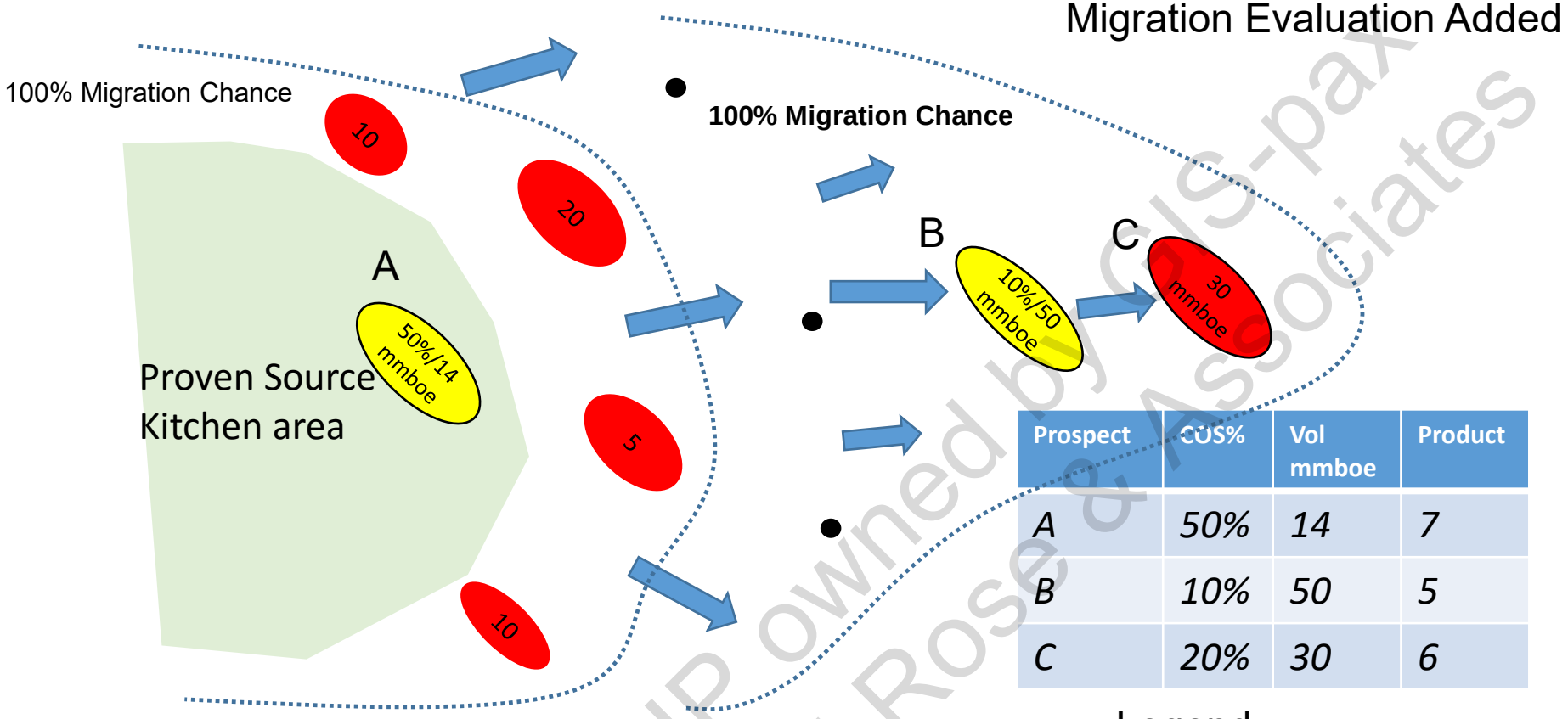
- So now if we drill C and it is a discovery…

Drill C.. The raw numbers



This is what happens to Prospect C in isolation….
But IF it works….

Example of Why PBE



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Legend

HC Field mmboe

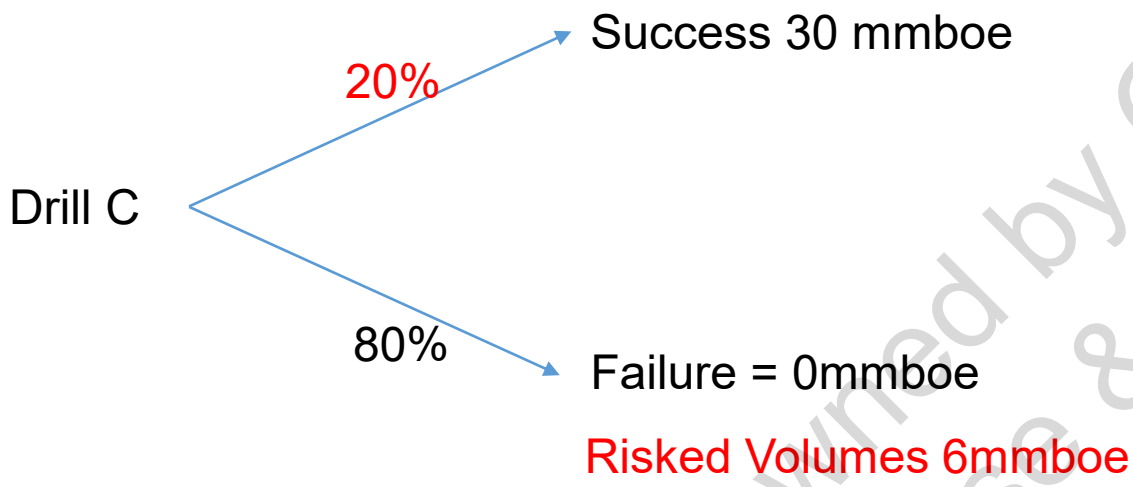
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

- So now if we drill C and it is a discovery… then the migration will be proven to prospect B!!
- In this case we have set the new migration risk to 100%

Drill C Evaluation..



- This is how C looks alone..

Drill C Evaluation..

If C works then the migration to B chance changes from 25% to 100% and the COS increases by a factor of 4 (25% to 100%)

Prospect B
COS=10%
MSV= 50mmboe
Risked= 5mmboe

COS=40%
MSV= 50mmboe
Risked= 20 mmboe

Delta= 15mmboe

Drill C

20%

Success 30 mmboe

80%

Failure = 0mmboe

Risked Volumes 6mmboe

- When we look at the impact of the C result on B .. This add 15mmboe of risked volume in the success case…

Drill C Evaluation..

If C works then the migration to B chance changes from 25% to 100% and the COS increases by a factor of 4 (25% to 100%)

Prospect B
COS=10%
MSV= 50mmboe
Risked= 5mmboe

COS=40%
MSV= 50mmboe
Risked= 20 mmboe

Delta= 15mmboe

Drill C

20%

Success 30 mmboe

Risked = 15 * 20% =3 mmboe

80%

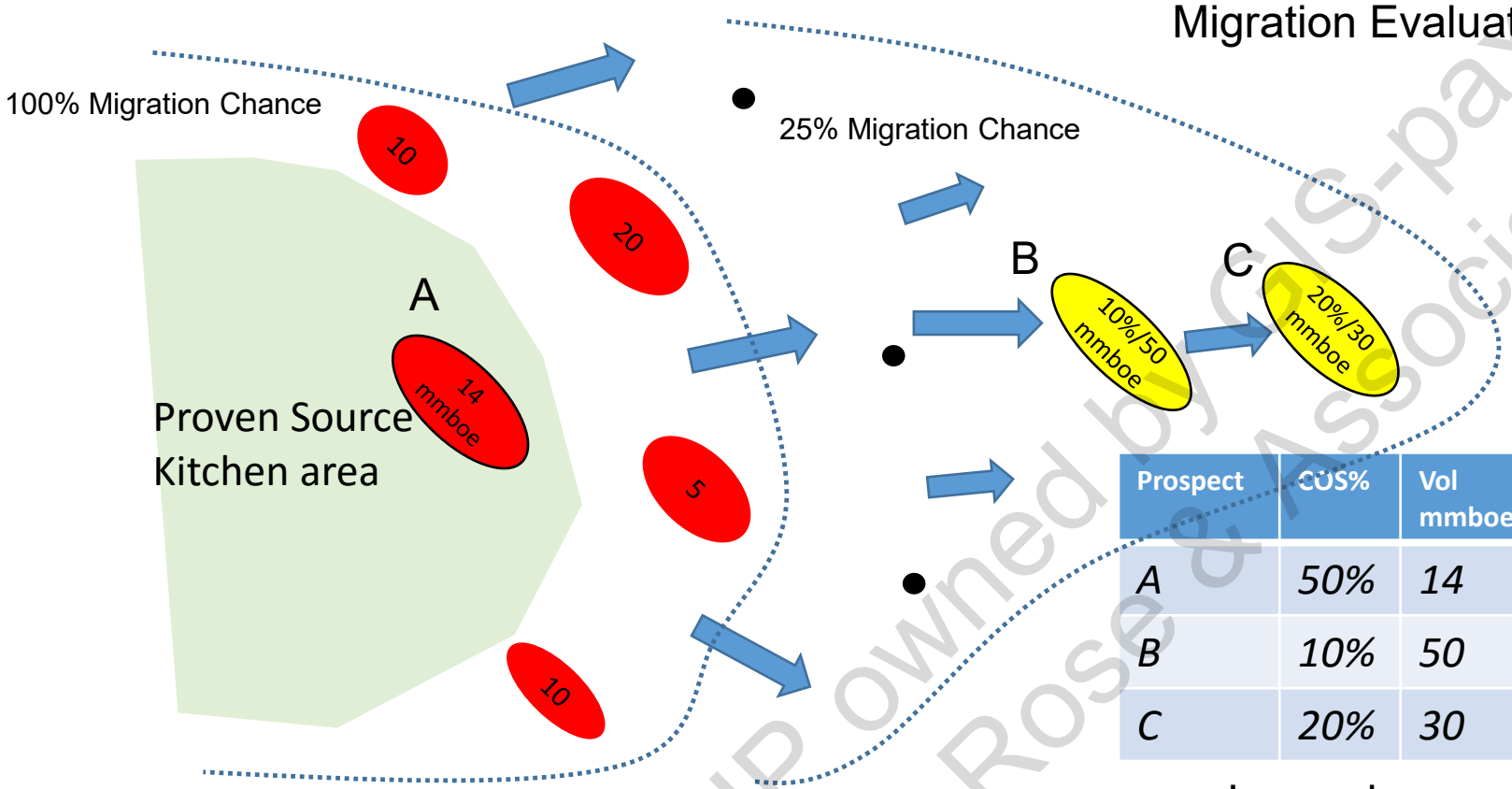
Failure = 0mmboe

Risked Volumes 6mmboe

Total Risked Volumes = 9 mmboe

- But this only happens 20% of the time when C works = the migration risk affecting B will change from 25% to 100% 20% of the time..
- This adds 3 mmboe of risked volumes to the overall risked result

A Success Result



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Legend

HC Field mmboe

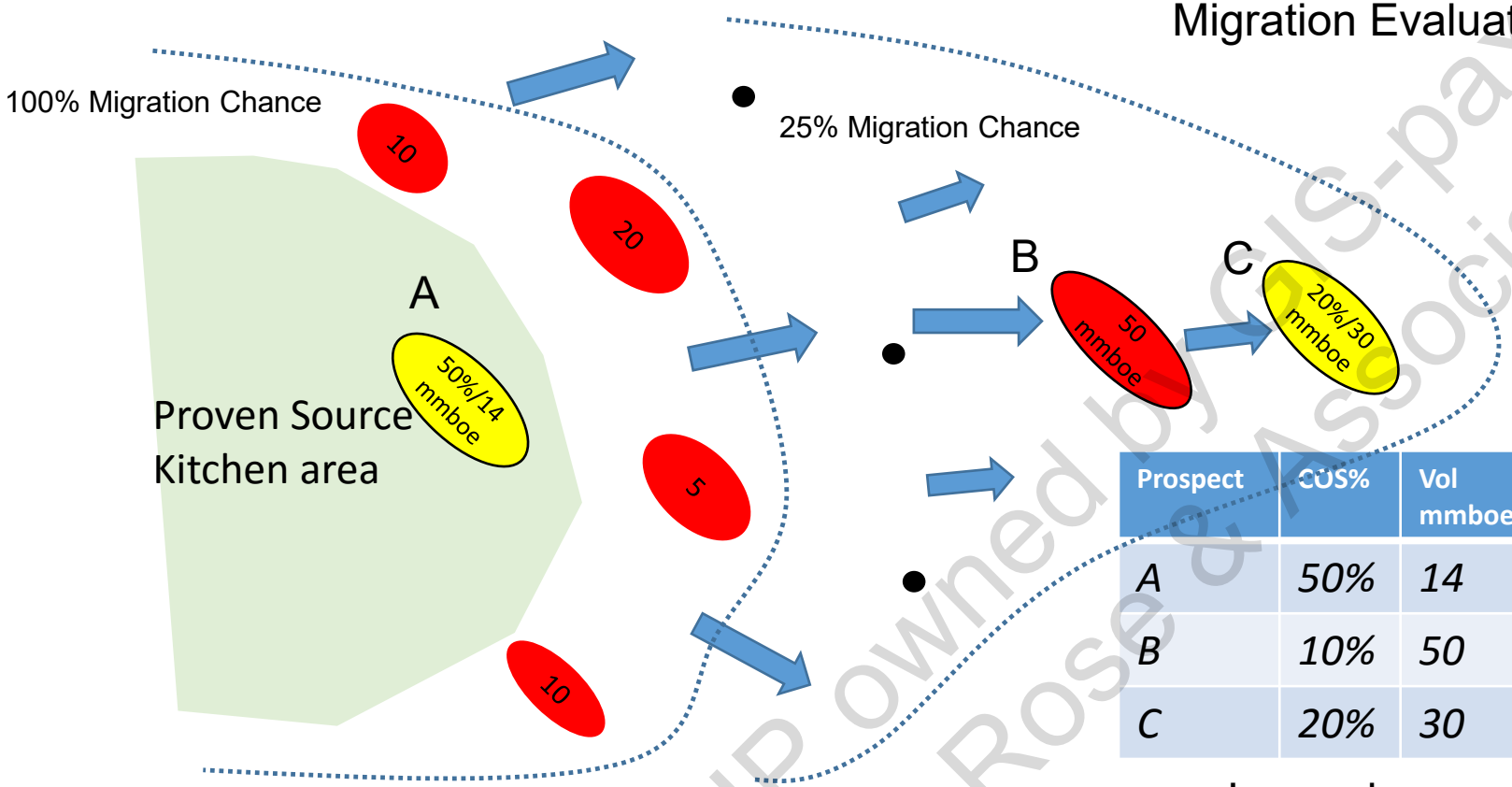
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

- A success at A does not affect the shared migration risk evaluation at B & C…

B success result



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Legend

HC Field mmboe

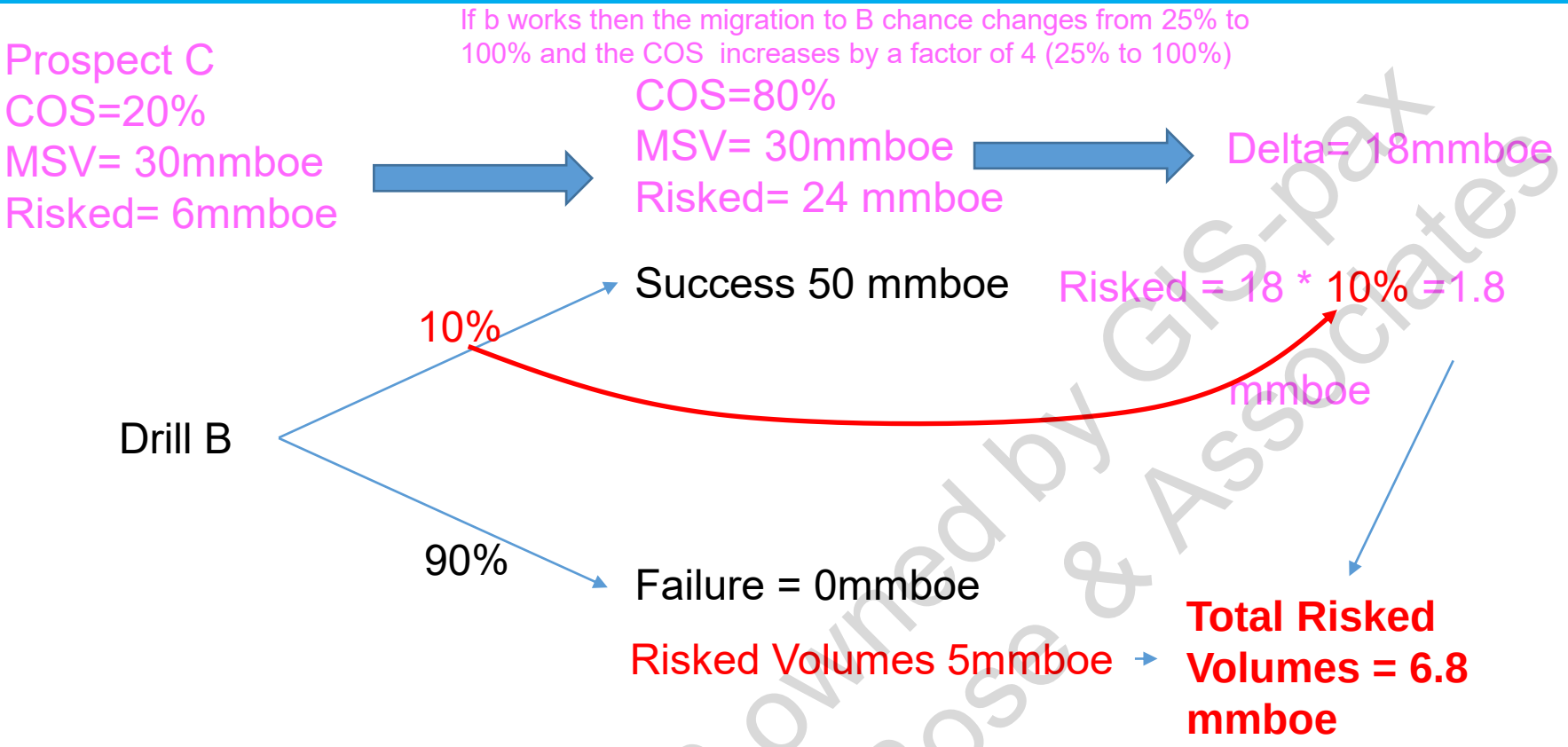
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

- A B success will impact C given that our interpretation is that B & C are in a polygon of equal migration chance..

Drill B maths..



- So 10% of the time C works and that means the migration risk affecting B will change from 50% to 100% 20% of the time..
- This adds 1.8 mmboe of risked volumes to the risked result

So in summary…

	Pg POS COS	Mean Volume	Risked Volume	Success Volumes	Total Risked Volumes
Prospect A	50%	14	7	0	7
Prospect B	10%	50	5	1.8	6.8
Prospect C	20%	30	6	3	9

On a risked basis drilling prospect C now looks like the best portfolio decision!!
Now how do we feel about that initial easy decision to drill prospect A???

The sharing of risks with real prospects will change what you drill – this IS PBE exploration and why we do it!

To do this we need maps of shared risks integrated with prospect data – that is what Player can do for you … and no other tool can.

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Why PBE explained...

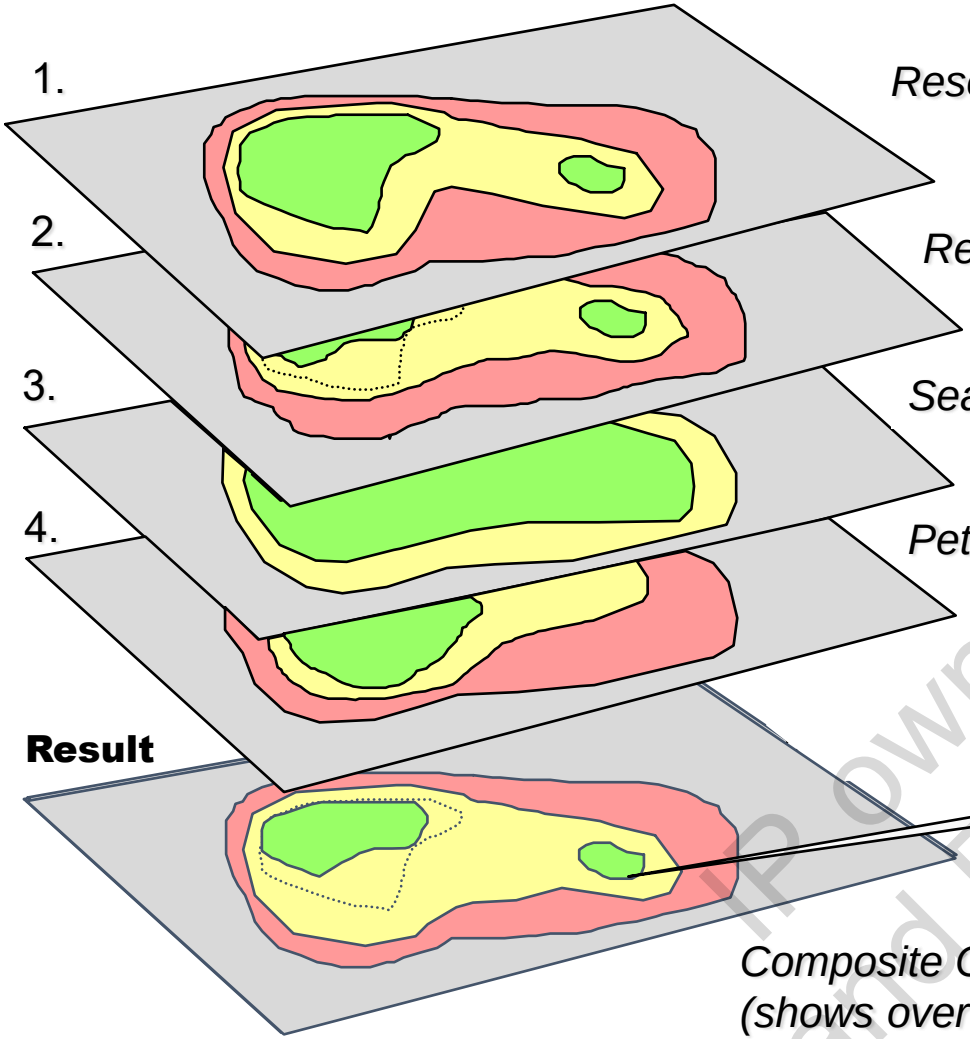
Why Bother with Play Mapping?

1. Play Mapping Types – why all the confusion?
   a) Goldilocks Maps = Traffic Light
   b) Average Prospect Chance Maps
   c) Split Risking Maps
2. Why seismic amplitudes will NOT be the silver bullet for exploration in mature basins.
3. Why Charge Models are dangerous and often wrong.
4. The mature basin “Green Blob” problem and the solution.
5. YTF – explained.
6. Summary

Why all the confusion?

- Some geologists get very emotional about the different types of play maps that are made in the industry today and what variety should be taught and used in their company..
  - typically the senior managers favour whatever variety that they were taught decades ago when they did real technical work in major oil companies
- This is because there is no industry consensus on how play mapping "should" be done
- The answer is - it does not matter! – its about understanding the geology NOT arguing about colour bars..
- So let me explain the 3 basic types used in the industry today with their advantaged and disadvantages and hence convince you of this conclusion
- The first and most common are companies that make "Traffic Light Maps"
  - Methodology championed by BP
  - Effectively the geologist divides each element (typically reservoir, seal and charge) into high/moderate and low risk areas
  - Followed by a "minimum" stack i.e stack is only green where all element maps are green. A red at any level equals a red in the stack

Simple Traffic Light Mapping

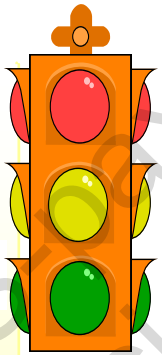


Reservoir Presence

Reservoir Effectiveness

Seal Presence + Effectiveness

Petroleum Charge



= "High" Risk

= "Moderate" Risk

= "Low" Risk

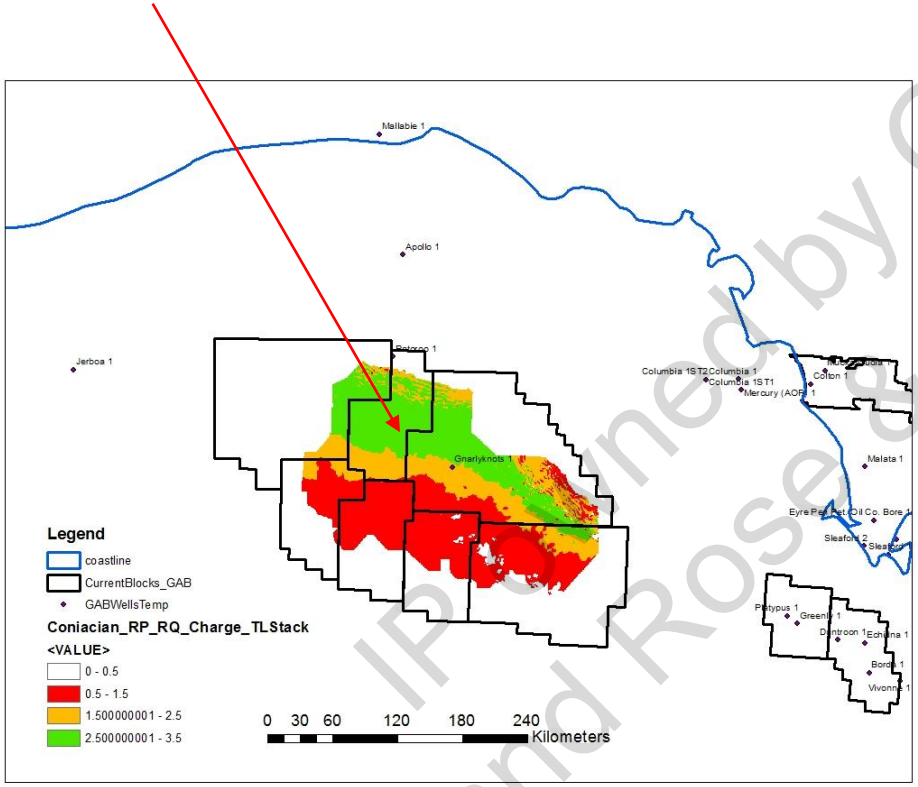
Low & mod. risk area reduced due to charge

Composite Common Risk Segment Map (shows overall play risk)

after Fraser 2012

Coniacian-Cenomanian Interval Traffic Light (Composite) Play Stack - Example

Goldilocks zone updip of postulated oil mature Cenomanian Source interval which received some Tertiary burial plus an area where the reservoir is likely to be present and not too deep..



Goldilocks Maps DO give spatial focus and identify sweet spot areas

Traffic Light Maps = Goldilocks Maps

- Relative Goodness maps highlight the areas where the separate play elements –typically reservoir, seal and charge are optimally overlain – these are the "goldilocks areas" where things are "best" – "just right" – this is a relative/qualitative scale NOT quantitative

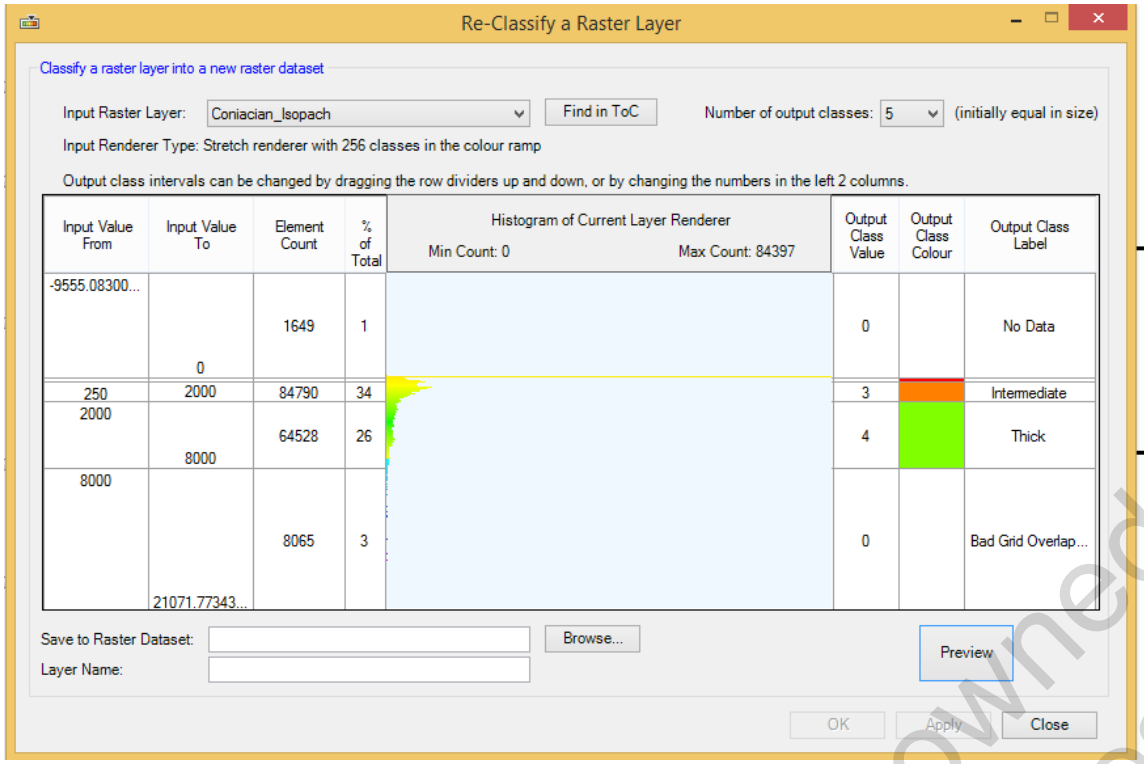
The map types are relatively easy and quick but..

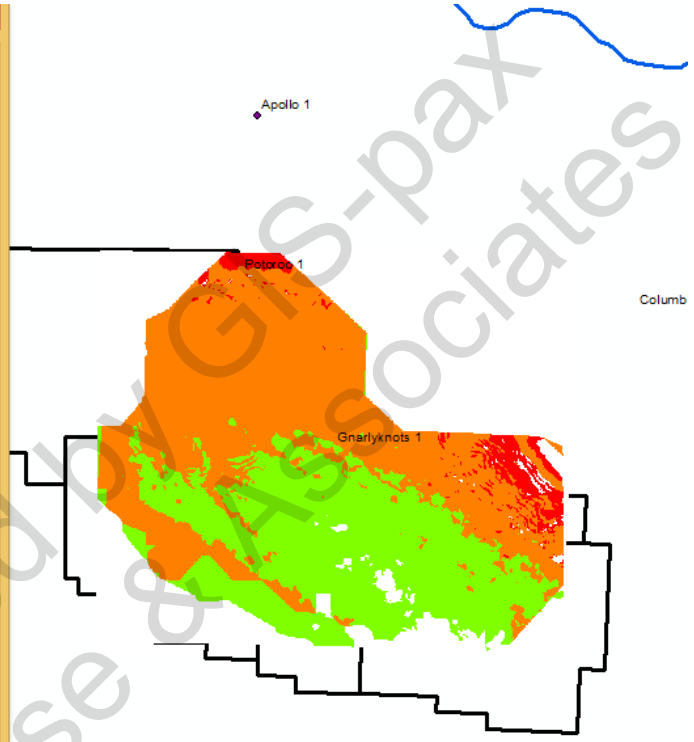
Traffic Light Maps have a few problems..

Traffic Light Issues

- Users commonly use a grids for risk evaluations and the selection of boundary values between the colours is “computer generated” and thus have no geological basis
- In this example the probability of reservoir presence is being predicted from an isopach grid of the whole play interval..

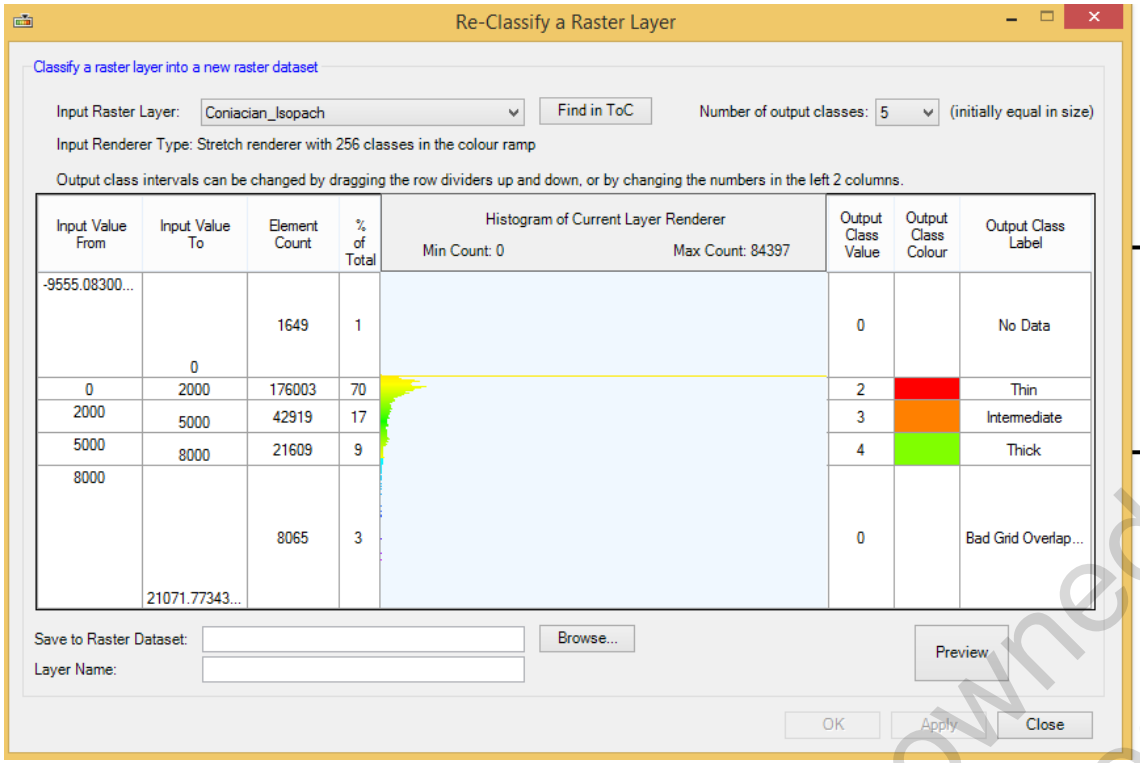
Example of Raster to Traffic Light Issue

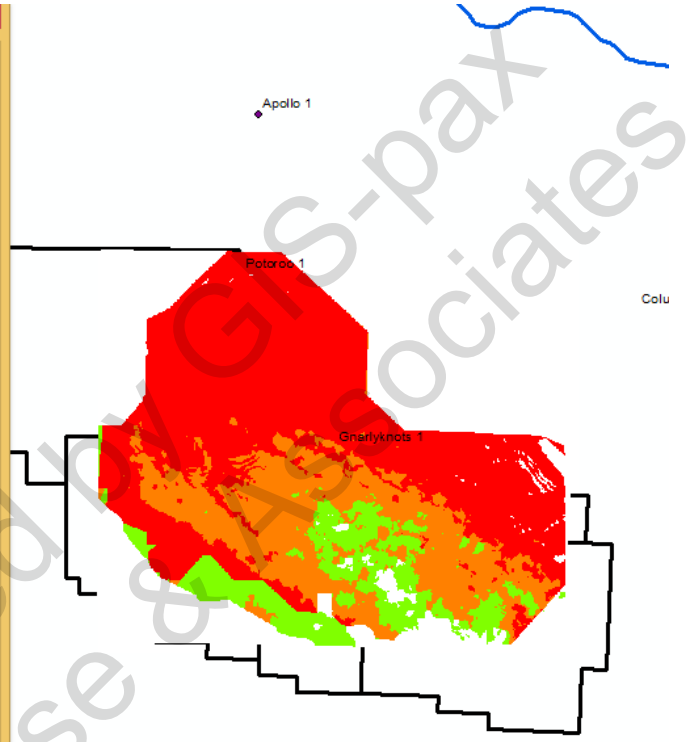




- Red-Orange at 500m Orange-Green at 2000m

Example of Raster to Traffic Light Issue

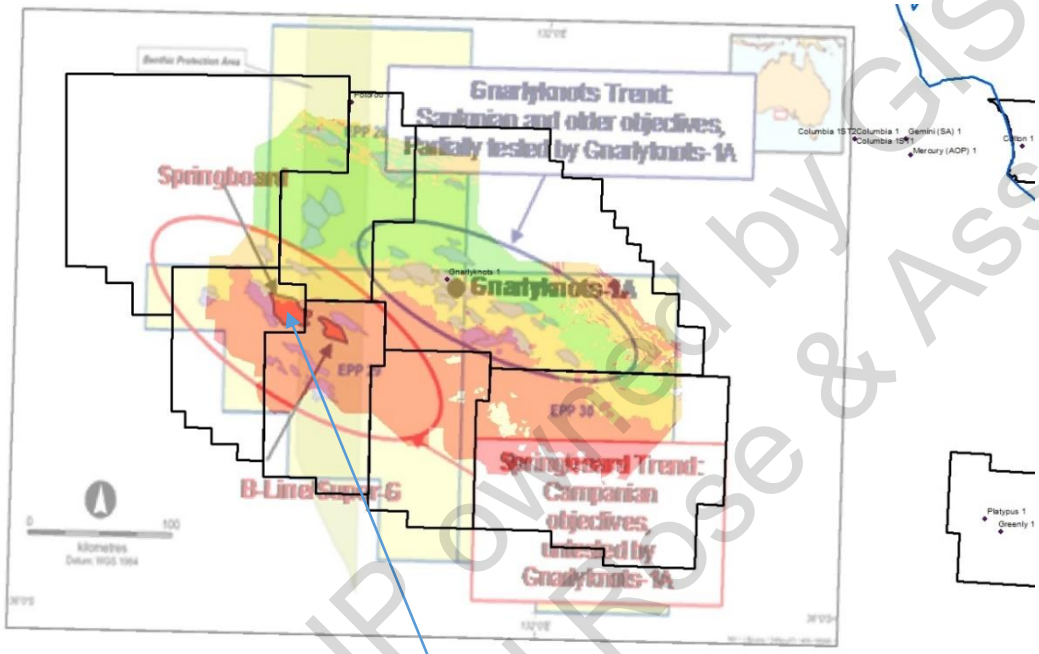




- Same raster…
- Red-Orange at 2000m Orange-Green at 5000m
- Boundaries being drawn by computer/arbitrary selection of grid boundaries NOT geological boundaries

Issues with Traffic Light Maps

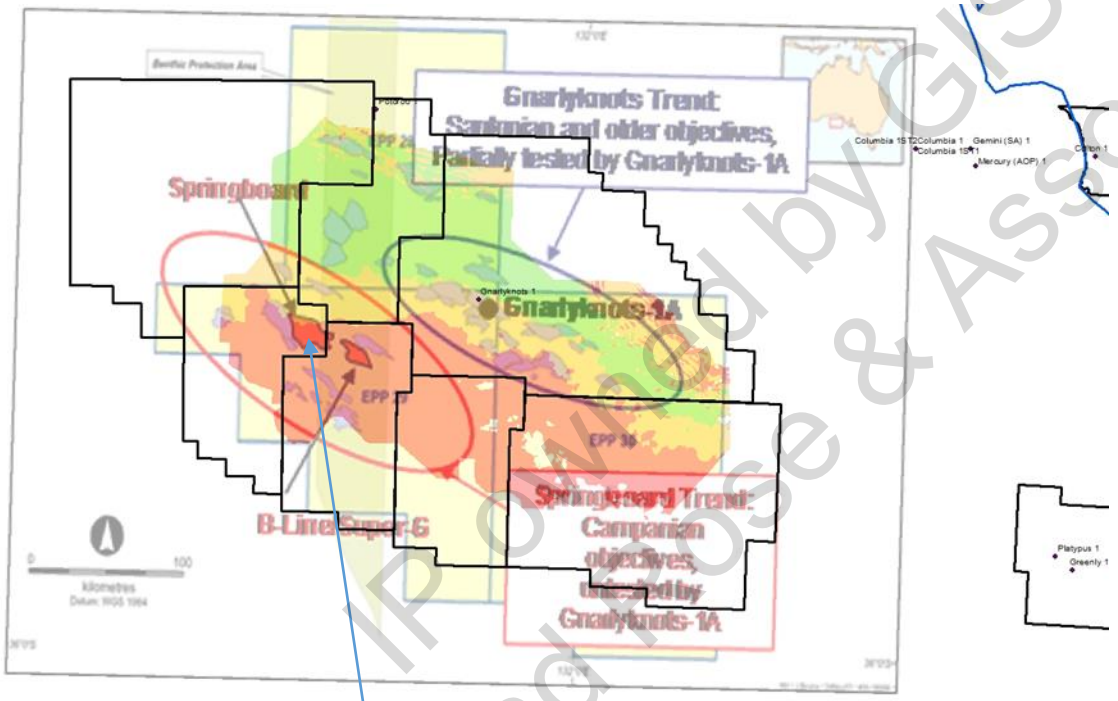
- The second issues is if you plot real prospects on the map there is NO relationship/linkage between the colours and the Pg/POS/COS



In this case a prospect here is in the “orange” – what does this mean? Lack of data? Mid range COS/POS/Pg? It certainly CAN’T be used to infer a POS/COS/Pg for the prospect..

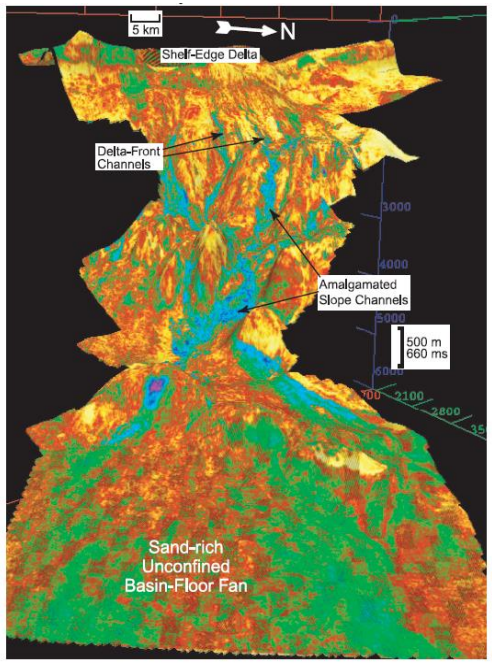
Issues with Traffic Light Maps

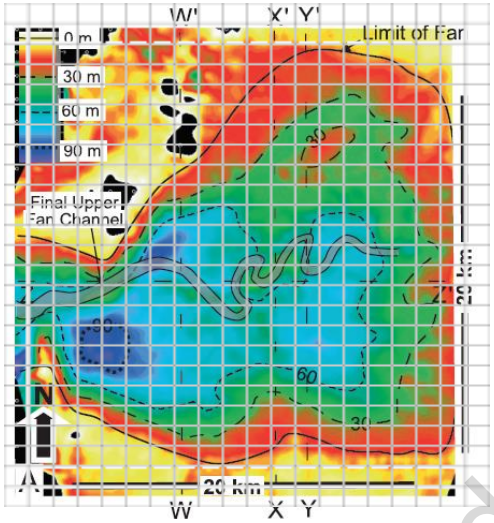
- The third issue is if a prospect is successful- a discovery-then there is no way of evaluating what the impact of this success will be on the adjacent prospects..

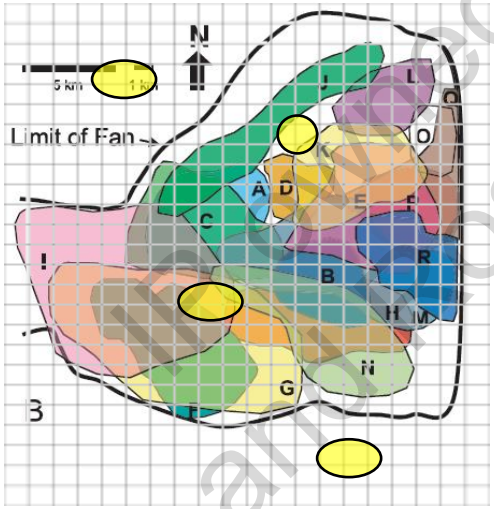


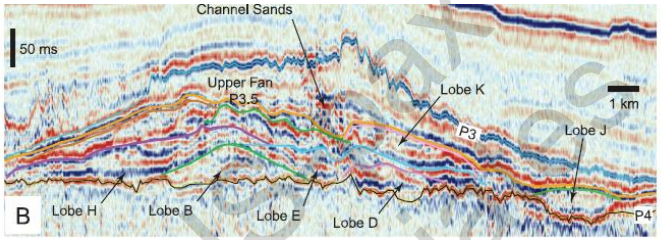
In this case if this prospect is successful what is the impact on these others on the springboard trend area prospects?

Complex Geology Traffic Light Questions..









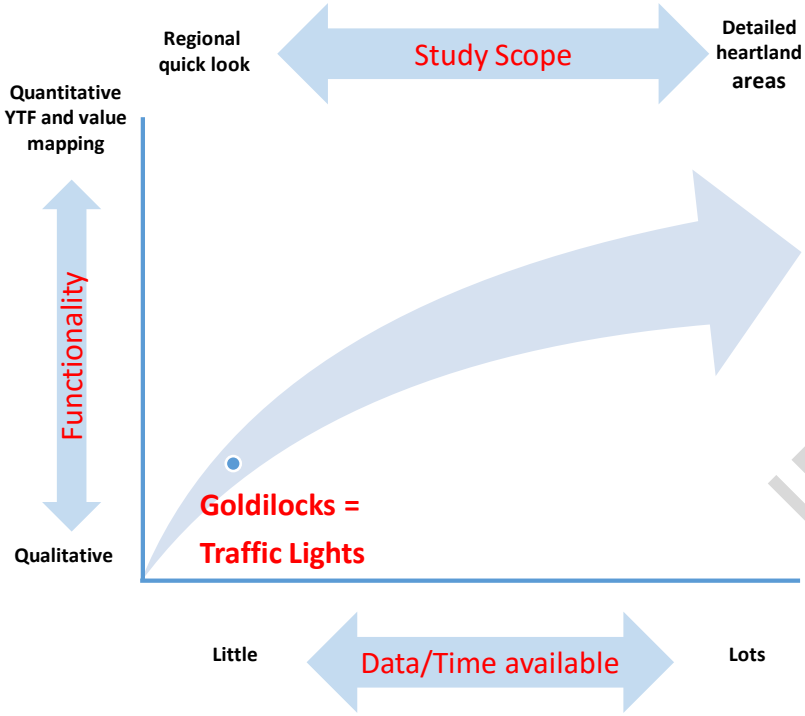
- We have a submarine fan imaged on a 2D seismic grid
- Its undrilled..
- Is there a single green blob over the lobes? Or lots of little ones? If they are undrilled should they be green? The seismic is good and it looks like a fan?! Does green mean proven or just “good”?
- Where is the boundary between the red and the orange? Is it simply an isopach value or geology?

The fourth issue is what do the colours actually mean? How do you deal with areas with complex geology?

Play Fairway definition?– stacking up all the green blobs for Reservoir/Seal/Charge always results in a simple green blob around the fields..

Play Maps Types- Traffic Light Maps Goldilocks Maps

- Useful for spatial focus – qualitative quicklook tool
- Grid based maps dangerous – non geological boundaries
- No link to prospect evolutions
- Nor impact of success on portfolios
- Not clear what colours mean so not good at defining play fairways



Play Map Type	Spatial Insight	Boundaries Geological?	Map Link to Prospect Risk Values	Complex Areas - Definition of play fairways	Portfolio Impact of success
Goldilocks	✓	x	x	x	x

Average Prospect Chance Maps

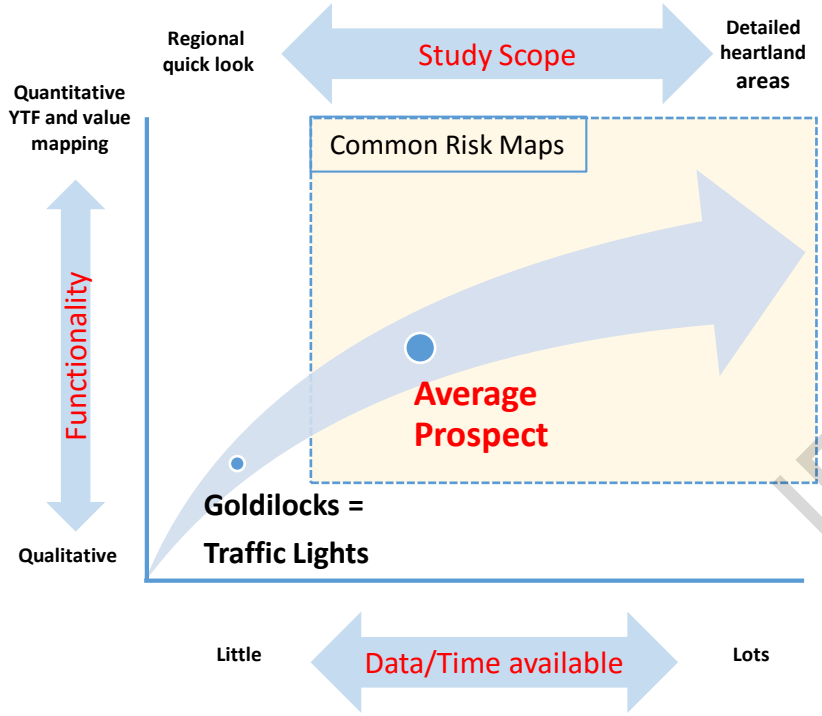
- The second main play map type is where companies try to emulate their prospect maths in a map form
- E.g. if a company has Reservoir Presence x Reservoir Effectiveness x Trap Effectiveness x Trap Presence x Charge then maps of all of these elements are normally made and the results are multiplied
  - Because we multiply these elements in our prospect maths
  - Note Trap Presence now normally included because that is what we do with prospects
- Typically the boundaries drawn are now NOT grids – they are polygons and the boundaries are geological boundaries – these are Common Risk Segment Maps (senso stricto)
  - Abrupt and significant changes of the geology
  - Key here is to record on each input map what the boundaries are based on..
  - One commercial software product does however still use a “rules based” approach to generate average Prospect Pg/POS/COS maps (i.e. when the isopach is > 200m the Pg Reservoir presence is 0.8 etc – we would not recommend this approach for numeric estimates – the product here would be a “goodness” map NOT a CRS/Play map in our nomenclature)
- If we have a CRS polygon with prospects in it now we also have some indication of what the prospect POS/COS/Pg’s might be. Not exact but an indication and guide.

The biggest problem

- With average chance maps is it tells us nothing about influence ie. If the play is “proven” or not
- i.e. a proven play segment 100% chance with a local prospect risk of 25% looks exactly the same as a 50% play segment with a 50% local risk. The overall Pg/POS/COS is the same but they are totally different beasts..

Play Chance Maps Types – Average Prospect

- These maps are numeric and based on geological boundaries
- There is a soft link with real prospects
- But they still cant be directly used for prospect evaluation nor deal with complex geology issues nor predict success impact.



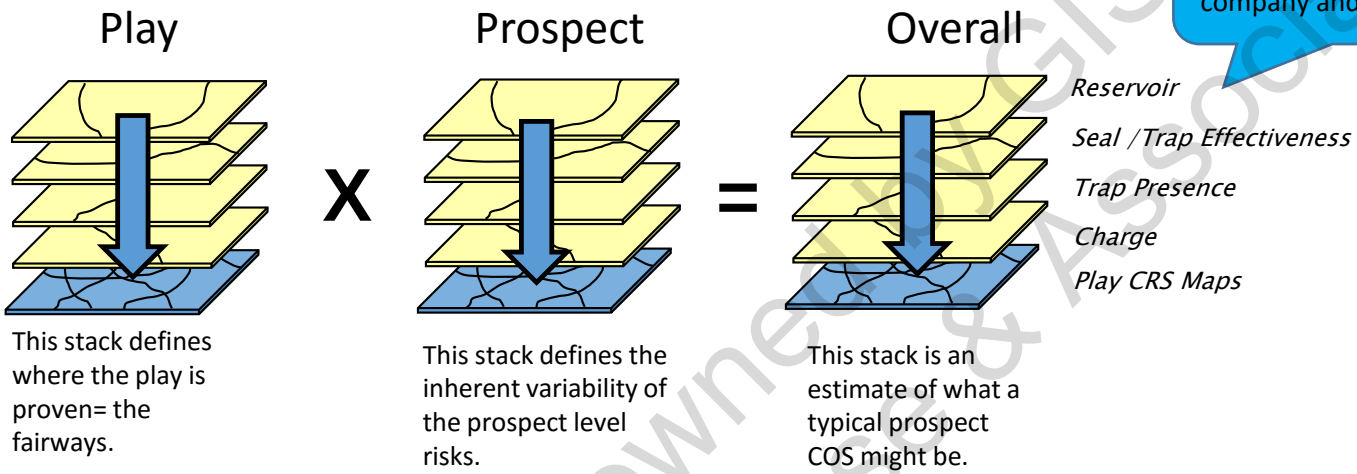
Play Map Type	Spatial Insight	Boundaries Geological?	Map Link to Prospect Risk Values	Complex Areas - Definition of play fairways	Portfolio Impact of success
Goldilocks	✓	✗	✗	✗	✗
Average Prospect	✓	✓	✓	✗	✗

Split Risking Play Maps

- The third main play map type is similar to Average Prospect Maps except the shared and local/prospect specific risks are separated out
  - Each Polygon has 3 values
- Methodology championed by Exxon (& Shell)
- These maps are ALWAYS polygons/CRS maps
- The boundaries are always geological not computer driven
- The key theoretical learning is HOW to do this splitting..
  - This is a skill NOT commonly taught in E&P companies and many managers and senior people have not see this in their careers – especially those from BP…
  - Note Every Senior Manager (often non-technical) is concerned about double dipping which they perceive might make your POS/COS/Pg estimates lower. We are Spitting the risk NOT double dipping. The numbers should not change!

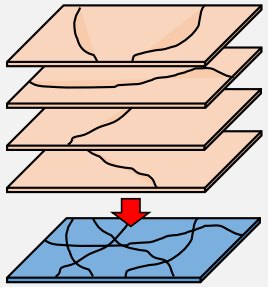
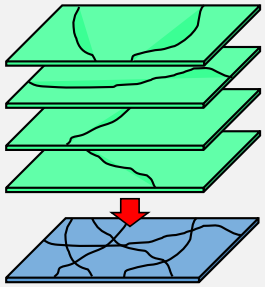
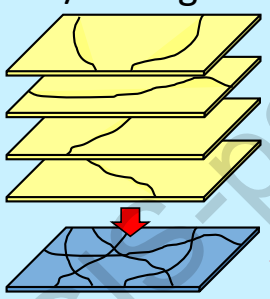
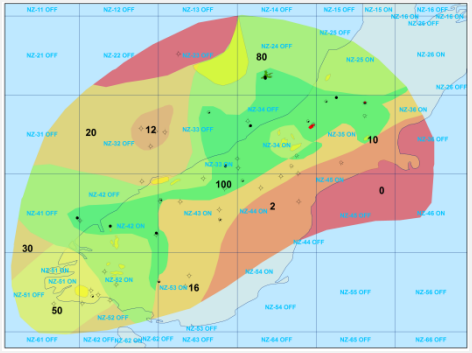
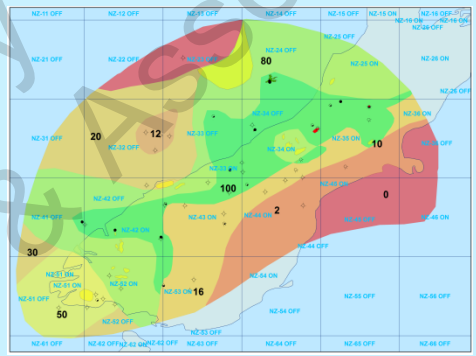
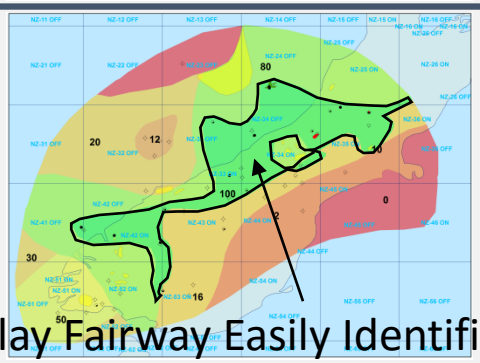
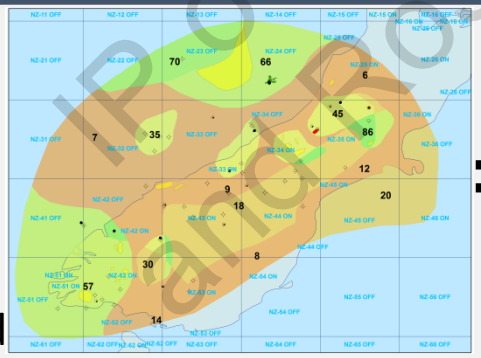
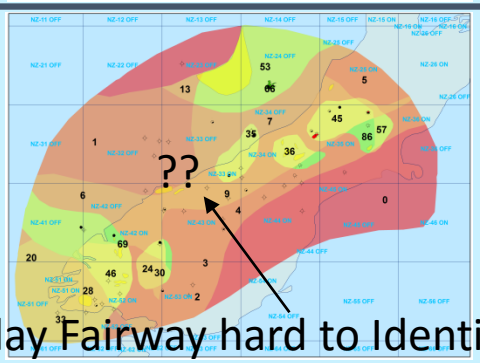
Split Risking Stacking

- Each Polygon has 3 values –
- shared/play x not/shared/local/prospect specific = Average Prospect POS/COS/Pg



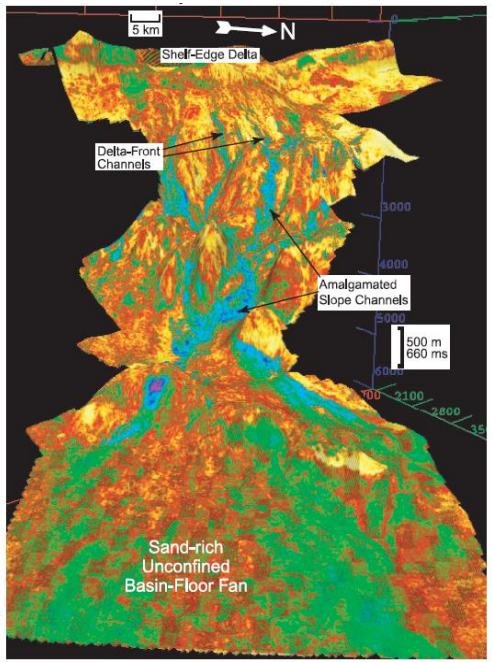
Split Risking Stacking

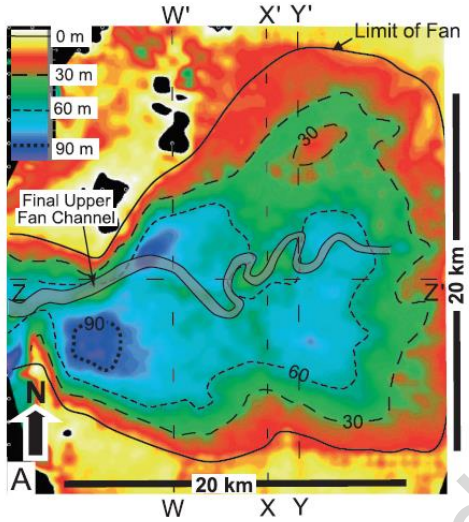
In areas of complex geology split risking will better define your play fairways….

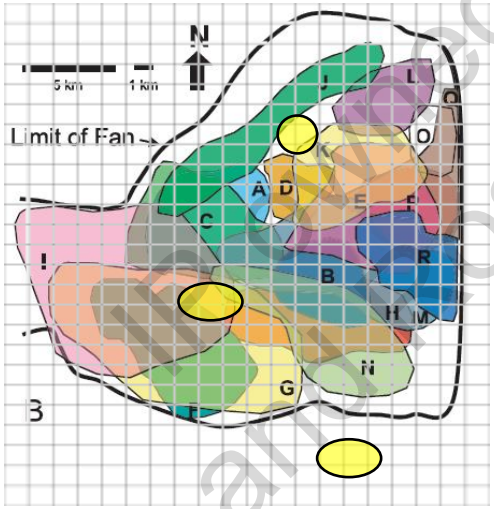
	Play		Prospect		Overall/Average Prospect Chance
		x		=	
	This stack defines where the play is proven: the "fairways".		This stack defines the inherent variability of the prospect level risks.		This stack is an estimate of what a typical prospect Pg/COS might be.
Layer-cake geology and ubiquitous charge		x		=	
lateral reservoir and seal variability with complex charge		x		=	
	Play Fairway Easily Identified				Play Fairway hard to Identify

Split Risk Example

Slope/Basin Fan Complex Evaluation



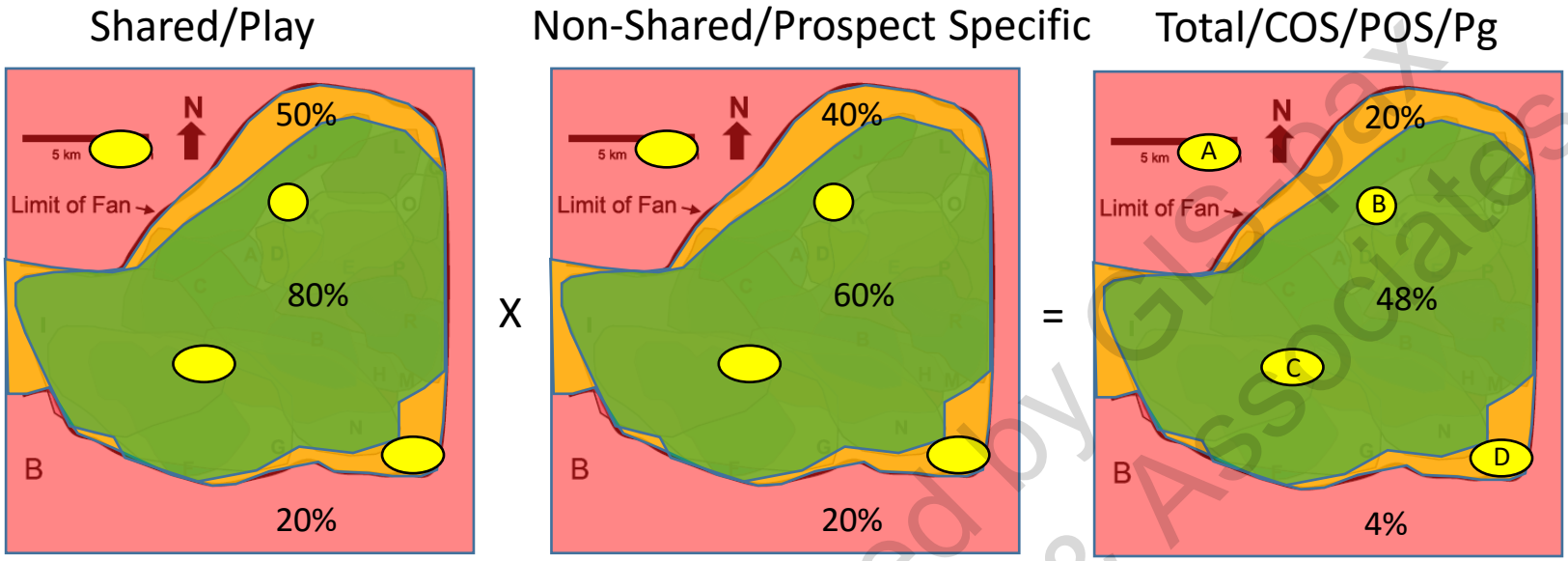




Undrilled Prospect

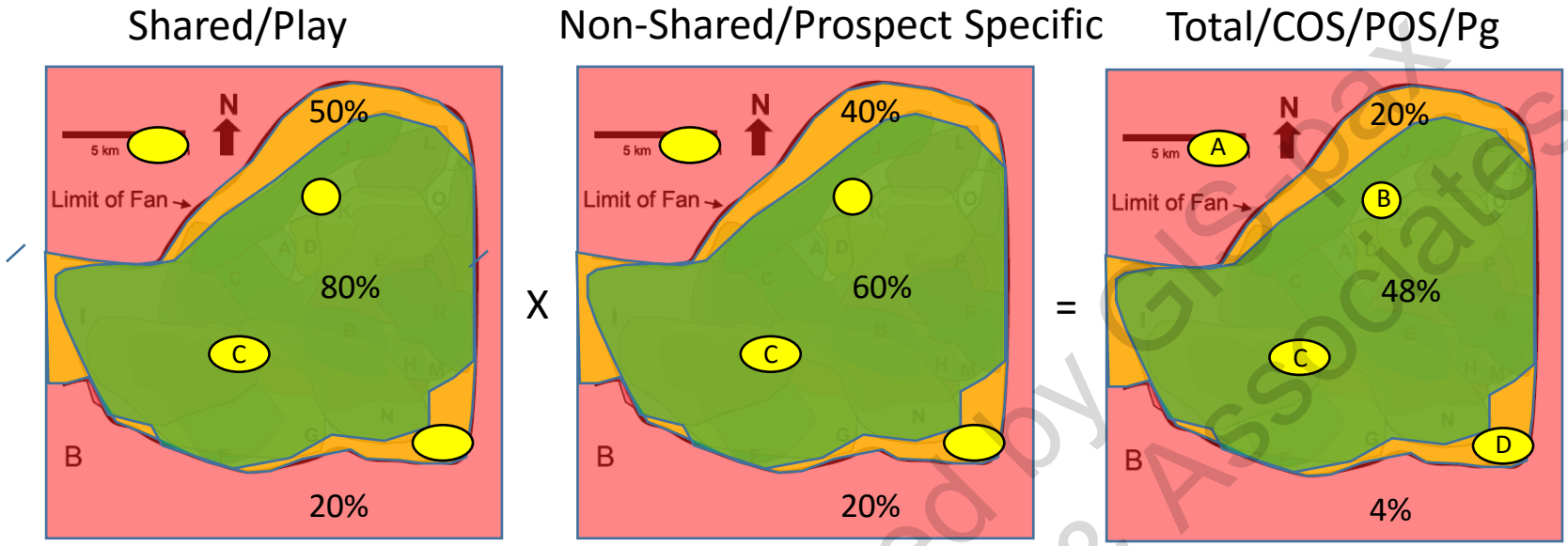
- We have a fan defined on a good quality 2D seismic grid
- Now we are going to evaluate the Reservoir Presence probability
- Process is the same for all other risk elements

Split Risking Example..



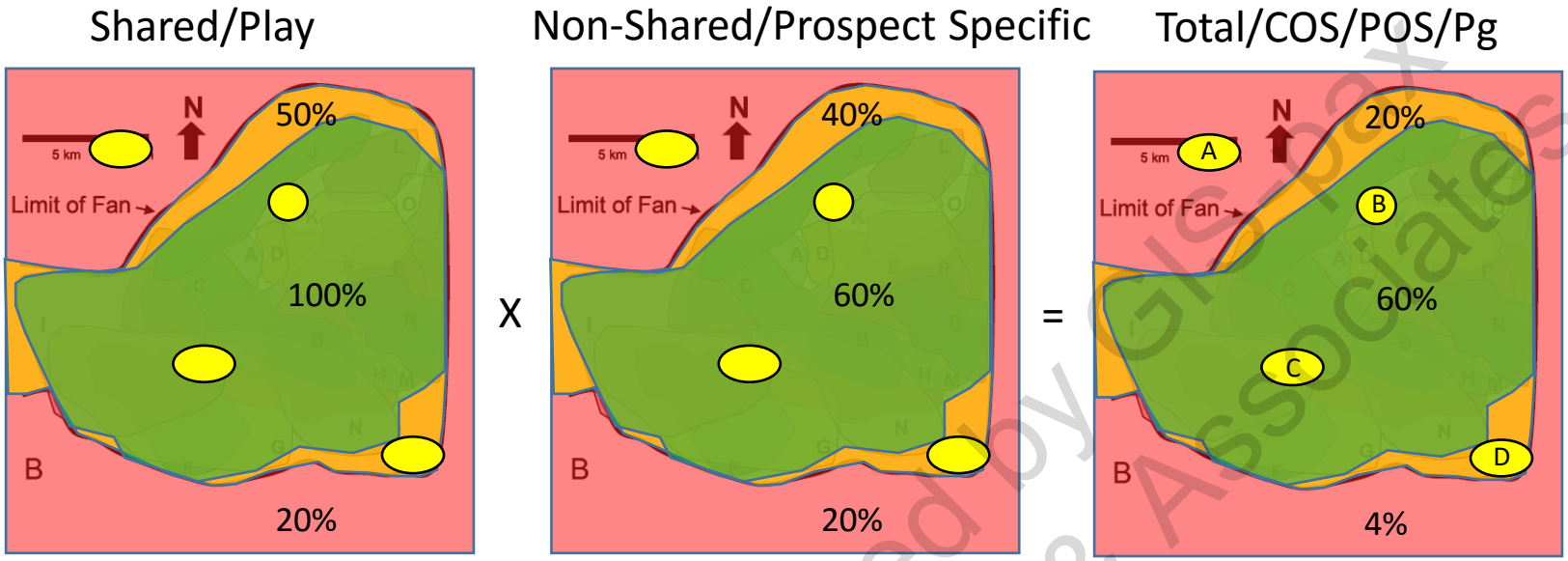
- We make estimates of the probability of reservoir presence ANYWHERE in the polygon then estimate the REPEATABILITY to estimate the AVERAGE Pg/POS/COS
- Note by doing this we do NOT have to map all the lobes and the maps are simple and quick to draw..(and we do NOT use raster values/nor use a grid)
- In this case prospects B&C would have Prospect chance values for Reservoir of ~50%

Split Risking Example..



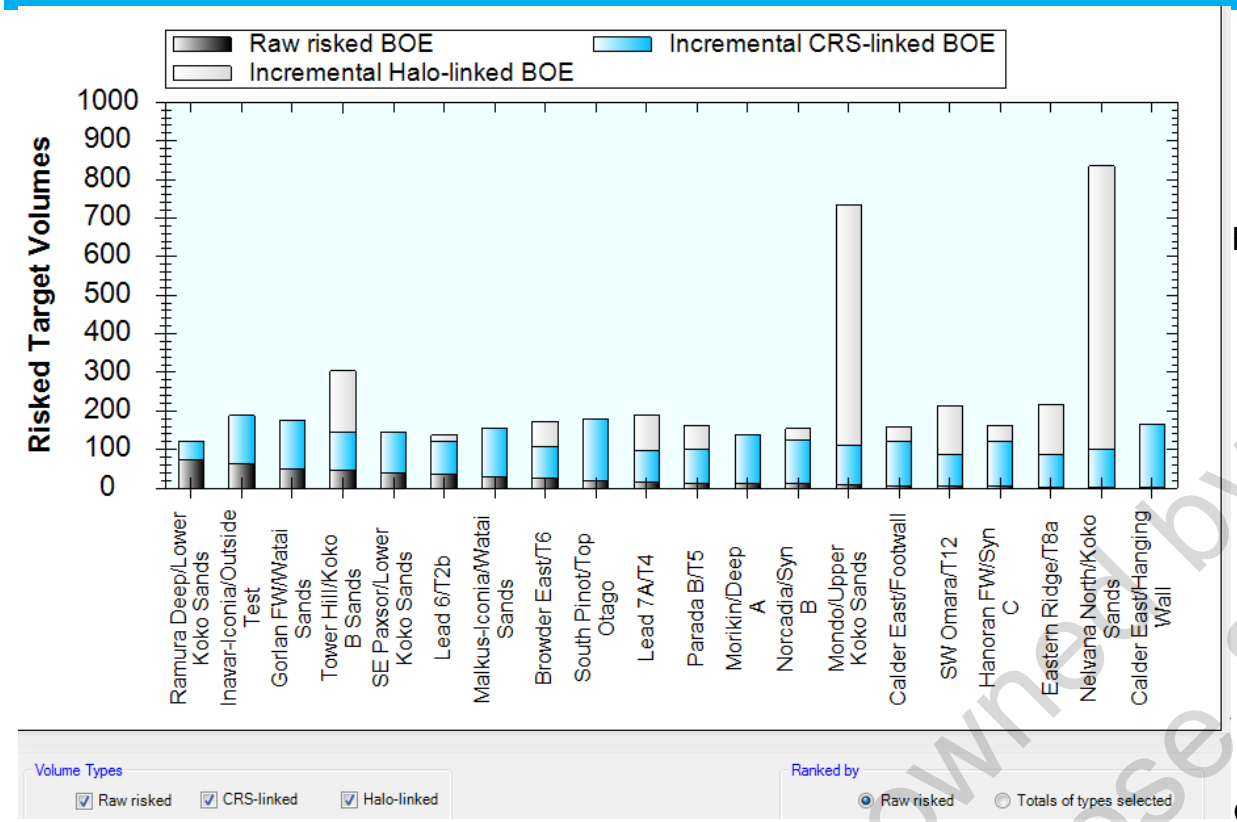
- So now if we drilled prospect C and it found sand what would happen?

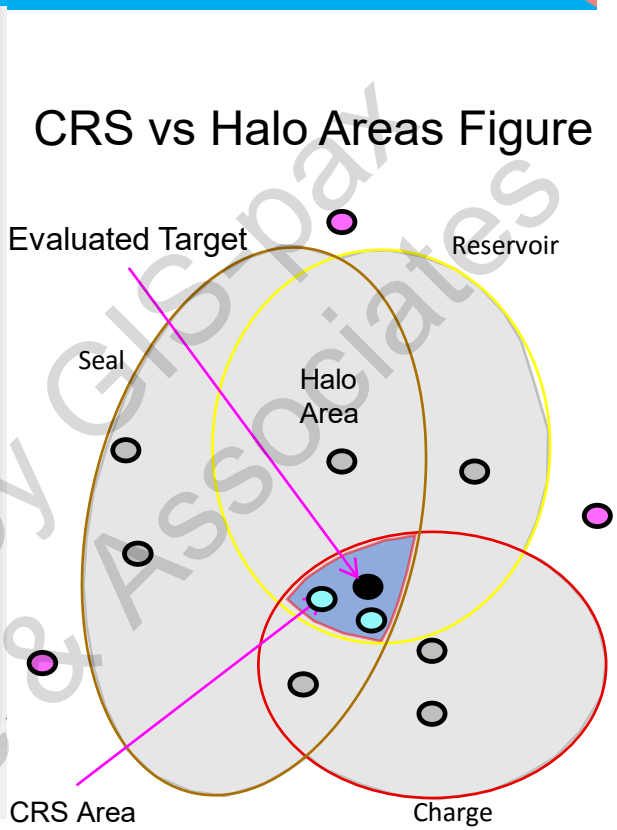
Split Risking Example..



- The play risk would now go to 100% in the central blob AND the prospect reservoir risk for prospect B would have increased from 48% to 60% AND prospects A&D would NOT be affected/changed..
- So if we do this for all the chance elements/maps then before we drill we can now calculate the effect of success of one prospect on all the other adjacent prospects.. These are called success volumes (& values) delivered from the portfolio based on success of each feature..

Example of Success Volumes Chart



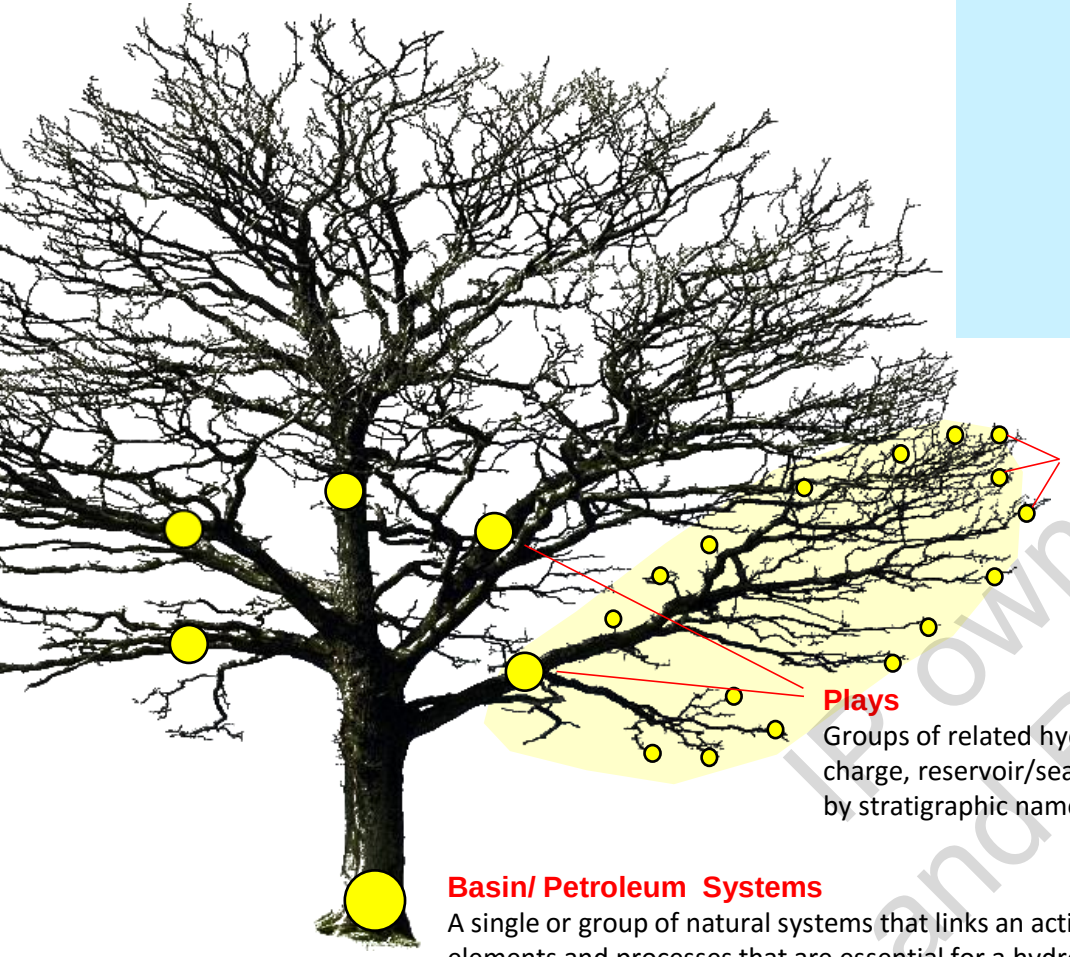


- This plot ranks the risked volumes (or values) of each prospect target plus the incremental impact that success will have on the adjacent prospects through the de-risking of play segments
- This will change what you drill…and its why its worth doing play analysis

Evaluated Target
Other targets who's risked volumes and value will change significantly if evaluated target is successful
Other targets who's risked volumes and value will change incrementally if evaluated target is successful
Other targets who's risked volumes and value will NOT change if evaluated target is successful

So Now We Can Properly Compare the Different Branches..

- **We normally drill single prospects**
  - Some will fail for local/prospect reasons and have zero impact on our understanding of the play potential
  - Others will prove/highgrade or condemn/downgrade a play –
  - PBE is understanding these linkages before you select which prospect to drill **AND** how these might change after you have drilled a prospect.



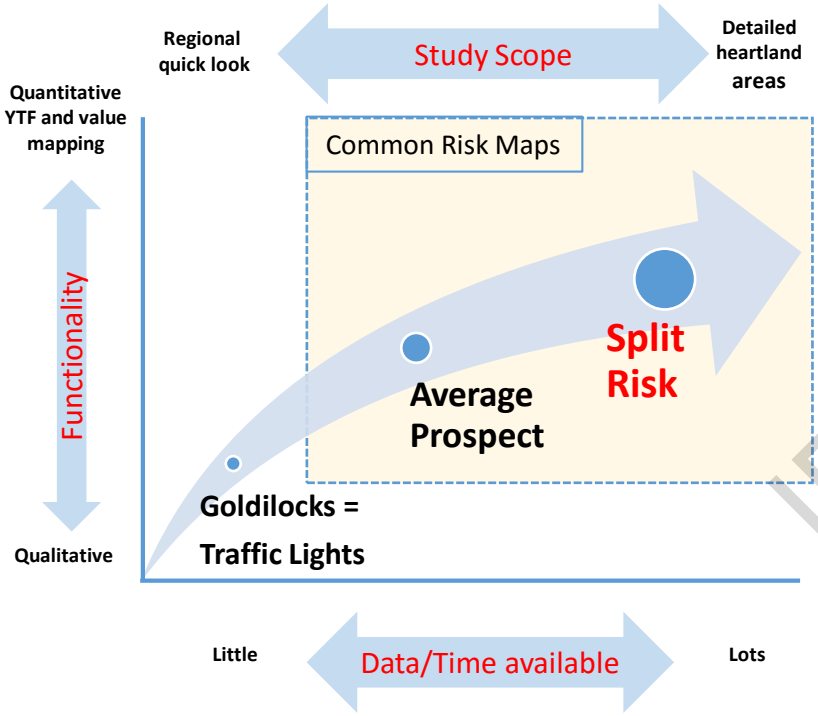
Prospects
A collection of potential traps some of which when drilled will be successful (oil or gas field) and some will fail and be quickly forgotten!

Plays
Groups of related hydrocarbon fields, pools and prospects that have similar charge, reservoir/seal and trap controls on their occurrence. Typically defined by stratigraphic name or age.

Basin/ Petroleum Systems
A single or group of natural systems that links an active or once active source rock with all of the geologic elements and processes that are essential for a hydrocarbon accumulation to exist in time and space. (Effective source socks linked via migration to one or more reservoir/seal pairs..)

Play Maps Types- Split Risk

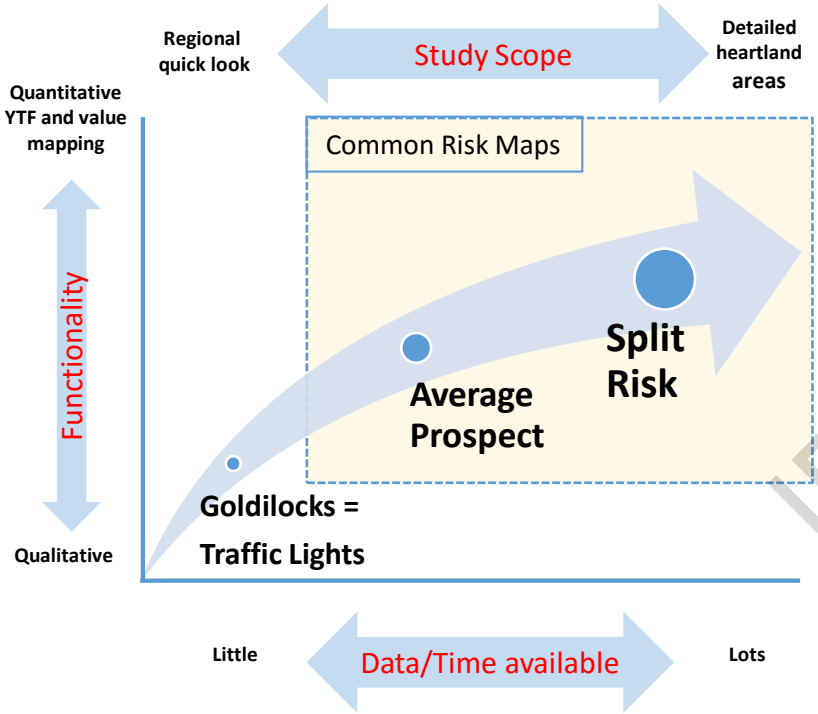
- The advantages are.
  - There is a direct numeric link between the play maps and the prospect risking estimates
  - In areas with complex geology the play fairways are readily defined and identified
  - The impact of success of one prospect on others can be quantified



Play Map Type	Spatial Insight	Boundaries Geological?	Map Link to Prospect Risk Values	Complex Areas - Definition of play fairways	Portfolio Impact of success
Goldilocks	✓	✗	✗	✗	✗
Average Prospect	✓	✓	✓	✗	✗
Split Risk	✓	✓	✓	✓	✓

Play Maps Types Summary

- There are 3 basic types of Play Maps but only split risk maps can deliver insightful analysis and deliver proper Play Based Exploration decisions
- There is no "correct" way to do Play Analysis – they all give spatial focus - its about understanding what else you want from the evaluation and focussing on the geology NOT arguing about colour bars..
  - We can make all types in Player easily.. and even move from one type to another in the same project*



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Split Risk	✓	✓	✓	✓	✓

*We actually recommend explorers make simple traffic light maps from their split risk map in puts for senior management consumption

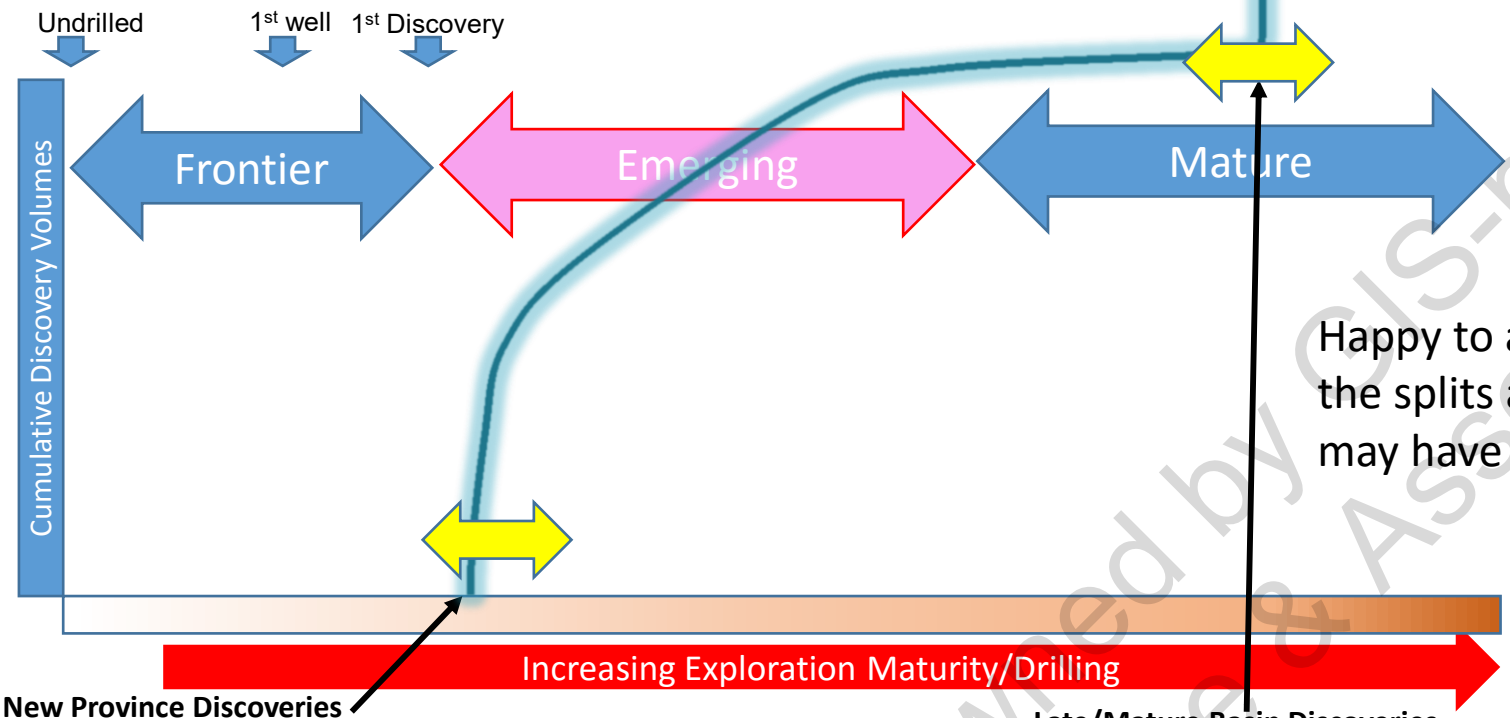
Why Bother with Play Mapping?

1. Play Mapping Types – why all the confusion?
   a) Goldilocks Maps = Traffic Light
   b) Average Prospect Chance Maps
   c) Split Risking Maps
2. Why seismic amplitudes will NOT be the silver bullet for exploration in mature basins.
3. Why Charge Models are dangerous and often wrong.
4. The mature basin “Green Blob” problem and the solution.
5. YTF – explained.
6. Summary

Amplitude Supported Exploration

- Is based on fantastic and impressive technology
- My personal experience is however that it is often a poor exploration tool even in mature exploration settings simply because the petrophysical/acoustic properties of the seal and reservoir intervals are highly variable and its hard to predict these accurately pre-drill even with “close” well control.
  - Its is obviously a technique that is less effective for deeper targets which are at or below “the amplitude floor”
  - Many Mesozoic rifts have less favourable initial contrasts between sand and shales making amplitude calibration more difficult than in the Tertiary sequences.
- But as an industry we worship this technology and hold it in high regard so how many large globally significant discoveries has it delivered recently in mature settings??

Here is my list of the big/significant discoveries of the last ~decade divided into frontier and mature discovery settings..



Happy to argue/debate the splits and add ones I may have missed..

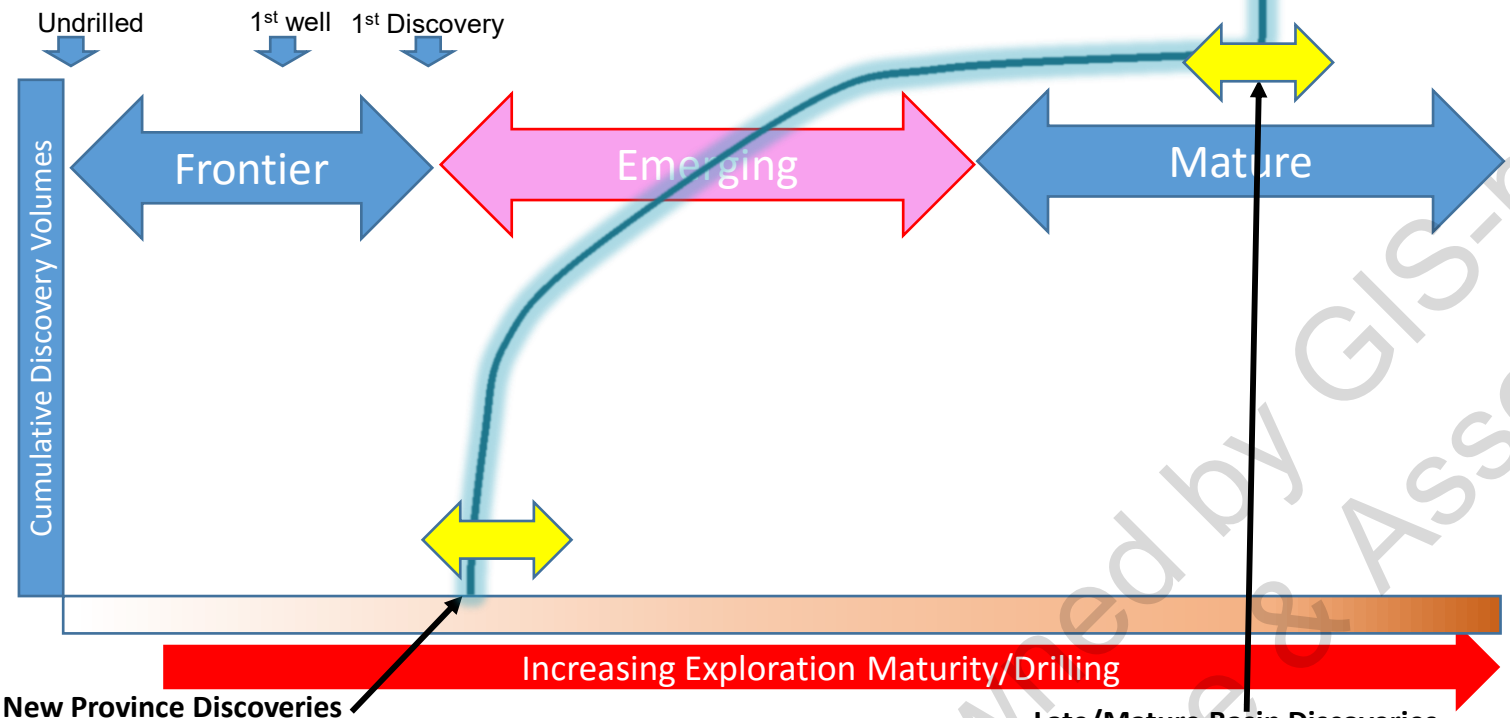
New Province Discoveries

- Mangala/India/Cairn/2005
- Lake Albert/Uganda/Tullow nee Hardman/2006+*
- Santos Subsalt/Brasil/Petrobras/2006
- Jubilee/Ghana/Kosmos/2007**
- Tamar/Israel/Noble/2009*
- Ravuma/Mozambique/Anadarko/2012*
- Senegal/FAR & Cairn/2014 SNE & FAN *
- Pobeda (Victory)/Kara Sea/Rosneft/2014
- Liza Exxon Guyana (2015)

Late/Mature Basin Discoveries

- Buzzard/UK/Nexen/2001(NAS)
- Wilcox DW GOM/Baha-2/Shell 2001 (NAS)
- Tawke/DNO/Kurdistan (2005) ++
- Perla/Venezula/Repsol-Eni/2009 (?NAS)
- Flemish Pass/Statoil/Canada/2009
- Johan Sverdrup/Norway/Lundin/2010 (NAS)
- Cameia/Angola/Cobalt/2012 (NAS)
- Zohr Eni Egypt 2015 (NAS)

So lets now colour up the amplitude supported discoveries as red....



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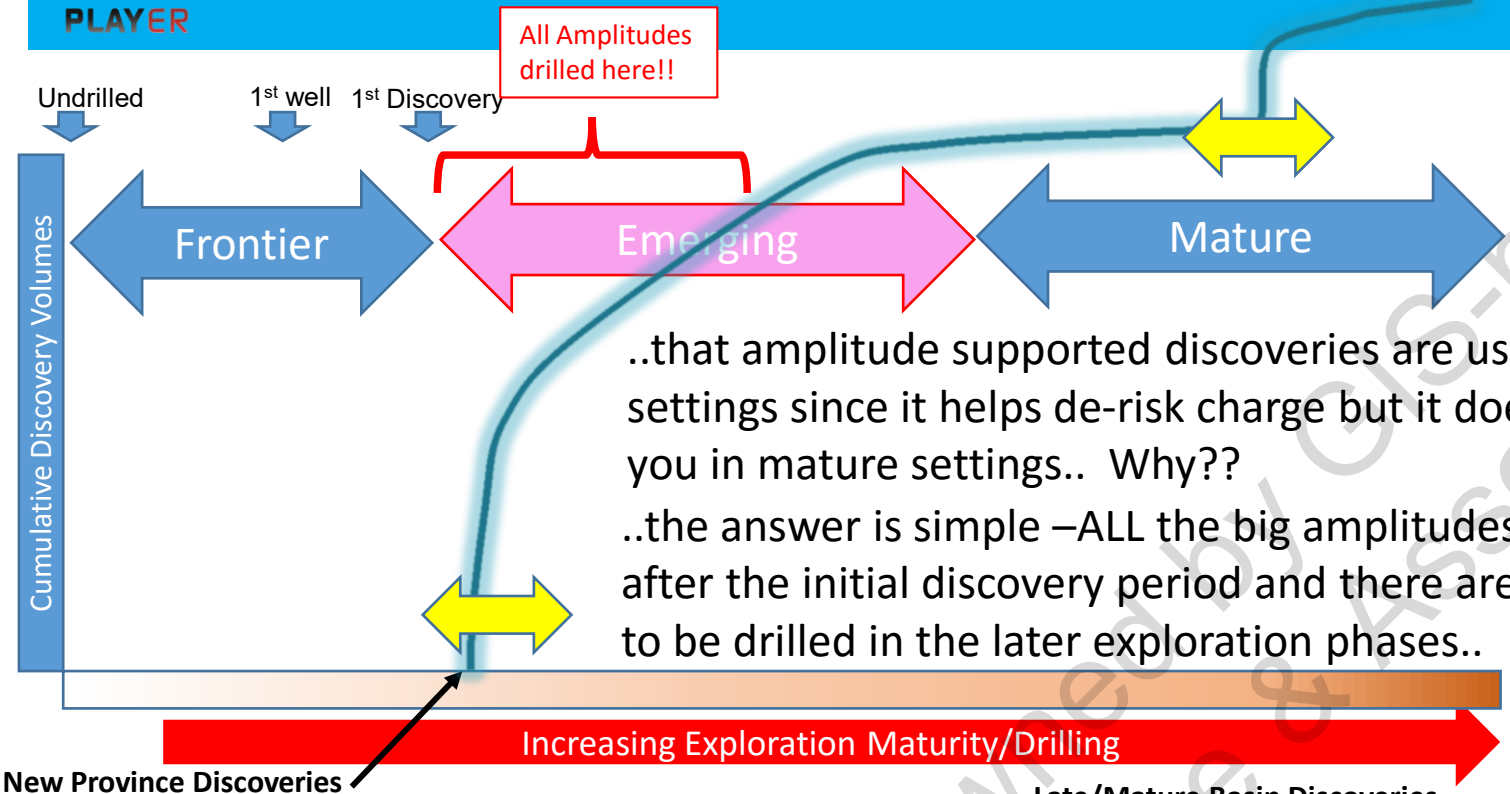
My conclusion is..



..that amplitude supported discoveries are useful in frontier settings since it helps de-risk charge but it does little for you in mature settings.. Why??

..the answer is simple –ALL the big amplitudes get drilled after the initial discovery period and there are none left to be drilled in the later exploration phases..

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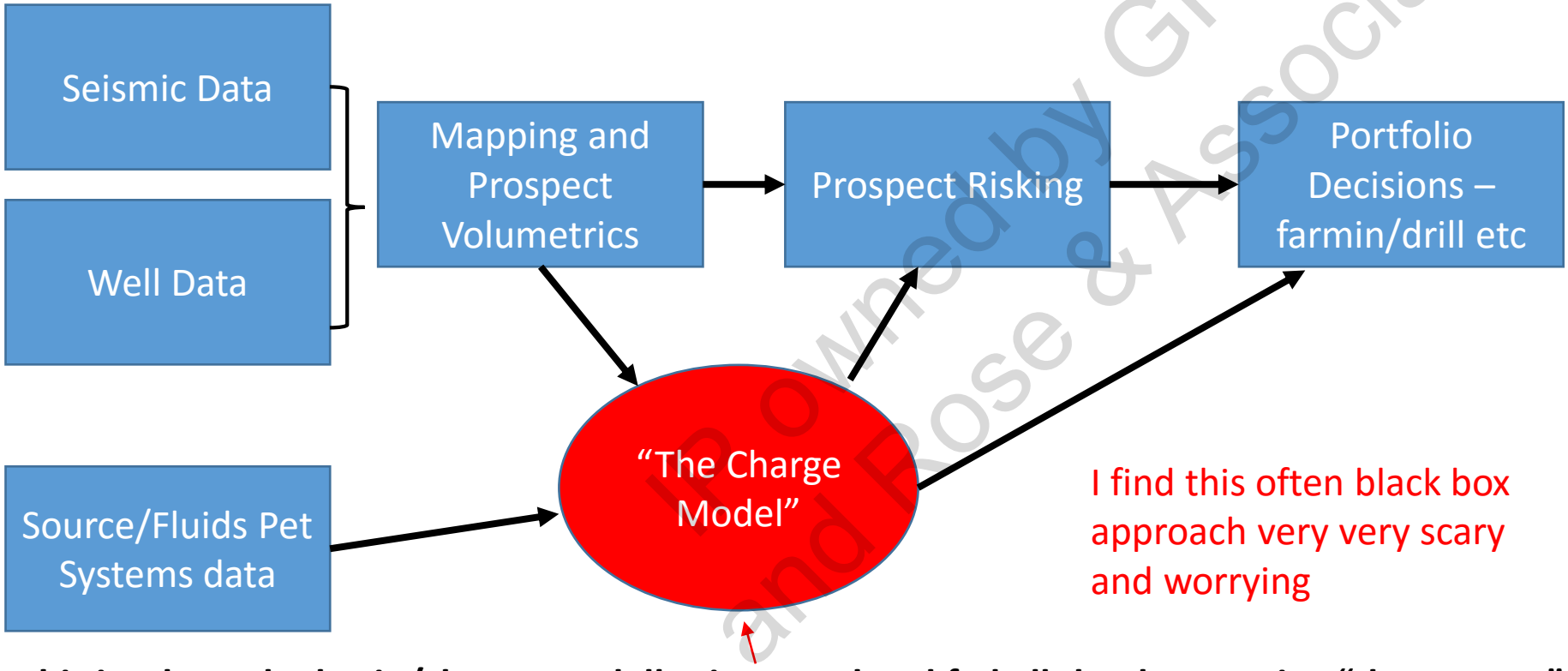
Common Workflows..

- All exploration companies do work and then shove the inputs together and then try and make decisions..
- I often see this workflow in companies



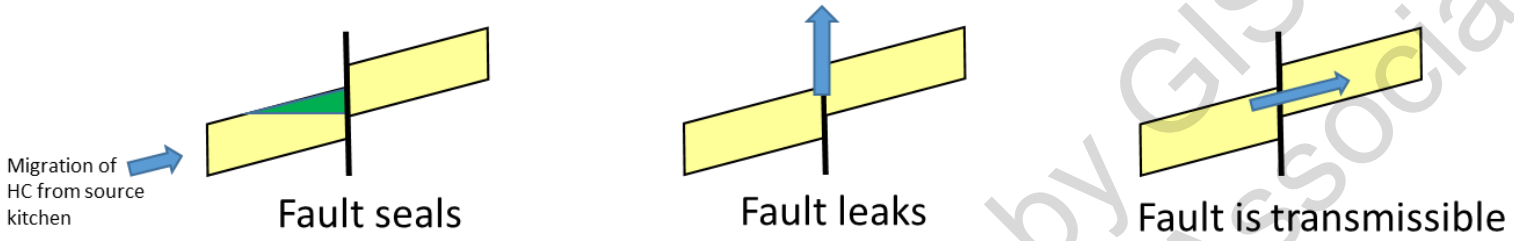
This is where the basin/charge modeller is central and fed all the data to give "the answer"

Sacred Cows

- Charge Modelling Software is very impressive kit
- Especially in animations when it spins in 3D and shows hydrocarbons migrating
  - Senior managers love this stuff
- But technology does not equal understanding and many of the inputs into these models are poorly qc'ed and poorly understood – especially by senior managers..
- Beyond specific boffin technical issues – always ignored..
  - Like in one of the main tools used widely in the industry today which still has no consideration of transient heat flow effects in the crust - this means that heat flow is overestimated and does not respond properly to crust thickness changes laterally or through time. This makes it impossible to correctly extrapolate from where you have temperature data (on the highs generally) to where the source rocks are (in the lows generally).
- There are generic issues with the whole process particularly surrounding the understanding of migration and source presence

Why Most Charge Models are Wrong and Dangerous I. Migration

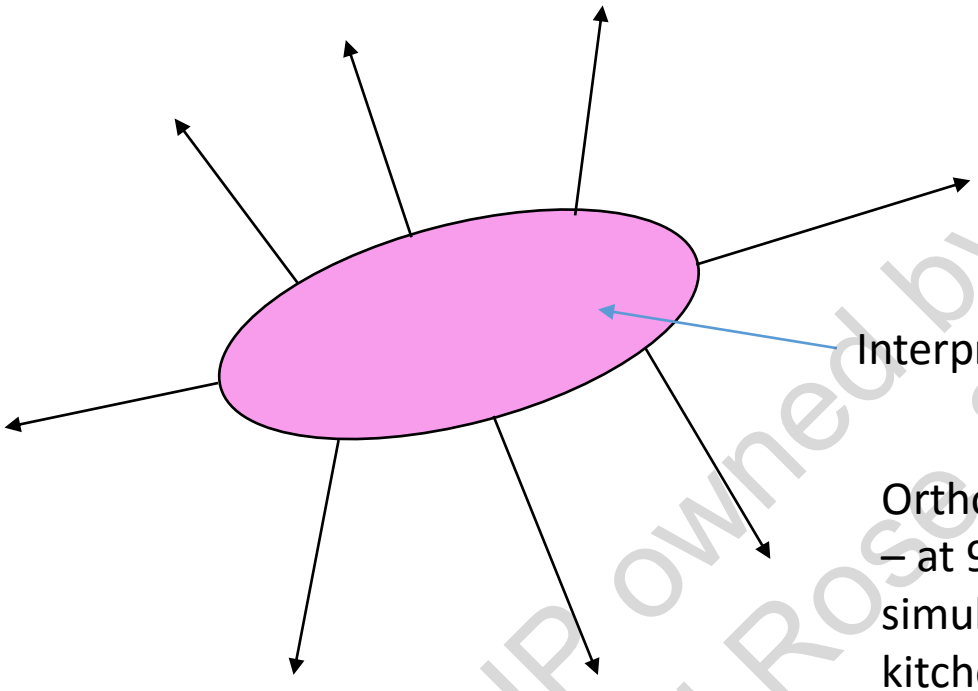
- Migration is an INPUT to these models NOT an output
  - Most/all basins have faults
  - When migration hits these faults we have no idea what will happen



  - So we tweak the migration models to fit the known distribution of hydrocarbons (and shows)
  - Every hc shows database I have seen has been full of misleading rubbish – so the quality of your migration is always limited by how well you have calibrated your pools and shows database

Typical Migration Calibration

Hairy Dog/ Amoeba Maps in Oz slang..



Interpreted mature kitchen area

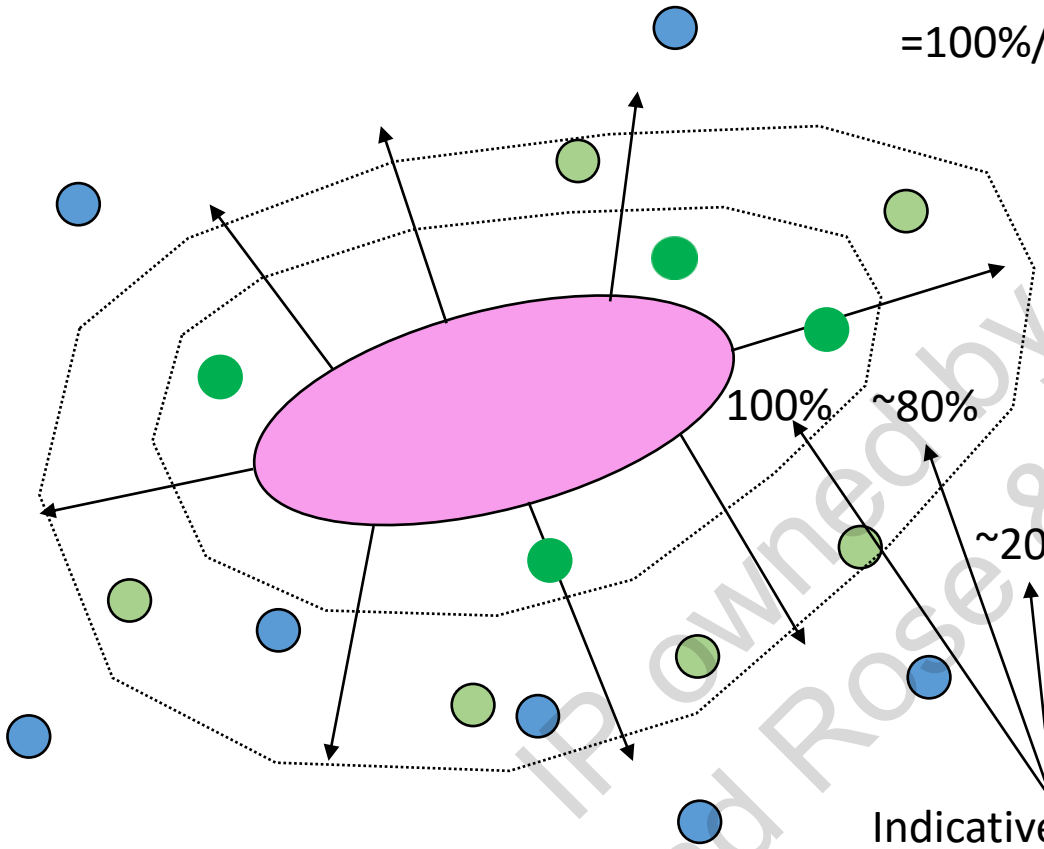
Orthocontours – migration lines – at 90 degrees to contours simulating migration from the kitchen in target play interval

(vertical migration from underlying SR interval assumed to be 100%)

Typical Migration Calibration

Hairy Dog/ Amoeba Maps in Oz slang..

Proven kitchen example – at least one discovery is present – SP &SM =100%/proven



HC Discoveries

Wells with shows in database

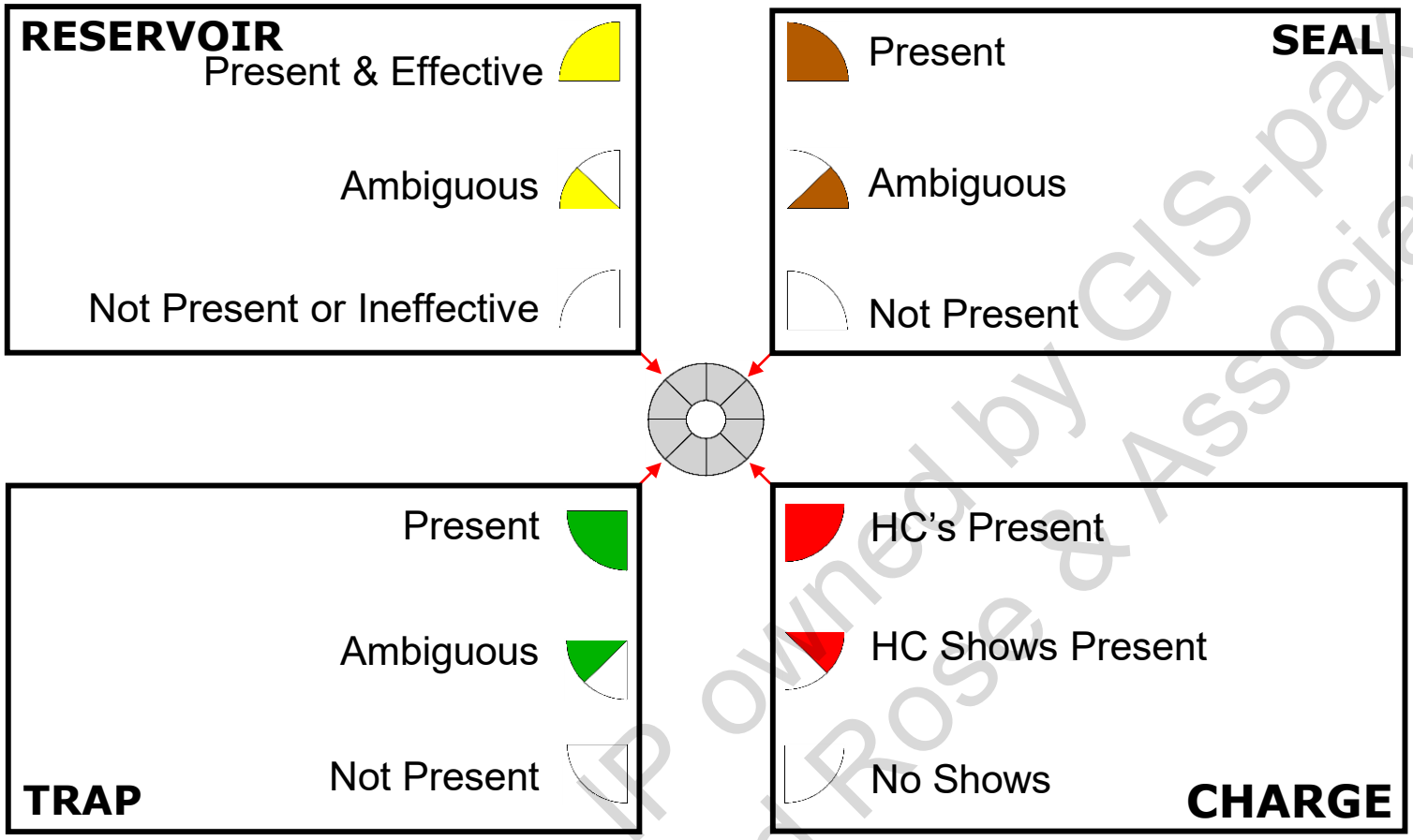
Wells with no shows in database

Indicative Common Risk Polygon Values

Migration Problems -2

- Even if you do have a quality shows and pools database that has been qc'ed
- The other key element that needs to be incorporated to understand migration is well failure analysis
- This needs to be done systematically (not in Excel)
  - And the interpretations change as the data changes

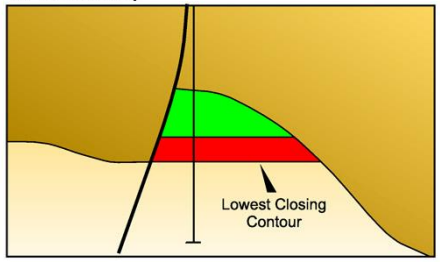
Systematic Failure Analysis



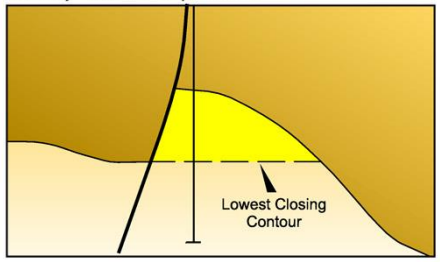
Player has a systematic post drill analysis (PDA) module that steps geologists through a well failure analysis for each of the user defined play intervals

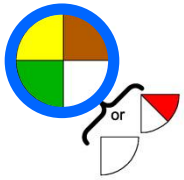
Player Post-drill Analysis Hierarchical Classification Scheme

1. Discovery

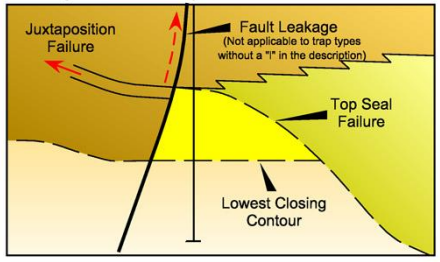


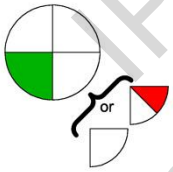
2. Dry Valid Trap Tests



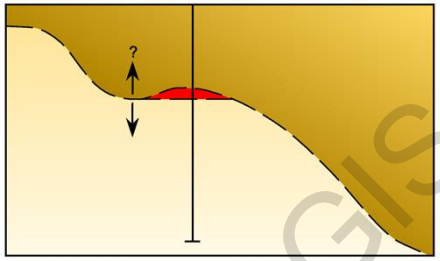


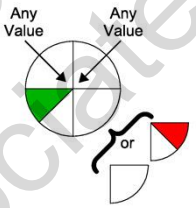
3. Dry Failed Trap Tests



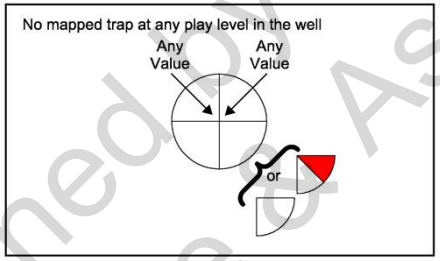


4. Dry Low Confidence Trap Tests

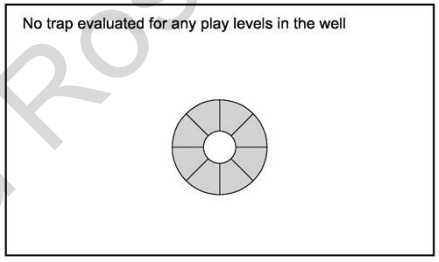




5. Off Structure Tests



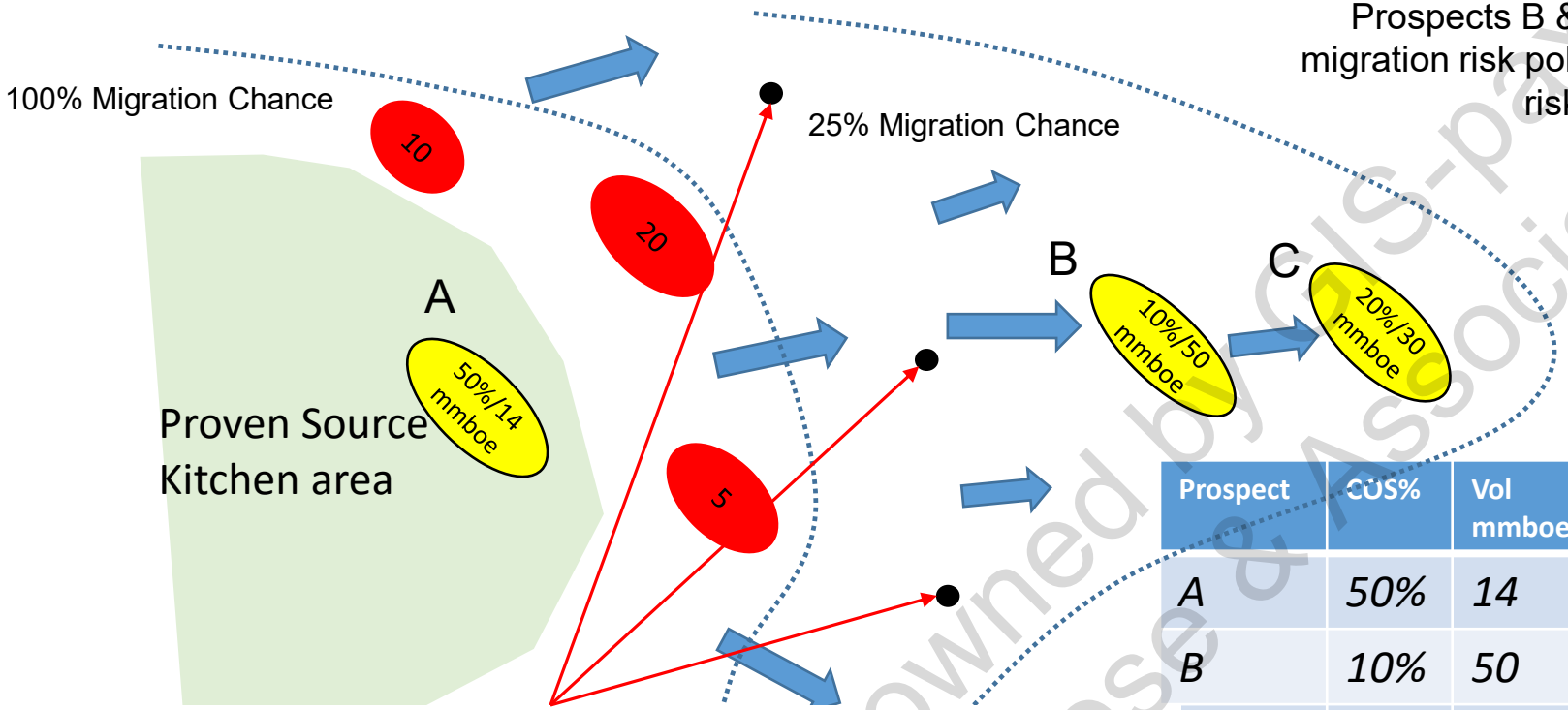
6. Unevaluated



We do this in a database that is evergreen - play by play

Back to that initial example

Migration Evaluation Added Prospects B & C in same migration risk polygon = shared risk



Prospect	COS%	Vol mmboe	Product
A	*50%*	*14*	*7*
B	*10%*	*50*	*5*
C	*20%*	*30*	*6*

The failure analysis of these three wells in this example are key to understanding the migration risk to prospects B &C..

- If they all TD'ed above this play they tell us nothing!
- If they all penetrated the play but we all off structure this also tells us nothing!
- But if they were all dry valids (charge failures) then we would need a good story to explain why we think they failed and B & C will work…

Understanding well failures is not academic… its key to understanding your prospectivity evaluations

Legend

HC Field mmboe

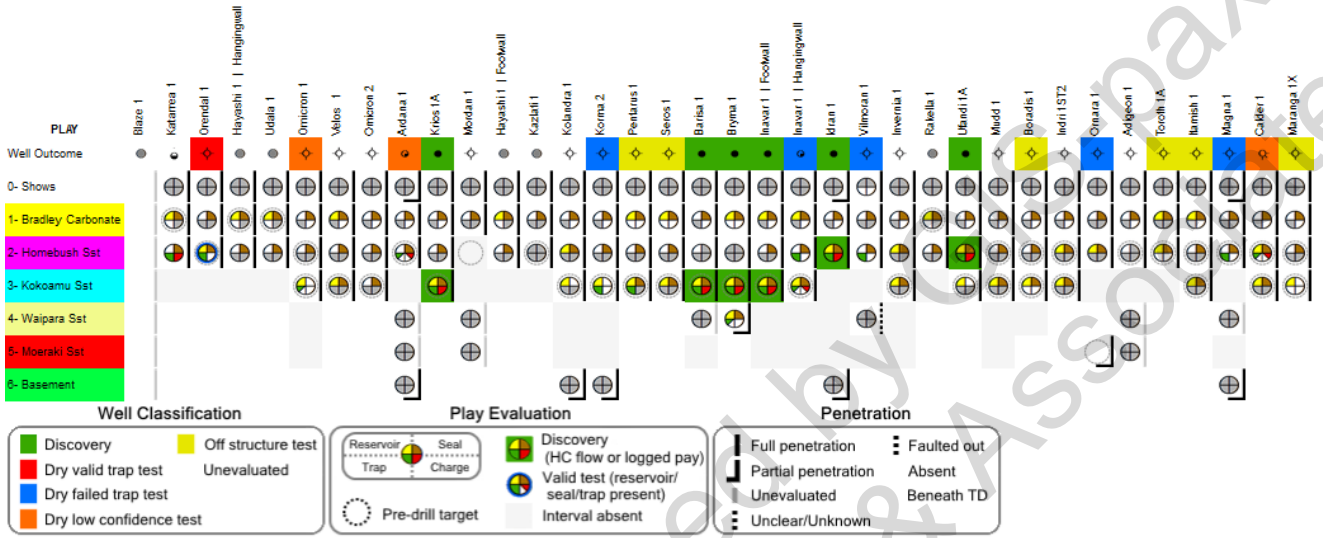
Dry Wells

Migration Directions

Prospect COS/mmboe mean volumes (mmboe)

Example Player Data

- This is an example of the PDA data collected by well and various play intervals



- This data is used to..
  1. Understand the well results- what the wells are telling us - explaining why a play interval in a particular well worked or failed
  2. Help constrain on maps both the known play limits and the distribution of the constituent play element maps for each play interval using any of the 3 main play map types that the industry uses
  3. Calibrate historical play level specific success rates and failure mechanisms which can be used to help calibrate prospect estimates

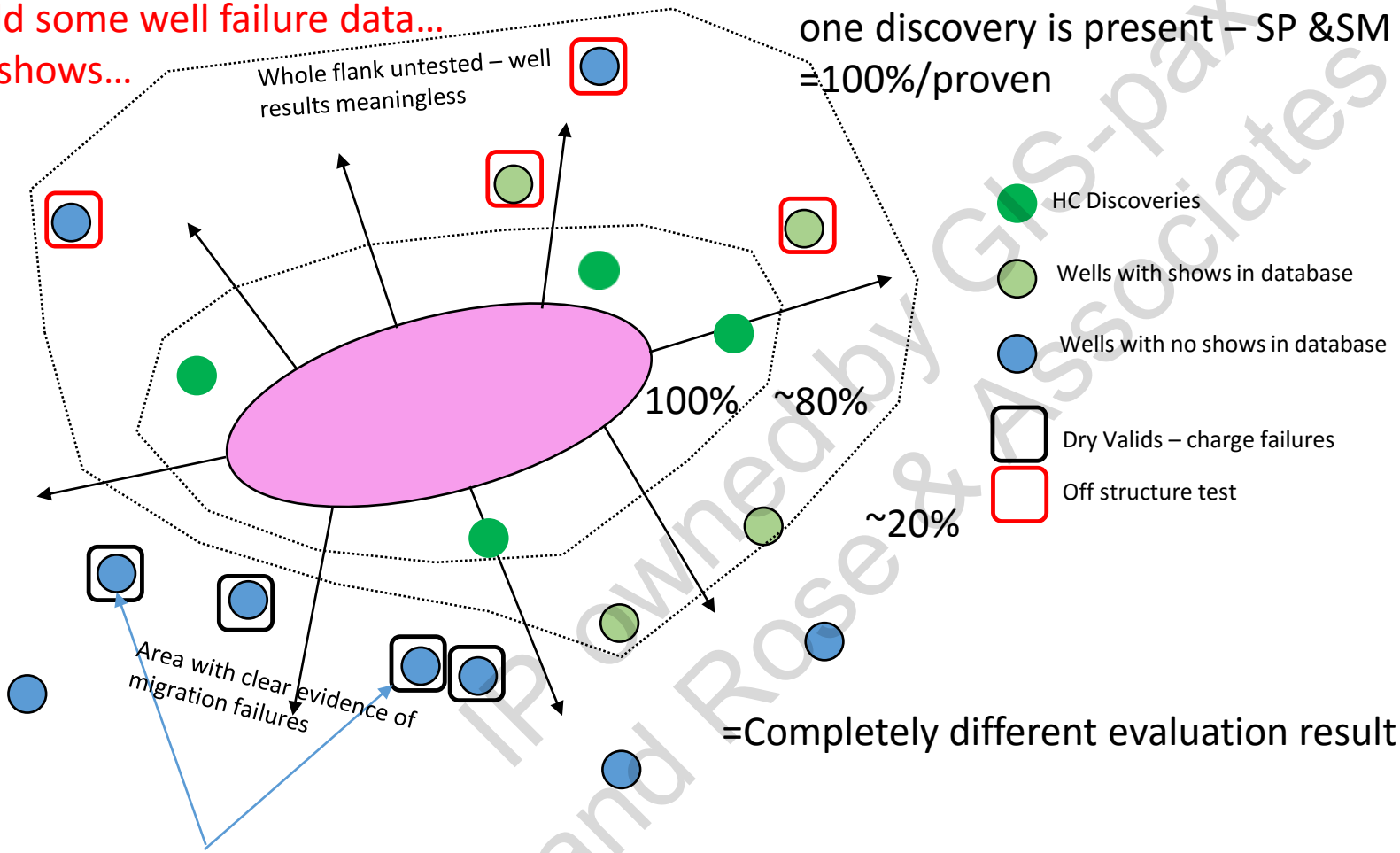
Typical Migration Calibration

Hairy Dog/ Amoeba Maps in Oz slang..

Now lets add some well failure data…

And qc the shows…

Proven kitchen example – at least one discovery is present – SP &SM =100%/proven



=Completely different evaluation result

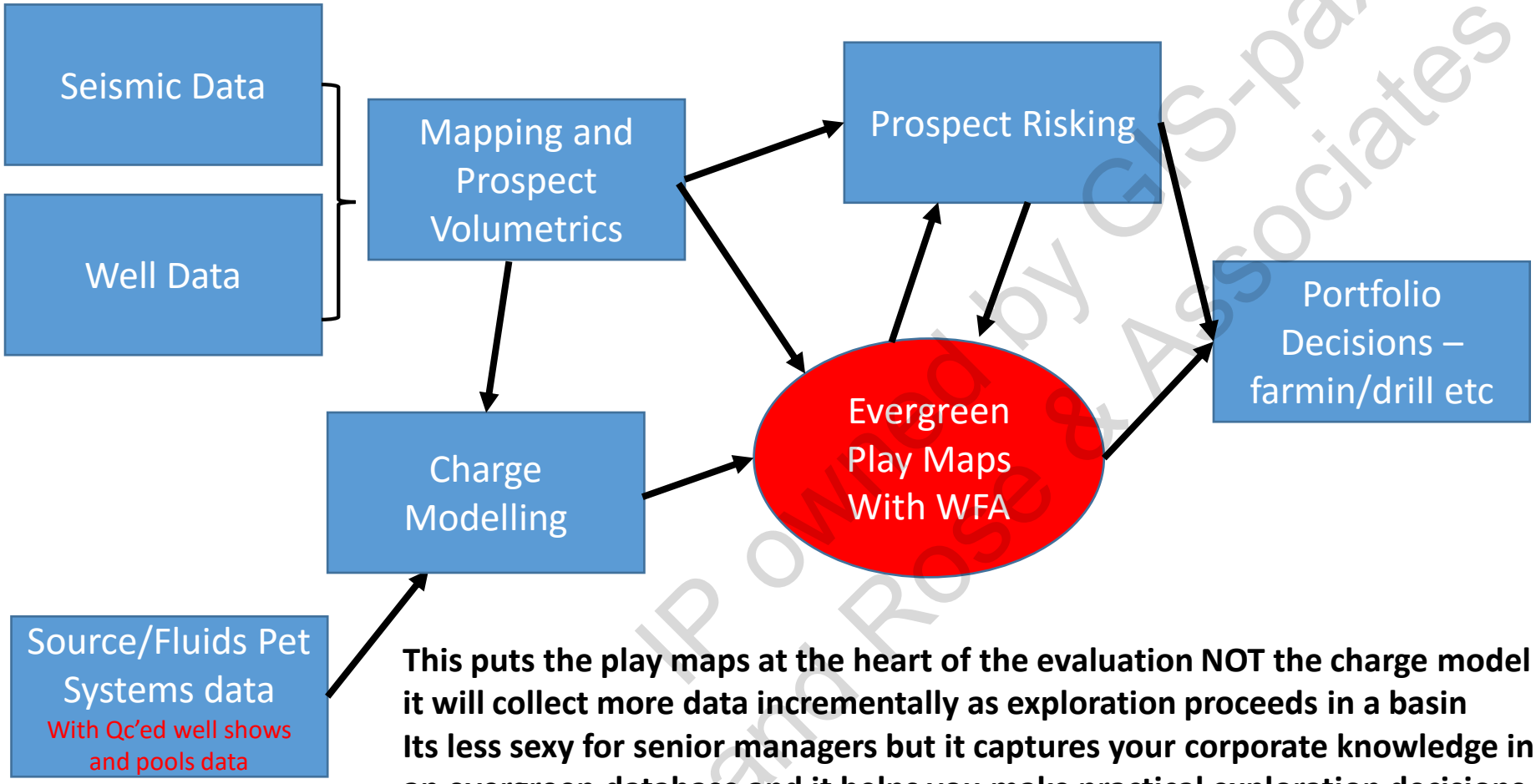
Shows in these wells qc'ed and corrected to "no shows"

Why Most Charge Models are Wrong and Dangerous 2. Source Presence

- The second major issue is understanding Source Presence
- As an industry we are poor at predicting Source PRESENCE particularly in frontier basins
  - maturity is easy and multi-1D models are available earlier and are often better than a 3D model – I like TWT vs Temperature
- The problem is especially critical in Australasia where we have many wispy/ephemeral non-marine source rocks which may or may not be present in the mature kitchens area
  - These are typically seismically invisible and very difficult to quantify in a charge model
- Most software tools offer the ability of evaluating multiple charge and migration models and turning this into a probability map
  - This averaging guesses and is clever but its actually not de-risking in any way areas where there is no source rock actually present!
    - I have NEVER seen a model where any of the input models are NON source rock outcomes…

Common Workflows..

- So when asked I always recommend this as a basic workflow



This puts the play maps at the heart of the evaluation NOT the charge model – it will collect more data incrementally as exploration proceeds in a basin
Its less sexy for senior managers but it captures your corporate knowledge in an evergreen database and it helps you make practical exploration decisions

Why Bother with Play Mapping?

1. Play Mapping Types – why all the confusion?
   a) Goldilocks Maps = Traffic Light
   b) Average Prospect Chance Maps
   c) Split Risking Maps
2. Why seismic amplitudes will NOT be the silver bullet for exploration in mature basins.
3. Why Charge Models are dangerous and often wrong.
4. The mature basin “Green Blob” problem and the solution.
5. YTF – explained.
6. Summary

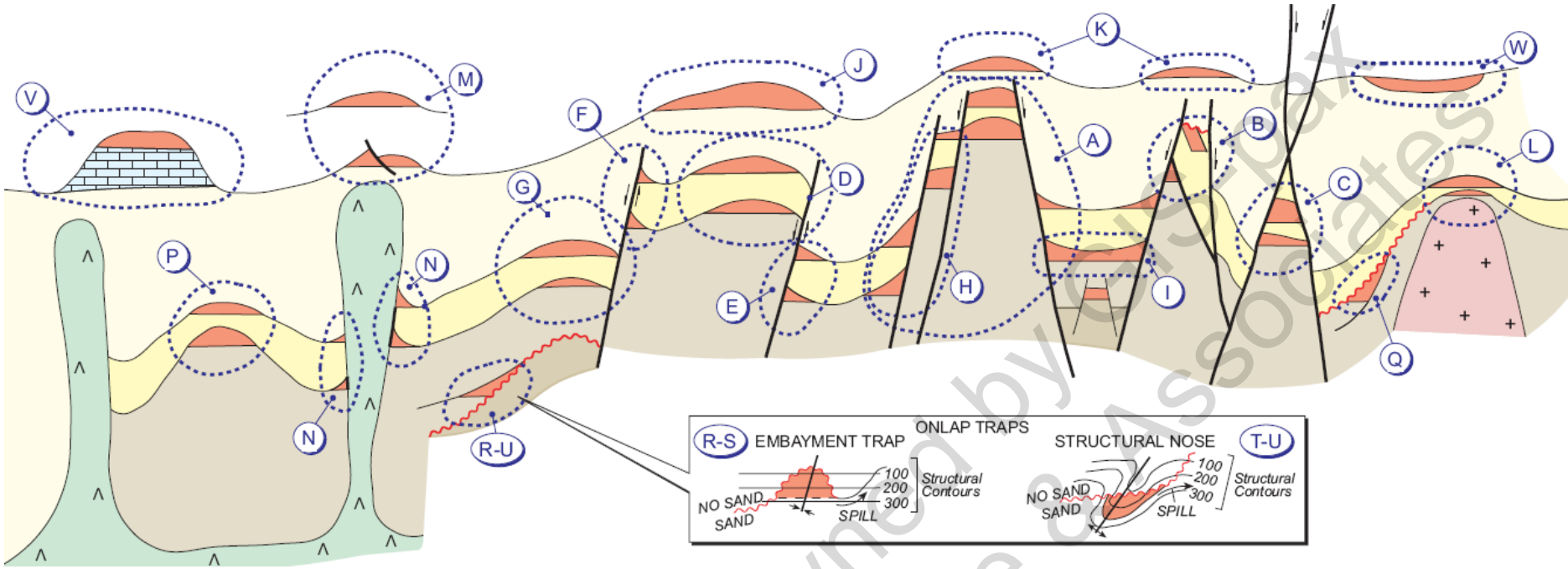
The Green Blob Problem

- In well explored mature basins many plays have extensive proven play fairways that are well defined
- These are always coloured green and in competitive environments they are heavily explored and drilled
- The issue most companies face is how does play analysis help in these areas?
- The answer is to classify the well tests, pools and prospects by trap types and try and identify new untested trap types in these well explored areas

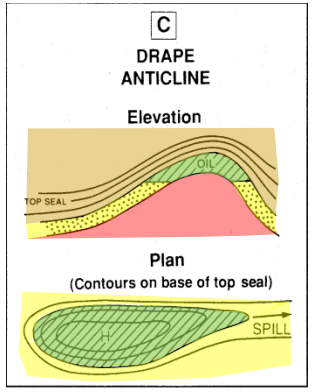
Player Structural Classification Scheme

- In Player we offer a two layered trap description scheme:
  1. Gross Structure – Genetic scheme describing how the trap formed? (What kind of beast is the trap?)
  2. Milton & Bertram – A Pool/Target level scheme that describes the surfaces bounding the reservoir (Where did we drill on the beast?)
     - Based on Milton & Bertram 1992 AAPG paper
- Why have a "fixed" scheme?
  - It's flexible and together these schemes can describe the specific location of a well on any trap type on the planet.
  - Prospect density data for specific trap types can then be collected using this schemer and used to calibrate yet-to-find estimates.

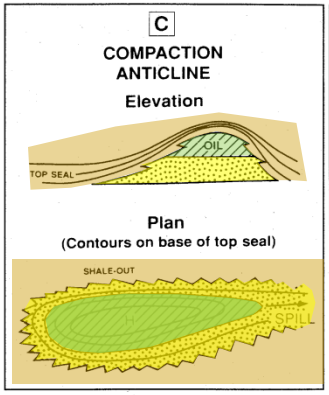
Gross Structure Global Scheme



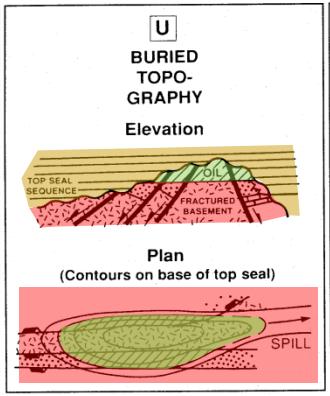
- Classifies ANY trap on the planet
- Hierarchical and flexible system



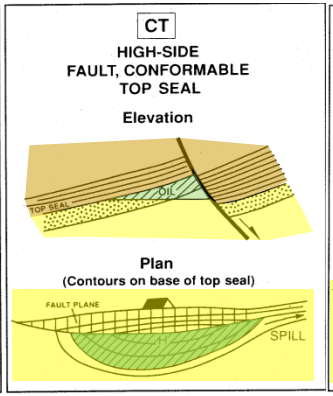
One-seal closure code C (drape anticline). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



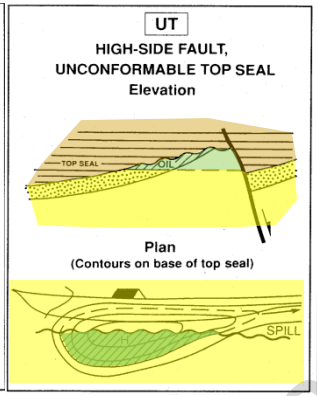
One-seal closure code C (compaction anticline). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



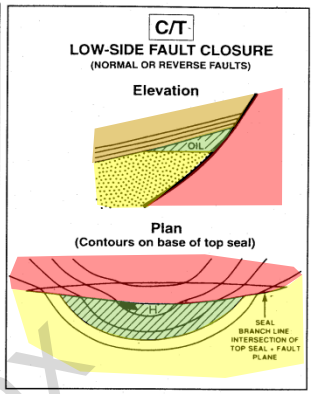
One-seal closure code U (buried topography). Oil fill is shown by cross-hatching, water by stippling.



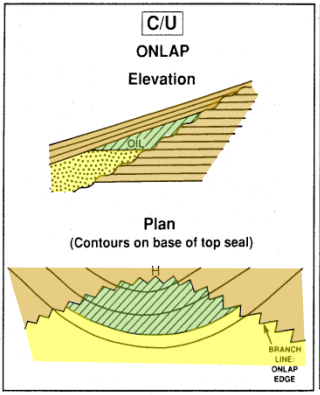
One-seal closure code CT (upthrown fault trap, conformable top seal). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



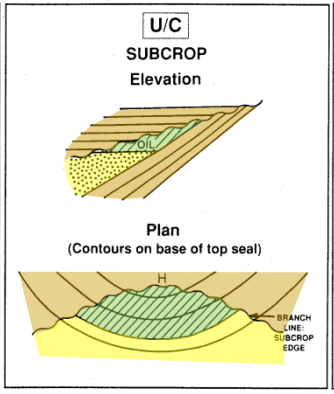
One-seal closure code CU (upthrown fault trap, unconformable top seal). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



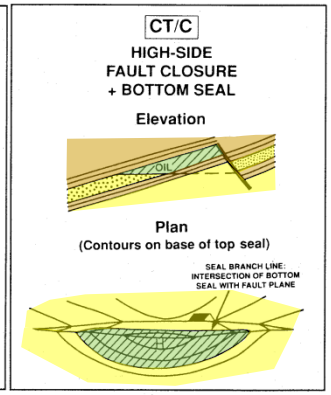
Poly-seal closure code C/T (downthrown fault trap, conformable top seal). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



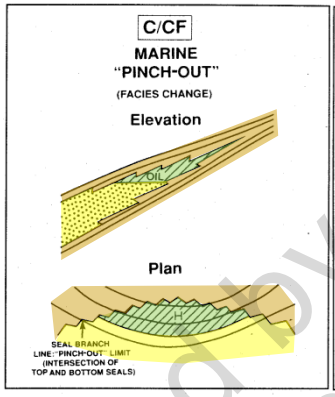
Poly-seal closure code C/U (onlap trap). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



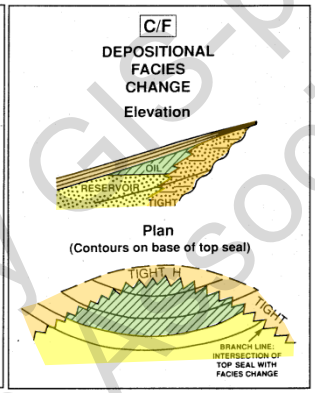
Poly-seal closure code U/C (subcrop trap). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



Poly-seal closure code CT/C (upthrown fault closure full beyond spill). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



Poly-seal closure code C/F (depositional facies change trap, e.g., shale-out). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.



Poly-seal closure code C/F (postdepositional facies change trap). Oil fill is shown by cross-hatching, water by stippling. H = structural high point.

KEY TO TRAP TYPE FIGURES

C: Conformable
U: Unconformable
T: Tectonic (Fault)
F: Facies Change
?: Unknown

NOTE:
No Divisor e.g. C,CT, etc = Monoseal Trap (No Base Seal)
with "/" e.g. C/T upper = Top Seal
lower = Bottom Seal

Proposed Trap-Style Classification Based on Trapping Mechanism

Primary Subdivision	Code	Relationship of Top Seal to Sealing Surface	Relationship of Bottom Seal to Surface	Examples
One-Seal Closures	C	Conformable	N/A*	Drape anticline, fold anticline, depositional mound.
	U	Unconformable	N/A	Buried hill, erosional remnant.
	CT	Conformable + Tectonic	N/A	High-side fault closure.
	UT	Unconformable + Tectonic	N/A	High-side fault closure with unconformable top seal.
Poly-Seal Closures	U/C	Unconformable	Conformable	Subcrop trap, palaeotopography with bottom seal.
	C/U	Conformable	Unconformable	Onlap trap, incised valley fill, lowstand wedge trap.
	CT/C	Conformable + Tectonic	Conformable	Overfull high-side fault closure.
	C/T	Conformable	Tectonic	Low-side fault closure.
	C/F	Conformable	Facies Change	Shale-out, diagenetic seal, fault gouge seal, tar seal.

*Not applicable.

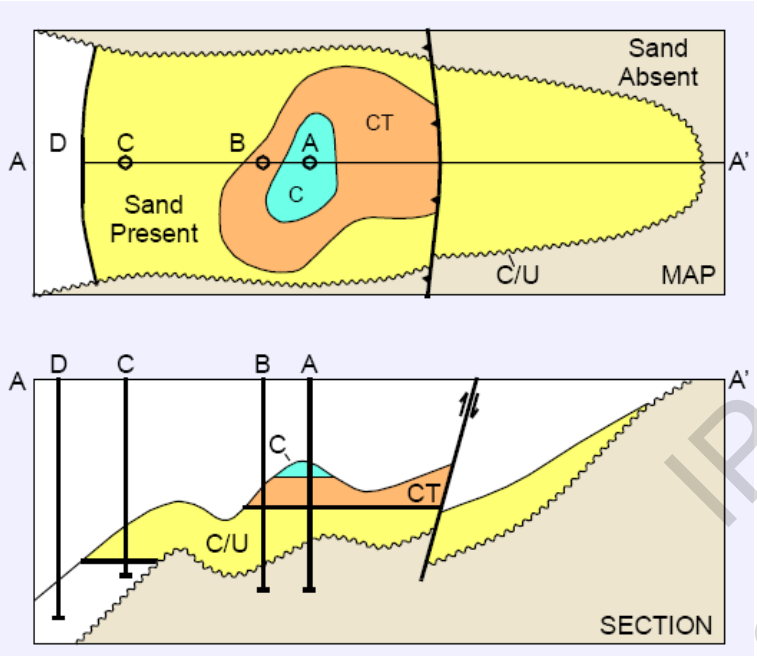
Milton & Bertram 1992 Pool Description Scheme

AAPG Bull., 76(7), 983-999

- Trap scheme is based on describing the surfaces that bound the hydrocarbon pool namely conformable beds (C), unconformable surface (U), fault (T) or facies/stratigraphic change (F).
- The scheme does NOT describe the generic origin of the trap (diapiric structure, compressional tectonics etc)

M&B "Where" the Prospect was Drilled on the "Gross Structure"..

- In this example the structure is a thrust cored fault block.
- Where you drill is critical – was it fault independent, fault dependent or a stratigraphic trap?
- We use a scheme published in the AAPG in 1992 by Milton & Bertram which is simple and comprehensive.



Wells can test more than one trap type within a single reservoir level as per the adjacent example.

Well A has tested 3 potential trap configurations.

(1) Fault independant anticlinal closure "C"
(2) Fault dependant upthrown closure "CT"
(3) An onlap trap "C/U"

- Well B has only tested (2) & (3) above
- Well C has only tested (3) above
- Well D has not tested any identified trap

Post the simplest trap type tested

e.g. for Well A post "C"
for Well B post "CT"
for Well C post "C/U"
for Well D post "_"

Subsalt Play Types in the DW GOM

- Gross structure would best suite this structural style..

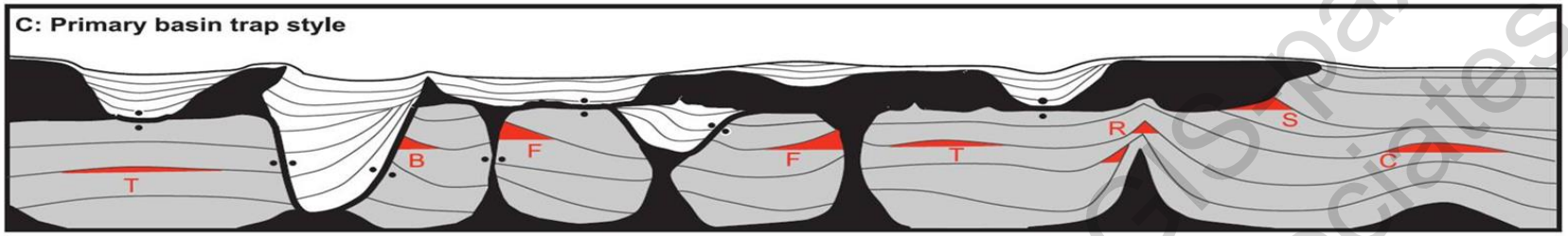
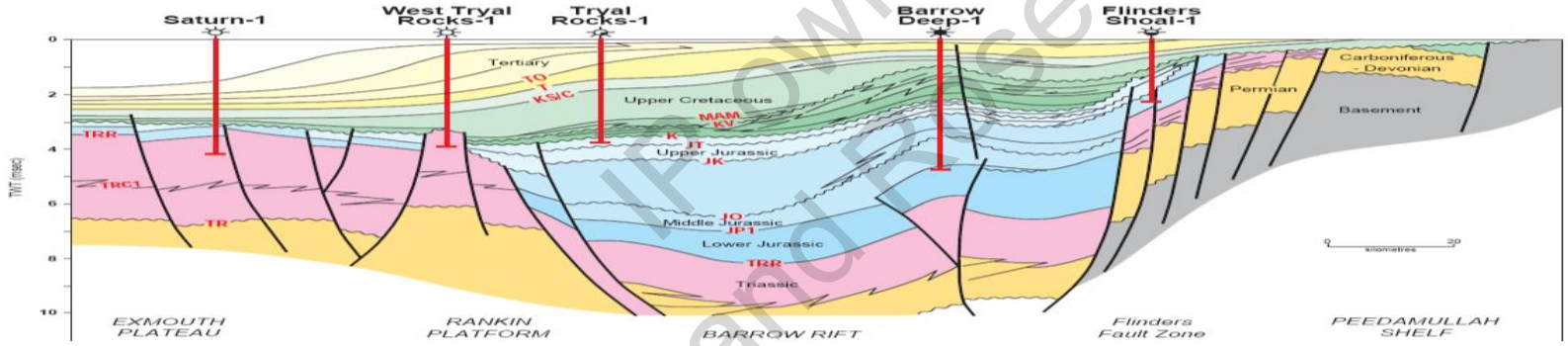


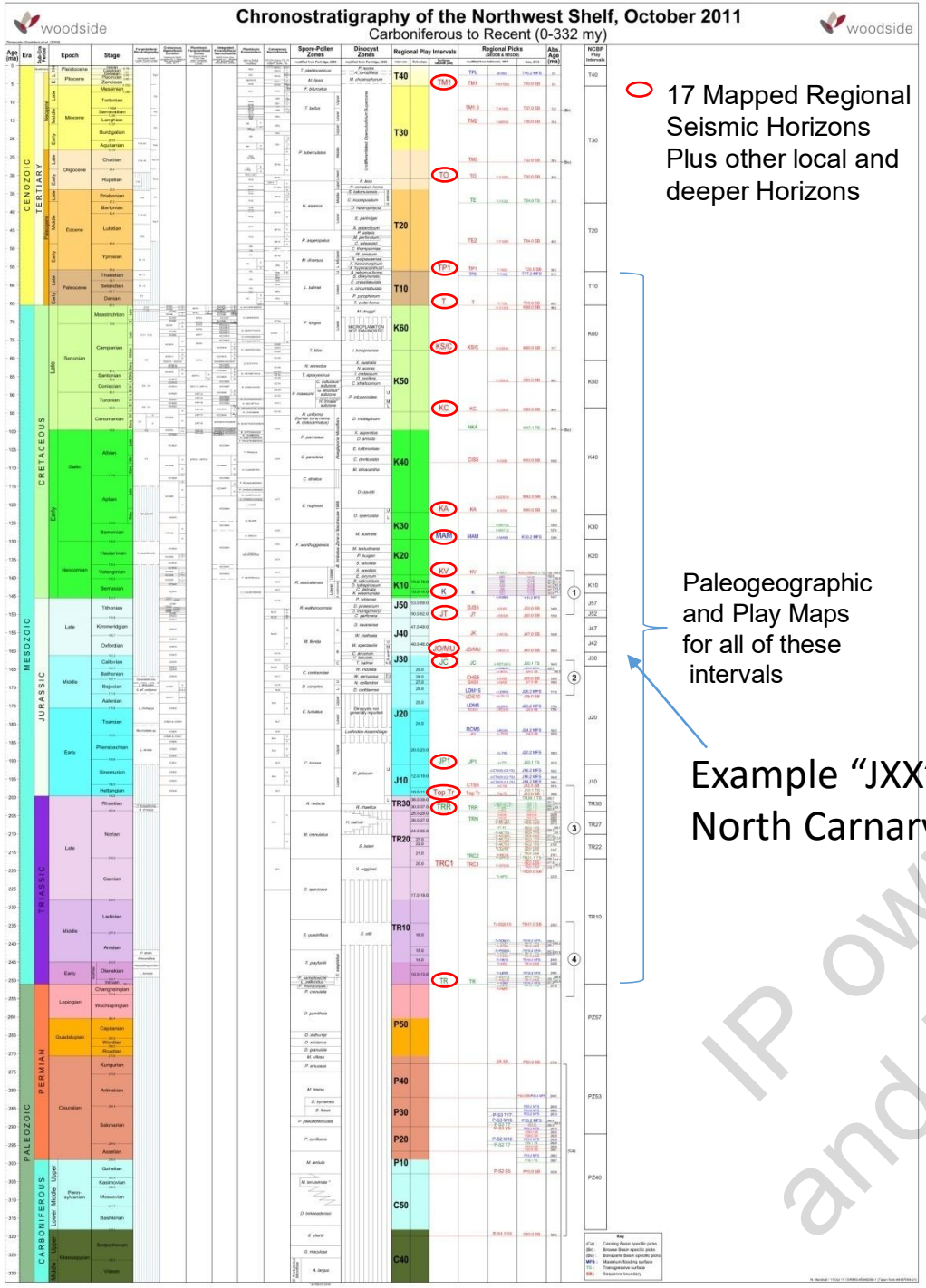
Figure 2. Schematic representation of salt-related geometries in the deep-water Gulf of Mexico. (A) Interpretation of top primary basin surface and distinction between primary and secondary basins. Salt is black, primary basins are gray, secondary basins are white, and welds are indicated by paired black dots. (B) Classification of the top primary basin surface according to the nature of the surface. This classification allows primary basin bounding features such as feeders, ridges, and bucket welds to be mapped. (C) Schematic salt geometry highlighting primary basin trap types: turtle structure (T), bucket weld (B), salt feeder (F), salt ridge (R), base-of-salt truncation (S), and salt cored fold (C).

- Whereas M&B might suffice for a simple rift/sag basin like



Example green blob data

- From the North Carnarvon Basin 3rd Party Study built from public domain data release by the govt agencies in Australia
- Data from the North Carnarvon Player Project - see details at www.cgss.com.au/current_projects.html



17 Mapped Regional Seismic Horizons Plus other local and deeper Horizons

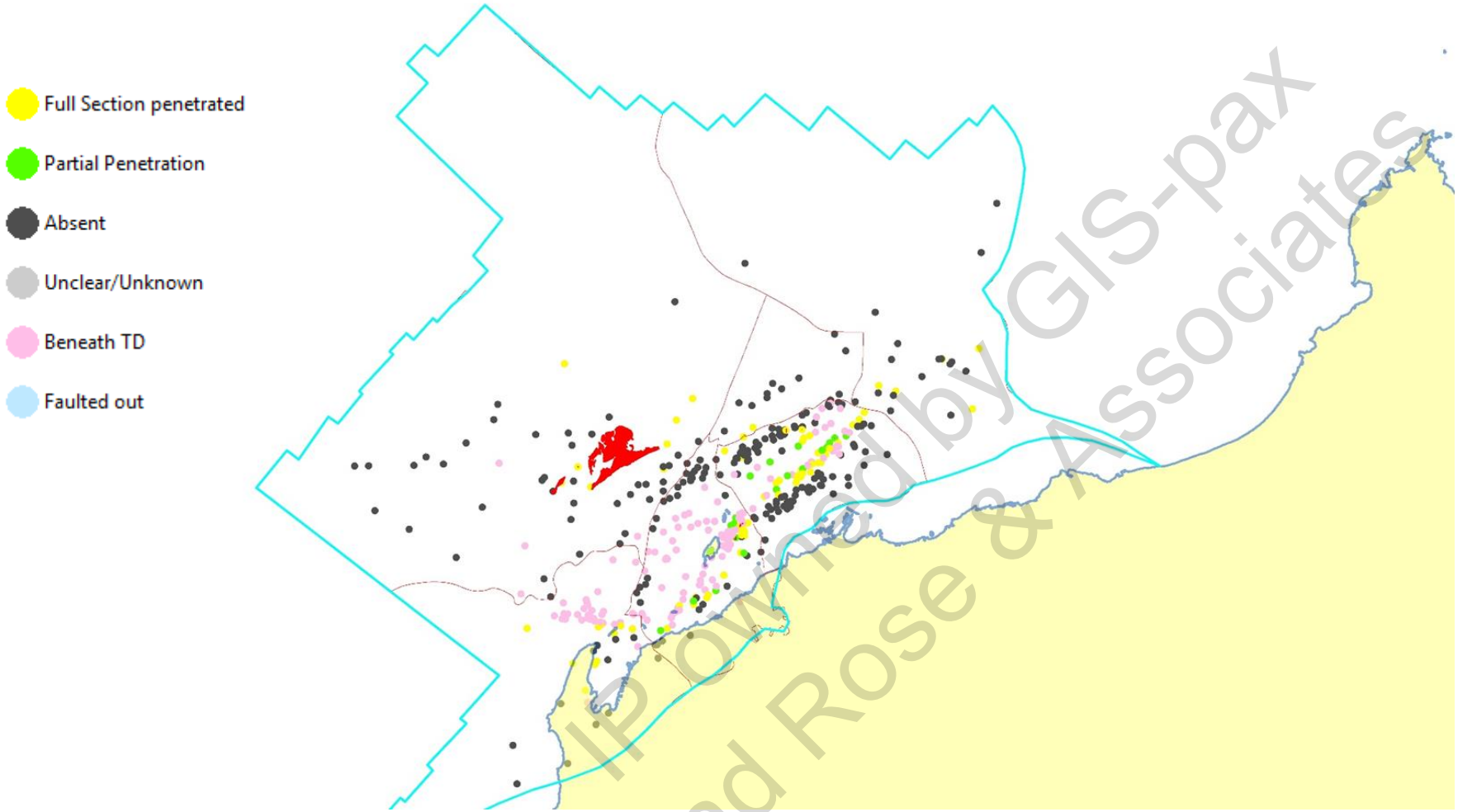
Paleogeographic and Play Maps for all of these intervals

Example "JXX" Play Interval North Carnarvon Basin

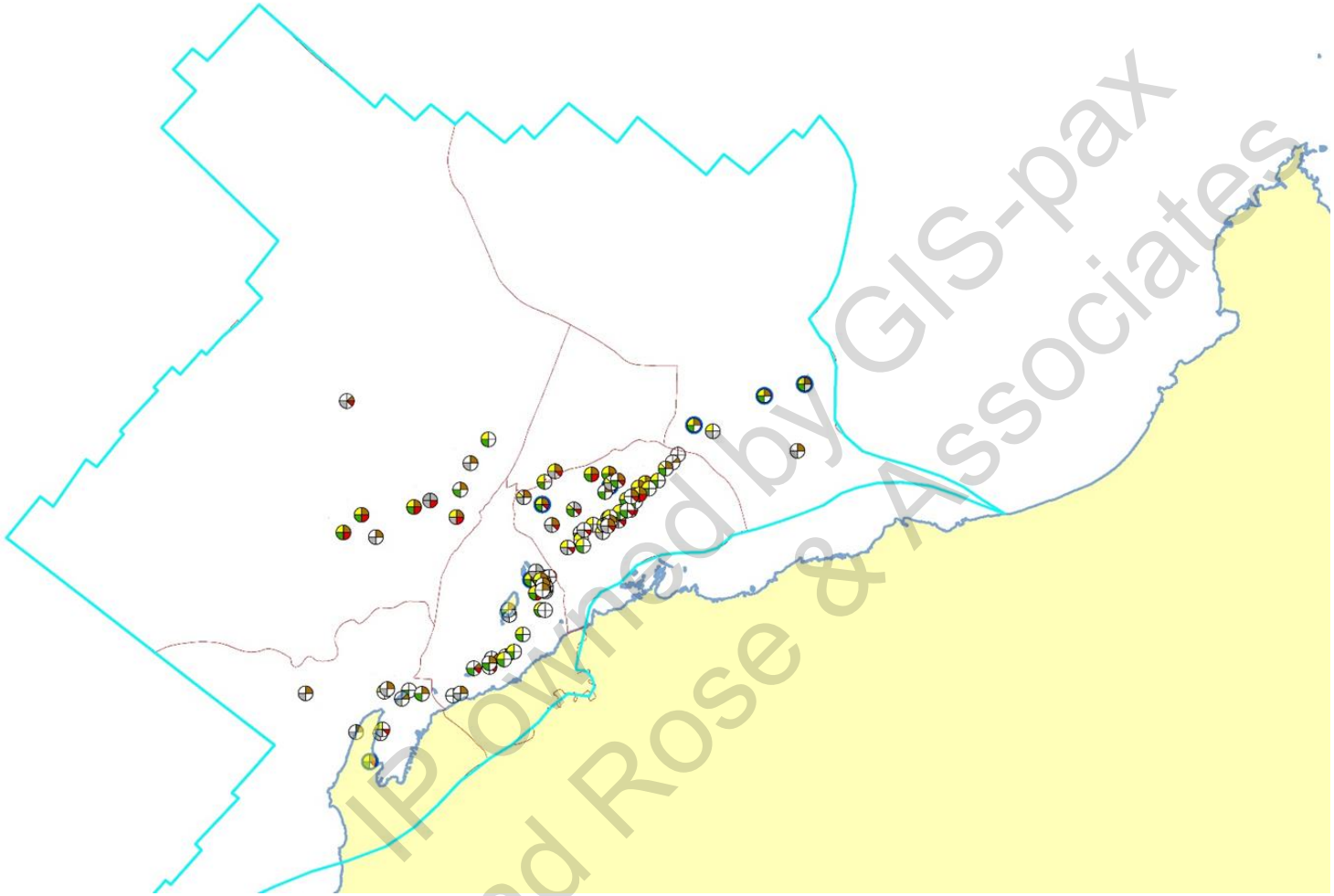
- Defined on Woodside Chronostrat Chart
- 17 Play Interval Evaluated
  - Triassic to Early Tertiary Interval

Play Intervals

JXX Play Penetrations



Well Failure Analysis Rosettes



Analysis of all JXX Failures

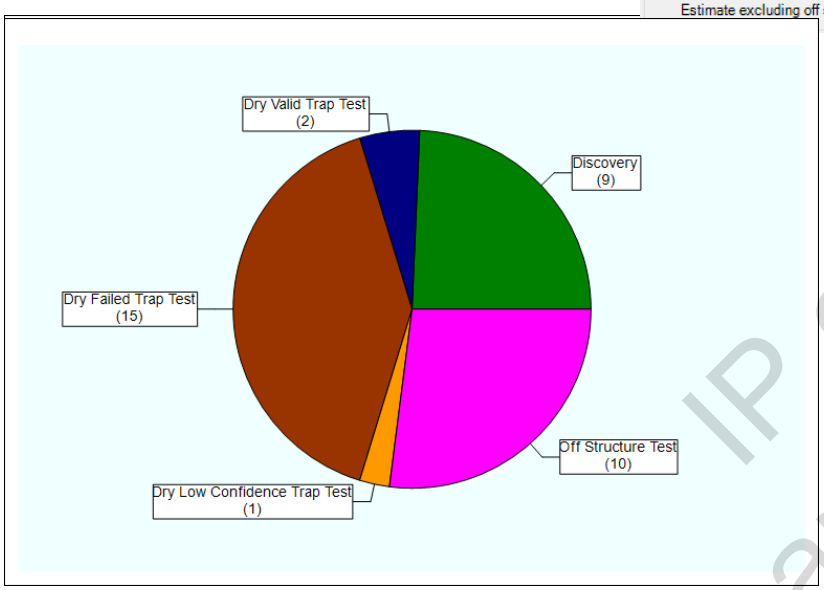
- Success Rates and Failure Mechanisms for the JXX Play Interval well tests..

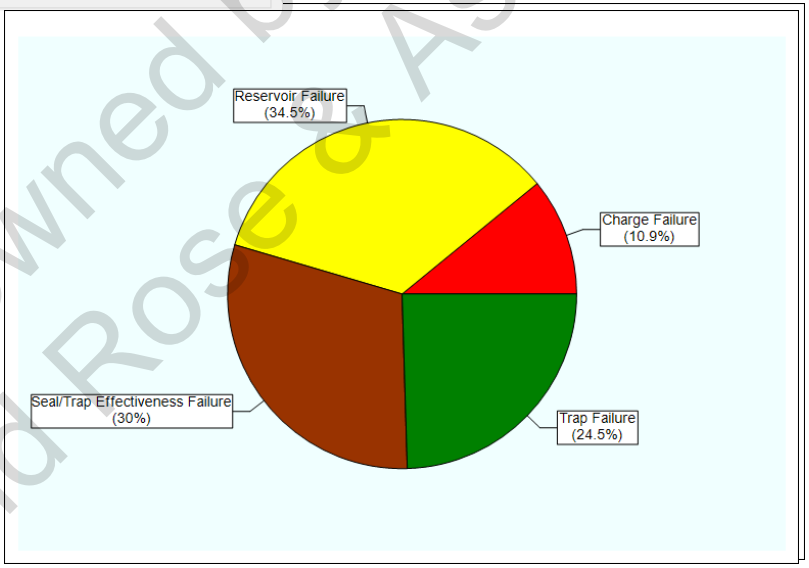
Well Success Types for Included Plays

Well Success Type	Count	Percent of All Wells	Percent of Evaluated Wells
Unevaluated	952	96%	
Off Structure Test	10	1%	27%
Dry Low Confidence Trap Test	1	0%	3%
Dry Failed Trap Test	15	2%	41%
Dry Valid Trap Test	2	0%	5%
Discovery	9	1%	24%

Implied Historical Success Rate Estimates

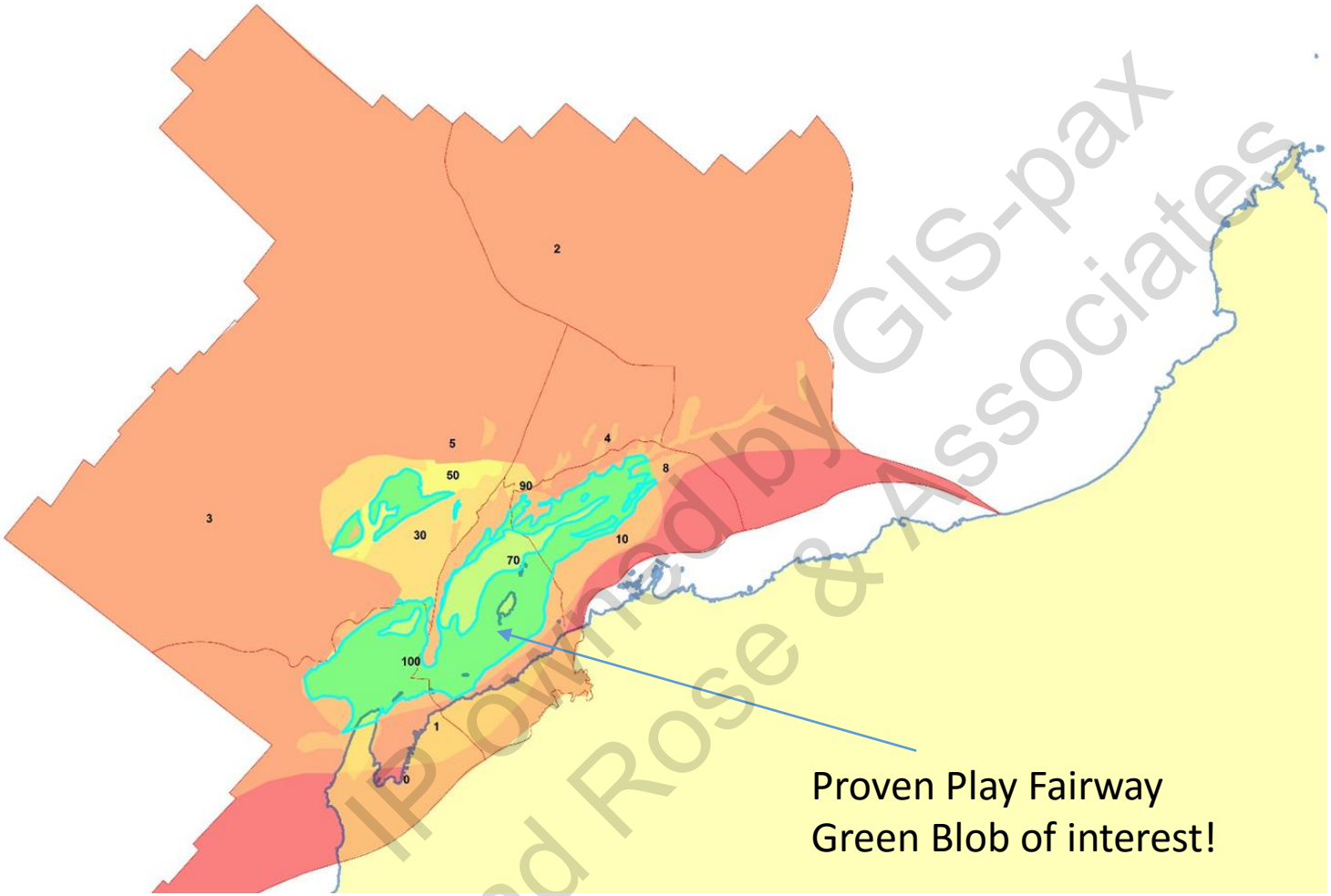
Estimate excluding off structure tests:	33%
Estimate excluding off structure and low confidence tests:	35%



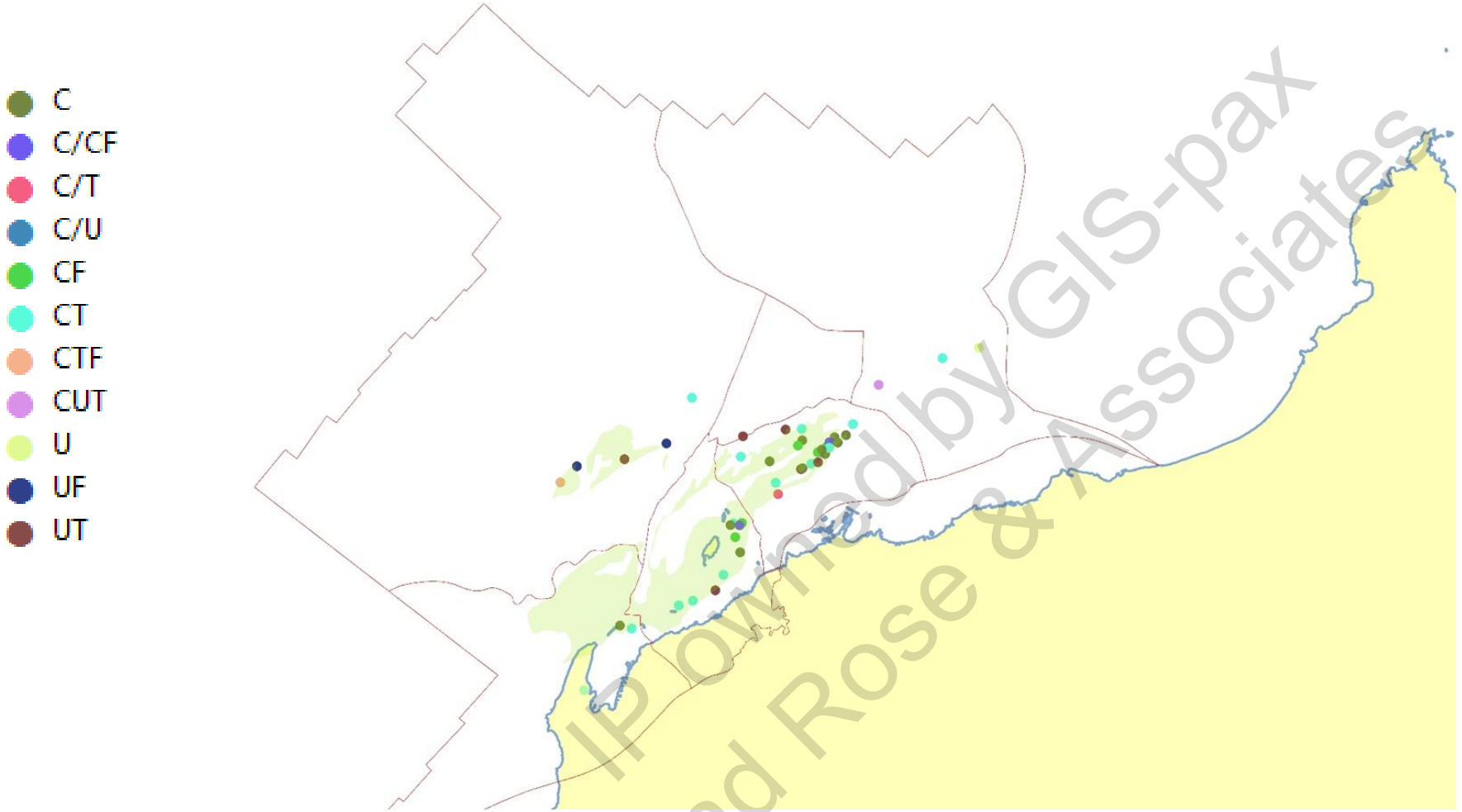


This is how you calibrate your prospect risking – against well failure analysis at the play NOT the well level

JXX Play Stack (Split Risking)

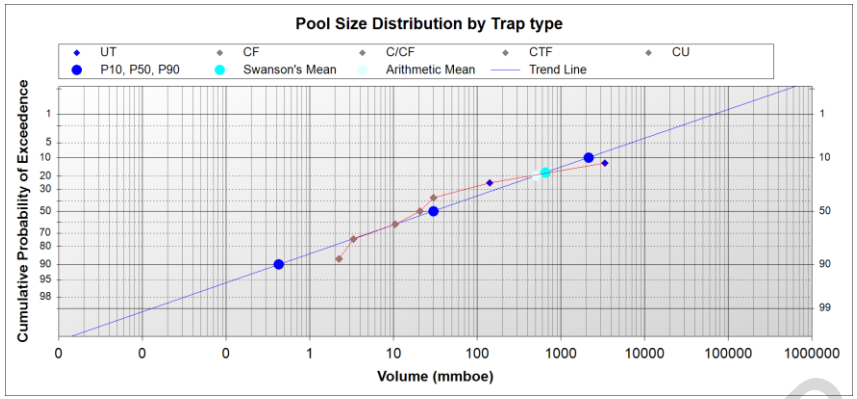


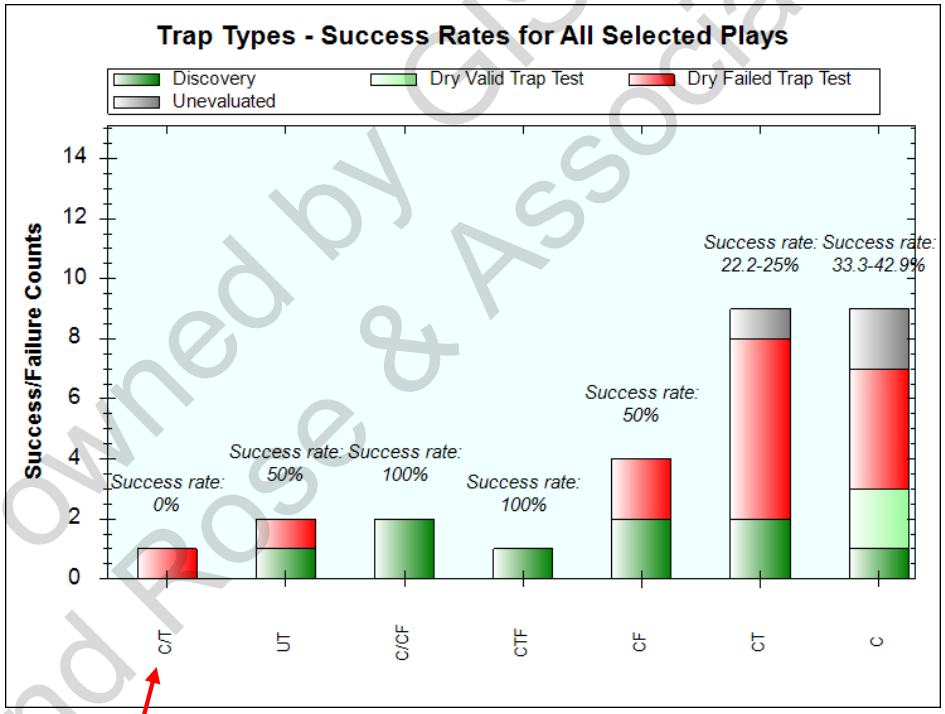
JXX tests – Trap Types Tested



JXX Trap Stats Proven Play Poly

- For proven play fairway only!
  - The rest failed for charge
- Success rates and field size distribution for different trap types





Lowside fault blocks – buttress traps

Example Conclusion..

- Only one well test drilled a lowside trap at the JXX level inside the proven fairway and this well failed due to interpreted juxtaposition and fault plane leakage..

- This trap type is an under explored – especially since the 80mmbbl Enfield Field is exactly this trap type but at a different play level!

- Green Blob exploration is all about trap analysis integrated with geological thinking..

Why Bother with Play Mapping?

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   c) Split Risking Maps
2. Why seismic amplitudes will NOT be the silver bullet for exploration in mature basins.
3. Why Charge Models are dangerous and often wrong.
4. The mature basin “Green Blob” problem and the solution.
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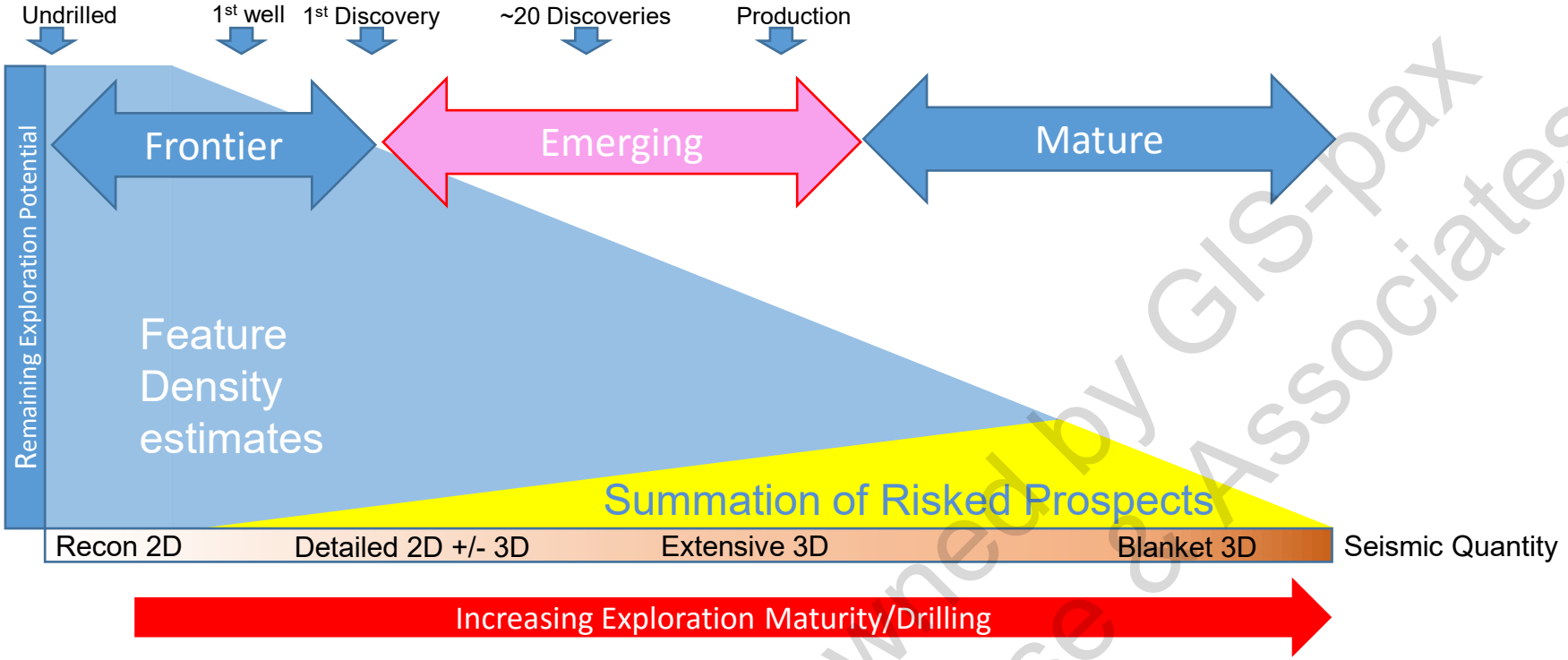
6. Summary

YTF Demystified



- All yet to find estimates are wrong – especially in frontier areas
  - We make them to facilitate business decisions
- In frontier areas we use pseudo prospects/feature density based on anolog data and in very mature basins we map prospects and add up the risked volumes
  - Most basins are midway and need both types of estimates

Play Map Structural Density YTF Estimates

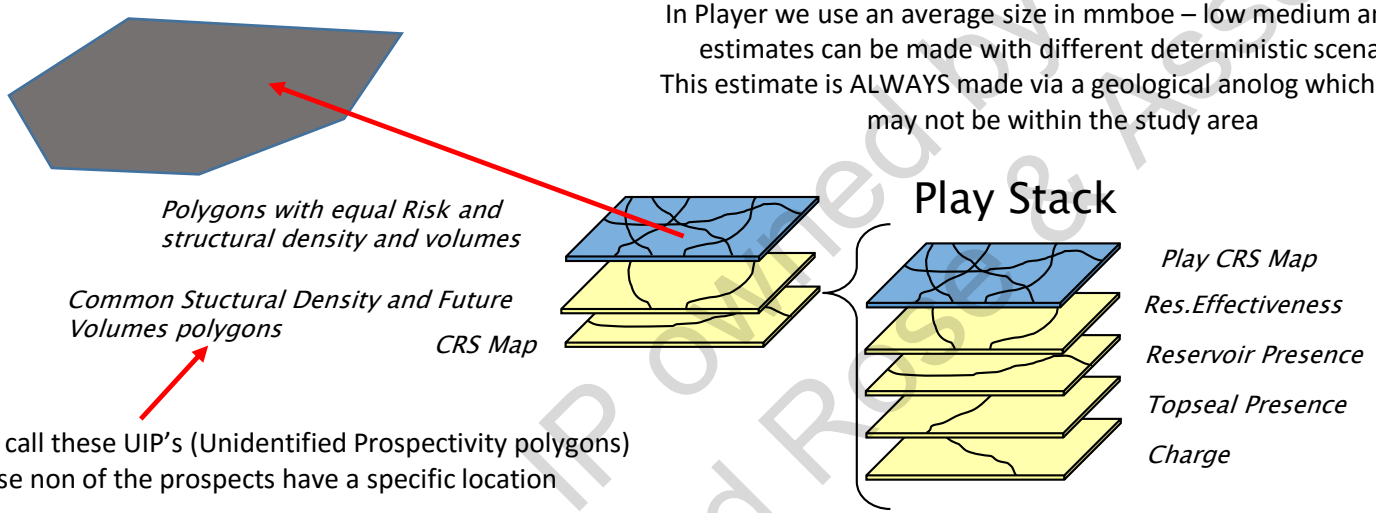
- In Player when we have made play maps we can use them to evaluate and integrate real and postulated prospects
- When convolved with economic and cost data we can then value blocks plays and basins..

This is the Total Chance Polygon Value estimate NOT the Play/Shared Values

YTF = No of features x Size x Probability of Success

= Area (km2) x Feature Density (no/1000sq km) x Future FSD x Pg from Play Map

In Player we use an average size in mmboe – low medium and high estimates can be made with different deterministic scenarios
This estimate is ALWAYS made via a geological anolog which may or may not be within the study area



If this evaluation is done using split risk play maps then the user can calculate the impact of success in each common risk segment. In addition the "dry hole tolerance" can also easily be calculated for each polygon (eg if you drill X wells what is the probability that you will have a success and derisk the play)

YTF Estimation In Player

- So for us…

YTF
Yet-to-find Volumes
Risked mmboe

=

Identified Prospectivity
Risked Volumes
mmboe

+

Unidentified Prospectivity
Risked Volumes
mmboe

- There are virtually no real basins where all the prospects are identified or postulated – its always a mixture…

Industry YTF Methodologies

The industry generally uses the following main methods to estimate the YTF in any area.

Creaming Curve extrapolation	As per previous slide – should be plotted against well count not time unless exploration effort (drilling) was at a consistent level throughout the evaluation period.
Hydrocarbon Density Method	Uses an estimate of the hydrocarbon volumes per unit area (typically mmboe/1000sq km) to estimate
Field Size Distribution top-up method(s)	Basically adds the missing fields into a field size distribution making the assumption that the population is log normally distributed
Geochemical/basin modelling estimates	BM tool estimates the volumes of oil and gas generated migrated and trapped in evaluated source rocks
Expert Estimates/Guestimates – Delphi/"Phone a friend"	Typically a numeric estimate of the number of remaining prospects/fields multiplied by the average field size
Prospect Structural Density Play Based Method	Estimates the structural feature density of traps and risks the results using a stacked play map – Exxon methodology

Comparison of YTF Techniques

YTF Method	Effort Required to generate an estimate	Usefulness in unproven basins	Ability to predict remaining potential of existing plays	Ability to predict new play intervals in a proven basin	Ability to predict a new trap type in a proven play	Spatial nature of predictions
Creaming Curve	Minimal	None	Yes	None	None	Not Spatial
HC Density	Minimal	None	None	None	None	Spatial
FSD top-up	Minimal	None	Yes	None	None	Not Spatial
Basin Modelling	Moderate	Moderate	Limited	Limited	None	Spatial
Delphi	Minimal	Possible	Possible	Possible	Possible	Rarely
Structural Density /Play Maps	Significant	High	High	High	Possible	Spatial

- The Structural Density/ Play Map approach is by far the most robust methodology since it is spatial, quantitative, can be applied to all phases of exploration and (in Player) it can help geologists both identify new trap types in proven play intervals and identify potential prospectivity in unproven play intervals late in the exploration history

Yet to Find

- Integrating real prospects into your play maps is key to estimating yet to find (and success volumes)
- Adding these risked prospect volumes to risked pseudo prospects is the key to an evergreen and meaningful calibrated YTF estimate.
- Every other method has major technical issues especially those based on charge models!

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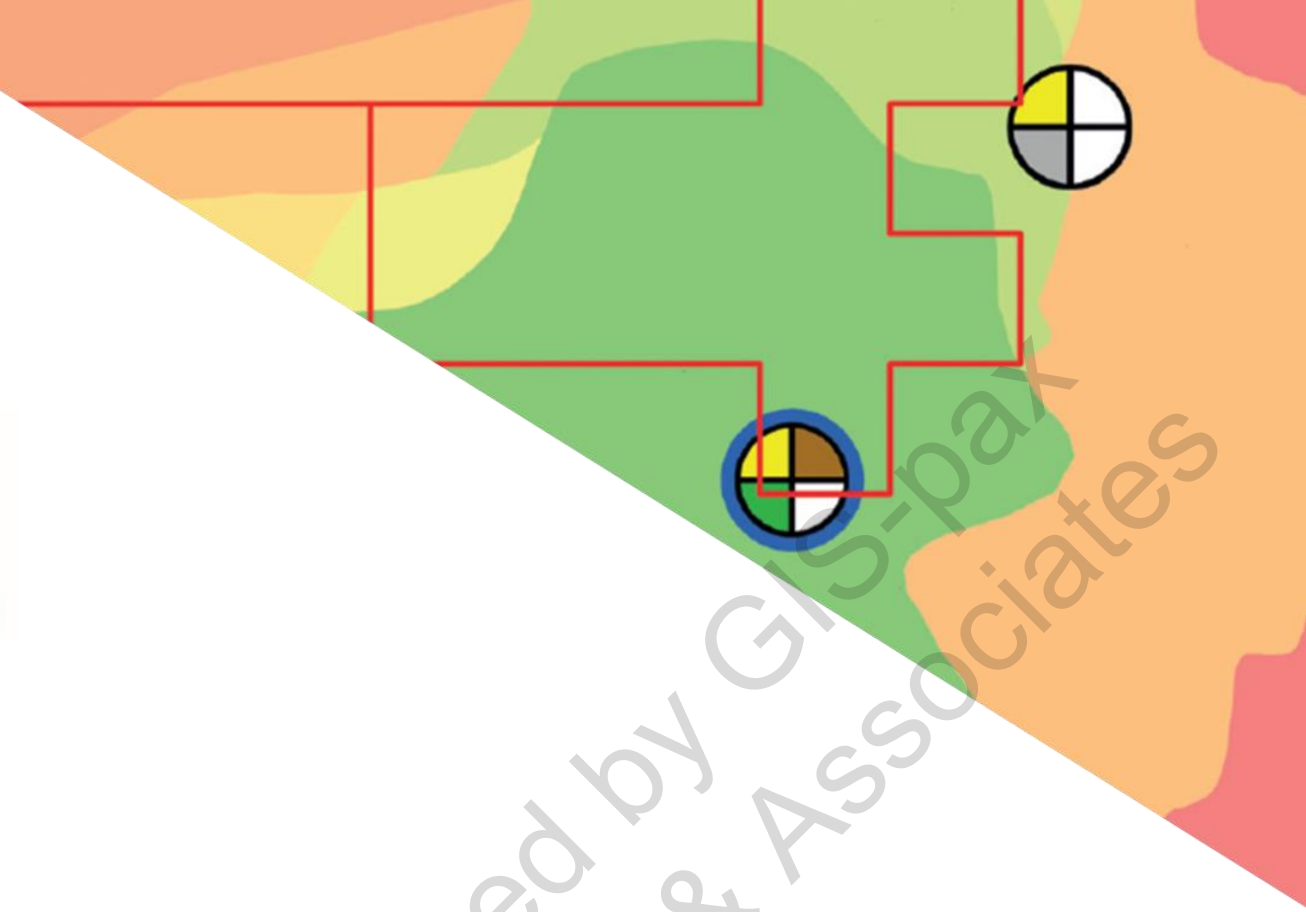


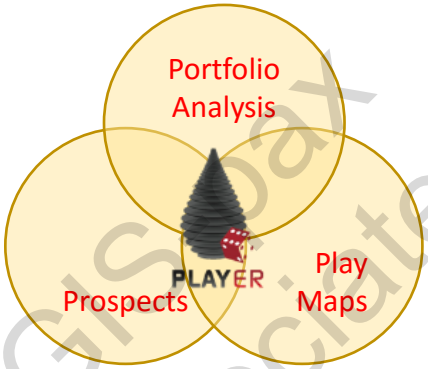
Summary

Why Bother with Play Mapping?

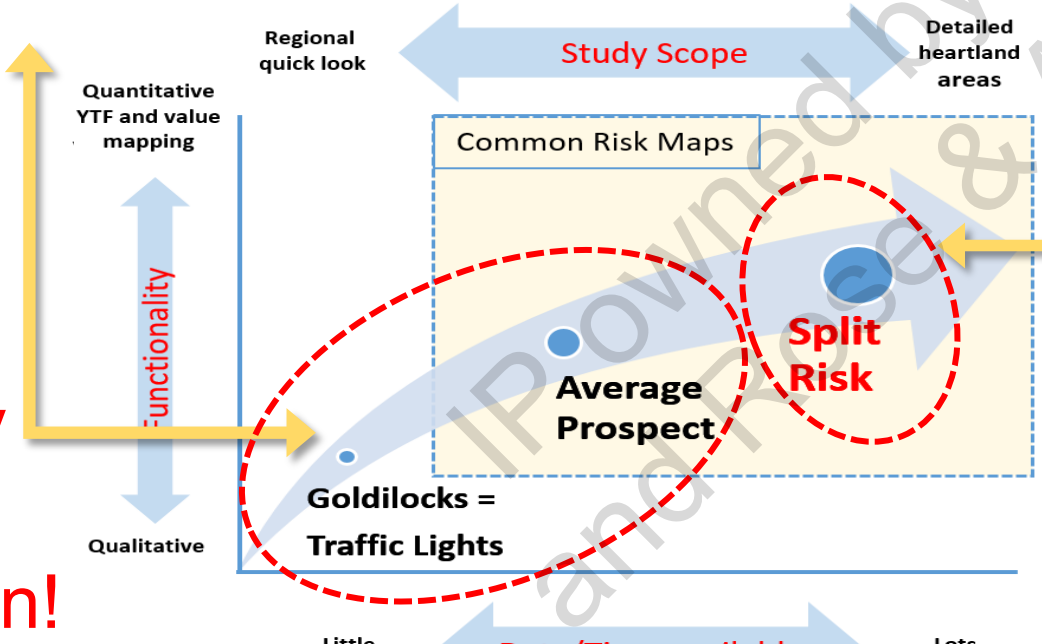
1. Play Mapping Types – why all the confusion?
   a) Goldilocks Maps = Traffic Light
   b) Average Prospect Chance Maps
   c) Split Risking Maps
2. Why seismic amplitudes will NOT be the silver bullet for exploration in mature basins.
3. Why Charge Models are dangerous and often wrong.
4. The mature basin “Green Blob” problem and the solution.
5. YTF – explained.
6. Summary

Play Mapping Types

These play mapping types have **NO** linkage between prospects and plays (or any kind of analysis)



Split risking play mapping types have **direct linkage** between prospects and plays and Player can do smart analysis



Not Play Based Exploration!

Play Based Exploration

“Luck is when preparation meets opportunity”

- Preparation = Play Maps – know what has worked and know what has not and why – well post drill analyses calibrate play maps.. nothing else can.
- Opportunity = a prospect – maybe in a data room or maybe in your own portfolio?! – now you know why this particular feature is significant and special. Without the preparation you are just guessing…
- This is how you make your own luck
- This is just basic common geological evaluation

Summary

- Play Mapping gives you spatial focus quickly so saves you time and money
- When integrated with well failure data and a qc'd shows database it is better and more useful than any charge model
  - It collects your corporate knowledge in a dynamic evergreen database structure
- There are different types of play maps but only split risk maps give quantitative play based evaluations (success volumes) and in areas with complex geology they are better at identifying the play fairways.
- Play Maps can underpin spatial yet to find estimates in both frontier and mature basins settings
- In proven play areas in mature basins trap type data can identify missed and overlooked opportunities
- At the end of the day it is all about sifting through the geological data in a structured and thoughtful way
  - Its people that find oil and gas – good software just helps and Player is the only tool that has all of this functionality structured so that working geologists can do quality play evaluations.

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Contacts

Contacts

- GIS-pax - Ian Longley ilongley@gis-pax.com
  - Note this presentation only covers a fraction of the Player Suite capabilities..
- Rose & Assoc - Jeff Brown JeffBrown@roseassoc.com