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

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)
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

IP owned by GIS-pax and Rose & Associates
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.
So why bother?! 
A simple example
Example of Why PBE

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

Table:

<table>
<thead>
<tr>
<th>Prospect</th>
<th>COS%</th>
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<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50%</td>
<td>14</td>
<td>7</td>
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<tr>
<td>C</td>
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<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>

Legend:
- HC Field mmboe
- Dry Wells
- Migration Directions
- Prospect COS/mmboe mean volumes (mmboe)
Example of Why PBE

- 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?!!

### Table

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### Legend

- HC Field mmboe
- Dry Wells
- Migration Directions
- Prospect COS/mmboe mean volumes (mmboe)
• 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.

Prospects B & C in same migration risk polygon = shared risk
Example of Why PBE


100% Migration Chance

25% Migration Chance

Prospect COS/mmboe mean volumes (mmboe)

Legend

- 100% Migration Chance
- 25% Migration Chance
- Dry Wells
- Migration Directions
- HC Field mmboe
- Prospect COS/mmboe mean volumes (mmboe)

Proven Source
Kitchen area

- A
  - 50% 14 mmboe
- B
  - 10% 50 mmboe
- C
  - 20% 30 mmboe

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

- So now if we drill C and it is a discovery...
Drill C. The raw numbers

Success 30 mmboe
20%

Failure = 0 mmboe
80%

Risked Volumes 6 mmboe

This is what happens to Prospect C in isolation....
But IF it works....
Example of Why PBE

- 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%

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Legend:
- HC Field mmboe
- Dry Wells
- Migration Directions
- Prospect COS/mmboe mean volumes (mmboe)
Drill C Evaluation..

- Drill C
  - 20% Success: 30 mmboe
  - 80% Failure: 0 mmboe

Risked Volumes: 6 mmboe

- This is how C looks alone..
Drill C Evaluation..

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

Drill C

Success 30 mmboe
20%

Failure = 0 mmboe
80%

Risked Volumes 6 mmboe

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%)

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

Delta= 15 mmboe

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

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Drill C Evaluation..

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

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

Delta = 15 mmboe
Risked = 15 * 20% = 3 mmboe

Total Risked Volumes = 9 mmboe

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%)

- 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

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

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</table>

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.

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

**Legend**
- HC Field mmboe
- Dry Wells
- Migration Directions
- Prospect COS/mmboe mean volumes (mmboe)
Drill B maths..

Prospect C
COS = 20%
MSV = 30mmboe
Risked = 6mmboe

COS = 80%
MSV = 30mmboe
Risked = 24 mmboe

Success = 50 mmboe
Risked = 18 * 10% = 1.8 mmboe

Failure = 0 mmboe

Delta = 18 mmboe

Total Risked Volumes = 6.8 mmboe

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

• 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...

<table>
<thead>
<tr>
<th>Prospect</th>
<th>Pg POS COS</th>
<th>Mean Volume</th>
<th>Risked Volume</th>
<th>Success Volumes</th>
<th>Total Risked Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospect A</td>
<td>50%</td>
<td>14</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Prospect B</td>
<td>10%</td>
<td>50</td>
<td>5</td>
<td>1.8</td>
<td>6.8</td>
</tr>
<tr>
<td>Prospect C</td>
<td>20%</td>
<td>30</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
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</table>

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.
Why PBE explained...
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**
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! – it’s about understanding the geology NOT arguing about colour bars.

So let me explain the 3 basic types used in the industry today with their advantages 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
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1. Reservoir Presence

Result

Composite Common Risk Segment Map (shows overall play risk)

Small low risk area removed due to burial depth (porosity)

2. Reservoir Effectiveness

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3. Seal Presence + Effectiveness

No change to composite risk

4. Petroleum Charge

Low & mod. risk area reduced due to charge

Simple Traffic Light Mapping

- = “High” Risk
- = “Moderate” Risk
- = “Low” Risk

after Fraser 2012
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.
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.

Traffic Light Maps = Goldilocks Maps

The map types are relatively easy and quick but..
Traffic Light Maps have a few problems..

**Goldilocks**

Yuck!
None of these are good!

Red
Orange
Green
• Users commonly use a grid 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

Example of Raster to Traffic Light Issue

IP owned by GIS-pax and Rose & Associates

GIS-PAX Pty Ltd © 2015
• The second issue 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.
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?
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..

- We have a submarine fan imaged on a 2D seismic grid
- It's 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?
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 Geographical?
Map Link to Prospect Risk Values
Complex Areas - Definition of play fairways
Portfolio Impact of success

Goldilocks ✓ ❌ ❌ ❌ ❌ ❌

Study Scope
Regional quick look
Detailed heartland areas

Functionality
Quantitative YTF and value mapping

Qualitative

Goldilocks = Traffic Lights

Data/Time available
Little
Lots
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 can’t be directly used for prospect evaluation nor deal with complex geology issues nor predict success impact.

<table>
<thead>
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<th>Boundaries Geological?</th>
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<tr>
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<td>✗</td>
<td>✗</td>
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<td>Average Prospect</td>
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Goldilocks = Traffic Lights

Common Risk Maps

Study Scope

Regional quick look

Detailed heartland areas

Qualitative

Quantitative

YTF and value mapping

Functionality

Data/Time available

Lots

Little
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 seen 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

Play

Prospect

Overall

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 COS might be.

Reservoir
Seal / Trap Effectiveness
Trap Presence
Charge
Play CRS Maps

This list of play elements is customisable in Player by company and project.
Split Risking Stacking

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

**Play**
- This stack defines where the play is proven: the "fairways".

**Prospect**
- This stack defines the inherent variability of the prospect level risks.

**Overall/Average Prospect Chance**
- This stack is an estimate of what a typical prospect Pg/COS might be.

### Layer-cake geology and ubiquitous charge
- [Image of play, prospect, and overall/average chance stacks for layer-cake geology]

### Lateral reservoir and seal variability with complex charge
- [Image of play, prospect, and overall/average chance stacks for lateral reservoir and seal variability]

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IP owned by GIS-Pax and Rose & Associates
Slope/Basin Fan Complex Evaluation

• 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%
So now if we drilled prospect C and it found sand what would happen?
- 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.
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.
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/dowgrade 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.

**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..)

**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.

**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!
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 Types

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<tr>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Split Risk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
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 - it's 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*

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

**Play Maps Types Summary**

<table>
<thead>
<tr>
<th>Play Map Type</th>
<th>Spatial Insight</th>
<th>Boundaries Geological?</th>
<th>Map Link to Prospect Risk Values</th>
<th>Complex Areas - Definition of play fairways</th>
<th>Portfolio Impact of success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldilocks</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Average Prospect</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Split Risk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Goldilocks = Traffic Lights

Quantitative

YTF and value mapping

Functionality

Regional quick look

Study Scope

Detailed heartland areas

Common Risk Maps

Little

Data/Time available

Lots

Qualitative

IP owned by GIS-Pax and Rose & Associates
1. Play Mapping Types – why all the confusion?
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5. YTF – explained.

6. Summary
• 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.

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/Venezuela/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)

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

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So let's now colour up the amplitude supported discoveries as red....

New Province Discoveries
- Mangala/India/Cairn/2005
- Lake Albert/Uganda/Tullow nee Hardman/2006*
- Santos Subsalt/Brasil/Petrobras/2006
- Jubilee/Ghana/Kosmos/2007**
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- Cameia/Angola/Cobalt/2012 (NAS)
- Zohr Eni Egypt 2015 (NAS)
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..

New Province Discoveries
- Mangala/India/Cairn/2005
- Lake Albert/Uganda/Tullow nee Hardman/2006+
- Santos Subsalt/Brasil/Petrobras/2006
- Jubilee/Ghana/Kosmos/2007**
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- Ravuma/Mozambique/Anadarko/2012*
- Senegal/FAR & Cairn/2014 SNE & FAN *
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6. Summary
All exploration companies do work and then shove the inputs together and then try and make decisions.

I often see this workflow in companies.

Seismic Data

Well Data

Source/Fluids Pet Systems data

Mapping and Prospect Volumetrics

Prospect Risking

Portfolio Decisions – farmin/drill etc

“The Charge Model”

I find this often black box approach very very scary and worrying

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 1. 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
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%)
Hairy Dog/ Amoeba Maps in Oz slang.

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

Indicative Common Risk Polygon Values

- HC Discoveries
- Wells with shows in database
- Wells with no shows in database

100% ~80% ~20%
• 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
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.
We do this in a database that is evergreen - play by play
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.
Example Player Data

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

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

This scheme is the Intellectual Property of GIS-pax and cannot be copied without permission

- This data is used to..

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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

Whole flank untested – well results meaningless

Area with clear evidence of migration failures

Dry Valids – charge failures

Off structure test

100% ~80%

~20%

HC Discoveries

Wells with shows in database

Wells with no shows in database

Shows in these wells qc’ed and corrected to “no shows”

=Completely different evaluation result
• 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

Seismic Data

Well Data

Mapping and Prospect Volumetrics

Prospect Risking

Source/Fluids Pet Systems data

Charge Modelling

Evergreen Play Maps With WFA

Portfolio Decisions – farmin/drink etc

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. It’s 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?
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5. YTF – explained.

6. Summary
• 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
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.
• Classifies ANY trap on the planet
• Hierarchical and flexible system
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).

**Milton & Bertram 1992**

**Pool Description Scheme**

AAPG Bull., 76(7), 983-999
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 independent anticlinal closure "C"
2. Fault dependent 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
• Defined on Woodside Chronostrat Chart
• 17 Play Interval Evaluated
  • Triassic to Early Tertiary Interval

Paleogeographic and Play Maps for all of these intervals

Example "JXX" Play Interval
North Carnarvon Basin

Play Intervals
Well Failure Analysis Rosettes
Analysis of all JXX Failures

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

This is how you calibrate your prospect risking – against well failure analysis at the play NOT the well level.
JXX Play Stack (Split Risking)

Proven Play Fairway
Green Blob of interest!
JXX tests - Trap Types Tested

- C
- C/CF
- C/T
- C/U
- CF
- CT
- ETF
- CUT
- CTF
- CTU
- UF
- U
- UT

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• 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
• 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.
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6. Summary
• 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 analog 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.

\[ YTF = \text{No of features} \times \text{Size} \times \text{Probability of Success} \]
\[ = \text{Area (km}^2\text{)} \times \text{Feature Density (no/1000sq km)} \times \text{Future FSD} \times \text{Pg from Play Map} \]

Polygons with equal Risk and structural density and volumes
Common Structural Density and Future Volumes polygons
CRS Map

Play Stack
- Play CRS Map
- Res. Effectiveness
- Reservoir Presence
- Topseal Presence
- Charge

In Player we call these UIP’s (Unidentified Prospectivity polygons) because none of the prospects have a specific location.

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 (e.g., if you drill X wells what is the probability that you will have a success and derisk the play).
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 – it’s always a mixture...
Industry YTF Methodologies

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creaming Curve extrapolation</td>
<td>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.</td>
</tr>
<tr>
<td>Hydrocarbon Density Method</td>
<td>Uses an estimate of the hydrocarbon volumes per unit area (typically mmboe/1000sq km) to estimate</td>
</tr>
<tr>
<td>Field Size Distribution top-up method(s)</td>
<td>Basically adds the missing fields into a field size distribution making the assumption that the population is log normally distributed</td>
</tr>
<tr>
<td>Geochemical/basin modelling estimates</td>
<td>BM tool estimates the volumes of oil and gas generated migrated and trapped in evaluated source rocks</td>
</tr>
<tr>
<td>Expert Estimates/Guestimates – Delphi/&quot;Phone a friend&quot;</td>
<td>Typically a numeric estimate of the number of remaining prospects/fields multiplied by the average field size</td>
</tr>
<tr>
<td>Prospect Structural Density Play Based Method</td>
<td>Estimates the structural feature density of traps and risks the results using a stacked play map – Exxon methodology</td>
</tr>
</tbody>
</table>
Comparison of YTF Techniques

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

- 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.
• 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!
Summary

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

Not Play Based Exploration!

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

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.
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